April 25 – GMOs, selective breeding, and The Botany of Desire

This lecture was a condensed version of a longer lecture that I sometimes offer on GMO's. The "full lecture" is, itself, a brief overview of this very challenging topic. The following notes are intended to accompany the "full lecture", and not the 30 minute version we had on April 25. **What you need to know for the final (i.e., from these notes) is simple: 1) the definition of a gene; 2) the definition of a GMO, and; 3) the three "noteworthy" GMOs we discussed inlecture (see Table bottom of p. 2).**

A thorough treatment of GMOs is beyond the scope of a single lecture, and the intent of this lecture was to familiarize ourselves with important issues underlying the GMO debate.

Students, voters, and the general public often ask: "are GMOs categorically 'good' or 'bad'?" Providing a tidy answer to this question is a fool's errand, because the GMO issue is challenging to understand for two reasons that we discussed:

I. GMO-related information that is crafted for consumption by the general public, and that is disseminated through popular communication channels (e.g., print, websites, political campaigns, radio, television) is heavily biased by groups that are motivated financially, politically, or socially to be decidedly "pro-GMO" or "anti-GMO". Consequently, the "facts" presented by either camp are often unreliable.

II. The GMO issue is broad and, upon closer inspection, is comprised of many complicated sub-issues.

How then, can we responsibly explore this topic? In other words, how can we gain clarity when our thinking is obscured challenges "I" and "II" listed above?

With regard to item "I": we stressed the importance of using peer-reviewed scientific literature as a source of information. We discussed how the peer-review process works, and how the process protects against false conclusions, propaganda, and misinformation. The peer-review process may be imperfect, but scientists cannot (or, at least have a very difficult time attempting to) buy space in peer-reviewed scientific journals in the way that special interest groups pay for page space or airwaves to report "facts" about GMOs (or any other topic). This is not to say that popular news sources are completely unreliable on this topic, but one must proceed with extreme

Reading peer-reviewed scientific articles

Most non-scientists find the peer-review literature difficult to understand. There are good reasons for this: the format is peculiar, information is not encapsulated into easily digestible "sound-bytes" but instead requires patience to process, and the language is often very specific and technical.

A GREAT approach is to focus upon special peer-review articles called "review articles". I understand that the language here is redundant and therefore confusing (i.e., peer-reviewed review article), so let's clarify. There are two types of peer-reviewed articles: 1) original research articles in which the author(s) describes a very specific set of experiments (e.g., "I fed monarch caterpillars GMO Bt corn pollen and examined mortality rates"), and; 2) review articles in which the author(s) synthesize all recent original research articles in a certain topic (e.g., what is known about the impacts of Bt crop pollen on non-target species).

Original research articles and review articles are both peer-reviewed, but review articles are usually broader and contain less confusing technical language. A focused non-scientist can read and understand a clearly-written review article. When studying a particular topic, it can be wise to focus on review articles. I did so in preparing this lecture.

caution. The line between objective journalism and propaganda is often blurry – especially in the age of electronic media.

Peer-review in science protects the integrity of the scientific method by ensuring that authors of any study have considered all plausible alternatives (i.e., they have run control experiments, and/or they identify what controls should be conducted in the future). This is not a formal requirement in popular media and is essentially absent in advertising. Thus, here again is a demonstration of the scientific method as not only a scientific principle, but also a general guideline for comprehensively thinking about any issue and being a responsible consumer of news and information.

With regard to item "II": In lecture, we identified 8 important sub-topics of the GMO debate. Taking each of these in isolation, we reported findings from the peer-review scientific literature. This was not possible or necessary for all issues, and in those instances I was clear to indicate when I was not reporting from the scientific literature. This list is surely incomplete – what issues are important to you and not on this list?

Topics of concern/debate regarding GMO crops/foods

1) **GMO = selective breeding?**
2) **Are they safe for humans?**
3) **Will they cause ecological/environmental damage?**
4) **Will they feed the world?**
5) **Will they decrease use of chemical pesticides?**
6) **GMO foods labelling?**
7) **"Organic" = GMO-free?**
8) **Socially responsible?**

This list should look familiar to you from lecture. Following is what I have found in the peer-reviewed literature (or other objective sources) for each of these questions. Again, this lecture is intended as an introductory overview. I encourage you to do your own research. What did I miss?

Prior to exploring this list above, I introduced three noteworthy GMOs.

Three noteworthy GMOs

GMO type	**Crop plants grown**	**Foreign/altered DNA** **a. source** **b. what gene codes for**	**Purpose**
Herbicide tolerant (HT) (e.g., Roundup ready glyphosates)	Many: corn, soy, cotton, alfalfa, canola…	Were you in lecture?	Were you in lecture?
Bt (*Bacillus thuringiensis*)	Many: corn, soy, cotton	Were you in lecture?	Were you in lecture?
FLAVR SAVR	Tomato (1st GMO food – 1994)	a. not foreign; altered b. inhibits pectinases	Delay ripening for longer shelf life / shipping

1) GMO technology = selective breeding.

Despite the assertions of many, including some scientists from outside of biology (here is the video of Neil de Grasse Tyson that I described: https://www.youtube.com/watch?v=KNtCV67biBA), the processes by which GMO foods are typically produced are fundamentally different that selective breeding. It is surprising to me that debate exists on this issue. Read the definitions below, and you decide for yourself.

GMO (genetically modified organism): An organism whose DNA has been directly manipulated, typically by addition of foreign DNA.

Selective breeding (artificial selection): the process by which humans breed plants/animals in order to develop or enhance specific desirable characteristics. This is accomplished by choosing which males and females will sexually reproduce and have offspring together.

2) Are they safe for humans?

So far, and to my knowledge, no scientific study has found a link between GMO foods human health risks that are specifically a result of the GMO technology. Skeptics remain unconvinced. There are a few reasons why: 1) many studies are funded by GMO-producing companies, 2) the technology is very young, 3) "absence of evidence is not evidence of absence" – we discussed what this means in lecture, and 4) interpretation of results varies in some studies.

As of now, there are no GMO foods on the market that have been definitively linked to human health effects.

Selected Sources

Domingo JL, and Bordonaba JG (2011). A literature review on the safety assessment of genetically modified plants. Environment International. 734-742

Hilbeck A et al. (2015) No scientific consensus on GMO safety. Environmental Sciences Europe.

3) Free of environmental/ecological damage?

We discussed negative impacts of HT crops to milkweeds (*Asclepias* spp.) in the midwestern USA. HT crops lead to increase spraying of herbicides, which have negative consequences on milkweed populations. *Asclepias* spp. are the host plants for monarch butterfly eggs and caterpillars. As these plants decline in numbers, so too do populations of monarch butterflies. Thus, the contention that GMOs are free of environmental/ecological damage is not true.

We also discuss the emergence of "superweeds" that have evolved to become resistant to herbicides sprayed on HT crops.

We also discussed Bt pollen and its potential toxicity to non-target organisms such as monarch caterpillars. Is this a widespread problem? I don't know, and I don't know if it is known. Can you find out by researching the scientific literature?

Selected Sources

Pleasants JM and Oberhauser KS (2012). Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. Insect conservation and diversity.

4) Help feed the world?

A recent review article indicates that farming with GMO crops can increase yield compared to conventional crops (Klumper and Qaim 2014). So, the thinking goes, if humans grow more food then we should theoretically be able to feed more people. The world is not so simple. The destiny of crops is seldom a straight line from field to table. The vast majority of USA-grown corn, for example, is GMO and is used as feed for livestock or in the production of ethanol fuel (Foley 2013, Iowa Corn 2015). The slim minority is eaten by humans, and much of that is ingested as high-fructose corn syrup. So, if we are concerned with feeding the world, are GMOs the panacea or is this perhaps a more complicated issue? The UN World Food Program identifies six primary causes of world hunger (https://www.wfp.org/hunger/causes): 1) poverty, 2) Inadequate agriculture infrastructure, 3) climate and weather, 4) war and displacement, 5) unstable food prices, 6) waste (1/3rd of all food produced). Considering these causes, and the way in which humans use current crop production, it seems unlikely that increasing yields via GMO technology is a serious solution to ending world hunger.

Selected sources:

Klumper W and Qaim M (2014). A meta-analysis of the impacts of genetically modified crops. PLoS ONE 9(11): 1-7. e111629.

Iowa Corn (2015). https://www.iowacorn.org/corn-production/ (not peer-reviewed)

Foley J (2013). It's Time to Re-think America's Corn System. Scientific American. Accessed online: https://www.scientificamerican.com/article/time-to-rethink-corn/# (this is essay peer-reviewed?)

UN World Food Program: https://www.wfp.org/hunger/causes. (This is not a peer-reviewed source)

5) Reduce pesticide use?

One of the great early promises of GMO crops is that they would lead to reduced application of pesticides. Has this promise been met? The answer is: it depends on the crop and the location. A review paper that examined 147 individual peer-reviewed research studies worldwide from 1994-2014 found that GMOs did indeed result in reduced pesticide application (Klumper and Qaim 2014). In contrast, an analysis of pesticide use in the USA during the first 16 years of GMO crops (1996-2011) finds that Bt crops lead to reduced pesticide application but HT crops lead to increased herbicide application. This makes sense given the design/purpose of these GMO crops – be able to explain this on assessments (you should be able to provide the missing information on the "Three noteworthy GMOs" table contained in these lecture notes.

Selected sources:

Klumper W and Qaim M (2014). A meta-analysis of the impacts of genetically modified crops. PLoS ONE 9(11): 1-7. e111629.

Benbrook CM (2012). Impacts of genetically engineered crops on pesticide use in the U.S. – the first sixteen years. Environmental Sciences Europe 24:1-13. (http://www.enveurope.com/content/24/1/24).

Bonny, S (2011). Herbicide-tolerant Transgenic Soybean over 15 Years of Cultivation: Pesticide Use, Weed Resistance, and Some Economic Issues. The Case of the USA. Sustainability 3(9): 1302-1322; doi:10.3390/su3091302

6) Are GMO foods labeled?

NO in California (or anywhere in the USA).

YES in the EU (European Union).

7) Does a food label reading "organic" mean the food is GMO free?

Any food bearing the label "USDA Organic" must contain fewer than 5% GMO ingredients.

Any food bearing the label "100% USDA Organic" must be 100% GMO free.

8) Are there important social justice issues surrounding GMOs?

Critics of GMO foods occasionally suggest that GMO crops infringe upon the rights of farmers and/or cause social injustices. Two common plotlines you might hear are:

8a) Bt cotton in India has caused increased suicides among farmers in India (due to increased debt).

8b) Monsanto and other large GMO-producing companies sue farmers when pollen from GMO crops blows into neighboring fields where GMO crop are not being grown, and where farmers do not have permission to grow crops that contain the GMO genes. This phenomenon is referred to as GMO genetic contamination.

For item 8a, an exploration of the peer-reviewed scientific literature is useful. An early study on this issue suggested this link, but the link was later refuted in other areas of India and in India as a whole. The initial conclusion linking farmer suicides and Bt cotton appears to have been an erroneous conclusion. This is an example of a scientist failing to consider alternative explanations of the data.

Selected sources:

Gruère, Guillaume P. et al., (2008), "Bt Cotton and Farmer Suicides in India, Reviewing the Evidence", International Food Policy Research Institute.

Gruère, G. & Sengupta, D. (2011), *Bt cotton and farmer suicides in India: an evidence-based assessment*, The Journal of Development Studies, 47(2), pp 316–337

For item 8b, the scientific literature is not necessary, but we need to look at the history of Monsanto. In my research, I found the following data describing lawsuits filed by Monsanto:

- Sued 147 defendants for patent infringement (1995-2016ish)
  (e.g., Bowman vs. Monsanto; Monsanto Canada vs. Schmeiser)

- 11 cases went to trial
- All were for intentionally planting patented GM seeds
- No lawsuits were for accidental GMO genetic contamination…
- …but Monsanto retains the right to sue for contamination at levels >1% (OSGATA vs. Monsanto)

So, Monsanto, to the best of my ability to research this issue, has never sued a farmer for growing contaminated crops (i.e., Non-GMO crops that contain patented GMO genes) due to GMO pollen blowing into his/her field. The 147 cases in which Monsanto sued farmers was for intentionally planting and growing patented GMO seeds without permission or having paid the annual royalty to do so. Whether or not this is socially responsible depends upon your values. I, and science, provide no answer.

I will, however, leave you with a couple of parting thoughts...
Imagine that a non-GMO farmer discovers that his/her crops contain patented genes that are, by definition, the property of the humans that created them. If the farmer doesn't want these genes in his/her crops, is it fair that they've been contaminated with them? Additionally, what happens if these genes persist or expand their presence in the genes of plants, and do so to the point that they can not be contained or controlled by the company that created them. Is this fair? Is this socially responsible? Again, the answers to these questions depend upon individual values…which hopefully are informed by careful research when issues are complicated.