UNDERSTANDING GENETICALLY MODIFIED CROPS AND OPINIONS ABOUT THEM … AT LEAST SORT OF

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UNIVERSITY OF ILLINOIS EXTENSION

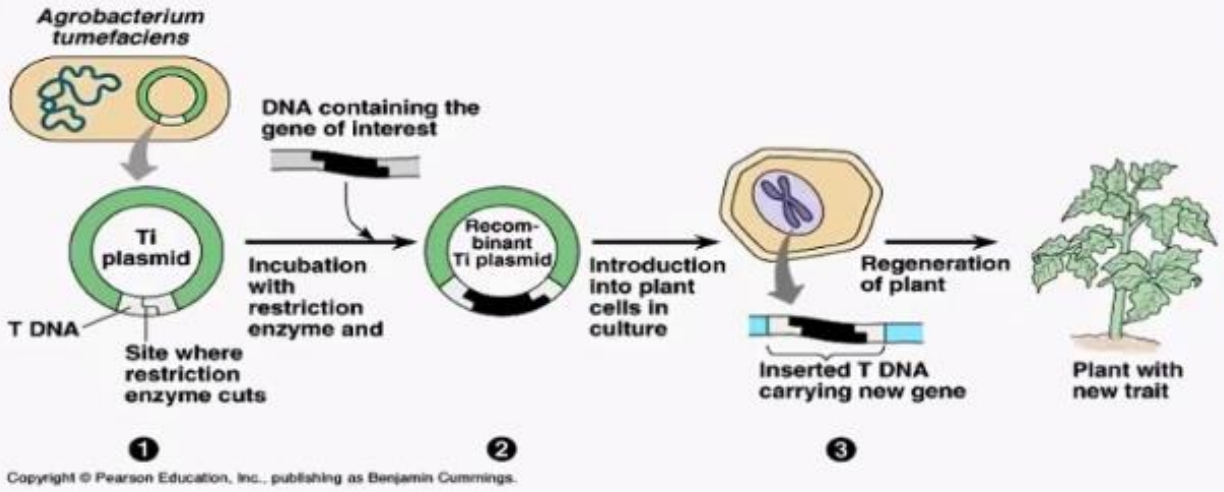
Plant breeding

- Selection of seed from desirable plants (usually foods)
- Crosses (hybridization) to increase desirable traits
  - Consider that desirable traits take many forms … yields, flavor, nutrition, health impacts, insect and disease resistance, suitability for storage and transport … and more
- Crosses are followed by back-crosses (repeatedly) to “concentrate” desirable traits for seed or clone production
- “Mutation breeding” to produce instead of just use traits that are desirable

All of these approaches moved wanted and unwanted genes into new varieties or hybrids … continued selection resulted in (or did not result in) optimal cultivars

- Biotechnological methods to move specific genes (within or between species) by means other than crossing by traditional breeding
- Gene mapping to identify traits not observable by physical observation

Genetic Engineering



Beneficial genes and traits from *any* organism may be used.

Genes are introduced / transferred by way of bacterial plasmids (left), viruses (vectors), “gene guns,” and very specific CRISPR and TALEN techniques

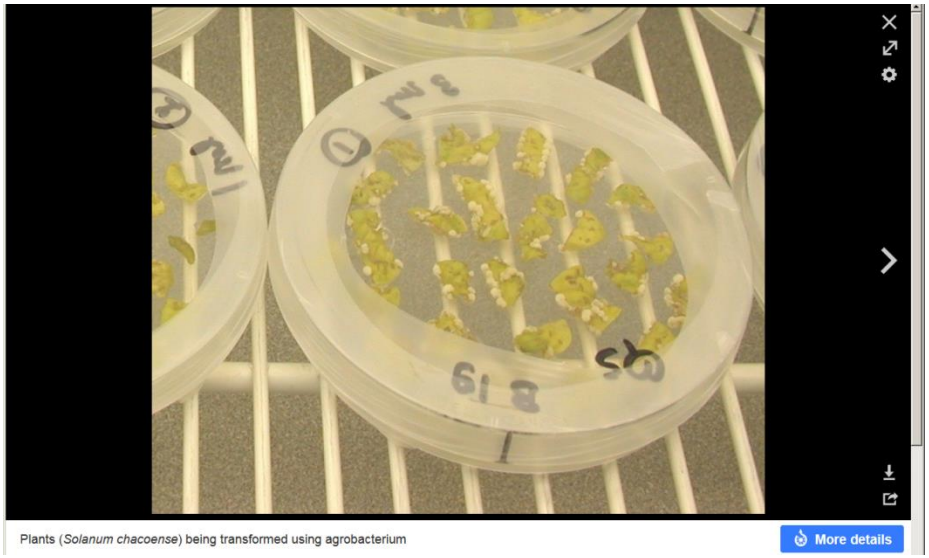
Transgenic methods for host plant resistance

- Advantages
  - Speed
  - Specificity of genetic change (in contrast with traditional breeding, including mutation breeding)
  - Phenomenal increase in possible genetic sources of resistance
- Disadvantages
  - Scientific and public concern about nontarget impacts and human health
    - Subsequent export and domestic market concerns
  - Pest biotypes that overcome resistance
  - Panacea and panic attitudes

Between or within species?

- Transgenic: Genes moved by biotech methods come from a different species (Bt corn, Roundup-resistant crops)
- Cisgenic: Genes moved by biotech methods come from the same species, but the crop is difficult or cumbersome to crossbreed by conventional means (potatoes, apples)
- Subgenic: Removal of genes by biotech methods (powdery mildew resistance in wheat, 2014 … no development yet)

After transfer or modification …



- Markers (genetic assessments or otherwise) determine success of modification
- Key inbreds are directly transformed, then traditional breeding is used to incorporate the new genes into additional hybrids or cultivars … with all the challenges involved in crosses, backcrosses, and production

References?

- Anti
  - http://www.gmeducation.org/
- Middle
  - "Fields of gold" … research on transgenic crops must be done outside industry if it is to fulfill its early promise. Nature 2013. http://www.nature.com/news/fields-of-gold-1.12897
  - "With GM crops, a good gauge of a statement's fallacy is the conviction with which it is delivered."
- Pro
  - The Truth About GMOs. Boston Review. http://www.bostonreview.net/forum/pamela-ronald-gmo-food

Better choice: *Straight Talk on Genetically Engineered Foods*. Center for Science in the Public Interest. 2015. http://cspinet.org/new/pdf/biotech-faq.pdf (still expresses opinions, but generally well balanced – in my opinion)

Genetically modified crops … on Wikipedia

- http://en.wikipedia.org/wiki/Genetically_modified_crops
  - A broad overview that includes …
    - In general, the way genes are transferred; see http://en.wikipedia.org/wiki/Techniques_of_genetic_engineering
    - The kind of traits developed or under development -- improved shelf life, disease resistance, stress resistance, herbicide resistance, pest resistance, production of useful goods such as biofuel or drugs, and ability to absorb toxins and for use in bioremediation of pollution. Some research and development has been targeted to enhancement of crops that are locally important in developing countries, such as insect-resistant cowpea for Africa[59] and insect-resistant brinjal (eggplant) for India.[60]
    - See the listing of examples of genetically modified crops.

Crop	Traits	Modification[specify]	Percent modified in US	Percent modified in world
Alfalfa	Resistance to glyphosate or glufosinate herbicides	Genes added	Planted in the US from 2005–2007; 2007–2010 court injunction; 2011 deregulated	
Canola/ Rapeseed	Resistance to herbicides (glyphosate or glufosinate), see Roundup Ready Canola high laurate canola,[114] Oleic acid canola[115]	Genes added	87% (2005 data[113])	21%
Corn	Resistance to glyphosate or glufosinate herbicides. Insect resistance via producing Bt proteins, some previously used as pesticides in organic crop production. Added enzyme, alpha amylase, that converts starch into sugar to facilitate ethanol production.[116]	Genes, some from Bt, added.[117]	Herbicide-resistant: 2013, 85%[118] Bt: 2013, 76%[118] Stacked: 2013, 71%	26%
Cotton (cottonseed oil)	Kills susceptible insect pests	Gene for one or more Bt crystal proteins added	Herbicide-resistant: 2013, 82%[118] Bt: 2013, 75%[118] Stacked: 2013, 71%[118]	49%
Papaya (Hawaiian)	Resistance to the papaya ringspot virus.[119]	Gene added	80%	
Potato (food)	NewLeaf: Bt resistance against Colorado beetle and resistance against Potato virus Y (removed from market in 2001[102]) "Innate" potatoes from Simplot that form less acrylamide when fried and bruise less[72]	Bt cry3A, coat protein from PVY[120] "Innate" potatoes added genetic material coding for mRNA for RNA interference[72]	0%	0%
Potato (starch)	Amflora: resistance gene against an antibiotic, used for selection, in combination with modifications for better starch production[121]	Antibiotic resistance gene from bacteria Modifications to endogenous starch-producing enzymes	0%	0%
Rice	Golden Rice: genetically modified to contain beta-carotene (a source of vitamin A)	Genes from maize and a common soil microorganism.[122][123]	Forecast to be on the market in 2015 or 2016[124]	
Soybeans	Resistance to glyphosate (see Roundup Ready soybean) or glufosinate herbicides Make less saturated fats (high oleic acid);[125] Kills susceptible insect pests	Herbicide resistant gene taken from bacteria added Knocked out native genes that catalyze saturation Gene for one or more Bt crystal proteins added	2013: 93%[118]	77%

Squash (Zucchini/Courgette)	Resistance to watermelon, cucumber and zucchini/courgette yellow mosaic viruses[115][126][127]	Coat protein genes of viruses.	13% (figure is from 2005)[113]	
Sugar beet	Resistance to glyphosate, glufosinate herbicides	Genes added	95% (2010); regulated 2011; deregulated 2012	9%
Sugarcane	Resistance to certain pesticides High sucrose content.	Genes added		
Sweet peppers	Resistance to cucumber mosaic virus[128][129]	Coat protein genes of the virus.		Small quantities grown in China
Tomatoes	Suppression of the enzyme polygalacturonase (PG), retarding fruit softening after harvesting,[130] while at the same time retaining both the natural color and flavor of the fruit	Antisense gene) of the gene responsible for the production of PG enzyme added	Taken off the market due to commercial failure.	Small quantities grown in China
Wheat	Resistance to glyphosate herbicide	Genes added	unknown	unknown

Plus …

- DroughtGard maize, production of pharmaceuticals by plants (carrot and tobacco), plants better suited for biofuels, materials, bioremediation.

See: http://en.wikipedia.org/wiki/Genetically_modified_crops

Currently …

- Widely planted in the US (and elsewhere)
  - Roundup (and other) herbicide-resistant canola, corn, cotton, soybean, sugarbeet
  - Bt corn and cotton (genes produce toxins that kill specific insects)
- Other crops …
  - Bt sweet corn
  - Papayas resistant to papaya ringspot virus
  - Summer squash resistant to certain “mosaic” viruses
  - Bruise-resistant potatoes, reduced acrylamides
  - Browning-resistant apples
- Pending (among others)…
  - Golden rice with vitamin A
  - Bt eggplant

Global Response to GMOs

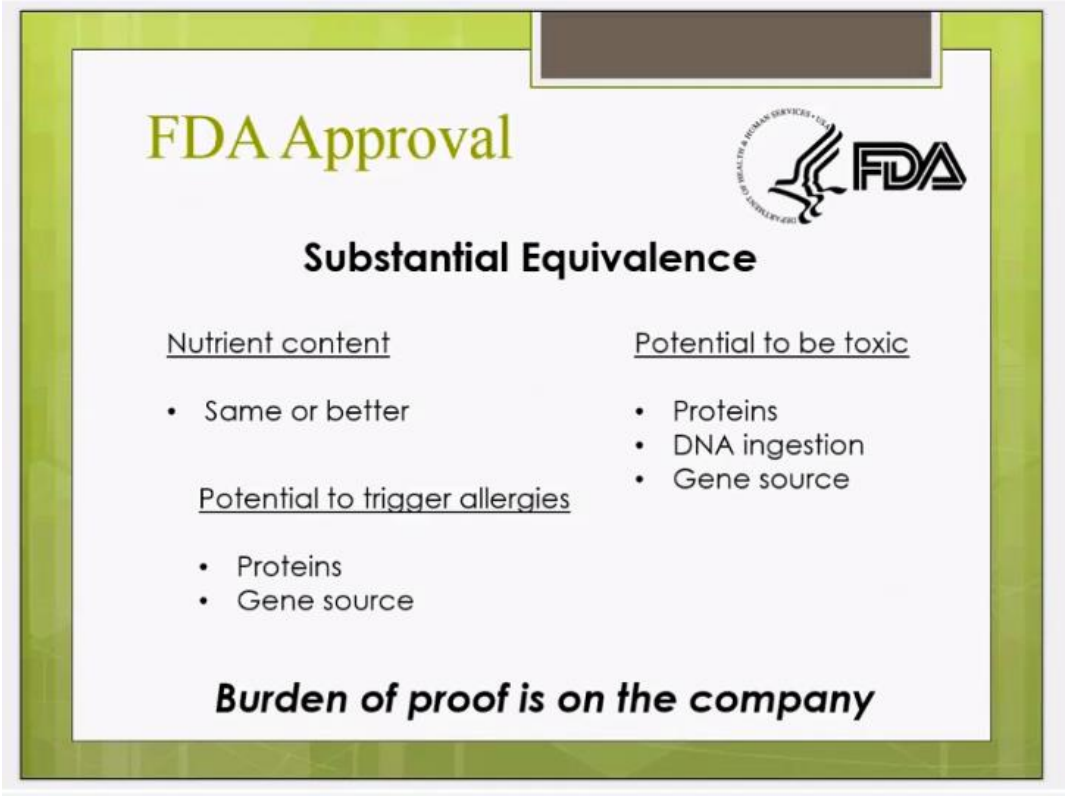
AS OF 2013, GMOS ARE **GROWN**, **IMPORTED**, AND/OR USED IN **FIELD TRIAL RESEARCH** IN **70 COUNTRIES**.

Source: ISAAA

Yield and economic benefit

- Genetically modified crops on Wikipedia …
  - http://en.wikipedia.org/wiki/Genetically_modified_crops
- In 2014 the largest review yet concluded that GM crops' effects on farming were positive. The meta-analysis considered all published English-language examinations of the agronomic and economic impacts between 1995 and March 2014. The study found that herbicide-tolerant crops have lower production costs, while for insect-resistant crops the reduced pesticide use was offset by higher seed prices, leaving overall production costs about the same.[58]
- Yields increased 9% for herbicide tolerance and 25% for insect resistance. Farmers who adopted GM crops made 69% higher profits than those who did not. The review found that GM crops help farmers in developing countries, increasing yields by 14 percentage points.[58]
- The researchers considered some studies that were not peer-reviewed, and a few that did not report sample sizes. They attempted to correct for publication bias, by considering sources beyond academic journals. The large data set allowed the study to control for potentially confounding variables such as fertiliser use. Separately, they concluded that the funding source did not influence study results.[58]

A Meta-Analysis of the Impacts of Genetically Modified Crops. Wilhelm Klümper, Matin Qaim. Published: November 03, 2014. PLOS ONE. DOI: 10.1371/journal.pone.0111629.
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0111629



Approvals required:

FDA Food safety
EPA Environmental safety
USDA Crop “compatibility”

- The Safety of Genetically Modified Foods Produced through Biotechnology (http://toxsci.oxfordjournals.org/content/71/1/2.full)

  - The Society of Toxicology (SOT) is committed to protecting and enhancing human, animal, and environmental health through the sound application of the fundamental principles of the science of toxicology. It is with this goal in mind that the SOT defines here its current consensus position on the safety of foods produced through biotechnology (genetic engineering).
  - The available scientific evidence indicates that the potential adverse health effects arising from biotechnology-derived foods are not different in nature from those created by conventional breeding practices for plant, animal, or microbial enhancement, ..
  - At present, no verifiable evidence of adverse health effects of BD (biotechnology-derived) foods has been reported, although the current passive reporting system probably would not detect minor or rare adverse effects or a moderate increase in effects with a high background incidence such as diarrhea.
  - A continuing evolution of toxicological methodologies and regulatory strategies will be necessary to ensure that the present level of safety of biotechnology-derived foods is maintained in the future.

Toxicity to humans … safety of GMO foods

- http://en.wikipedia.org/wiki/Genetically_modified_food_controversies
  - While there is concern among the public that eating genetically modified food may be harmful, there is broad scientific consensus that food on the market derived from these crops poses no greater risk to human health than conventional food.[1][2][3] The safety assessment of genetically engineered food products by regulatory bodies starts with an evaluation of whether or not the food is *substantially equivalent* to non-genetically engineered counterparts that are already deemed fit for human consumption.
  - Equivalency … opponents argue that patents, etc. contradict the equivalency argument … but trademarking and other royalty-producing registrations are used for countless varieties of conventionally bred crops as well.

More on toxicity … the Séralini affair

- http://en.wikipedia.org/wiki/S%C3%A9ralini_affair
  - Paper published in Food and Chemical Toxicology reported negative impacts of a Bt corn and Roundup … widely criticized scientifically and widely cited by GMO critics
  - Brings up issues of
    - Scientific methods in toxicology testing
    - Bias
    - Methods of publication and reporting

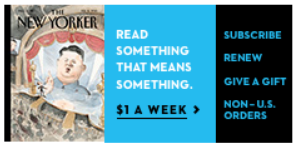
Séralini, Gilles-Eric; Clair, Emilie; Mesnage, Robin; Gress, Steeve; Defarge, Nicolas; Malatesta, Manuela; Hennequin, Didier; De Vendômois, Joël Spiroux (2012). "Long term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified maize". *Food and Chemical Toxicology* **50** (11): 4221–31. doi:10.1016/j.fct.2012.08.005. PMID 22999595. **(Retracted)**

Death by GMO?

- The story purports to reveal the death of a man in Spain, caused by his consumption of a genetically modified tomato containing genes from fish.
- Source: Satirical news site *World News Daily Report.* Its disclaimer states, "WNDR assumes however all responsibility for the satirical nature of its articles and for the fictional nature of their content. All characters … – even those based on real people – are entirely fictional and any resemblance between them and any persons, living, dead, or undead is purely a miracle."
- There are no GMO tomatoes approved for sale in Europe, and the only GMO tomato ever to be marketed anywhere, the GMO Flavr-Saver tomato, did not contain any genes from fish. Even it is no longer on the market.

Story site: http://worldnewsdailyreport.com/doctors-confirm-first-human-death-officially-caused-by-gmos/. Fact-check site: http://www.inquisitr.com/1899679/did-gmo-tomatoes-kill-juan-pedro-ramos/

- OMG GMO SMDH. New Yorker magazine, September 24, 2013 (http://www.newyorker.com/tech/elements/omg-gmo-smdh)
- Seeds of Doubt, New Yorker magazine, August 26, 2014 (http://www.newyorker.com/magazine/2014/08/25/seeds-of-doubt)
  - Comments, tweets, and emails to Michael Specter (New Yorker), Nathanael Johnson (Grist), and Mark Lynas reveal the emotional nature of anti-GMO opinions



SEPTEMBER 24, 2013

"OMG GMO" SMDH

BY MICHAEL SPECTER

I recently watched "OMG GMO," Jeremy Seifert's aggressively uninformed "documentary" about the corporate duplicity and governmental callousness that he says drives the production of genetically engineered crops—which are, in his view, such barely concealed poisons that he actually dressed his children in full hazmat gear before letting them enter a field of genetically modified corn. Seifert explained his research process in an interview with Nathanael Johnson of Grist: "I didn't really dig too deep into the scientific aspect."

…

Seifert asserts that the scientific verdict is still out on the safety of G.M. foods—which I guess it is, unless you consult actual scientists. He fails to do that. Instead, he claims that the World Health Organization is one of many groups that question the safety of genetically engineered products. However, the W.H.O. has been consistent in its position on G.M.O.s: "No effects on human health have been shown as a result of the consumption of G.M. foods by the general population in the countries where they have been approved."

…

By themselves, genetically engineered crops will not end hunger or improve health or bolster the economies of struggling countries. They won't save the sight of millions or fortify their bones. But they will certainly help. First, though, we have to adopt reality as our principal narrative. For people like Jeremy Seifert, that may be too much to ask.

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SEEDS OF DOUBT

An activist's controversial crusade against genetically modified crops.

BY MICHAEL SPECTER

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Shiva, who expressed her anger on Twitter: "#MarkLynas saying farmers shd be free to grow #GMOs which can contaminate #organic farms is like saying #rapists shd have freedom to rape."

Shiva: “The Centers for Disease Control and Prevention has said that in two years the figure of autism has jumped from one in eighty-eight to one in sixty-eight,” she said, referring to an article in *USA Today*. “Then they go on to say obviously this is a trend showing that something’s wrong, and that whether something in the environment could be causing the uptick remains the million-dollar question. “That question’s been answered,” Shiva continued. She mentioned glyphosate, the Monsanto herbicide that is commonly used with modified crops. “If you look at the graph of the growth of G.M.O.s, the growth of application of glyphosate and autism, it’s literally a one-to-one correspondence. And you could make that graph for kidney failure, you could make that graph for diabetes, you could make that graph even for Alzheimer’s.”

Shiva had committed a common, but dangerous, fallacy: confusing a correlation with causation. (It turns out, for example, that the growth in sales of organic produce in the past decade matches the rise of autism, almost exactly. For that matter, so does the rise in sales of high-definition televisions, as well as the number of Americans who commute to work every day by bicycle.)

In a recent speech, Shiva explained why she rejects studies suggesting that genetically engineered products like Pental's mustard oil are safe. Monsanto, she said, had simply paid for false stories, and "now they control the entire scientific literature of the world." *Nature, Science,* and *Scientific American*, three widely admired publications, "have just become extensions of their propaganda. There is no independent science left in the world."

Monsanto is certainly rich, but it is simply not that powerful. Exxon Mobil is worth seven times as much as Monsanto, yet it has never been able to alter the scientific consensus that burning fossil fuels is the principal cause of climate change. Tobacco companies spend more money lobbying in Washington each year than Monsanto does, but it's hard to find scientists who endorse smoking. The gulf between the truth about G.M.O.s and what people say about them keeps growing wider. The Internet brims with videos that purport to expose the lies about genetically modified products. Mike Adams, who runs a popular Web site called Natural News, recently compared journalists who are critical of anti-G.M.O. activists such as Shiva to Nazi collaborators.

The most persistent objection to agricultural biotechnology, and the most common, is that, by cutting DNA from one species and splicing it into another, we have crossed an invisible line and created forms of life unlike anything found in “nature.” That fear is unquestionably sincere. Yet, as a walk through any supermarket would demonstrate, nearly every food we eat has been modified, if not by genetic engineering then by more traditional cross-breeding, or by nature itself. Corn in its present form wouldn’t exist if humans hadn’t cultivated the crop. The plant doesn’t grow in the wild and would not survive if we suddenly stopped eating it.

When it comes to medicine, most Americans couldn’t care less about nature’s boundaries. Surgeons routinely suture pig valves into the hearts of humans; the operation has kept tens of thousands of people alive. Synthetic insulin, the first genetically modified product, is consumed each day by millions of diabetics. To make the drug, scientists insert human proteins into a common bacteria, which is then grown in giant industrial vats. Protesters don’t march to oppose those advances. In fact, consumers demand them, and it doesn’t seem to matter where the replacement parts come from.

Concerns

- Resistance management
  - High-dose expression, amount and suitability of refuges (covered in part in discussion of HPR)
  - Related concerns re: herbicide resistance traits
    - Failure to implement resistance management programs for glyphosate (Roundup)
    - Pending threats to nearby crops with use of 2,4-D-resistant and dicamba-resistant soybeans
- Pollen contamination and outcrossing
  - Within species to organic crops
  - Outcrossing to wild plants
- Potential threat to nontarget organisms in agroecosystems
  - Monarchs, specific parasitoids, etc.

Traits for herbicide resistance

- Glyphosate resistance … glyphosate used in nearly all US corn and soybean plantings
  - No resistance management plans (refuges)
  - Resistant weeds have evolved
  - NOT “super weeds”
- Registration of (glyphosate and) 2,4-D- or Dicamba-resistant soybeans
  - Growth regulators with potential for drift damage
  - Currently used in grassses (corn, wheat, lawns)
  - Potential for drift and crop damage pits vegetable and fruit growers against corn and soybean growers

Genetic drift

- Outcrossing
  - Potential issue for ~~sorghum~~ and canola, for example, because of related weeds (Johnson grass and mustards, etc.)
    - Troublesome for either BT traits (protection against insects) or herbicide resistance
- Pollen drift to organic crops
  - Does occur (from GMO and non GMO crops of same variety and maturity nearby)
  - Impact?

Consumer opinions and therefore market and export opportunities

- Labeling … see http://www.marklynas.org/2013/10/why-we-need-to-label-gmos/ by a now pro-biotech writer, Mark Lynas
  - Referenda in several states, most defeated … your thoughts?
- Science
  - Biased?
  - Aloof?
  - Scientific illiteracy? (And mistrust)
- GMO's enabling role in food system problems
  - Large farms, government subsidies, monocrops, hypoxia in the Gulf of Mexico, herbicide drift
- Monsanto's reputation
  - Not easy to love

These issues muddy the waters on discussion safety of biotechnology-derived foods

Labeling Legislation

Passed

CT
ME

Failed

CA
CO
OR
WA

Pending

VT

U.S. House (4/18/14):
"Safe and Accurate Food Labeling Act"

I've heard that …

And they say …

How many "hits" come up for a Google search of "safety GMO crops"?

3,510,000

Cartoon from "Beware of false balance …" at http://undsci.berkeley.edu/article/sciencetoolkit_04. Are there similar concerns with reporting on … ?

- Climate change
- Clean Water Act