

Science AMA Series: We authored a recent report on experiences with and prospects for genetically engineered crops (sometimes referred to as GMOs) for the National Academies of Science, Engineering, and Medicine, Ask Us Anything!

NAS-GMO-Report <sup>1</sup> and r/Science AMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

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#### CORRESPONDENCE:

**DATE RECEIVED:**  
September 20, 2016

**DOI:**  
10.15200/winn.147428.85845

**ARCHIVED:**  
September 19, 2016

**CITATION:**  
NAS-GMO-Report , r/Science , Science AMA Series: We authored a recent report on experiences with and prospects for genetically engineered crops (sometimes referred to as GMOs) for the National Academies of Science, Engineering, and Medicine, Ask Us Anything!, *The Winnower* 3:e147428.85845 , 2016 , DOI: [10.15200/winn.147428.85845](https://doi.org/10.15200/winn.147428.85845)

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How can we show the public that gmos are not, by nature, bad?

[TheHarbinger1628](#)

OK--I am new to Reddit and see that there are quite a few questions and comments related to public perception. These are not easy to answer. Some people have commented on the problem of "science illiteracy" and others have brought up the fact that some of the research is done by or funded by industry. First, just a little bit on science literacy. Of course I wish citizens new more about how to distinguish a good scientific study from a bad one. And, I think more effort should be put into science education that stresses thinking over memorization. That said, I have been studying ecological and health effects of GE crops and foods for a long time and feel very informed on that. I think I'm pretty good at science in general. However, if somebody asked me how I know that climate change is happening or why I use a cell phone even though some studies indicate that they cause cancer, my answer will not be technical. I don't know enough about climate science or cancer biology to evaluate all of the studies. What I rely on more than anything is trust in consensus among specialist researchers in the field who I regard as doing independent research. When there are disagreements among such researchers I can look into some of the studies in more detail and see what the core disagreements are based on. Sometimes that can lead me to decide on one conclusion over another...but not always. More to come. Fred Gould

I once took a plant biotech seminar and learned that it's possible to put transgenes into chloroplast DNA instead of nuclear DNA, which prevents the transgene from being passed on in the gametes and spreading out into wild plants. But I've had a hard time finding more information on this.

Is that a valid option and if so, why isn't it actually implemented? So much focus is put on human health in GMO debates, but spreading transgenes out into the environment seems like one of the most real and serious risks of GMOs to me.

[therearenodogs](#)

From Neal: Transformation of chloroplasts is, for most crops, technically very difficult, which is why you don't hear as much about it as transforming the nuclear genome. There are lots of reasons, as you say, why plastome transformation would be useful. I'd like to improve photosynthesis and also get plants to produce certain compounds--the chloroplasts would be terrific vehicles for these changes.

What would you consider to be the most exciting breakthrough in GMOs, and what kind of changes can we look forward to in the next decade?

[Itz\\_The\\_Bees\\_Knees](#)

From Neal: I used to think it would be something like one of my projects going after something like plants to detect landmines. Maybe so. Now I see genome editing being used as more of a plant breeding tool to accelerate delivery of traits into farmers fields. So, it might be an GMO-invisible approach. Can we use technology, breeding and other approaches to make farming more sustainable? Can we increase photosynthesis in crops and introduce nitrogen fixation to non-legumes? Can we make corn and soybean perennials and fruit trees annuals? There are plenty of grand challenges to address pest and stresses to help feed and clothe people--I'd like to think GE has a role.

What would you consider to be the most exciting breakthrough in GMOs, and what kind of changes can we look forward to in the next decade?

[Itz\\_The\\_Bees\\_Knees](#)

From Neal: I think the ability to engineer crops to fix their own nitrogen--like legumes can--would be a huge win in agricultural sustainability. There are dozens of winning ideas--higher photosynthesis rates, drought and salt resistance, and plants to detect landmines and nuclear fallout are a few things that people are working on.

Thanks for doing this AMA! To Prof. Gould, what are the prospects of land crops being engineered for marine growth? Like growing fruits and vegetables underwater - as a pest deterrent?

[benchmark345](#)

To convert a land grown crop into one that grows in a marine environment would require a huge amount of engineering. As pointed out in the comments on your question, it would probably be easier to engineer quality traits into plants that already grow in marine environments.

Is it possible to use seeds from GMOs, or are most/all sterile? With GMOs pushing more and more farmers to use fewer strains/breeds of plants, is there an increased risk of a catastrophic blight given so many farms will have clones of the same plant, or is this a myth in your opinion? (edit: your, not you)

[ee\\_in](#)

From Neal: Yes and many reasons why you'd want to alter seed biology, as well as that for flowering. You may wish to make sure transgenes don't "escape" by crossing into wild relatives. You may wish to make biofuel plants to make a lot of shoots and no flowers. The whole field of practical plant biotech research area got knocked after the USDA patent that was derided as "Terminator."

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[ee\\_in](#)

Yes, what someone called the "Terminator" or "Traitor" technology was patented by a USDA ARS scientist and there was a lot of public pushback. I can think of ecological reasons to make sterile seeds to limit gene flow--same for pollen--same for decreasing flowering. Plant breeders have been able to do all these things without using GMOs and we don't seem to worry about it. Think about bananas, seedless watermelons, and other examples--these types of plants don't really exist in nature--they are the products of human intervention and ingenuity.

The official reports from all sorts of government groups and scientific societies are important, and I rely on such assessments and consensus sorts of documents on many scientific fronts. Especially those that our outside of my field.

But many of the people who seem to be the most misinformed dismiss these anyway, claiming payoffs and other conspiracies.

What do you think is the best outcome for these kinds of documents? Are you reaching for policy makers? General public? Do you think this accomplished what you'd hoped?

[mem\\_somerville](#)

OK--This is to answer your question, but others have asked similar questions.

There are some people who think GE crops are the best thing since sliced bread and there are others who see them as the devil incarnate. I doubt that our report will change their minds.

Our report is aimed at the public and policy makers (scientists are part of the public too). Our report doesn't lend itself to sound bites because it says that the committee didn't think GE crops could be characterized as one thing. Some could be problematic and some could be good, and the same crop with the same trait could be good or bad depending on where and how it was grown, and what the market access was for the farmers who grew them etc.

As indicated in my other responses, we have tried to make this report as open-access as possible. My hope is that the report will help teachers and other leaders move the public and policy makers away from sound bites and into substantial conversations.

I'd love to see high schools and college's use our report to start conversations in their humanities and science courses. I'd especially love it if university students would go through our report and show us where we are wrong, or missed important references.

We've already had people write to us and point out errors. They are posted on our website at <http://nas-sites.org/ge-crops/2016/05/01/errata/> I'll give the student who finds the most errors a free trip to the National Academies offices in Washington DC.

And for you older folk--- Take our report (on your cell phone) to your next cocktail party or barbeque and when your buddy tells you some "fact" about GE foods, have her/him read what our report says...then start a conversation on how we really know what we know. Fred Gould

The conservation of food plant genetic resources such as indigenously maintained crop land races has been identified by the FAO as one of biggest priorities for helping us meeting global food demand under changing environmental conditions in the future. In your experience, how has the introduction of GMOs into the fields of the indigenous farmers who help maintain these landraces affected their diversity? Further, have you utilized landraces genetics in your programs? If so, how have farmer's been compensated?

Great AMA!

[Kazookidfunfunfun](#)

From Neal: I think it's mostly neutral. I and colleagues addressed this issue in a paper--at least to some degree: Kwit, C. H.S. Moon, S.I. Warwick, C.N. Stewart, Jr. 2011. Transgene introgression in crop relatives: molecular evidence and mitigation strategies. Trends in Biotechnology 29: 284-293.

Stable gene introgression has to happen to affect landraces, wild relatives, etc., and introgression from GE crops to these other plants seems to be a rare event. If introgression occurs, it could be positive, negative or neutral.

What will the use of CRISPER / Cas9 mean to GMO? . How long until I can build my own little shop of horrors plant?

[ShoNff](#)

From Neal: Potentially it can mean precision-bred non-GMO crops--that are not regulated as GMO. If we think about simple gene knockouts of single proteins, they aren't GMOs in any sense of the word. For any GE or non-GE plant breeding outcome, reasonable safety assurance is required as well as trait stability.

How do scientists know which genes can be added to an organism to improve it? Wouldn't some genes be "incompatible" with the organism? Or, how do scientists ensure that the genes are incorporated into the organism's genome? (Thanks for answering!)

[aelin\\_farseer](#)

From Neal: I think that today most plant breeders still don't know what genes to target and select for-- they simply select on traits and maybe try to figure out the genetic basis later. For certain traits like insect resistance, an obvious choice are genes/proteins from organisms known to kill target insects-- like Bt--Fred Gould knows a lot more about this than me. Most of the time plant biotech does use a rational/systematic approach in gene searching for effective control of traits. There are a lot of failures that don't make it out of the lab. Many traits have a complex genetic basis. Some traits we understand a lot better than others.

Who funds/ or how does your research get funded?

With the emergence that some research in certain fields has been sponsored by and influenced by certain companies and industries, it has discredited a lot of the particular field, do you think GMO research also has/or will have this stigma?

[Mirora\\_de VR](#)

Currently, my only research on genetically engineered crops come from the USDA competitive grants

program called BRAG--The Biotechnology Risk Assessment Program.

[https://nifa.usda.gov/sites/default/files/resources/2016%20BRAG%20PD%20Meeting%20Booklet\\_0.pdf](https://nifa.usda.gov/sites/default/files/resources/2016%20BRAG%20PD%20Meeting%20Booklet_0.pdf)

I have other active grants from NSF, NIH, and the W.M. Keck Foundation.

Between 1993 and 2000 I received about \$168,000 in funding from biotech companies but haven't had company support since then for a number of reasons. This amount compares to more than \$11,000,000 that I have received from NSF, USDA, NIH and philanthropic groups not associated with GE crops.

I work for NC State University, and some of its faculty receive funding from biotech companies. Fred Gould

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[Mirora\\_de\\_VR](#)

From Neal: There's definitely an anti-industry stigma. For me, over my career government agencies funded most of it--well over 80%. USDA, NSF, DOE and other agencies, together with with farmer groups and foundations-- about 90% has come from not-for profit entities. Of the industry funding there has been a mix of big ag, little ag and non-ag. I'm happy to say that none of our industry grants ever had any stipulations about not publishing our work, and they've never tried to control the outcomes of the results.

What crop, if modified, has most benefit for humans.

[nullpassword](#)

This is a fantastic question. Corn is the most widely grown crop in the world--most yields. If we could engineer perennality (spelling) into corn and nitrogen fixation, it would make it a lot more sustainable. Perennials are better at sequestering carbon than annuals. Not having to fertilize with nitrogen would mean a lot less N runoff/pollution.

I was wondering how the soil is impacted by the use of plants that grow larger fruits. Is there any greater form of soil degradation because of the larger plants and larger fruits they produce?

[Lurker-below](#)

The bigger the plant (if it is a perennial) the more carbon it should be able to theoretically sequester underground. The higher the yield (seeds and fruit), the more C, N etc., that is removed from the system.

Who is modifying the foods that make it to grocery store shelves? Is it all private companies (i.e. Monsanto) or is research from Universities and/or non-private entities influential at all. What kind of oversight or regulations exist on what genetic modifications are used?

[FullMetalBasket](#)

From Neal: The only non-industry GE food product I know about is the GE virus-resistant papaya developed by Cornell 20 years ago that's widely grown in Hawaii. Most of the other ingredients from GE crops in the grocery store are largely invisible to the consumer--such as vegetable oil (ingredient: soybean oil) and processed food with corn and soybean. Indeed, many products like soybean oil have no DNA and protein in the food and are indistinguishable from their non-GE counterparts.

Could GMO's cause problems if they "escaped" and started mixing with the natural ecosystem? Is that even possible?

[Alsothorium](#)

From Neal: I've studied this for over 20 years. There are precious few examples of transgenes being moved from engineered crops to wild relatives or weeds in the field--transgene introgression. We can make the crosses and do introgressions in the lab and greenhouse, and even in controlled field experiments, but in real life--not so much. There are lots of theories--my personal favorite--we proposed quite a few years ago, was that crop genes (including transgenes) would 'dilute' the weediness or wildness of the weedy or wild plant, which is why it seldom happens. See: Stewart, C.N., Jr. M.D. Halfhill and S.I. Warwick. 2003. Transgene introgression from genetically modified crops to their wild relatives. *Nature Reviews Genetics* 4: 806-817.

In the whole GM debate I always point to Norman Borlaug the so called father of the green revolution who is credited with saving a billion lives worldwide by helping to develop GM crops as the third world needs better resistant and higher yielding crops to sustain their population.

My question is, currently what percentage of company and academic funding is dedicated towards tailoring GM crops towards third world countries compared to first world, and will this likely change over the coming years?

Many thanks for your AMA.

[NoodleScience3](#)

From Neal: Not nearly enough is being done to improve the lives of poorer people in the world--agriculture included. Few entities outside of the Gates Foundation seems interested in funding research to explicitly help the people who need help the most. Nonetheless, some products made for the developed world--like Bt cotton--are being grown in less developed world--but not enough.

Ahhh Frankenfood!! Actually, I'm a proponent. Just curious about the assurances that it's just as healthy (or more) than non GMO food. How is this tested? Are there actually human research trials or are there just lab tests and extrapolation?

[Mister\\_Mxyzptlk69](#)

From Fred Gould Lots of people wonder about how these GE crops and foods are tested. Our report has a full chapter with about 200 references just devoted to reviewing the information on the kinds of testing done to determine if a GE crop could bring with it a health risk. Depending on what country you are in, there are somewhat different requirements for testing, but generally they start by comparing the GE crop variety to a similar conventionally bred variety to see if there is a difference in the nutritional content of the two crop varieties. This composition analysis also looks for specific anti-nutrients and naturally occurring plant toxins to see if their levels have changed. More recently, researchers, but not regulatory agencies, have started to use high throughput genetic testing to see if there are any

differences. Beyond that, many countries require that the GE crop and the related conventional crop variety be fed to lab animals to see if any differences can be found in growth, survival, or in any internal organs or blood workup. The length of these tests varies depending on specific regulations in the country --typically, the tests are only performed once and the data are shared. In our report we did a careful reading of many of the animal studies that were done by/for regulatory agencies, by university researchers, and by industry. While we found problems with the experimental designs and the statistical analyses of some of the tests, as well as the power of the tests to find differences, taking all of the tests together, we found no evidence that GE crops that are now commonly found on the market are any less safe than their conventional counterparts. (We have more than two pages devoted to a careful examination of the Seralini lab articles because those articles have raised concerns for many people--while we see no wrong doing in the work, we found that the statistics used were not appropriate and the results were only preliminary) We also looked at two other sources of information about safety of GE crops: 1) the health and conversion efficiency of livestock that eat GE crops and 2) epidemiological information over a twenty-year period for countries where people do and do not eat GE foods. The results from both of these sources show no evidence of negative health impacts. You can see the findings from chapter 5 of our report that focuses on health effects here: <http://nas-sites.org/ge-crops/2016/05/16/findings-and-recommendations/>

What technologies do you see that will allow us to overcome the limitations of plant regeneration? Specifically I was thinking about corn which requires regeneration from calli to transform and is limited to being done in a select number of varieties.

[Frank Steine](#)

From Neal: A great question. I was part of a big group of scientists that got together last year to discuss this very issue. The grail of plant genetic engineering is to avoid tissue culture altogether and transform egg or pollen on the plant flower. For most species this is hard. So for most species it might be best (for now anyway) to limit the time in tissue culture and maybe also reprogram certain plant developmental pathways for inducible shoot regeneration. The team's perspective on strategies are here: Altpeter, F., N.M. Springer, L.E. Bartley, A.E. Blechl, T.P. Brutnell, V. Citovsky, L.J. Conrad, S.B. Gelvin, D.P. Jackson, A.P. Kausch, P.G. Lemaux, J.I. Medford, M.L. Orozco-Cárdenas, D.M. Tricoli, J. Van Eck, D.F. Voytas, V. Walbot, K. Wang, Z.J. Zhang, C.N. Stewart, Jr. 2016. Advancing crop transformation in the era of genome editing. *Plant Cell* 15:1510-1520 doi: <http://dx.doi.org/10.1105/tpc.16.00196>

I'm currently at NCSU, so it's pretty cool to see this post on the front page. I'll ask something simple: what are your thoughts on GMO product labels?

[howlitup](#)

With these hundreds of great questions, it hard to know who to respond to...but for a student? from my university, I need to respond.

Our committee had long conversations with FDA and they rightly maintained that by law, they could themselves only require labeling if there was a difference between GE and Non-GE foods in terms of nutrition or health effects. However, they pointed out that Congress didn't have that restriction and that in the past Congress has required labeling for non-health reasons (e.g. country of origin of produce). In our report, we didn't take a stand on whether or not to label. We said that there was no health reason to label but that citizens have the "right-to-know" what they are buying. Since our report came out, the congress has passed a mandatory labeling law, but there are questions of whether all consumers will have equal access to the labels if you need a smart phone to read the content of the label. fred gould

What are scientists doing to prevent crops from overtaking natural plants and becoming "super crops," thus destroying ecosystems?

Or rather, when GE crops grow where they aren't supposed to, what steps have you taken to stop these crops from becoming invasive?

[DallasGenoard](#)

From Neal: Most crop varieties grown today didn't exist a few years ago, and most of the ones that existed a few years ago don't exist today. If crops of any sort were invasive, the latter wouldn't be the case. Crops are generally not invasive. When humans disappear from earth, so will corn. It needs us more than we need it.

How do we change the narrative on GMO foods and convince the March against Monsanto's that it isn't such a bad thing and that GMO foods are of significant benefit to mankind?

[Gawkawa](#)

As a number of commenters have said, people do get entrenched in positions they have taken earlier. Often when we get into discussions we are thinking a lot about how we can change somebody else's opinion, but how often do we go into these encounters thinking that our opinion may change. Our committee was well aware of this dynamic in ourselves and others. We tried to come to meetings and to the literature with fresh eyes.

In putting our report on the website in searchable form, our hope was that people would have the opportunity to look at the spots in the report that addressed their question or concern, and that they could look for themselves at the evidence we used to come to our conclusions. --With that information in hand we hoped that they would then have more of an ability to judge for themselves if our conclusions had merit. One issue brought up below is that many studies are run or funded by industry. We realized that some readers wouldn't trust such studies. For this reason we went over more than 900 of the studies that we quoted and have a special section on the website where we list the first author of every one of those papers and that author's affiliation. For about half of the papers we were also able to find the source of funding for the study and posted that as well. You can find this list by going to the "report" drop down menu. There is a separate list for chapters 3, 4, and 5. <http://nas-sites.org/ge-crops/2016/05/02/reference-funding-chapter-4/> <http://nas-sites.org/ge-crops/2016/05/02/reference-funding-chapter-5/> <http://nas-sites.org/ge-crops/2016/05/02/reference-funding-chapter-6/>

Fred Gould