Genetically Modified Foods: Benefits and Concerns

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- **Disclosures:** I certify that, to the best of my knowledge, no aspect of my personal or professional circumstances places me in the position of having a conflict of interest with this presentation.
After completing this continuing education course, nutrition professionals should be able to:

1. Define genetically modified organisms (GMOs) and provide at least four examples of foods or food ingredients that have been genetically modified.
2. Summarize the history and science behind GMOs.
3. Identify at least six reported benefits of GMOs.
4. Identify at least six risks associated with GMOs.
5. Discuss how patent regulations impact research and farming practices.
6. Describe the current U.S. political climate in relation to GMOs.
7. Advise clients who express interest in avoiding or limiting genetically modified foods in their diets.
70-80% of foods eaten in the U.S. contain at least one genetically modified (GM) ingredient

89% of the corn and 94% of the soy being grown in the U.S. is genetically modified

(Grocery Manufacturers Association, n.d.)
(USDA, 2016)
Genetically modified organisms (GMOs): living organisms (plants, animals, bacteria, or fungi) which contain genetic material (DNA) which was physically transformed by human beings in a way that does not occur naturally.

- Recombinant DNA technology
- Genetic engineering

(World Health Organization, 2017)
GMO Foods Commonly Available in the United States

- GMO Foods Commonly Found in the United States
  - Canola
  - Corn
  - Soybeans
  - Sugar Beets
  - Papaya
  - Zucchini and yellow summer squash

(Non-GMO Project, 2016)
(USDA, 2016)
Brief Overview of GMO Cellular Biology - Genetic Engineering

• Foreign section of DNA - inserted into the genome of the host organism
• Bacterial intermediaries (often Agrobacterium tumefaciens)
• Vector - needed to insert the new DNA segment into an existing strand of DNA.
• Vectors - generally viral in origin.
• Viruses - insert themselves into host DNA.
• Antibiotic resistant marker gene - inserted into the vector.
• Resulting cells then exposed to an antibiotic - kills off those cells in which the new DNA segment was not inserted.

(Kuure-Kinsey M, McCooey B., 2000)
(Key, Ma, and Drake, 2008)
Gene Editing

- Technically **not** categorized as genetic engineering
- Does not introduce foreign genes from plant pests into the crops
- Smaller changes to DNA than traditional genetic engineering
  - null segregants
  - classic gene delivery systems
  - cisgenics/intragenics
  - site-directed nucleases
- Used to create some genetically altered varieties of plum, pineapple, apple, grape, corn, wheat, mushrooms, soybeans, etc.

(Chang, 2017)
(Camacho et al, 2014)
Historic Timeline of Genetics

- See separate handout for full timeline

Adoption of genetically engineered crops in the United States, 1996-2016

- Percent of planted acres
- HT soybeans, HT cotton, Bt cotton, Bt corn
- Data for each crop category include varieties with both HT and Bt (stacked) traits.
Definition of Organic

- **USDA - Organic**
  - An ecological production management system
  - Promotes and enhances biodiversity, biological cycles and soil biological activity.
  - Labeling term that indicates that the food or other agricultural product has been produced through approved methods
  - Integrates cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity.
  - Synthetic fertilizers, sewage sludge, irradiation, and genetic engineering are not allowed.

(Gold, M., 2016)
Non-GMO Project certification
  - Signifies that the food item is not genetically modified.

The Non-GMO Project - a non-profit that helps to encourage the growth of non-GMO crops, educates consumers, and provides customers with verified non-GMO choices

Sales of Non-GMO Project Verified food products increased from $0 in 2010 to $3.5 billion three years later.

(Non GMO Project website, 2016)
(Smith, MD, 2014)
Reported Benefits of GMO Foods

- Potential to reduce world hunger
- Increased crop yields
- Potential for reduced need for pesticides
- Reduced greenhouse emissions during farming
- Can grow in inhospitable environments
- Less costly
- Higher levels of selected nutrients
- Specific genetic manipulations
- Financial benefits to farmers
- Lack of data showing risk to humans
- In most cases, no need for premarket testing in the United States
Between now and the year 2050 – population of the world is expected to increase by about one-third, from 7.4 billion to 9.6 billion

Around 870 million people currently suffering from hunger and malnutrition

Growing demand for food

Food production will need to double in the next 35 years to keep up with the demand

(U.S. Census Bureau, 2017)  
(Van Montagu, M., 2013)  
(O’Neil, 2014)
• Scientists - working to make plants more efficient by converting more sunlight energy into food

• Potential to increase food and energy produced by agriculture

• The Gates Foundation - giving a consortium of institutions $25 million to test improvements suggested by computational models on improved crop yields

(O'Neil, 2013)
GM IR Corn, resistant to corn boring pests:
  - Yield +7% all years (U.S. and Canada)

GM HT Soybeans:
  - Yield: 1\textsuperscript{st} generation-nil; 2\textsuperscript{nd} generation- +9% (2014, U.S. and Canada)

GM HT Canola:
  - Yield +6% (to 2004 in U.S.), +10.7% (to 2004 in Canada)
  - Yield +3.4% for one variety, +11% for another variety (2014, Canada)

GM HT Sugar Beet:
  - Yield +3.2% (2014, U.S. and Canada)

GM VR Papaya:
  - Yield between +15% and + 77% (1999-2012, U.S.)

GM Squash:
  - Yield +100% (U.S.)

(Brookes G, Barfoot P., 2016)
Reported Benefits: Increased Crop Yields

- *Monsanto’s website mentions:*
  - Marker-assisted breeding nearly doubled the rate of yield gain compared to traditional breeding
  - Insect and herbicide tolerance, help to increase yields by protecting the yield that would otherwise be lost due to insects or weeds
  - Mexico - yield increases of 9% with herbicide tolerant soybean
  - Romania - yield increases of 31% with herbicide tolerant soybeans
  - Philippines - average yield increase of 15% using herbicide tolerant corn and an average yield increase of 24% using insect resistant corn
  - Hawaii - yields of virus resistant papaya were increased by 40%
  - India - yield increase of more than 50% using insect resistant cotton

(Monsanto, 2012)
Reported Benefits: Reduced Need for Pesticides

- Genetic insertions - code for a select herbicide or pesticide to be produced by the resulting plant (plant-incorporated protectant)
- Potential to reduce the use of pesticides
- Herbicide tolerance
- Virus resistance

(World Health Organization (WHO), 2017)
Reported Benefits:
Reduced Need for Pesticides

Pesticide Use

The pesticide active ingredients used on soybeans are classified in this report as herbicides, insecticides, fungicides, or other chemicals. Herbicides were used most extensively, applied to 98 percent of soybean planted acres (Fig. 2). Insecticides and fungicides were applied to 18 percent and 11 percent of planted acres, respectively. Among herbicides, glyphosate potassium salt was the most widely used (59 percent of planted acres), followed by glyphosate isopropylamine salt (30 percent) (Table 2).

![Graph showing Pesticide Use]

Table 2. Top Herbicides Applied to Soybean Planted Acres, 2012

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>% of Planted Acres</th>
<th>Crop Year* Average Rate (lbs/acre)</th>
<th>Total Applied (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate potassium salt</td>
<td>59</td>
<td>1.628</td>
<td>70,826,000</td>
</tr>
<tr>
<td>Glyphosate isopropylamine salt</td>
<td>30</td>
<td>1.330</td>
<td>29,550,000</td>
</tr>
<tr>
<td>Chlorimuron-ethyl</td>
<td>11</td>
<td>0.023</td>
<td>187,000</td>
</tr>
<tr>
<td>2,4-D, 2-EHE</td>
<td>11</td>
<td>0.519</td>
<td>4,098,000</td>
</tr>
<tr>
<td>Flumioxazin</td>
<td>11</td>
<td>0.076</td>
<td>602,000</td>
</tr>
</tbody>
</table>

*The period starting immediately after harvest of the previous year’s crop and ending at harvest of the current year’s crop.

USDA data does not differentiate between GM and conventional crops.

(USDA, 2012 Agricultural Chemical Use Survey - Soybean Highlights, 2013)
Farmers who continue to farm conventionally may be those with low levels of pest/weed problems, and thus have insecticide/herbicide usage levels below that would be reasonably expected.

Use of low tillage/no tillage programs is less prominent for conventional soybean growers vs. GM HT growers.

Herbicide usage - 2014:
- (Average ai use (kg/ha) index 1998=100)
- Conventional soybeans: 121.3
- GM HT soybeans: 162.7

Reported Benefits: Reduced Need for Pesticides

(Brookes G, Barfoot P., 2016)
Reported Benefits: Reduced Greenhouse Emissions During Farming

- Reduced fuel use - less frequent herbicide or insecticide use
- Reduced energy use in soil cultivation
- One application of pesticide spray can use 1.045 L of fuel, which can generate 2.87 kg/ha of carbon dioxide emissions
- Reduced or no-till farming methods are also encouraged for use on GM crops
- Potential to reduce greenhouse gas emissions as well
- In Canada, growth in no-tillage canola acreage increased from 0.8 million ha to 2.6 million ha, half of the total canola area, between 1996 and 2005. Of this area, 95% is planted with GM crops. In the U.S., the no-tillage cotton crop area increased from 0.2 million ha to 1 million ha over the same period, and 86% was for GM crops.

(Brookes G, Barfoot P., 2006)
(Brookes G, Barfoot P., 2016)
Reported Benefits: Reduced Greenhouse Emissions During Farming

- Reduced tillage - increased soil carbon sequestration; reduction in 8.05 billion kg of carbon dioxide emissions in 2005
- 2014 - Permanent carbon dioxide savings from reduced fuel use, equivalent to removing 1.07 million cars from the road
- 2014 - Additional probable soil carbon sequestration gains - equivalent to removing 8.89 million cars from the roads
- 2014 - Combined GM crop-related carbon dioxide emission savings from reduced fuel use and additional soil carbon sequestration equal to the removal from the roads of 9.95 million cars, equivalent to 34% of all cars in the UK

(Brookes G, Barfoot P., 2006)  
(Brookes G, Barfoot P., 2016)
Reported Benefits: Reduced Greenhouse Emissions During Farming

- **Carbon sequestered (kg of carbon/ha/year)**

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn, conventional</td>
<td>-3</td>
</tr>
<tr>
<td>Corn, reduced</td>
<td>72</td>
</tr>
<tr>
<td>Corn, no-till</td>
<td>244</td>
</tr>
<tr>
<td>Soybean, conventional</td>
<td>-146</td>
</tr>
<tr>
<td>Soybean, reduced</td>
<td>-114</td>
</tr>
<tr>
<td>Soybean, no-till</td>
<td>-43</td>
</tr>
</tbody>
</table>

- **Tractor Fuel Consumption**
  - Intensive tillage: traditional cultivation: mouldboard plough, disc and seed planting etc.: 49.01 liters/ha for U.S. soybeans 2014, 54.50 liters/ha for U.S. maize 2014

(Brookes G, Barfoot P., 2016)
Reported Benefits: Can Grow in Inhospitable Environments

- GMO crops can grow in various climates
- According to the United Nations Food and Agriculture Organization, people would need to grow 70 percent more food by 2050 to keep up with population growth and that climate change is decreasing the available arable land
- GMO crops potentially can produce higher yields, grow in dry and salty land, withstand high and low temperatures, and tolerate insects, disease and herbicides

(Freedman, 2013)
Reported Benefits: Less Costly

- Engineered to grow faster and require fewer applications of pesticides - reducing costs
- Unlabeled GMOs – Less Costly
  Supports of GMO foods - labeling would increase food costs for the average consumer. Costs associated with record keeping by farmers, manufacturers, and retailers and associated with potential lawsuits would in turn raise consumer costs
- Discounts on crop insurance premiums

(Brookes G, Barfoot P., 2012)
(Johnson S, Strom S, Grillo K, 2008)
(Editors at Scientific American, 2013)
Reduced cost of using machinery for spraying crops

Executive Summary published by the National Center for Food and Agricultural Policy - biotechnology-derived crops were grown on 156 million acres in America in 2006.

2006 - improved biotech crop production of 7.778 billion pounds, lower associated costs of around $1.9314 billion, and decreased pesticide use of 110.06 million pounds.

Higher yields, reduced production costs increased net returns to growers by $2.629 billion (13%) in 2006

(Brookes G, Barfoot P., 2012)
(Johnson S, Strom S, Grillo K, 2008)
(Editors at Scientific American, 2013)
Reported Benefits: Higher Levels of Selected Nutrients

- Golden Rice - vitamin A (beta-carotene)
- Vitamin A deficiency - blinds as many as 500,000 children worldwide every year
- ¾ cup of Golden Rice - recommended daily amount of vitamin A
- “Yet Greenpeace and other anti-GMO organizations have used misinformation and hysteria to delay the introduction of Golden Rice to the Philippines, India and China.” (Editors at Scientific American, 2013)
- Work is being done to genetically engineer cassava to have 30 times as much beta-carotene, four times as much iron, and higher levels of protein and zinc than regular cassava.
- A strain of corn was created with 169 times the amount of beta-carotene, six times the vitamin C, and double the folate compared to regular corn.

(Editors at Scientific American, 2013)
Reported Benefits: Specific Manipulations

- Conventional breeding-used to select for favorable traits in plants for thousands of years
- Genetic engineering - allows scientists to insert gene(s) from another species of plant, bacterium, virus, or animal
- This precision is less likely to produce surprises than conventional breeding
- Traits include, include, but are not limited to:
  - Abiotic stress tolerance, altered growth/yield, disease resistance, herbicide tolerance, insect resistance, modified product quality, and a pollination control system

(Freedman, 2013)
(Key, Ma, and Drake, 2008)
(ISAAA, 2017)
Reported Benefits:
Financial Benefits to Farmers

- Increased yields and fewer insecticide applications - cost effective
- Farmers - eager to find opportunities to make more money
- 2014 - Global farm income benefit from biotech crops was $17.7 billion. This is equivalent to having added 7.2% to the value of global production of the four main crops of soybeans, maize, canola and cotton.
- Since 1996, farm incomes have increased by $150.3 billion

(Brookes G, Barfoot P, 2016)
Reported Benefits:
Financial Benefits to Farmers

• 2014 - Biotech maize income rose due to higher yields and lower costs (increased by $5.3 billion).
• Since 1996 - biotech maize sector gained an additional $41.4 billion.
• Farm incomes significantly rose for the GM soybean and canola sectors as well.
  - GM HT in soybeans - boosted farm incomes by $5.2 billion in 2014; since 1996 over $46.6 billion of extra farm income
  - Canola (largely North American) - an additional $4.86 billion has been generated (1996–2014).
• 2010 - Farmers in developing countries received 54.8% of the farm income from GMO crops, mainly from GM cotton and soybeans

(Brookes G, Barfoot P, 2012)
(Brookes G, Barfoot P, 2016)
OECD (Organisation for Economic Co-operation and Development) Guidelines-90 day feeding studies, required by the EU

Target animal species, housing, dosage, gender, number of animals, methods used to measure body weight, food consumption, and clinical biochemistry are specified.

Toxicology and allergenicity studies – use isolated proteins or molecules, often made by recombinant bacteria

129 transgenic crops submitted to the FDA between 1995-2012 – no significant differences in crude measures of protein, fat, ash, fiber, amino acids, fatty acids, calcium, and phosphate

Concentration of new protein low; researchers feel this keeps risk low

(DeFrancesco, 2013)
(Snell et al, 2012)
Humans have been consuming genetically modified foods since 1996
• 600+ published safety assessments
  - (Few of those studies involved humans, or animals > 90 days, and those that found negative effects are attributed to poor study design)

(GMO Pundit aka David Tribe, n.d.)
No Need for Premarket Testing in the United States

- U.S. FDA - GMO crops considered to be substantially equivalent to their non-GMO counterparts.
- Between 1995 and 2012, of 129 transgenic crops submitted to the FDA, no significant differences in crude measures of protein, fat, ash, fiber, amino acids, fatty acids, calcium, and phosphate were reported by biotech companies.
- Since the concentration of new proteins produced by the inserted genes are low, biotech scientists working in the GMO field feel this also keeps risk low.
- Due to this substantial equivalence classification, GM crops don’t need premarket testing in the United States.
- Premarket approval of the substance as a food additive would be required if a GM food differs significantly in structure, function, or composition from its counterpart.
- The FDA encourages biotech companies to consult with them.

(Library of Congress, 2015)
(DeFrancesco, 2013)
(Snell et al, 2012)
Reported Concerns of GMOs

- Biotech patent holders limiting research
- Potential Health and Safety Risks
  - Exposure to allergens
  - Antibiotic resistance
  - Endocrine disruption
  - Reproductive disorders
  - Accelerated aging
  - Increased cancer risk
- Increase in herbicide resistant weeds
- Increased levels of herbicide/pesticide ingestion
- Lack of FDA Testing Requirements
- Lack of sustainability and genetic drift into conventional crops
- Environmental impact
- Ethics
  - Unnatural organisms
  - Lack of long-term human studies
  - May impact low income people the most
Reported Concerns: Potential for Abuse of Patent Protection and Licensing Agreements

- Safety testing – Mostly limited to biotech companies and their affiliates
- Independent testing - not being done for the most part
- No human long-term safety testing has been conducted
- How are biotech companies able to have such tight control?
- They **license** the seeds to farmers, just like you are licensing your computer’s software. The biotech companies do NOT sell the GM seeds.

(Hansen H, Hemmelgarn M, 2012)
Reported Concerns: Potential for Abuse of Patent Protection and Licensing Agreements

- Biotech companies - obtain utility patents that protect genetically modified organism technology
- Farmers - required to sign/agree to stewardship agreements saying that they are licensing, NOT purchasing these GM seeds
- Farmers - not allowed to save seeds or share them with researchers under the agreement
- Biotech companies - own the GM seeds and the resulting plants.
- Biotech companies and their designees - only ones permitted to do any safety testing
- FDA - human safety testing is not required for genetically modified crops

(Rowe, 2011)
As stated in a publication by Elizabeth A. Rowe from the University of Florida Levin College of Law:

“There is currently a void in the scientific knowledge relating to the effects of genetically modified foods on human health and the environment. Patent law perpetuates that void by allowing patent holders to control and restrict independent research in the area. This is facilitated mostly through no-research clauses in license agreements with farmers. This further exacerbates the problem of incomplete information about genetically modified foods and may ultimately threaten public health and safety.”

(Rowe, 2011)
Reported Concerns: Potential for Abuse of Patent Protection and Licensing Agreements

- Farmers who save seeds - violating the agreement and are infringing on the patent
- Farmers - not being allowed to use, sell, or give away GM seeds for breeding, research, generation of herbicide registration, or seed production
- Farmers - sued for saving seeds
- Monsanto sued Mississippi farmers who planted Roundup Ready® soybean seeds and retained seeds for replanting; Court of Appeals ruled in favor of Monsanto
- Monsanto v. McFarling, decided by the U.S. Court of Appeals for the Federal Circuit in 2002
- Monsanto v. Trantham, a federal district court case decided in 2001 -- have supported Monsanto's right to prevent farmers from saving the patented seeds

(Rowe, 2011)  
(Pbs.org, n.d.)
Independent scientists - cannot test seeds, compare the seeds to others, or investigate the environmental impact of GM crops without prior approval.

Any research requires permission from the patent holder of the seed or gene.

Researchers who do receive permission to do research on GM seeds must submit any findings to the biotech company for review before publication.

Biotech companies - decide which research is to be published and which is not to be released.

These requirements and restrictions limit research on GM seeds.

Current university research - biotech company oversight/review

(Rowe, 2011)
In addition, Rowe said:

“The fact that these no-research clauses could pose a direct threat to public health and safety and because they involve our food supply, it makes the call for action all the more compelling. These licenses provide greater restrictions than patent law itself allows. Some commentators have argued, for instance, that the license terms are inconsistent with the patent exhaustion doctrine, which allows the purchaser of a patented product to use it without owing further duties to the patent owner.”

(Rowe, 2011)
Further research - clearly needed on the long-term impact of consuming genetically modified foods.

Most available studies are animal studies.

GM supporters - lack of research showing safety concerns is a sign that GM foods are safe for human consumption.
Using genes from foods that people are commonly allergenic to in GMOs is discouraged

Traditionally developed foods - usually not tested for allergenicity

Proposed allergen tests for GM foods - evaluated by the Food and Agriculture Organization of the United Nations (FAO) and WHO

No allergenic effects were found for currently available GM foods

FlavrSavr tomato – fish gene, taken off the market

(WHO, 2017)
(The Conversation, 2015)
Bøhn et al tested 31 soybean batches (GM soy, conventionally grown soy, and organic soy)

Measured nutrient and elemental composition, including residues of herbicides and pesticides.

Organic soybeans - more sugars, such as glucose, fructose, sucrose and maltose, significantly more total protein, zinc and less fiber than both conventional and GM-soy.

Organic soybeans also contained less total saturated fat and total omega-6 fatty acids than both conventional and GM-soy.

GM-soy contained high residues of glyphosate and AMPA (aminomethylphosponic acid – the major degradation product of glyphosate) (mean 3.3 and 5.7 mg/kg, respectively).

Not So Substantially Equivalent After All (Bøhn et al, 2014) (Mesnage et al, 2016)
Mesnage et al tested GM-corn - NK603 Roundup-tolerant GM maize

- Alterations in the levels of enzymes of glycolysis and TCA cycle pathways
  - An imbalance in energy metabolism.
- Changes in proteins and metabolites of glutathione metabolism
  - Indicative of increased oxidative stress.
- An increase in polyamines including N-acetyl-cadaverine (2.9-fold), N-acetylputrescine (1.8-fold), putrescine (2.7-fold) and cadaverine (28-fold)
• Zobiole et al - photosynthetic parameters of GM soy were reduced linearly as glyphosate rates increased.
  - Spraying GM soy with glyphosate was shown to reduce iron, zinc, and manganese concentrations.
  - Macro- and micronutrient accumulation - strongly reduced by increased doses of glyphosate
  - Photosynthesis, nutrient accumulation and biomass production in glyphosate-resistant soy - strongly affected by glyphosate
• Agapito-Tenfen et al - compared GM maize to a similar non-GM hybrid maize
  - 32 differently expressed proteins
Most GM crops - engineered to tolerate the pesticide Roundup®’s active ingredient, glyphosate, remains in the resulting food.

Bt-toxin produced by GM corn and other crops kills insects - creates holes in their digestive tracts.

Bt-toxin - ends up in corn chips, corn tortillas, and other ingredients derived from corn.

Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

(Smith, 2013)
Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

- Gluten-related disorders - associated with increased intestinal permeability
- Gaps between intestinal cells - particles from the gastrointestinal tract enter the bloodstream - may trigger immune or allergic reactions.
- Bt-toxin and glyphosate ingestion – correlated to structural damage to microvilli in animal studies
- 2009 - Teleostea fish-45 days-scanning electron microscope, structural changes in the gills, buccopharynx, and esophagus, erosion of basement membrane in intestine

(Smith, 2013)  
(Senapati and Ghosh, 2009)  
(Fares and El-Sayed, 1998)
Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

- 1998 – Mice fed transgenic potatoes for 2 weeks-CryI gene of Bacillus thuringiensis
- Microscopic structure of the mice ileum
- Both groups-mitochondria showed signs of degeneration, disrupted short microvilli at the luminal surface
- Mice fed on the 'delta-endotoxin', several villi - abnormally large number of enterocytes (151.8 in control group versus 197 and 155.8 in endotoxin and transgenic-treated groups, respectively).
- 50% cells-hypertrophied and multinucleated

(Smith, 2013)  
(Senapati and Ghosh, 2009)  
(Fares and El-Sayed, 1998)
2011 – Cry1Ab and Cry1Ac Bt toxins (10 ppb to 100 ppm) - alone and combined with Roundup were tested on human embryonic kidney cell line 293

- 100 ppm of Cry1Ab - mitochondrial succinate dehydrogenase activity significantly decreased
- 100 ppm of Cry1Ab - plasma membrane alterations (Could this lead to gaps between cells?)
- With Roundup, Cry1Ab and Cry1Ac exposures slightly reduced caspase 3/7 activations
- Showed that Bt-toxin can affect human cells as well.

Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

(Smith, 2013)
(Mesnage, Clair, Gress, Then, Székács, and Séralini, 2011)
(Aris and Leblanc, 2011)
Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

- 2011-Aris and Leblanc - Serum GLYP and GLUF were detected in non-pregnant women; not detected in pregnant women.

- Serum 3-MPPA and CryAb1 toxin were detected in pregnant women, their fetuses and non-pregnant women.

- Cry1Ab toxin - detected in:
  - Pregnant women [28/30 (93%), range (nd–1.5 ng/ml) (0.19±0.30 ng/ml)]
  - Nonpregnant women [27/39 (69%), (nd–2.28 ng/ml) (0.13±0.37 ng/ml)]
  - Fetal cord [24/30 (80%), range (nd–0.14 ng/ml) and mean±SD (0.04±0.04 ng/ml).

- Appear to cross the placenta to the fetus

(Smith, 2013)
(Mesnage, Clair, Gress, Then, Székács, and Séralini, 2011)
(Aris and Leblanc, 2011)
Reported Concerns: Bt-toxin Induced Hypersensitivity to Allergens

- 2008 - Mice exposed to Bt-toxin - direct immune response; also reacted to foods that had not previously triggered an immune response
- MON810 maize induced altered the percentage of T and B cells and of CD4+, CD8+, γδT, and RT subpopulations of weaning and old mice fed for 30 or 90 days, respectively, at the gut and peripheral sites.
- Increase of serum IL-6, IL-13, IL-12p70, and MIP-1 after MON810 feeding.
- *Can this be related to increased incidence of Celiac disease and other types of wheat allergies and intolerances, despite the fact that GM wheat is not yet available for sale in the United States?*
- Not conclusive evidence to documenting such effects in humans
- Further research is needed

(Finamore, Roselli, Britti, Monastra, Ambra, Turrini, and Mengheri, 2008)
(Smith, 2013)
Reported Concerns: Antibiotic Resistance

- Vectors (carrier DNA) - contain antibiotic resistance markers, all genetically modified organisms are therefore antibiotic resistant

- If antibiotic resistance genes from GM foods are transferred to bacteria during the digestion process, the resulting infection would be quite difficult for doctors to treat. The statistical significance of such an occurrence happening is quite low per the GMO Compass website. “The probability of a successful transfer of an antibiotic resistance gene to a bacterium is very low. Estimates from laboratory experiments place the probability at anywhere from 1:10,000,000,000,000 to 1:1,000,000,000,000,000,000,000,000,000”

- Most common antibiotic resistance genetic markers - confer resistance to antibiotics kanamycin and ampicillin

(GMO Compass, 2006)
Study - effects of feeding mice a diet containing MON810, its parental control maize, or a control pellet diet containing GM-free maize for 30 and 90 days.

The immunophenotype of intestinal intraepithelial, spleen, and blood lymphocytes of control maize fed mice was similar to that of pellet fed mice.

MON810 maize induced alterations in the percentage of T and B cells and of CD4+, CD8+, γδT, and αβT subpopulations of weaning old mice fed for 30 or 90 days, respectively, showed these changes at the gut and peripheral sites.

Increased serum IL-6, IL-13, IL-12p70, and MIP-1β after MON810 feeding was also found.

Gut and peripheral immune responded to GM crop ingestion.

(Finamore, Roselli, Britti, Monastra, Ambra, Turrini, Mengheri, 2008)
• Study - 168 pigs equally divided into two groups
• Either fed a mixed GM soy and GM corn (maize) diet or a non-GM soy and corn diet over 22.7 weeks,
• Researchers measured feed intake, weight gain, mortality, and blood biochemistry of these pigs.
• No differences between pigs fed the GM and non-GM diets for feed intake, weight gain, mortality, and routine blood biochemistry measurements. GM diet - associated with gastric and uterine differences in pigs.
• GM-fed pigs - uteri that were 25% heavier than non-GM fed pigs (p=0.025).
• GM-fed pigs - higher rate of severe stomach inflammation with a rate of 32% of GM-fed pigs compared to 12% of non-GM-fed pigs (p=0.004).
• Severe stomach inflammation - worse in GM-fed males vs. non-GM fed males by a factor of 4.0 (p=0.041), and GM-fed females vs. non-GM fed females by a factor of 2.2 (p=0.034).
• Difference seen in uterine weight warrants further study

(Carman et al, 2013)
Accelerated Aging

- Study - 10 female mice fed a genetically modified soybean diet vs. 10 female mice fed a comparable non-GMO diet

- Many proteins indicative of hepatocyte metabolism, stress response, calcium signaling and mitochondrial activity - differently expressed in GM-fed mice

- May indicate a more marked expression of senescence markers in those receiving the GM soy compared to controls.

- Hepatocytes of the GM-fed mice revealed mitochondrial and nuclear modifications consistent with a reduced metabolic rate. 2-D electropherograms - 39 liver proteins were more significantly expressed in GM-fed mice, and 10 proteins were significantly decreased in that group.

- Body weights and liver weights - not statistically different between both groups.

- The sample size used in this study was relatively small

- More research is needed on the effects of GMO consumption on liver aging parameters

(Malatesta et al, 2008)
Increased Cancer Risk

- Study - Gilles-Éric Séralini - rats eating a common type of GM corn and Roundup® laced water, 2 years - high rate of cancer
- Originally published - Food and Chemical Toxicology, September 2012
- Retracted - Food and Chemical Toxicology 2013
- Republished - Environmental Sciences Europe 2014, 26:14
- Female rats - treated groups died 2–3 times more than controls, large mammary tumors
- Male rats - liver congestions and necrosis were 2.5–5.5 times higher; kidney nephropathies 1.3–2.3 greater. 4 times more large palpable tumors than controls, up to 600 days earlier

(Freedman, 2013)
(Séralini et al, 2014)
Séralini - an anti-GM campaigner, and critics charged that in his study, he relied on a strain of rat that too easily develops tumors, did not use enough rats, did not include proper control groups and failed to report many details of the experiment, including how the analysis was performed. After a review, the European Food Safety Authority dismissed the study's findings.

- Possibly unfairly dismissed - breed of rat in the study is commonly used in respected drug studies, typically in numbers no greater than in Séralini's study; that the methodology was standard.
- Study size too small for conclusive results.
- More articles about the retraction of this article than the information itself.
- Yes, the research study is flawed.
- There is a need for further research to either refute or confirm these results.

(Freedman, 2013)
(Séralini et al, 2014)
Increased Cancer Risk

- Naturally occurring swapping groups of genes - happening in plants for half a billion years, and leads to few surprises.

- Changing a single gene may have unexpected ripple effects, including the assembly of new proteins that potentially can be toxins or allergens.

- Glyphosate - commonly sprayed on GM crops
  - Classified as a probable carcinogen by the WHO in 2015
  - IARC - glyphosate ‘probably carcinogenic to humans’ (Group 2A).
  - IARC reviewed about 1000 studies to make this determination
  - International Agency for Research on Cancer (IARC) received a backlash from industry groups as a result
  - Evidence mostly from tumors in rats and mice
  - People working with the herbicide - increased risk of non-Hodgkin lymphoma (Europe)
  - The Agricultural Health Study (U.S.) - found no link to non-Hodgkin lymphomas

(WHO, 2016), (Freedman, 2013), (Cressey, 2015)
Inhibits the **Shikimate Pathway** –

This pathway converts carbohydrates to aromatic amino acids, and is only found in plants and bacteria.

Human cells do not use this pathway, but our intestinal bacteria do.

Glyphosate inhibits the incorporation of shikimate into all three aromatic amino acids (tyrosine, tryptophan, and phenylalanine).

Interferes with intestinal flora and as a result, with the sulfur containing amino acids (cysteine and methionine), and aromatic amino acids.

The gastrointestinal tract is a metabolically significant site of sulfur amino acid metabolism in the body.

About 20% of dietary methionine is transmethylated to homocysteine and trans-sulfurated to cysteine in the GI tract.

Cysteine is the rate-limiting amino acid for glutathione synthesis, the major cellular antioxidant in mammals.

(Hollander and Amrhein, 1980)
(Bauchart-Thevret, Stoll, and Burrin, 2009)
# Glyphosate in Foods

- Acceptable daily intake (ADI): 1.75 mg/kg bw/day in the U.S.
- 0.3 mg/kg bw/day in the European Union

<table>
<thead>
<tr>
<th>General Mills</th>
<th>Glyphosate</th>
<th>AMPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Cheerios</td>
<td>- 1,125.3 ppb</td>
<td>- 26.4 ppb</td>
</tr>
<tr>
<td>Honey Nut Cheerios</td>
<td>- 670.2 ppb</td>
<td>- 14.5 ppb</td>
</tr>
<tr>
<td>Wheaties</td>
<td>- 31.2 ppb</td>
<td></td>
</tr>
<tr>
<td>Trix</td>
<td>- 9.9 ppb</td>
<td></td>
</tr>
<tr>
<td>Gluten Free Bunny Cookies Cocoa &amp; Vanilla</td>
<td>- 55.13 ppb</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kelloggs</th>
<th>Glyphosate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Flakes</td>
<td>- 78.9 ppb</td>
</tr>
<tr>
<td>Raisin Bran</td>
<td>- 82.9 ppb</td>
</tr>
<tr>
<td>Organic Promise</td>
<td>- 24.9 ppb</td>
</tr>
<tr>
<td>Special K</td>
<td>- 74.6 ppb</td>
</tr>
<tr>
<td>Frosted Flakes</td>
<td>- 72.8 ppb</td>
</tr>
<tr>
<td>Cheez-It (Original)</td>
<td>- 24.6 ppb</td>
</tr>
<tr>
<td>Cheez-It (Whole Grain)</td>
<td>- 36.25 ppb</td>
</tr>
<tr>
<td>Kashi Soft-Baked Cookies, Oatmeal Dark Chocolate</td>
<td>- 275.58 ppb</td>
</tr>
</tbody>
</table>
Glyphosate in Foods

- Acceptable daily intake (ADI): 1.75 mg/kg bw/day in the U.S.
- 0.3 mg/kg bw/day in the European Union

<table>
<thead>
<tr>
<th>Nabisco</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ritz Crackers</td>
<td>270.24</td>
</tr>
<tr>
<td>Triscuit</td>
<td>89.68</td>
</tr>
<tr>
<td>Oreo Original</td>
<td>289.47</td>
</tr>
<tr>
<td>Oreo Double Stuf Chocolate Sandwich Cookies</td>
<td>140.90</td>
</tr>
<tr>
<td>Oreo Double Stuf Golden Sandwich Cookies</td>
<td>215.40</td>
</tr>
</tbody>
</table>

(Food Democracy Now!, 2016)
## Glyphosate in Foods

### PepsiCo

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stacy’s Simply Naked Pita Chips (Frito-Lay)</td>
<td>812.53</td>
</tr>
<tr>
<td>Lay’s: Kettle Cooked Original</td>
<td>452.71</td>
</tr>
<tr>
<td>Doritos: Cool Ranch</td>
<td>481.27</td>
</tr>
<tr>
<td>Fritos (Original) (100% Whole Grain)</td>
<td>174.71</td>
</tr>
</tbody>
</table>

### Campbell Soup Company

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldfish crackers original (Pepperidge Farm)</td>
<td>18.40</td>
</tr>
<tr>
<td>Goldfish crackers colors</td>
<td>8.02</td>
</tr>
<tr>
<td>Goldfish crackers Whole Grain</td>
<td>24.58</td>
</tr>
</tbody>
</table>

### Little Debbie

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oatmeal Crème Pies</td>
<td>264.28</td>
</tr>
</tbody>
</table>

### Lucy’s

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oatmeal Cookies Gluten Free</td>
<td>452.44</td>
</tr>
</tbody>
</table>

### Whole Foods

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>365 Organic Golden Round Crackers</td>
<td>119.12</td>
</tr>
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</table>

### Back to Nature

<table>
<thead>
<tr>
<th>Product</th>
<th>Glyphosate (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crispy Cheddar Crackers</td>
<td>327.22</td>
</tr>
</tbody>
</table>

(Food Democracy Now!, 2016)
<table>
<thead>
<tr>
<th>Commodity</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, seed</td>
<td>0.5</td>
</tr>
<tr>
<td>Animal feed, nongrass, group 18</td>
<td>400</td>
</tr>
<tr>
<td>Artichoke, globe</td>
<td>0.2</td>
</tr>
<tr>
<td>Asparagus</td>
<td>0.5</td>
</tr>
<tr>
<td>Avocado</td>
<td>0.2</td>
</tr>
<tr>
<td>Banana</td>
<td>0.2</td>
</tr>
<tr>
<td>Barley, bran</td>
<td>30</td>
</tr>
<tr>
<td>Beet, sugar, dried pulp</td>
<td>25</td>
</tr>
<tr>
<td>Beet, sugar, roots</td>
<td>10</td>
</tr>
<tr>
<td>Berry and small fruit, group 13-07</td>
<td>0.2</td>
</tr>
<tr>
<td>Carrot</td>
<td>5.0</td>
</tr>
<tr>
<td>Coconut</td>
<td>0.1</td>
</tr>
<tr>
<td>Coffee, bean, green</td>
<td>1.0</td>
</tr>
<tr>
<td>Corn, pop, grain</td>
<td>0.1</td>
</tr>
<tr>
<td>Corn, sweet, kernel plus cob with husk removed</td>
<td>3.5</td>
</tr>
<tr>
<td>Fig</td>
<td>0.2</td>
</tr>
<tr>
<td>Fish</td>
<td>0.25</td>
</tr>
<tr>
<td>Fruit, citrus, group 10-10</td>
<td>0.5</td>
</tr>
<tr>
<td>Fruit, pome, group 11-10</td>
<td>0.2</td>
</tr>
<tr>
<td>Fruit, stone, group 12</td>
<td>0.2</td>
</tr>
<tr>
<td>Commodity</td>
<td>Parts per million</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Guava</td>
<td>0.2</td>
</tr>
<tr>
<td>Herbs subgroup 19A</td>
<td>0.2</td>
</tr>
<tr>
<td>Hop, dried cones</td>
<td>7.0</td>
</tr>
<tr>
<td>Mango</td>
<td>0.2</td>
</tr>
<tr>
<td>Nut, tree, group 14</td>
<td>1.0</td>
</tr>
<tr>
<td>Oilseeds, group 20, except canola</td>
<td>40</td>
</tr>
<tr>
<td>Okra</td>
<td>0.5</td>
</tr>
<tr>
<td>Olive</td>
<td>0.2</td>
</tr>
<tr>
<td>Oregano, Mexican, leaves</td>
<td>2.0</td>
</tr>
<tr>
<td>Papaya</td>
<td>0.2</td>
</tr>
<tr>
<td>Passionfruit</td>
<td>0.2</td>
</tr>
<tr>
<td>Pea, dry</td>
<td>8.0</td>
</tr>
<tr>
<td>Peanut</td>
<td>0.1</td>
</tr>
<tr>
<td>Peanut, hay</td>
<td>0.5</td>
</tr>
<tr>
<td>Peppermint, tops</td>
<td>200</td>
</tr>
<tr>
<td>Pineapple</td>
<td>0.1</td>
</tr>
<tr>
<td>Pistachio</td>
<td>1.0</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>0.2</td>
</tr>
<tr>
<td>Quinoa, grain</td>
<td>5.0</td>
</tr>
<tr>
<td>Rice, grain</td>
<td>0.1</td>
</tr>
<tr>
<td>Rice, wild, grain</td>
<td>0.1</td>
</tr>
<tr>
<td>Shellfish</td>
<td>3.0</td>
</tr>
<tr>
<td>Commodity</td>
<td>Parts per million</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Soybean, hay</td>
<td>200.0</td>
</tr>
<tr>
<td>Soybean, hulls</td>
<td>120.0</td>
</tr>
<tr>
<td>Soybean, seed</td>
<td>20.0</td>
</tr>
<tr>
<td>Spearmint, tops</td>
<td>200</td>
</tr>
<tr>
<td>Spice subgroup 19B</td>
<td>7.0</td>
</tr>
<tr>
<td>Starfruit</td>
<td>0.2</td>
</tr>
<tr>
<td>Stevia, dried leaves</td>
<td>1.0</td>
</tr>
<tr>
<td>Sugarcane, cane</td>
<td>2.0</td>
</tr>
<tr>
<td>Sugarcane, molasses</td>
<td>30</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>3.0</td>
</tr>
<tr>
<td>Tamarind</td>
<td>0.2</td>
</tr>
<tr>
<td>Tea, dried</td>
<td>1.0</td>
</tr>
<tr>
<td>Tea, instant</td>
<td>7.0</td>
</tr>
<tr>
<td>Teff, forage</td>
<td>100</td>
</tr>
<tr>
<td>Teff, grain</td>
<td>5.0</td>
</tr>
<tr>
<td>Vegetable, fruiting, group 8-10 (except okra)</td>
<td>0.10</td>
</tr>
<tr>
<td>Vegetable, leafy, brassica, group 5</td>
<td>0.2</td>
</tr>
<tr>
<td>Wasabi, roots</td>
<td>0.2</td>
</tr>
<tr>
<td>Watercress, upland</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Increased Herbicide Use

- GMO crops - genetically engineered to withstand herbicides, ex. Roundup-Ready soybeans
  - or - to contain their own pesticides, ex. “Bt” (Bacillus thuringiensis) corn and cotton
- Bacillus thuringiensis (Bt) - a soil bacterium that produces insecticidal toxins.
- Genes from Bt - inserted into crop plants to make them capable of producing an insecticidal toxin and therefore resistant to certain pests

(Hemmelgarn, 2013)
(EPA, 2014)
(EPA, 2001)
Increased Herbicide Use

- Plant-incorporated protectants - pesticidal substances produced by GM plants. The resulting pesticide and its genetic material are regulated by EPA.

- EPA - Plant-Incorporated Protectants undergo safety testing, including testing for oral toxicity, in vitro digestibility assay, amino acid sequence homology comparisons, and an acute oral toxicity test.

- “Due to limitations of obtaining sufficient quantities of pure protein test substance from the plant itself, an alternative production source of the protein is often used such as the Bacillus thuringiensis source organism or an industrial fermentation microbe.”

(Hemmelgarn, 2013)
(EPA, 2014)
(EPA, 2001)
GM crops often designed to withstand herbicides, including 2,4-D and dicamba. (2,4-D - one of the two major ingredients in Agent Orange)

- Glyphosate - routinely sprayed on many herbicide-resistant GM crops, ex. corn, soy, canola, sugar beets and most recently, alfalfa

- U.S. Department of Agriculture’s pesticide use data, Charles Benbrook, Professor at the Center for Sustaining Agriculture and Natural Resources at Washington State University - herbicide-resistant crop technology led to a 527-million-pound increase in herbicide use in the United States between 1996 and 2011.

- Benbrook projects that the new 2,4-D and dicamba-resistant GMO crops could drive herbicide usage up by about another 50 percent
Bt corn - can adversely affect non-target insects if they are closely related to the target pest, as is the case with Monarch butterfly.

Humans - many terms of magnitude larger than the caterpillars adversely affected by the Bt toxin. Therefore, small amounts of this toxin could likely only have a subtle, subclinical effect on humans.

Are the slight, subtle effects of this pesticide enough to weaken the intestinal walls of some people?

Further study is needed to determine the similarity between the human intestinal tract and that of the caterpillar, the intended target of this Bt toxin.
Delta endotoxins are a group of Bt toxins. Delta endotoxins - rapidly broken down in the stomach and thus are not potential food allergens. Ontario study - detected the delta endotoxin Cry1Ab in the blood serum of pregnant women, their fetuses, and nonpregnant women. The health significance of this observation is unknown. Delta endotoxins - rapidly paralyze the insect’s digestive system, so damage to the plant stops soon after the insect is exposed to the toxin. These plants are engineered to produce their own Bt toxin. Therefore, the pesticide would be within the interiors of these plants as well, not just on their surfaces.
Gene Transfer

• According to the WHO’s website, gene transfer from genetically modified foods to cells of the body or to bacteria in the gastrointestinal tract would cause concern if the transferred genetic material adversely affects human health.

• Ex. Transfer of antibiotic resistance genes used in creating GMOs

• Probability of transfer is low

• Use of technology without antibiotic resistance genes has been encouraged by a recent FAO/WHO expert panel

(WHO, 2017)
Herbicide-resistant crop technology led to a 239 million kg (527 million lb) increase in herbicide use in the United States between 1996 and 2011.

Bt crops reduced insecticide applications by 56 million kilograms (123 million pounds).

Pesticide use increased by an estimated 183 million kgs (404 million lbs), or about 7%.

Spread of glyphosate-resistant weeds in herbicide-resistant weed management systems led to increased amounts of applied herbicides.

The article also said, “If new genetically engineered forms of corn and soybeans tolerant of 2,4-D are approved, the volume of 2,4-D sprayed could drive herbicide usage upward by another approximate 50%. The magnitude of increases in herbicide use on herbicide-resistant hectares has dwarfed the reduction in insecticide use on Bt crops over the past 16 years, and will continue to do so for the foreseeable future.”

(Benbrook, 2012)
Ethics- Unnatural Organisms

• Some people - feel that scientists are “playing God” and ethically should not alter the genomes of living organisms

• Some vegetarians - concerned that genes from animals may be inserted into their vegetables, thus making the vegetables contain a component of animal origin.

• FlavrSavr tomato – arctic flounder gene

• Calgene withdrew from the market in 1997. “The tomato included a modified gene from a breed of arctic flounder that, it was hoped, would allow the tomatoes to be more resistant to frost and cold storage. Activists decried these so-called "fish tomatoes," protesting their entry into our food supply.” (Pbs.org, n.d.)

• Orthodox Union (OU, Jewish kosher certification authority) and the Islamic Jurisprudence Council (IJC) - approved GMO foods

• The new technology does not conflict with religious dietary laws

(Ciola, 2012)
(Hazzah, 2000)
(Pbs.org, n.d.)
Lack of Long-term Human Studies

- Biotech companies have not conducted any long-term human studies.
- Such studies would be time consuming and costly.
- GM products - introduced into the food supply without the general public’s knowledge.
- Commonly consumed foods such as corn and soy for example are quite likely be GM in the United States.
- *Is the entire population of the United States unknowingly participating in a huge long-term human uncontrolled longitudinal study?*
Strategies to reduce mixing - clear separation of the fields within which GM crops and conventional crops are grown
Genetically modified pollen can escape and potentially introduce the engineered genes into wild populations
Persistence of the gene after the GMO has been harvested
Unintentional and unwanted contamination of conventional and organic crops
Around 1,000 farmers sued for infringing on patents due to pollen drift contamination
Ten-year study - Germany, Switzerland, and Belgium
- Maize pollen spread over a kilometer from the field in a concentration of several thousand pollen grains per square meter.
- The authors (Hofmann, Otto, and Wosniok) concluded that buffer zones in the kilometer range are needed to prevent unwanted exposure of fields to GMOs.

(WHO, 2017)
(Hemmelgarn, 2013)
(Fried, 2014)
(Hofmann, Otto, and Wosniok, 2014)
Lack of Sustainability and Genetic Drift Into Conventional Crops

- Susceptibility of non-target organisms (e.g. insects which are not pests) to the gene product
- Stability of the gene
- Reduction in the spectrum of other plants, loss of biodiversity
- Increased use of chemicals in agriculture
- Environmental safety aspects of GM crops vary considerably according to local conditions
- Control of seed markets by chemical/biotech companies
- Sustainable agriculture and biodiversity - benefit most from the use of a rich variety of crops
- Range of varieties used by farmers - reduced mainly to GM crops
- Exclusive use of herbicide-tolerant GM crops - farmer dependent on agricultural chemicals
- Biotech scientists do not feel that reliance on licensed seeds, or the possibility of genetic drift of GM traits to native plant populations should factor into the sustainability issue

(WHO, 2017)
Environmental Impact

- Toxin in the corn pollen - may be detrimental to the larvae of monarch butterflies
- Other studies – impact of Bt corn on monarch butterflies was negligible
- September 2000, StarLink corn, not approved for human consumption - found in Taco Bell taco shells
- Scientists - at a loss to explain the declining bee populations
- Bees collect pollen to make their honey
- Further research - needed to look into the effect of Bt laced pollen on bees as well

(Pbs.org, n.d.)
May Impact Low Income People the Most

- Low-income people - affected the most
- Cannot afford to buy foods labeled as “organic” or “non-GMO” due to the increased expense
- Many GM crops are grown and used in third-world countries, which have a substantial amount of low income residents.
Who Regulates GMO Foods?

• **United States:**
  - FDA-Center for Food Safety and Applied Nutrition-regulates safety of food for human consumption from biotech crops
  - FDA-voluntary process, substantial equivalence
  - EPA-regulates transgenic crops which contain/produce pesticides
  - USDA-Plant Protection Act-Animal and Plant Health Inspection Service (APHIS)-regulates agricultural plant pests and noxious weeds-looks at environmental impact

(DeFrancesco, 2013)
Who Regulates GMO Foods?

- U.S, Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS)
  - Several genetically engineered (GE) crops that rely on new approaches are outside the scope of its regulations

“If APHIS concludes that a GE organism does not pose a plant pest or noxious weed risk, then APHIS would not require a permit for the importation, interstate movement, and environmental release (outdoor use) of the GE organism.”

(USDA/APHIS, 2017)
Who Regulates GMO Foods?

- **Europe:**
  - Requires developers to prove safety (no GRAS status)
  - Regulation (EC) 258/97 novel foods and food ingredients

(DeFrancesco, 2013)
FDA does not require the same type of safety testing for genetically modified crops that is required for new pharmaceuticals.

FDA - foods derived from new plant varieties are regulated by FDA under the FD&C Act.

Limited to identifying **significant changes in a food's composition**

Allergens, proteins that change the composition of the vegetable

“The FD&C Act requires premarket approval of any food additive -- regardless of the technique used to add it to food. Thus, substances introduced into food are either (1) new food additives that require premarket approval by FDA or (2) **GRAS, and are exempt from the requirement for premarket review**, for example, there is a long history of safe use in food. Generally, whole foods, such as fruits, vegetables, and grains, are not subject to premarket approval because they have been used for food for lengthy periods of time.” (Maryanski, 2009)

Proteins, carbohydrates, and fats - are GRAS (generally recognized as safe).
Substances added to food via genetic engineering - well-characterized proteins, fats, and carbohydrates, generally recognized as safe.

Bt toxin - made of protein, a mixture of Cry and Cyt proteins, used worldwide for insect control.

Cry toxins interact with receptors on the host cell surface

Cyt toxins interact with membrane lipids

Glyphosate, also known as Roundup, or N-(Phosphonomethyl)glycine - an amino acid derivative, and has the backbone of the amino acid glycine.

Used as a herbicide and antifungal agent.

According to the PubChem website, allowable tolerances range by the type of food product, and range from a low of 0.1 ppm in poultry and meat to a high of 400 ppm in alfalfa.
Other examples of proteins: Botulinum toxin, ricin, all enzymes, all antibodies, and some hormones including insulin and oxytocin are proteins.

FDA regulations - would require identification of expressed allergens resulting from genes inserted from known allergenic plants.

Bt-toxin and glyphosate – may affect the body’s reaction to ingested allergens, but labeling is not required.

These are not known allergens themselves.
Regulations (or Lack of Associated Regulations)-Europe

- Codex Alimentarius Commission (Codex) - a joint FAO/WHO organization that gathers the standards, codes of practice, guidelines and recommendations of the Codex Alimentarius, the international food code
- Codex - developing principles for human health risk analysis of GM foods
- The Cartagena Protocol on Biosafety (CPB) - an environmental treaty
- Regulates transportation of living modified organisms (LMOs).
- Requirement - exporters seek consent from importers before the first shipment of LMOs intended for release into the environment.

(WHO, 2017)
Regulations (or Lack of Associated Regulations)-Europe

- Procedure for approval - rather complex, requires agreement between the Member States and the European Commission

- Between 1991 and 1998, the marketing of 18 GMOs was authorized in the EU by a Commission decision

- In the EU, labeling is required for items derived from biotechnology or containing GMOs.

- 1% minimum threshold for DNA or protein resulting from genetic modification for labelling

(WHO, 2017)
• GMO labeling – in the United States
  - Currently voluntary
  - Codes/QR hyperlinks required for most packaged foods by July 29, 2018
• Not possible to track the extent of a patient’s intake of GM foods or to devise a plan to avoid purchasing genetically modified foods
• Unless consumers, hospitals, nursing homes, and restaurants take the extra step of buying everything organic or non-GMO labeled (very unlikely and expensive)

Strong opposition from Monsanto and the Grocery Manufacturers’ Association.

Did not pass
Regulations (or Lack of Associated Regulations)-United States

- Bill H.R.4432-Safe and Accurate Food Labeling Act of 2014
- Also known as the “DARK Act (Deny Americans the Right-to-Know Act)” since it is designed to destroy the GMO labeling movement
- Introduced April 9, 2014 by Rep. Mike Pompeo
- Preempts any state and local labeling requirements with respect to bioengineered food.

“Requires the Secretary to issue regulations setting standards for a natural claim on food labels. Preempts any state or local regulations that are not identical to the requirements of this Act.”

(Congress.gov, 2014)
(Greenberg, 2016)
Regulations (or Lack of Associated Regulations)-United States

- **National Bioengineered Food Disclosure Standard**
- Public Law 114-216
- **Signed into law July 29, 2016**
- “require that the form of a food disclosure under this section be a text, symbol, or electronic or digital link, but excluding Internet website Uniform Resource Locators not embedded in the link, with the disclosure option to be selected by the food manufacturer”
- “FEDERAL PREEMPTION.—No State or a political subdivision of a State may directly or indirectly establish under any authority or continue in effect as to any food or seed in interstate commerce any requirement relating to the labeling of whether a food (including food served in a restaurant or similar establishment) or seed is genetically engineered (which shall include such other similar terms as determined by the Secretary of Agriculture) or was developed or produced using genetic engineering, including any requirement for claims that a food or seed is or contains an ingredient that was developed or produced using genetic engineering.”
Hawaii – Bill 113 signed by Mayor Billy Kenoi on December 5, 2013
- Encourages and supports community-based farming and farm training programs
- Bans any new GMOs from being grown in Hawaii.
- Allows current farms of GM papayas to remain

Connecticut (June 2013) and Maine (Jan. 2014) - regulations passed to require that GM foods be labeled
- Regulations contain clauses requiring at least four other states to pass similar regulations before they are put into effect.

Vermont – April 2014, labeling of foods that contain genetically engineered ingredients, took effect July 1, 2016 and pre-empted one week later

(Smith, 2013)
(Huffington Post, 2013)
(Hopkinson and Evich, 2014)
(Maine Organic Farmers and Gardeners Association, 2017)
(Strom, 2014)
Vermont was being sued – by the Grocery Manufacturers Association (GMA), the Snack Food Association, the International Dairy Foods Association and the National Association of Manufacturers.

They felt that the GMO labeling law would put undue restrictions on the freedom of speech of food sellers for an issue that is not based on health, safety, or science.

This suit was dropped because the federal law preempted Vermont’s law.

Labeling regulations are seen as compelled commercial speech.

The First Amendment in the U.S. Constitution - the freedom of speech.

This amendment was written to prevent the government from banning speech if it disagrees with the message. This does NOT allow the government to allow companies to hide information from consumers because those companies do not agree with the message.

(Baertlein, L., 2014)
(The Heritage Guide to the Constitution, 2012)
(Adler, J., 2016)
How many people are aware that they are consuming genetically modified foods everyday on a regular basis?

Editors at Scientific American - mandatory GMO labels not beneficial, would “only intensify the misconception that so-called Frankenfoods endanger people's health.” (Scientific American, Editors, 2013)

The authors feel that labeling of GMOs would limit available options. “In 1997, a time of growing opposition to GMOs in Europe, the E.U. began to require them. By 1999, to avoid labels that might drive customers away, most major European retailers had removed genetically modified ingredients from products bearing their brand. Major food producers such as Nestlé followed suit. Today it is virtually impossible to find GMOs in European supermarkets.” (Scientific American, Editors, 2013)

These authors feel that labeling would raise the average family’s food costs by as much as $400 per year due to the increased water and pesticide applications used for conventional crops.

“Legally mandating such a label can only serve to mislead and falsely alarm consumers.” (AAAS, 2012)
Pros of Mandatory Labeling

- People have a right to know what is in their food.
- People are concerned about ingredients that may be related to health issues.
- People are concerned about ingredients related to environmental issues.
- Mandatory labeling will allow people to identify and choose to avoid such foods.
- Voluntary labeling is not sufficient to informing consumers about the presence of GM ingredients.
- Once made aware of the issue, most Americans support mandatory labeling.
- At least 64 countries have established mandatory labeling regulations.

(Byrne, Pendell, & Graff, 2015)
Cons of Mandatory Labeling

- Such labels seem to imply a warning about negative health effects.
- Theoretically, if an allergenic substance is present in a GM food, the FDA regulations would require a label stating its presence.
- Increased food costs associated with labeling of GM foods would be passed to the consumers.
- Currently, consumers who prefer non-GM food can purchase verified non-GM foods or organic foods.
- Food manufacturers are fearful that consumers will stop purchasing their products—“Experience with mandatory labeling in the European Union, Japan, and New Zealand has not resulted in greater consumer choice. Rather, retailers have eliminated GM products from their shelves due to perceived consumer aversion to GM products.”
- “The food system infrastructure (storage, processing, and transportation facilities) in this country could not currently accommodate the need for segregation of GM and non-GM products.”

(Byrne, Pendell, & Graff, 2015)
Labeling of GMOs in U.S. and Abroad

- Article 18 of the Cartagena Protocol - handling, transport, packaging and identification of LMOs.
- Identification of LMOs as well as additional documentation.
- 170 countries signed this protocol; the United States was not one of them

(Convention on Biological Diversity, 2016)
The following are at high probability of being GMO:

- Alfalfa (~ 10%)
- Canola (~ 94%)
- Corn (~ 92%)
- Cotton (~ 94%)
- Papaya (~ 94% in Hawaii)
- Soy (~ 94%)
- Sugar Beets (~ 98.5%)
- Zucchini and Yellow Summer Squash

Also look for:

- Flax
- Rice

(Non GMO Project, 2016)
(USDA, 2016)
Consumer Knowledge of GMOs

According to a study of 1,148 individual conducted by Rutgers and GfK Custom Research in 2013:

- Fewer than half of Americans (43%) are aware that GM foods are currently for sale in supermarkets.
- Only one quarter (26%) believe that they have ever eaten a food containing GM ingredients.
- When asked “What information would you like to see on food labels that is not already on there?”, only 7% mentioned GM food labeling. 6% said they would like information about where the food product was grown or processed.
- The lack of suggesting GM labeling is likely due to lack of knowledge that GM products are so prevalent in the marketplace.
- When asked to rate various kinds of information on food labels, 59% said that it was very or extremely important to have information about whether the product contains GM ingredients on a label.
- When asked specifically whether GM foods should be required to be labeled, 73% said yes.

(Hallman, Cuite, and Morin, 2013)
How to Advise Clients Who Want to Consume GMOs

- Choose commercially available products containing:
  - Sweet corn
  - Soy, soy protein
  - Beet sugar
  - Canola oil
  - Other foods previously mentioned
How to Advise Clients Who Would Like to Limit/Avoid GMOs

• Avoidance is almost impossible to achieve
• Weigh the benefits vs. risks of consuming GMOs

• **Advise clients interested in limiting GMOs to look for:**
  - Organic produce
  - Organic and Non-GMO Project Verified grains
  - Organic oil
  - Cane sugar (vs. beet sugar)
  - Organic honey
How to Advise Clients Who Would Like to Limit/Avoid GMOs

- Check labels for the following ingredients: corn (including dextrose), soy (including soy-based lecithin), canola oil, sugar (sourced from sugar beets, not cane), and cottonseed oil, vegetable oil (can be GMO soy oil)

- GMO (Round-up ready) alfalfa was recently approved - primarily used in feed for dairy cows and beef cattle; may also contribute to pork, lamb, sheep, and honey production.

- Many non-organic meats, poultry, and dairy products - animals fed GMO grain.

(Hemmelgarn, 2013)
What to Look for When Eating Out

- Organic restaurant
- Locally grown - farmers who can verify that they are using non-GMO seeds, and feeding their livestock non-GMO crops
- Ask to speak with the restaurant’s manager or chef - sources of ingredients in the dish being ordered
Both sides of the debate should be considered when advising clients.

More research is needed.

Labeling of GM foods in the United States is warranted to help consumers make informed choices.
Questions? Thank You!
You must complete a brief evaluation of the program in order to obtain your certificate. The evaluation will be available for 1 year; you do not have to complete it today.

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