The genetically modified food debate: Where do we begin?

By Nathanael Johnson (series of articles and responses appears on Grist.ORG)

I've lingered at the fringes of the debate over genetically modified foods since the '90s, hoping that some solid fact would filter out and show me clearly who was in the right. But that hasn't happened. Every shred of information, it seems, is contested, and all this turbulence keeps the water muddy.

Now the debate is coming to a head again. Britain is reconsidering its restrictive position. Here in the U.S., bills to require the labeling of GM foods were introduced to the legislatures in 28 states this year. Now that I'm writing on food for Grist, I can't keep waiting on the sidelines for someone else to clear this up. I'm going to have to figure it out for myself.

A project like this requires humility. Many people — including, I'm sure, many of you — may have greater expertise in this area than I do. If so, let me know where you think I should be pointing the searchlight. Or, if you're like me, and just want to get reliable information from someone who's not bent on convincing you one way or the other, well, come along for the ride.

My goal here is to get past the rhetoric, fully understand the science, and take the high ground in this debate — in the same way that greens have taken the high ground in talking about climate. It's hard to make the case that we should trust science and act to stem global warming, while at the same time we are scoffing at the statements [PDF] of *snort* *scientists* on genetic modification.

Now that doesn't mean we have to stop thinking, and simply accept everything that the voice of authority lays in front of us. I'm going to look at the science critically, and take into account the efforts of agricultural corporations to cant the evidence. When Mark Lynas made his speech saying that he'd changed his mind about genetic engineering, I was unconvinced, because he didn't dig into the evidence (he provides a little more of this, though not much, in his book). Lynas did, however, make one important point: There are parallels between opposition to GM crops and other embarrassingly unscientific conspiracy theories. If there are grounds to oppose genetic engineering, they will have to be carefully considered grounds, supported by science.

Of course people who are concerned about genetic engineering don't have a monopoly on error and overstatement. As the journal *Nature* put it in a special issue in on transgenic crops:

People are positively swimming in information about GM technologies. Much of it is wrong — on both sides of the debate. But a lot of this incorrect information is sophisticated, backed by legitimate-sounding research and written with certitude. (With GM crops, a good gauge of a statement's fallacy is the conviction with which it is delivered.)

Over the next few weeks, I'll be writing a series of pieces, attempting to highlight legitimate concerns and identify the arguments that should be taken out back and … retired. In the courtroom, a judge will often work with both sides to determine a set of facts that all can agree upon, before moving on to argue about how the law should apply to those facts. I'd like to do something similar here: sort out established facts, and gain a sense for what the bulk of the science indicates.

I'm going to start with the most politicized issue: Is there any evidence that genetically modified food is directly harmful to people who eat it**?** There's a one-word answer to this: no.

If you aren't prepared to take my word for it (especially that particular word), things get a bit more complicated**.** The most persuasive evidence is that millions of people have been eating genetically modified foods for the past 20 years without any obvious ill effects**.** If anyone exhibited acute symptoms after eating GM food, we would have seen it**.**

At the same time, the absence of evidence of harm does not prove safety**.** If the effects were subtle and chronic, and showed up in only a small subset of the population, it's possible that we could have missed something**.** And we don't know what to look for.

That's the point Margaret Mellon made when I called her at the Union of Concerned Scientists, in Washington, D.C. Mellon has been critical of U.S. policies on genetically engineered crops**.** "People need to understand how hard it is to use the scientific method to address the issue of, 'Is genetic engineering safe**?**'" she said.

The problem: It's not a yes-or-no question**.**

"It does *not* appear," Mellon said, "that there's any risk that applies across the board to all genetically engineered food and to all people**.**Each plant is different, each gene insertion is different, each person's response is different**.**"

In other words, every GM food could be wonderfully healthy until one particular gene insertion causes things to go awry in just such a way that it messes with the immune system of one particular person**.** How do you deal with this**?**

"You need to make a list of all the things that might be potential problems and analyze each of these risks in a wide variety of genetically engineered products," Mellon said**.**

Dozens of scientific advisory panels have done this sort of brainstorming **.** The World Health Organization [PDF], for example, reached the fairly common conclusion that the problems in genetically engineered foods are fundamentally the same as the dangers that arise naturally in plant breeding**.** Each relies on mutations randomly mixing up the genome**.** Each sometimes provides unexpected outcomes — try to make corn disease-resistant, end up with too many toxins in the kernels**.** In both GM and conventional breeding, scientists rely on screening to weed out the bad cobs**.**

However, researchers generally acknowledge that there's something a little different about genetic engineering**.** The United Kingdom's 2003Genetic Modification Science Review [PDF], led by David King, puts it this way: "By virtue of the different processes involved, there will be some sources of uncertainty and potential gaps in knowledge that are more salient with respect to GM food production techniques**.**"

If you have no idea what that means, that's because it's incredibly vague**.** Sure, King is saying, there's something unusual about transferring a firefly gene into a tomato — that kind of thing doesn't happen very often in nature**.** (Although it does happen, amazingly — scientists have found examples of genes moving between different species**.**) But we don't know what that difference implies**.** The report goes on to say that the science so far suggests that those implications have amounted to nothing so far. All the same, this unique technique does create "uncertainty and potential gaps in knowledge."

The quest for greater certainty on genetic engineering leaves you chasing shadows: When you're dealing with gaps in knowledge, rather than hard data, it's hard to tell what's an outlandish hypothetical, and what's the legitimate danger. Anything, of course, is possible, but we shouldn't be paralyzed by unknown risks, or we'll end up huddled in our basements wearing tinfoil hats. Exhibit A:

There's no way to completely eliminate risk. The real question is, have we thought through the realistic potential for problems, and put regulatory safety nets out to protect ourselves?

Trying to answer that opens another can of worms. Critics like Mellon say that, right now, the producers of GM crops aren't required to do any testing at all. GM boosters say that regulations are so onerous they stifle innovation. Clearly, someone is wrong here. I'll take that up in my next post.

The GM safety dance: What's rule and what's real

By Nathanael Johnson

In my initial foray in this series looking for facts behind the rhetoric on transgenic food, I reasoned that, since we can't eliminate risk, we'd better have the right regulatory safety net in place.
As soon as I asked this, however, I was met with an apparent contradiction: Critics of genetic engineering say the industry is not required to do any safety testing. The developers of GE crops say they have to do a ridiculous amount of safety testing. Both are correct.

If you try to cross-check the claims of people on either side of the GM debate, you run into problems, because these warring clans speak different dialects. Their foundational assumptions point them in opposite directions, facing different landscapes and talking past each other. This can leave outsiders feeling that someone is lying. But often the miscommunication comes down to a difference in perspectives: One side says, "We're right!" and the other — instead of explaining how that specific claim might actually be wrong — answers, "That's poppycock. You're left!"

When I began reporting on regulation of GE crops, I thought it would be easy to fact-check the assertion that there's no required safety testing for transgenic crops. Surely, I thought, it would take no more than one phone call. Actually, it took quite a bit more work than that — but I return successful from my quest, and I think I can sort out this debate once and for all.

First, some quick background: In 1974, Paul Berg, often called the father of genetic engineering, persuaded other molecular biologists to lay out the potential hazards of their work. These scientists imposed a moratorium on their research while they formed guidelines for the science going forward. Those guidelines were eventually translated into a set of bureaucratic hurdles. A genetic engineer has to get a permit from the USDA for field tests, and, after several years of trials, petition

for deregulation of the crop. If the crop is pest-resistant, the EPA regulates it as pesticide, and demands more data. Finally, the FDA evaluates the plant for safety and nutritional content.
All this sounds reassuring. Then I spoke with Michael Hansen, a critic of GM foods at the Consumers Union.
"There's absolutely no requirement for any safety testing," Hansen said.

I told him that didn't make any sense: I'd just learned about all kinds of testing.

"Well, the companies are supposed to do a voluntary consultation," he said, "but it's voluntary. Look at what the FDA says when they approve a food: 'It is our understanding that *Monsanto* has concluded this is safe.' They just rubber-stamp it."

This legalese is patently ridiculous, but I wanted to stay focused long enough to resolve this question of regulation. "But is it really voluntary in practice?" I asked. "Do you know of a case where a company did no safety testing?"

Hansen didn't. In practice, companies generally do voluntary testing, he said, but there's no guarantee that they are doing the right sort of testing. Hansen would like to see more long-term feeding studies that use the actual crop that humans are going to eat. Often, he said, instead of feeding rats the food, researchers will just feed them proteins from the genes they are adding. Furthermore, he added, the companies can do these studies over and over until they get results they like, and only show those favorable results to the government.

When I began talking to people on the other side of the debate, they seemed baffled by the assertion that testing was voluntary. They didn't know what I (or Hansen) was talking about. Finally, I reached Val Giddings at the Information Technology and Innovation Foundation. He was once a biotech products regulator at USDA and worked closely with the FDA while it was enshrining the rules to govern transgenic foods, and understood how all this worked. The murkiness arises from a consultation process laid out in 1992, he said.
Here's the deal: The process is technically voluntary, but in practice, absolutely everyone does "volunteer." That's because the FDA can stop any food (GM or otherwise) from going to market. It would be incredibly foolish for a company to spend a lot of money on a new breed of plant while thumbing its nose at the agency, Giddings said.

In other words, it's voluntary — but if you don't volunteer, the FDA is standing there to whack you with a very big stick. Moreover, regulatory review from the USDA and the EPA is mandatory in every sense — there's nothing even legalistically voluntary about that. But it's the FDA that's most responsible for insuring that the food doesn't harm people.

"In my opinion it is misleading to and past the point of dishonesty to claim that FDA does not require safety testing," Giddings emailed me. "A Jesuit would blush at the rhetorical convolutions to which the activist opponents resort to make it seem otherwise."

I pushed him on this. What if a company decided just to opt out?

The FDA, Giddings wrote, "frankly cannot really envision any circumstances under which anybody placing a 'bioengineered' food on the market would have the temerity NOT to consult with them."

Hansen had left for a Codex Alimentarius meeting in Rome, but when I suggested by email that the FDA regulations were mandatory in practice, he shot back a response, disagreeing hotly. He restated his objections and added a salient piece of evidence: A report by former EPA scientist Doug Gurian-Sherman showing that companies had refused to hand over data that the FDA had requested. If FDA oversight was truly mandatory in practice, the agency should be able to get the information it wants, Hansen pointed out.

I read the report [PDF]. Gurian-Sherman had gotten documents relating to the FDA's consultation process through the Freedom of Information Act. In six cases the FDA had asked for more data, and, half the time (three of six), the companies had said no. In two of those cases the FDA had asked for more information about the genetically engineered corn's stalks (that is, the agency was satisfied with the safety of the corn itself, but it also wanted some data on the leaves, which are sometimes fed to livestock).

I could see why a company might resist pressure to test its corn stover, and why the FDA might let it off the hook: It's hard to argue that leaves and stalks are a threat to human health. But the final case was more perplexing: The FDA had asked for more numbers on the BtCry1F protein. The company (Dow AgroSciences) had reported the average level, and the FDA suggested it could also provide the minimum and maximum amounts it had found in individual samples.

Why had Dow AgroSciences said no? It should be easy to look up the low and high values from the tests, and send those in. And it might be germane because an average could hide a few dangerously high maximums.

When I asked Giddings about this, he said that a company would only refuse the FDA if they thought the request was truly unreasonable. "These people are terrified of the FDA," he said. "Usually their approach during these consultations is just to close their eyes and think of England." (Dow AgroScience did not respond to my request for comment.)

But BtCry1F, he said, is utterly safe. It turns into the pesticide Bt that's used in large quantities by organic farmers. It attacks structures in the insect gut that aren't present in humans. In this case, the FDA must have simply agreed with the company that, no matter what the maximum, there was nothing to worry about, Giddings guessed.

He was right. When I asked Jason Dietz, a policy analyst at the FDA, about this case, he filled in the details:

"We said, you could improve on the submission by doing this [adding min and max numbers]. The company said, we understand, we see what you are suggesting, but we think that looking at the means [i.e. averages] would get at the same end point. And we said, yes, we agree, that rationale makes sense to us."

If a company refuses to hand over information that the FDA really wants, Dietz said, the agency will ask more forcefully. And if it's not satisfied with the data it gets, the FDA won't sign off on the crop, he said. But that's never happened. When the FDA insists, companies always have handed over the data.

“We haven’t been in a position of needing to write a letter saying that we think your product is unsafe and unlawful,” Dietz said. “And I think that speaks to the strength of the consultation process.”

I also asked Dietz about Hansen’s indignation over the FDA’s “rubber-stamp” way of saying that the safety determination is made by the biotech company rather than the agency. Dietz responded that this is simply a reflection of the process: It was set up so that the companies would do the testing and pay for it.

“It’s the manufacturer’s responsibility to insure that the product is safe,” he said. “It’s their safety assessment. What we do when we evaluate their safety assessment is we look to make sure the safety and regulatory questions have adequately been resolved, and then we say we have no questions about your safety assessment.”

The bottom line is that the FDA requires all foods to be safe, he said. Insuring safety has meant that every firm bringing a genetically engineered food to market has gone through the consultation process, and has done safety testing.

After I hung up with Dietz, the phone rang again. It was Doug Gurian-Sherman, the author of the report criticizing FDA regulations. (Gurian-Sherman is now with the Union of Concerned Scientists.) “I gotta say,” I told him, “I really am beginning to think that it’s just incorrect to say that companies aren’t required to do any safety testing.”

This launched a conversation that lasted nearly two hours. I’ll spare you the rehashing of FDA policy and cut straight to the conclusion.

The issue isn’t in how much authority the FDA *can* exert — it certainly can, and for all practical purposes does, require testing. The issue is in how much authority the FDA *chooses* to exert. Since the requirements for safety testing aren’t spelled out in regulations, but instead determined on a case-by-case basis, Gurian-Sherman says it’s correct to say there’s no required safety testing.

The difference between Gurian-Sherman and Giddings on this comes down to their respective assessments of the risk. Giddings thinks genetically engineered foods are as safe as, or safer than, conventional crops, so the FDA testing looks onerous, and it seems obvious that it’s obligatory. Gurian-Sherman thinks that there’s a small, but very serious, chance that some future GE food could cause harm, so he’s troubled by the fact that there aren’t specific requirements written into the regulations.

So: Are people like Hansen and Gurian-Sherman right to say there’s no required safety testing?Or is Giddings right that the testing is *de facto* mandatory?

In a very real way, both are right. Still, after doing this reporting, I won’t be saying that there’s no required safety testing: saying so implies that GE food is unregulated and untested, and that simply isn’t the case. The FDA does a thorough job; it just focuses tightly on a few potential dangers, looking for allergens, amplification of toxins that naturally exist in the plant, and changes in nutritional composition.

When I asked Dietz why they didn't cast a wide net, and ask for a rundown of all the compounds in each GE crop, he said: "An analysis like that would be very hard to interpret because it would capture everything, and it would be hard to identify those things that would be most important to safety. What we use is a focused approach that targets those things that we know, if they were changed, might be a problem."

This seems eminently reasonable — *if* genetic engineering is just an extension of conventional breeding. But if GE foods are fundamentally different, the FDA's approach appears, as Gurian-Sherman put it, "so thin that it would never raise a red flag if something *were* dangerous." There are significant questions even about the problems the FDA focuses on, he said. (There's a good overview of those concerns here.)

This understanding leads us right back to the question my last post left us with: Is there something fundamentally different about GE food? In my next post , I'll be looking at the ways genetic engineering is similar and distinct from other forms of plant breeding.

P.S. I'm reading your comments (the thoughtful ones, at least), and I will, indeed, delve into many of the issues raised there. Gurian-Sherman told me that he is concerned about health risks from GE foods, but that's last on his list, behind concerns about the environment, monopolies, and the direction of agriculture. I'll get to all that stuff.

Genetic engineering vs. natural breeding: What's the difference?

By Nathanael Johnson

If you are new to this series, I've been trying to break down the competing claims about genetic engineering . I'm not an expert: When I told a friend I was writing about GMOs he asked, "So are you for them, or against?" My answer: "I'm trying to figure that out."

The next step in trying to figure that out is to really understand how genetic engineering works. Is this process simply a minor extension of plant-breeding techniques? Or is there a way in which genetic engineering represents a fundamental discontinuity with the age-old practice of farmers selecting seeds?

That's what I asked Pamela Ronald, a scientist at U.C. Davis who uses genetic engineering to study rice. I approached Ronald because she's not one of those scientists who is so used to looking through the microscope that she loses sight of the big ecological picture. Her husband, Raoul Adamchack, teaches organic agriculture at Davis, and together they wrote the book *Tomorrow's Table* , which makes the case for incorporating genetic engineering into organic practices. Nor is Ronald among the progress-addled optimists who rush to embrace every new technology. She gave birth to her third child in her outdoor hot tub, because the science suggests that — for a normal pregnancy, with one kid already out, and a hospital nearby — it's actually safer.

When I started to ask questions, Ronald asked if we could back up a bit. "I end up asking people, 'What is it that bothers you about genetic engineering?'" she said. "Is it the idea of moving genes from one species to another? Well, what we do here is rice — we put rice genes into rice plants. Is it that you don't like corporations? Well, I'm at a university here, and we're funded by the government. Is it that you don't like profits? Well, we have no private funding, and the rice we are developing is all for developing countries. We don't make money off our discoveries."

What bothers me about genetically engineered crops, I told her, is that the technology seems to disrupt the co-evolutionary relationship between farmer and plant. I like the idea of farmers saving seeds and coaxing plants toward a greater harmony with their environment (the seasons, the pests, the culture), rather than buying their seeds each year from Monsanto. Plus, in that slow process of selection, it might be easier to weed out any unintended effects that cause problems.

"So," she said, "in the developed world almost everyone buys their seeds, but the people using our rice can't afford that. They need to self their seeds" (i.e., they self-pollinate their seeds each year to provide for the next).

In the U.S. farmers buy hybrid seeds, which don't work as well if you try to save the next generation. But the farmers in Bangladesh, who use rice Ronald pioneered, save seeds every year. The seeds ~~are genetically engineered, yes~~ are breed to contain genes discovered with GE* – but then they continue that process of co-evolutionary selection. As for the risk of unintended problems, Ronald said, "Any time you introduce a new seed there's some risk, but the risks are small and the benefits are huge. I just think we need to work with whatever technology works best to achieve the goals of sustainable agriculture."
As with birth, it's a question of appropriate technology. I wanted to see for myself what it meant to create new seed, and how we might parse the risks of the various methods for doing it. The next day I drove up to Davis. Ronald was traveling, so she left me in the care of Randy Ruan, her lab tech.

Ruan told me to meet him outside the greenhouse. He'd leaned a red bicycle (with an Obama button pined to a pannier) against the glass. He seemed a little bemused by my interest.

"Take as many pictures of rice as you like," he said.

He had a point. Everything pretty much looked like rice. But the story behind each plant was slightly different.

When doing marker-assisted breeding, scientists cross their plants through pollination, hoping to get an exciting new combination of traits. As new plants emerge, they can take a tiny piece of tissue and see if it contains the genes they were hoping for. If not, they can discard the plants. It's conventional breeding, assisted by a keyhole through which to peek at the DNA.

The problem with conventional breeding, marker-assisted or otherwise, is that it's messy, said Margaret Smith, a plant breeder at Cornell. (I followed up with her to fill in the nitty gritty of how things worked.) You're mixing two whole strands of DNA and swapping lots of genes at once, Smith explained. Researchers crossbreed generation after generation with a plant that displays an interesting mutation, creating thousands of plants, most of which they will destroy. It's not exactly the slow dance with the land that I'd imagined.

This rice was exposed to radioactivity to induce mutations. FN stands for "fast neutron."
Another way to tweak crops is to induce mutations by dousing seeds in mutagenic chemicals or zapping them with radiation. This causes bits of DNA to copy incorrectly, which causes more changes than you generally see with genetic engineering. "You're just rolling the dice and hoping to get something interesting," Smith said.
It works. As it turns out, the 20-pound bag of organic brown rice on top of my refrigerator was a strain (Calrose 76) that mutated after exposure to 25 kR of Cobalt-60 gamma radiation.

The most common mode of experimentation in Ronald's lab, of course, is genetic engineering. Ruan gamely pointed out a few examples. Ronald had mentioned that there were two main projects for which her lab is known: the discovery of the gene XA21, which confers resistance to bacterial disease — good for farmers in the developing world who can't afford antibacterial pesticides; and a gene that allows rice to tolerate submergence better — good for those same farmers, who now have an herbicide-free way of drowning weeds without drowning the rice.

There are two main ways of genetically engineering plants: shooting them with a gene gun, or using the microbe *Agrobacterium tumefaciens*. A gene gun literally shoots pellets coated with DNA through plant tissue. As a result of this pure mechanical force, a few genes end up in the nucleus and are incorporated into it. Ronald's lab, however, uses Agrobacterium. With a little arm twisting, I got Ruan to take me to the lab and walk me through the process.

Mosaics outside the Ronald lab in Robbins Hall.

I wanted to understand in detail how this worked because, years ago, I had attended a lecture given by Ignacio Chapela, a critic of genetic engineering, and his critique had turned on these details. Genetic engineers often make it sound as if they are cutting and pasting DNA in precise places, he said, but the genes are sprayed into the genome at random. The thing that really bothered Chapela is that scientists bundle the gene they want with several others: They will build a sequence starting with a promoter (or "on switch"), then the gene they want to transfer, then a marker (which displays some visible trait to show them everything is working), and a terminator (the "off switch").
Throw all this at a genome and it could cause trouble: The terminator sequence could break off, Chapela pointed out, and all of a sudden the plant is expressing not just the trait you want, but also whatever comes right after that in the genome. Plants often have inactive genes for the manufacture of toxins, for instance, and the randomness of genetic engineering could turn them on.

All this, it turns out, is absolutely true. But it's also occurring all the time in the wild and in plant breeding, without the assistance of genetic engineering. The process for building the bundle of genes is, in actuality, incredibly precise. Because researchers are working with a relatively small amount of DNA, they really can cut and paste with precision. To this sequence, they add a bit of DNA called a plasmid — which catches both ends of the sequence, turning it into a circle. Plasmids are strange and fascinating things: They are essentially tools that bacteria use to swap genetic information between species — an instrument for creating transgenics built by evolution.

Next comes Agrobacterium. This particular microbe specializes in injecting plasmids into plant DNA. In the wild it does this with genes that make the plant form a home in which the Agrobacterium thrive. Scientists simply replace those plasmids with the ones they've constructed.

Chapela was correct to say that this part of the process is random; there's no control over where the Agrobacterium insert their payload, and there is a chance that this bundle of DNA can fracture.But, Smith told me, the same thing happens during normal breeding. The promoter might, certainly, turn on unwanted genes. But the promoter, which almost always comes from the cauliflower mosaic virus, is doing the same thing all the time in the wild.

The difference, Chapela had hypothesized, was that genetic engineering methods would lead genes to fall into more vulnerable and unstable sections of the genome. But that hasn't happened. Analyses of thousands of genomes show that introduced genes fall randomly amid the DNA strands . The genes introduced by humans have proven to be no more likely to break up or move around the genome . (I'm not getting to Chapela's main point, that engineered genes were spreading with pollen. More on that later.)
Of course, Chapela's objection was just one possible scenario — others have and will continue to be raised. The point is, it's easy to overestimate the risk of the new while underestimating the risks of the status quo. Species appear to be fairly stable, but beneath the surface, we live in a churning ocean of genetic flux.

In 2003, when the United Kingdom's GM Science Review Panel (chaired by climate hawk Sir David King) looked closely at this issue, it concluded that genetic engineering was no more likely [PDF] to produce unintended consequences than conventional breeding:
Conventional plant breeding can produce gross undirected and unpredictable genetic changes and in that sense has considerable uncertainty. This is well documented and we know much about the types of change at a cellular level.

A special feature of GM breeding is that it allows the transfer into crop plants of one or a few genes from what might be radically different organisms. Conventional breeding cannot, for example, form plants that can assemble complex human immunoglobulins as has been achieved in GM plants. This inevitably raises uncertainty about whether there are any novel genetic interactions and whether these are potentially harmful …

A further special feature of GM breeding is that the products of particular gene constructs may become present in radically different foodstuffs, effectively independently of any biological relationships … this can hold important implications for risk management policy in areas such as the avoidance of exposures to any allergens that might pass through regulatory screening.

As a result, genetically engineered foods are screened for potential allergens. It's frequently pointed out that Pioneer Hi-Bred mistakenly introduced an allergen into soybeans when it added a gene from

Brazil nuts. The rest of the story is that we know about this because there was the right testing regime, and the product never went on the market — the company (and the regulators) knew what to look for and successfully weeded the plant out.

So what's the takeaway of all this? Before I finished up my conversation with Margaret Smith, I asked her if there might be some evolutionary wisdom in the way genetic material gets swapped during normal reproduction that was fundamentally different than techniques of genetic engineering. We don't know of any, she said. But she added:

I think we need to be thoughtful, and as we learn more we need to continue to think about this carefully. We're learning more every day — just look at the revolution in epigenetics — and that could change the way we approach this. But my message on this is that we shouldn't just stop because there are unknowns. Every technology has unknowns. We just have to be as thoughtful as we can.

Those of us who are suspicious of genetically engineered foods need to be thoughtful, too. It makes no sense, for instance, to protest GMOs while accepting that irradiated organic mutants should be exempt from any special regulation. It makes no sense to try to ban all genetically engineered foods if we aren't concerned about the rice-to-rice transfers that people like Ronald are doing.

I still think that we have an important role to play in making sure the technology isn't used inappropriately. But it's not useful to flail blindly against something we don't understand.

Update: Pamela Ronald made it clear during our initial conversation that, while she used genetic engineering for gene discovery, it was her collaborators, using marker-assisted selection who actually developed rice for farmers. I omitted this because I thought that a discussion of the distinction between basic and applied science would be tangential to the main point: How is GE different from conventional breeding?
This distinction, however, raises another important question, namely: Is genetic engineering actually a useful tool for sustainable agriculture? I'll be getting to that.
I did make one real mistake. Ronald's lab found the submergence tolerance gene Sub1, which is indeed the gene that was released in the Bangladeshi varieties, but it was introduced through marker-assisted selection. I regret the error.

Is extremism in defense of GM food a vice?

By Nathanael Johnson

When a study came out in 2012 associating gruesomely lumpy rats with genetically modified food, critics trashed it so thoroughly that a group of researchers and advocates called foul. This went beyond legitimate scientific critique, they wrote. It was evidence that "those with a vested interest attempt to sow unreasonable doubt around inconvenient results."

More recently, a long-term GM feeding trial of pigs received a similar (though milder) treatment.Tom Laskawy here at Grist made the point that , though this study had flaws, the dismissals seemed knee-jerk — ideological rather than thoughtful.
So is there an echelon of corporate Pinkertons pouncing on any scientist who dares to dissent from the GM consensus? Are researchers who raise doubts about GMOs unfairly punished? It's hard to assess while smoke billows and rhetorical bullets fly. It's much easier to judge with the clarity of hindsight. The historical picture is sharper and simpler, and I think it really does show that scientists who step out of line on this issue are savaged in a manner that's out of all proportion to their errors. These errors are real, but they should be exposed in the spirit of collaboration rather than castigation.

Back in 1998, Arpad Pusztai was just beginning his third year of research on the safety of transgenic potatoes when a TV program asked him to do an interview about his preliminary results.

A Cold War defector to Britain from Hungary, Pusztai was a world expert on lectins — naturally occurring proteins that provide plants with a measure of pest resistance. Scientists had added genes for lectin production to potatoes, and Pusztai was feeding these potatoes to rats to test for adverse effects. He'd become more concerned when he saw that the rats he'd fed with transgenic potatoes were slightly smaller, and had less-reactive immune cells, than the others. (In the end, after statistical analysis, the only real difference was a slight change in gut cells.)

All these years later, we know what happened. The lectins themselves probably weren't hurting the rats: Pusztai had cleverly designed his experiment with a control group of rats that ate non-transgenic potatoes plus a pure dose of lectin, so the problem (if there was a problem at all), was some unknown element of the transgenic potatoes. It seemed obvious to point to genetic engineering itself; that would be the only other difference, right?

Actually, no. We've come to understand that the DNA differences between two potatoes in a field are usually more significant than the difference between a parent plant and its genetically modified progeny. The comparison you'd want to make to test the effect of genetic engineering would be a transgenic plant versus its unmodified clone. And you'd want to make sure that these plants grow side by side, because we know that plants alter their gene expression in response to weather, soil, and history. Plants can even turn on genes to produce natural pesticides when afflicted by insects.

When you taste the terroir in wine, it's not just the soil's effect on the grape, it's also the grape's epigenetic *response*. In a very real way what you're tasting is not just cause and effect, but a conversation. You're tasting a complex dialogue between the grape and the mineral soil beneath it, the quality of sunshine on its leaves, the hand of the vintner. All of these factors can create genetic shifts more profound than a gene inserted by a scientist. And any of these changes might provoke a slight reaction in gut cells.

Back in 1998, however, people didn't really understand any of this. So when Pusztai looked at his underweight rats, he attributed the cause to the one difference staring him in the face: genetic engineering. And, as Peter Pringle recounts in *Food, Inc.,* he said as much on TV.

The TV presenter asked the obvious question: “So if genetically altered food can affect rats in this way, could they possibly have long term effects in humans too**?**” Pusztai was cornered. He could have replied that it was far too early for such a judgment and that he would not want to comment until his work had been peer reviewed**.** Instead he said that he would not eat genetically modified foods if he could help it, until there was more evidence about their safety**.** And then he added a bombshell: “It’s very unfair to use our fellow citizens as guinea pigs**.**”

All hell broke lose. The telephone lines running to the Rowett Institute, where Pusztai worked, jammed with calls from activists, government ministers, and industry heavyweights**.** Scientists began to pick apart Pusztai’s techniques**.** The media wallowed happily in the mess**.** There were rumors that the command had come down from the White House, to Downing Street, to the Rowett Institute, to smother the frenzy**.** The director of the Institute, facing “a megacrisis we didn’t remotely anticipate,” sealed Pusztai’s lab, confiscated his notebooks, and forbade him from further communication with the press**.** And, though the director had given Pusztai permission to speak about the preliminary results on TV and offered congratulations immediately afterward, once the frenzy started he put Pusztai on indefinite leave**.**

Let’s pause here for a moment to consider how this looks**.** Suppose you were the director of the Rowett Institute: If you wanted to inflame fears about GM food, would there be any better way to do it than shutting down suspicious research before it’s finished and firing the researcher**?** A group of scientists rallied to support Pusztai, writing: “Those of us who have known Dr**.** Pusztai’s work or have collaborated with him were shocked by the harshness of his treatment**.**”

Here’s what might have happened under less volatile conditions: Pusztai would have gone on to (um) *finish his experiments*, and, after peer review, would have come to more tempered conclusions**.** (Even under the actual, high-pressure conditions, the paper, eventually published in *The Lancet* , had much more modest findings**.**) Other scientists would have made their critiques, and Pusztai would have eventually zeroed in on the real cause of the problems. Everyone, including the biotech industry, would have come out ahead**.**
Instead, this affair effectively ended Pusztai’s career, and it polarized the debate **.** Even plant geneticist and prominent GM food supporter Nina Fedoroff (who wrote this excellent analysis of the affair , delving much more deeply than I have into the science) thought Pusztai’s treatment was inappropriate**.** “The whole thing was badly botched,” she emailed**.**
The botching continued. Ignacio Chapela, a UC Berkeley professor and author of a controversial paper suggesting that transgenic genes were mingling with traditional varieties, was denied tenure shortly after the university signed a $25 million sponsorship agreement with the agribusiness company Novartis (now Syngenta)**.** A group of independent professors, invited by UC Berkeley to assess the situation, concluded that “there is little doubt” that the Berkeley-Novartis deal was partially to blame**.**
Lawrence Busch, a professor of sociology at Michigan State University, who led this review, said the sponsorship “played a very clear role and an unsatisfactory role in the tenure process**.**” (Chapela

Science writer Emily Waltz has catalogued other examples of what looks like overreaction to research suggesting problems with genetically engineered crops**.** Much of the criticism is legitimate (if ferocious) scientific exchange. But some of it is probably orchestrated by industry. There's evidence that the Bivings Group, a PR firm, spread false information about Chapela using pseudonyms on an Internet forum for scientists. And we know that Syngenta has stooped to ad hominem attacks.

You could say the same and more about activists campaigning against biotech: Anti-GMO trolls relentlessly bully and defame scientists, while spreading misinformation. Groups of thugs, like those that trampled a plot of Golden Rice recently, try to stop experiments. Swiss researchers running recent GM trials spent 78 percent of their research funds on security.

But there's a crucial difference: Anti-GMO activists aren't in positions of power. The Golden Rice experiments, unlike Pusztai's, will be completed. I haven't found any example of a scientist losing her job for a finding that's favorable to biotech.

I'm not saying we should smother criticism of science, or give a pass to studies that suggest there's a problem with GM food. I'm all for thoughtful critiques, just not knee-breaking. It's possible to assess unexpected new findings skeptically in the larger context of the existing corpus of science without setting phasers on utter destruction.

For instance, the study comparing pigs given conventional and GM feed exactly repeated Pusztai's error. (The researchers said they couldn't get genetic matches to GM feed because of intellectual property restrictions, but they could have partnered with any researcher at a university in the United States, which have permission to study patented seeds.) And when long-term feeding trials are done so as to compare apples to apples, they've reinforced the conclusion that genetically modified foods are safe . Stating these points is an appropriate response. And that's the response most scientists have made.

Given the power of corporate influence, however, I think it's also appropriate to provide extra shelter and support for legitimate scientists with unpopular views. This is one way in which climate science is very different from genetic engineering: Reasonable climate skeptics, like Richard Muller and his team, have been given the space to check their theories and — rather than being hounded and radicalized — they've generated data that changed their minds and resulted in a stronger consensus.

Here's a proposal for putting this into practice: Why not fund a team of scientists with concerns about GM foods to address popular fears under open, rigorous conditions? Instead of having top-flight pro-GM scientists attack the studies after publication, it would make a lot more sense to have some of these people on the team from the beginning, helping to design the experiments.Whatever the results, science could only win.

20 GMO questions: Animal, vegetable, controversy?

By Nathanael Johnson

This is a slightly unusual end-of-the-year list. Instead of a selection of the best or worst news over the year, this is simply a bullet-point summation of what I've learned about GMOs in 2013.

When I started this series, I proposed to cut through the debate by finding the facts that both sides agree upon. I also proposed to do this (back in July) "over the next few weeks." Ha. Not only has this taken me much longer, I've also learned that this controversy has turned into something resembling trench warfare, where the two sides refuse to agree on anything, lest they give up an inch of their hard-won position. So I don't expect everyone to agree with the list below, but I do expect that reasonable people on both sides will concede (if only under their breath) that the bulk of the evidence leads to these conclusions.

As I've dug into this over the past six months, I know I've provided more detail than all but the most fascinated readers really wanted. In this list, therefore, I've aimed for brevity. If you want more nuance I'll include links to the longer stories, which, in turn, contain links to even more technical scholarly articles, not to mention a detailed dissection of my every sentence in the comments.

I've heard that GMOs are totally unregulated, is that true?

Nope. In the United States, GM food is regulated by the USDA, the FDA, and the EPA. The FDA process is technically voluntary, but every creator of GM food has opted to jump through those hoops, so it's voluntary in name only. Genetically engineered foods are regulated much more heavily than many other new technologies, including other modes of genetically modifying crops, like mutagenesis.

Caveats: The regulatory process is not transparent — you can't just go on the web and look up the tests that have been performed. And non-food plants may escape regulation, as was the case in this instance.

More nuance here.

Do the big seed companies prevent scientists from doing research on their patented plants?

They used to. Not anymore. I've been asking university scientists if they've run into restrictions, but the system seems to be working.

More nuance here.

Are there dangers for scientists working on genetically engineered plants?

Yes. Anyone who challenges an accepted paradigm — like the consensus that genetic engineering is basically safe – will come under attack (see Copernicus, Galileo, and Thomas Kuhn). On the other hand, there are huge rewards for anyone who is able to overturn a paradigm.

There are dangers on the other side too: Scientists have had to abandon their work on genetic engineering because of popular resistance to the technology.

More nuance here, and here.

Is genetic engineering more likely than other forms of plant breeding to create unforeseen changes?

Slightly. Here's the National Research Council's assessment of how likely it is that a technique will lead to something unexpected. (Biolistic transfer and Agrobacterium transfer are what we normally think of as "genetic engineering.")

Is that difference relevant?

Hard to say, but so far it probably hasn't been relevant. Note that there is one method more likely to cause unintended changes than genetic engineering: mutagenesis. Our worries about genetic engineering (paradoxically) have led to a surge in the use of mutagenesis, and even that hasn't led to problems. Crop scientists back-cross both mutated and genetically engineered plants, breeding them with the parent variety for generations to eliminate any unwanted changes.
More nuance here, and here.

What about newer forms of genetic engineering?

We're now seeing many new plants bred for disease resistance using gene-silencing techniques, which, as you can see, isn't included on the chart above. Others will follow. Each will have to be evaluated on its own merits.

Isn't genetic engineering more likely to create allergens?

If you are moving genes from a plant that contains a lot of known allergens, then absolutely, you've got to watch out. And we do a really good job testing for this. There's a different danger in introducing some unknown allergen — and we don't have great ways of testing for *that.*

So, does the chance that novel allergens could emerge make genetic engineering dangerous?

Every immunologist I've talked to — including those suggested to me by activists concerned about GMO allergens — told me that the risk of novel allergens arising through genetic engineering is very low.

More nuance here.

But what about those studies suggesting that GMOs are harmful?

A couple of those do exist. It's important to look at them carefully, with an open mind. It's also important to do the same with the hundreds of studies suggesting that GMOs aren't harmful. When you consider the evidence in sum, the products out there look pretty darn safe.

More nuance here.

Isn't it possible that some subtle, unintended shift in corn DNA is causing the obesity epidemic, the rise of autoimmune disorders, autism, and Morgellons disease?

It is possible. But all the new technologies we've introduced, from cellphones to pesticides to SUVs, have the same association. There are a lot of other hypotheses to explain these things with actual evidence backing them up. When I spoke with scientists working on these problems, none of them thought that a connection to genetic engineering was likely. And Morgellons is caused by the tiny spider drones the CIA has been injecting under your skin.

More nuance here.

Have genetically engineered crops reduced insecticide applications?

Yes, in a big way. This advantage may evaporate as insects develop resistance (some already have). But scientists have created variations on the insect resistant crops and entomologists say that genetic engineering will continue reducing insecticides if we use it well.

More nuance here.

Haven't the decreases in insecticides been dwarfed by increases in herbicides?

Yes. We know for sure that farmers are now using a lot more of the herbicide glyphosate. As a result, more glyphosate-resistant weeds developed. At the same time, farmers began reducing other herbicides. And if you zoom out to look at all the herbicide-resistant weeds (not just glyphosate-resistant ones), the overall rate at which they've developed hasn't been changed by genetic engineering.

Caveat: Glyphosate is much less toxic to humans than most other herbicides, so you could argue that increasing glyphosate and decreasing other herbicides is good.

Caveat to the caveat: Glyphosate does its job so well that it completely eliminates weeds like milkweed from fields. That decline in biodiversity on farms threatens insects, like monarch butterflies.
More nuance here.

What about soil and carbon? Have GMOs led to carbon capture and soil preservation by facilitating an increase in no-till and low-till farming?

In South America, yes. In the United States GM seeds have helped some farmers make the transition to conservation tillage, but that hasn't amounted to a big change.

More nuance here.

Who has profited from genetically engineered crops?

Seed companies like Monsanto have made a lot of money. Farmers have reaped some of the rewards. And eaters have benefited a little from slightly lower prices.

More nuance here, and here.

Aren't there big problems caused by the fact that genetically engineered seeds are patented?

Sure. There have been all sorts of nasty lawsuits over patented seeds. Any time useful inventions are locked up, innovation slows down. It used to be that seeds were all open source, that is, farmers shared their innovations freely. But this isn't a problem unique to genetic engineering: Conventionally bred plants can be patented, and genetic engineers can make their inventions open source.
More nuance here.

But that's nothing, what about Monsanto forcing farmers to buy their seeds by spreading the terminator gene?

That's just not happening. The so-called terminator gene never got off the ground. And this general technology (with the clunky name GURT) would actually be a good thing in my opinion, because it would prevent genetically engineered DNA from spreading too far.

Is genetically engineered pollen spreading into regular old plants?

Yep. And this can cause problems for organic farmers, who lose a big premium if they have too many genetically engineered seeds in their harvest. It can also cause problems when an organic farmer's pollen spreads into a field of genetically engineered plants.

More nuance here, and here.

Do genetically engineered crops help or hurt poor farmers?

It's hard to tell. In sum GMOs improve economics for farmers, but this could mean that the richest are getting much richer while the poorest get a little poorer. There are a few recent studies that have taken this into account and they suggest that even smallholders benefit from GM crops. Scientists are working on a few crops designed specifically to help the poor.

More nuance here, and here, and here.

Do we absolutely need genetically engineered crops to feed the world?

No. So far GMOs have mainly been used in animal feed and biofuels. Genetic engineering has helped minimize the amount of grain lost to insects and weeds, but it hasn't boosted intrinsic yields.
More nuance here.
Labeling

So should we label GMOs?

This is opinion, not fact, but I think so. Look, it may not make much sense to fixate on this one particular technology, but like it or not, people are fixated. Labeling removes the fear of the unknown.

What I learned from six months of GMO research: None of it matters

By Nathanael Johnson

About a third of the way through this series on GMOs, after a particularly angry conflagration broke out on Twitter, I asked my wife, Beth, if I could tell her what had happened. I was hoping to exorcise those digital voices from my head. Someone had probably accused me of crimes against humanity, shoddy journalism, and stealing teddy bears from children — I forget the details, thank goodness. But I remember Beth's response.
"No offense," she said, "but who cares?"

It's a little awkward to admit this, after devoting so much time to this project, but I think Beth was right. The most astonishing thing about the vicious public brawl over GMOs is that the stakes are so low.

I know that to those embroiled in the controversy this will seem preposterous. Let me try to explain.

Let's start off with a thought experiment: Imagine two alternate futures, one in which genetically modified food has been utterly banned, and another in which all resistance to genetic engineering has ceased. In other words, imagine what would happen if either side "won" the debate.

In the GMO-free future, farming still looks pretty much the same. Without insect-resistant crops, farmers spray more broad-spectrum insecticides , which do some collateral damage to surrounding food webs. Without herbicide-resistant crops, farmers spray less glyphosate, which slows the spread of glyphosate-resistant weeds and perhaps leads to healthier soil biota. Farmers also till their fields more often, which kills soil biota, and releases a lot more greenhouse gases. The banning of GMOs hasn't led to a transformation of agriculture because GM seed was never a linchpin supporting the conventional food system: Farmers could always do fine without it . Eaters no longer worry about the small potential threat of GMO health hazards, but they are subject to new risks: GMOs were neither the first, nor have they been the last, agricultural innovation, and each of these technologies comes with its own potential hazards. Plant scientists will have increased their use of mutagenesis and epigenetic manipulation, perhaps. We no longer have biotech patents, but we still have traditional seed-breeding patents. Life goes on.
In the other alternate future, where the pro-GMO side wins, we see less insecticide, more herbicide, and less tillage. In this world, with regulations lifted, a surge of small business and garage-biotechnologists got to work on creative solutions for the problems of agriculture. Perhaps these tinkerers would come up with some fresh ideas to usher out the era of petroleum-dependent food. But the odds are low, I think, that any of their inventions would prove transformative. Genetic engineering is just one tool in the tinkerer's belt. Newer tools are already available, and scientists continue to make breakthroughs with traditional breeding. So in this future, a few more genetically engineered plants and animals get their chance to compete. Some make the world a little better, while others cause unexpected problems. But the science has moved beyond basic genetic engineering, and most of the risks and benefits of progress are coming from other technologies. Life goes on.

The point is that even if you win, the payoff is relatively small in the broad scheme of things. Really, why do so many people care?

All or nothing

The anthropologist Glenn Davis Stone has pointed out that each side of the debate has agreed to talk about GMOs as if "GMOs" are a single entity up for approval or rejection. This makes zero sense. Pro-GMO partisans, for example, often lump all the different GM plants together as a universal good that we must accept if we want to avoid starvation. The logic here is Malthusian: We are outgrowing our food supply, and the productivity gains of the Green Revolution are falling off, so we need something to save us. That thing, according to this line of thought, is genetic engineering. Set aside the problems with the Malthusian argument for a moment. We still have to ask: What type of GMOs? Are we talking about rice engineered to feed the poor in Indonesia, or soy engineered to feed pigs in a country suffering from calorie surpluses? Those two plants don't belong in the same argument.

Anti-GMO partisans also frequently treat GMOs as a monolithic entity, and that's not any more logical. If you care about the environment it would make sense to support the responsible use of insect-resistant GMOs to help farmers move beyond chemical agriculture. It's hard to argue with scientists like Bruce Tabashnik when they present evidence that insect-resistant plants have helped the environment in the places they've been used fastidiously. Thoughtful greens might, at the same time, oppose herbicide-tolerant GMOs until we can figure out a better solution than just spraying more. Again, the different forms of GMOs don't belong in the same argument.

But in the past, greens — including me — have intuitively opposed all GMOs. Because those insect-resistant crops are part of an industrial complex that we dislike, it's hard to get excited about the fact that they reduce insecticide applications. We oppose GMOs because we oppose the unsustainable agricultural system they serve.

I soured to this argument after realizing that it shares the same reasoning used by those opposed to contraception and sex ed. The argument supposes that you can throttle back an institution you dislike (monoculture, premarital sex) by denying it the technologies that reduce its risks (Bt corn, condoms). But, just as teens are going to keep having sex, our unsustainable food system is going to keep on chugging along whether we allow the use of mitigating technology or not. I think it makes sense to support the GMO uses that give us small environmental improvements. Insisting on abstinence-only farming is a non-starter.

If GMOs aren't a monolithic entity, the stakes in this fight fall even further. It's harder to get worked up about an issue when it's a mixed bag of good and bad.

But people *do* get worked up

I could tell there was something unusual about the GMO controversy by the responses to the first pieces I wrote. People with an indefatigable passion for the subject picked apart, and exhaustively debated, every point. Initially I'd expected to read every comment and help moderate, but that went out the window as the threads regularly swelled to over 200 comments. The group GM Watch ginned up menacing pictures of me surrounded by clouds of evil darkness. Sources I'd interviewed critiqued my pieces stridently, and sometimes publicly. All of this was weird, and trying, but it was also exhilarating. Nothing else I've written, in more than a decade of working as a journalist, has generated this mixture of fascination and hostility.

I spent hours on end emailing with peeved sources, trying to identify the root of their frustration so I could make a correction or amend my position in a later post. And, while my learn-as-I-go experiment certainly led to mistakes and oversights (followed by corrections, of course), much of the time these people weren't taking issue with the facts I'd presented. What seemed to bother them was my failure to interpret the evidence in a way that fit into a larger narrative.

GMOs = Afghanistan in the 1980s

If the stakes are so low, why do people care so much? I think it has something to do with the role GMOs play in the stories we tell ourselves about agriculture in the modern world. When Dan Charles was researching his (terrific) book, *Lords of the Harvest*, he bumped up against some of the same quandaries I encountered, and concluded that the importance of these narratives was tantamount. "The dispute over genetic engineering involves facts, to be sure," he wrote. "But its parties disagree far more passionately over the *story.* They quarrel over the nature of the characters, the plot, and over the editing. They also feud over the unknowable: the ending."

The debate isn't about *actual* genetically modified organisms — if it was we'd be debating the individual plants, not GMOs as a whole — it's about the stories we've attached to them. Both sides have agreed that this thing, this rhetorical construct we call GMOs, will be used to talk about something bigger. It's the setting for a proxy war, like the one in Afghanistan during the 1980s. In that case, people paid attention to the conflict because it was a stand-in for the Cold War. But few people actually cared about the details of Afghan politics — though those details turned out to be crucially important on Sept. 11, 2001.

Similarly, people care about GMOs because they symbolize corporate control of the food system, or unsustainable agriculture, or the basic unhealthiness of our modern diet. On the other side, people care about GMOs because they symbolize the victory of human ingenuity over hunger and suffering, or the triumph of market forces, or the wonder of science. These larger stories are so compelling that they often obscure the ground truth.

Beneath all this is a fundamental disagreement about technology. At one end you have the Ivan Illich position, which suggests our innovations are hurting more then helping us. At the other end are the technological utopians who see restraints on innovation as intolerably prolonging the suffering that would end in a more perfect future. Hardly anyone sits at these extremes, but most of us have an inclination to err on the side of humility or audacity. This is a hugely important discussion, but it's hard to talk about in the abstract, so we attach it to the example we have at hand: GMOs. The reason it's so hard to see the facts here is that the actual genetically modified organisms have been crowded out by the things they represent. This is a problem.

I'm not opposed to using GMOs as a metaphor to discuss our technological hubris (or prowess) — I just want us to be explicit about it. We should notice when the metaphor begins to diverge from the ground truth. The facts on the ground, in turn, can help us adjust our thinking on the larger issue.

We need metaphors — they're how we come to understand the world. But they grow sterile and useless without a continual exchange between the abstract and the incarnate, between meaning and reality. They become, in fact, cliches — words we repeat without thinking. Which, sadly, is where too much of the conversation about GMOs remains stuck today.

Crop flops: GMOs lead ag down the wrong path

By Tom Philpott

Editor's note: *After we ran What I learned from six months of GMO research: None of it matters , Nathanael Johnson's essay concluding his "Panic-Free GMOs" series, we heard from a lot of people who think that GMOs really do matter. We're publishing three responses: one from Denise Caruso, author of* Intervention: Confronting the Real Risks of Genetic Engineering and Life on a Biotech Planet *; one from Ramez Naam , author of* The Infinite Resource: The Power of Ideas on a Finite Planet *; and — to kick things off today — one from Tom Philpott, whose work long graced these pages and who is now at Mother Jones .*

Before I respond to Nathanael Johnson's assertion that the "stakes are so low" in the debate over GMOs, I want to address a smaller point. "The debate isn't about *actual* genetically modified organisms — if it was we'd be debating the individual plants, not GMOs as a whole," Johnson writes. That's a good place to start: actually existing GMOs. What traits are on the market today, in use by farmers? First, I'll note that there's no shortage of land devoted to GMOs. Since the novel seeds hit the market in 1996, global GM crop acreage has expanded dramatically, reaching 420 million acres by 2012, reports the International Service for the Acquisition of Agri-biotech Applications. That's a combined landmass more than four times larger than California . The pro-GMO ISAAA hails this expansion as "fastest adopted crop technology in the history of modern agriculture."
Yet, for all of that land devoted to GMOs, there are just two traits in wide use: herbicide resistance and pest resistance (Bt). Note, in the below ISAAA chart, the "<1″ at the bottom. That represents the percentage of all global GMO acres planted in crops that aren't either herbicide- or pesticide-tolerant: that is to say, less than 1 percent.

Now, one might ask: But isn't the industry on the brink of rolling out wonder crops — new varieties that are more nutritious, or use water more efficiently, or need less fertilizer? One way to tell is to peek into the U.S. Department of Agriculture pipeline of new GMO products being considered for deregulation. Here we can expect to find the stuff the industry has tested and found rugged and ready for field conditions. What's in there? Thirteen products — nine of which involve herbicide tolerance or insect resistance. Of those nine, five are engineered to resist two herbicides — a dispiriting trend I'll explore more below. The others are an apple variety engineered not to brown, a eucalyptus designed to resist freezing, a potato charged with bruising less easily, and an alfalfa type meant to contain less lignin.
Something tells me that none of these novelty items are destined to crack ISAAA's <1 percent box.

It's true that rice engineered to deliver beta-carotene is due out in 2016 in the Philippines , and that citrus trees engineered to resist a ruinous pathogen have shown promise . Then there are those virus-resistant GM papayas in Hawaii — though it should be noted that the state's entire papaya production covers about 2,000 acres, the size of a moderately sized corn farm in Iowa. But until the "golden rice" and the novel oranges prove effective, durable, and acceptable to a large swath of growers, we live in a world in which upwards of 99 percent of GMOs are engineered for the two traits mentioned above.

And that means that actually-existing GMOs remain essentially an appendage of the pesticide industry, which has dominated the technology from the start. But a fixation on pesticides doesn't fully answer the question of why the industry's vaunted innovation has stagnated into variations on two themes, with a few promising products at the margin. Monsanto, for one, has signaled its intention to diversify away from pesticides by entering what might be called the climate-change-services business ; and back in 2008, the company pledged to create seeds that would "reduce by one-third the amount of key resources required to grow crops by the year 2030," while also doubling yields. More than five years later, where's the progress? For that, I think, we have to look to the fact that genes and traits (the cool things we want plants to do in the field) don't always track on a one-to-one basis. There are single genes that confer resistance to particular herbicides or express the toxic-to-insects trait of *Bacillus thuringiensis*, the basis of Bt corn and cotton. But there's no one gene that regulates the way a plant uses water — which probably explains why Monsanto's "drought-tolerant" corn, deregulated by the USDA in 2012, has fallen with such a thud. In its Final Environmental Assessment of the crop, the USDA delivered quite a caveat. "It is prudent to acknowledge," the agency declared, that the Monsanto product's ability to fend off drought "does not exceed the natural variation observed in regionally-adapted varieties of conventional corn (representing different genetic backgrounds)." Translation: In areas of the U.S. corn belt where drought is typically a factor, conventional breeders had already developed varieties that do just as well under drought conditions as Monsanto's genetically altered product.

Churning out crops designed to require less nitrogen — which involves another complex process beyond the scope of a single gene — has so far proven to be an equally vexed project .
So what we have here, in essence, is a bit of a carnival-game scheme: an industry that lives by trumpeting elusive promises while quietly profiting from old tricks. In that sense, I agree with Johnson: stakes are low in the GMO debate, in that it's an industry that's wildly overhyped — by champions and foes alike.

But there's another sense in which stakes are high indeed. The industry's core traits, herbicide and pesticide resistance, have proven vulnerable. Nearly half — and growing — of all U.S. farms are plagued by weeds resistant to Monsanto's herbicide Roundup , and farmers have responded by jacking up their Roundup doses and adding to them older, more toxic herbicides. Meanwhile, a pest called the western corn rootworm has evolved resistance to Bt corn. Here's NPR's Dan Charles , writing last summer:

It appears that farmers have gotten part of the message: Biotechnology alone will not solve their rootworm problems. But instead of shifting away from those corn hybrids, or from corn altogether, many are doubling down on insect-fighting technology, deploying more chemical pesticides than before. Companies like Syngenta or AMVAC Chemical that sell soil insecticides for use in corn fields are reporting huge increases in sales: 50 or even 100 percent over the past two years.

The failure of these products — a profitable failure, if you make both GMOs and pesticides — has brought industrial-scale agriculture to a crossroads. Farmers could respond by making tweaks that have been proven to maintain productivity while slashing herbicide, insecticide, and fertilizer use — simple changes like adding another crop to the rotation and planting fall cover crops, as demonstrated by a landmark 2012 study by Iowa State University researchers .

Such a relatively minor change in farming practices would bring enormous benefits to society — to name a few, more carbon stored in soil, less fouling of drinking water with agrichemical runoff, and greater resilience to drought in the heart of the U.S. grain belt. U.S. farm policy could and should underwrite a shift to a more diversified and low-input agriculture — an unlikely prospect, given that the industry deftly invests a chunk of its profits in lobbying Congress , and that its "feed the world" rhetoric has won over a broad swath of progressive thought leaders.

Or farmers could head down the path paved for them by Monsanto and its very few peers in the agrichemical/GMO game, including Dow and DuPont. This way involves responding to the plague of resistant weeds by adding yet another herbicide to the mix, through those double-herbicide-resistant products now marching through the USDA's deregulation process.

In a 2012 paper , Penn State researchers pondered what would likely happen if those products make their way onto farm fields. Chances are "actually quite high" that they will give rise to a new generation of superweeds that resist both Roundup and the older, more toxic herbicides that will come into use. And farmers will likely respond just as they responded to the advent of Roundup resistance — by applying ever higher doses. Here's what the Penn State team envisions:

From Mortensen, at al, "Navigating a Critical Juncture for Sustainable Weed Management," BioScience, Jan. 2012The authors predict that glyphosate (Roundup) use will hold steady at high levels — and use of other herbicides, like 2,4-D, will soar.

So it seems to me that the stakes in this fight are indeed quite high. Yet, given what's going on within the halls of the USDA and on our farm fields — corn and soy covers more than half of U.S. cropland , and nearly 90 percent of it is GMO — I wonder if the agrichmemical industry hasn't already won.

Why GMOs matter — especially for the developing world

By Ramez Naam

Editor's note: *After we ran What I learned from six months of GMO research: None of it matters , Nathanael Johnson's essay concluding his "Panic-Free GMOs" series, we heard from a lot of people* *who think that GMOs really do matter. We're publishing three responses: one from Tom Philpott , whose work long graced these pages and who is now at Mother Jones ; one from Denise Caruso,* author of Intervention: Confronting the Real Risks of Genetic Engineering and Life on a Biotech Planet *; and, today, one from Ramez Naam , author of* The Infinite Resource: The Power of Ideas on a Finite Planet **.**

The folks at Grist have kindly allowed me to pen a guest post here with a few thoughts on Nathanael Johnson's excellent series on genetically modified foods and in particular his most recent piece on what he learned from 6 months investigating the GMO debate: that none of it really matters **.**
This most recent piece nails several key points that often go completely missed. When we get down to the specifics, we find that today's GMOs are neither planetary panacea nor unbridled poison. The passionate, emotion-filled debate is more about the lenses through which we see the world as it is about genetically modified foods themselves. The GMO debate is often an emphatic and barely-disguised metaphor for our larger debate about whether technology is destroying the world or saving it, whether we should try to control nature or live within it.
That's not to say the debate, when it touches on GMOs themselves, is balanced. The scientific consensus is that GMOs are as safe to eat as any other food , that they reduce soil-damaging tillage , reduce carbon emissions, reduce insecticide use , and reduce the use of the most toxic herbicides in favor of far milder ones. GMOs have limitations, and some of their benefits are threatened by the rise of pesticide resistance. Even so, on balance, GMOs are safe and produce real benefits. As I wrote at Discover Magazine last year, GMOs achieve many of the goals of organic agriculture **.** (To balance that out, let me state that I also wrote there that GMO supporters should embrace sensible GMO labeling **.**)
But Johnson is also right that, in the U.S., the stakes are not at present world-changing. U.S. farmers could likely get by without GMOs. We might see upticks in toxic pesticide use and river runoffs, in soil-harming tillage, and in carbon emissions, but none of those would prove catastrophic. There might be a very slight reduction in crop yield, but not by much, and not for long. The vast majority of us would never notice.

In that context, I agree that the current debate is more about abstractions, metaphors, and worldviews than it is about the realities on the ground.

Even so, I think there are two important reasons we *should* care about GMOs, and view them, certainly not as panaceas, but as imperfect but important tools that can improve the lives of millions of people *right now* and possibly have an impact on *billions* of lives and millions of square miles of nature in the decades to come.

Why We Should Care — The Long Term

The Food and Agriculture Organization of the UN estimates that we need to grow 70 percent more food by 2050 **.** Either we do this on the same land we have today, or we chop down forest to create farms and pastures to meet that demand, something no one wants to do.
Jon Foley at the Institute on the Environment points out, quite rightly, that it's meat consumption, not population, that's driving global food demand. So we could, instead, reduce meat

consumption . That's a noble goal. Unfortunately, meat consumption has roughly quadrupled in the last 50 years , primarily driven by increasing wealth in the developing world, with no sign of stopping. I welcome any practical plan to reduce meat consumption worldwide, but until then, we have to find a way to keep boosting food production.

Another way to feed the world is to close the "yield gap" between farms in the rich and poor worlds. Farmers in the U.S. grow twice as much food per acre as the world overall, largely because they can afford farm equipment, fuel, fertilizer, and pesticides that many farmers in the developing world can't. Some of this gap, undoubtedly, will be closed as poverty drops around the world. But it's unrealistic to assume that all of it will.

What are we to do? On the horizon are some GMOs in development that could provide a dramatic boost here.

1. **Better photosynthesis.** Corn and sugarcane grow nearly twice as much food per acre as the crops humans eat most: rice and wheat. Why? Corn and sugarcane have a better way of doing photosynthesis — of turning light, plus water, plus CO2 into carbohydrates. This newer system is called C4 photosynthesis. Researchers around the world — funded by nonprofits like the Gates Foundation — are working on creating C4 Rice and C4 Wheat. Those crops could grow 50 percent more food per acre.
2. **Self-fertilizing crops.** Fertilizer boosts plant growth by adding nitrogen, and access to fertilizer is one reason rich nation farms grow so much more food per acre than their developing world counterparts. But fertilizer runoff is also responsible for the Gulf dead zoneand similar zones around the world. Some crops, though, can fertilize themselves by pulling nitrogen from the air. Legumes, like soy, peas, and clover do this. Another nonprofit funded GMO research area is to transfer this ability to cereal crops, creating self-fertilizing wheat, corn, and rice . That would have two advantages: It would boost yields for poor farmers who can't afford additional fertilizer; and it would cut down on nitrogen runoff that creates these ocean dead zones.

These are just two projects among many, along with creating more drought-resistant crops, more salt-resistant crops, and crops that have higher levels of vitamins and minerals that people need.

Now, let me be very clear. Most of these are research projects. They're not in the here and now. They're not going to arrive this year, and probably not in the next 10 years. And we do continue to make great progress in improving crops through conventional breeding. But we're unlikely to ever get to, say, C4 rice or C4 wheat through conventional breeding.

The bigger point here isn't that we absolutely need GMOs to feed the future world. If we banned all future GMO development and planting, we'd most likely muddle through in some way. Humanity is good at innovating, particularly when our back is to the wall. But we'd be fighting this battle to keep increasing food output with one arm tied behind our back. We might make *less* progress in boosting yields, without GMOs, meaning food prices would be higher, hunger would be higher, or we'd have more pressure to chop down forests to grow food.

Or maybe we'd be just fine. But given the size of the challenge, and the absence of any credible evidence of harm from GMOs, robbing ourselves of this part of our toolkit strikes me as foolish.

Why We Should Care — The Here and Now

By Ramez Naam

The future's easy to discount. So let's come back to the present, and in particular, the present reality for the 6 billion people who live outside of the rich world.

Until recently, the majority of the acres of GM farmland in the world have been in rich nations. Today, the U.S. ranks first, followed by Brazil and Argentina (what we'd call middle income nations), and then Canada (another rich nation). That means that when we look at how GM crops perform, we tend to focus on how they do in countries where farmers have access to farm equipment, fertilizer, pesticides, irrigation, and so on. And in those countries we see a real but modest benefit.

In the developing world, it's markedly different.

India allows only one genetically modified crop: GM cotton with the Bt trait, which makes the cotton naturally resistant to insects and reduces the need to spray insecticides. In the U.S., there's a broad consensus that Bt corn has reduced insecticide spraying (which is good) but less evidence that it's increased how much food is actually produced per acre, at least to a significant degree. In India, where quite a large number of farmers can't readily afford pesticides, and where they lack farm equipment, meaning that pesticides must be applied by hand, the situation is dramatically different.

For the decade between 1991 and 2001, cotton yields in India were flat, at around 300 kilograms per hectare (a hectare is about 2.5 acres). In 2002, Bt cotton was introduced into the country. Farmers adopted it quickly, and yields of cotton soared by *two thirds* in just a few years to more than 500 kilograms per hectare.
Between 1975 and 2009, researchers found that Bt cotton produced 19 percent of India's yield growth , despite the fact that it was only on the market for 8 of those 24 years. The simpler view is that Bt cotton, in India, lifts yields by somewhere between 50 percent and 70 percent. You can see for yourself in the graph below.

Why does this matter? There are 7 million cotton farmers in India. Several peer reviewed studies have found that, because Bt cotton increases the amount of crop they have to sell, it raises their farm profits by as much as 50 percent , helps lift them out of poverty and reduces their risk of falling into hunger . By reducing the amount of insecticide used (which, in India, is mostly sprayed by hand) Bt cotton has also massively reduced insecticide poisoning to farm workers there — to the tune of 2.4 *million* cases per year.
You may perhaps be wondering: Don't GMOs lead to more farmer suicides in India? And while farmer suicides in India are real, and each one is a tragedy, the link is false. Farmer suicides have been going on long before GMOs, and, if anything, the farmer suicide rate has slightly droppedsince the introduction of GM seeds.
In China we've seen similar impacts of Bt cotton , with multiple studies showing that Bt cotton increased yields, boosted the incomes of 4 million smallholder farmers, and reduced pesticide poisoning among them.

All of this is to say that GM crops have more impact in poor countries than rich ones**.** Where other types of inputs, like fertilizers, farm equipment, and pesticides are harder to afford, GM crops have more to offer**.** That can help increase food, reduce pressure on deforestation, and lift farmers out of poverty**.**

But the world's poorest countries, and in particular India and the bulk of sub-Saharan Africa, don't allow any GM *food crops* to be grown**.** India came close to approval for a Bt eggplant (or Bt brinjal)**.** Studies showed that it was safe, that it could cut pesticide use by half, and that it could nearly double yields by reducing losses to insects**.** But, while India's regulators approved the planting and sale, activists cried out, prompting the government to place an indefinite moratorium on it**.** Similar things have happened elsewhere. The same Bt eggplant was supported by regulators in the Philippines who looked at the data, but then blocked by the court on grounds that reflected not specific concerns, but general, metaphorical, and emotional arguments that Nathanael Johnson describes as dominating the debate**.**

That's a pity. Because if Bt food crops could produce similar size gains in the developing world, that would be a tremendous benefit**.** Insect losses are a tremendously larger challenge in India and Africa than in the U.S. Boosting the amount of food that a farm produces by half or more means less hunger, more income for farmers (still the majority of the population in the world's poorest countries), and more ability of people to pull themselves out of poverty**.**

The same arguments that kept Bt eggplant out of the Philippines have also been used, often by western groups, to keep GM crops out of virtually all of Africa, as documented by Robert Paarlberg in his powerful (and to some, infuriating) book *Starved For Science* **.**

I have absolutely no doubt that the opponents of genetically modified foods, and particularly those campaigning against their planting in the developing world, are doing this with the best of intentions**.** They fully believe that they're protecting people in Africa, India, the Philippines, and elsewhere against poisons, against corporate control of their food, or against destruction of their environment**.** Yet I wish more of them would read Nathanael Johnson's carefully thought-out series here and in particular his argument that most of the debate is highly inflamed **.**

Most of the perceived ills of genetically modified foods are either illusory or far smaller than believed**.** And what the data suggests is that the benefits, while modest in the rich world today, might be quite substantial in the future, and are already much larger in the parts of the world where the battle over GMO approval is most actively raging**.**

GMOs are neither poison nor panacea**.** What they are is a toolkit, a varied one, with real benefits to the environment and millions of people today; with the real potential to have a larger positive impact *immediately* if they're allowed to; and with the possibility of a dramatically larger benefit down the road as the science behind them improves**.**

Ramez Naam (@ramez on Twitter) is the author of The Infinite Resource: The Power of Ideas on a Finite Planet, a book about the challenges of energy, climate change, food, water, and population, and our best chances to innovate to overcome them**.**