# CREDITS

Nico Guiton

- Primary writer and researcher for Chapter 1: GMO History- A Background For and Look Back at Genetic Modification
- Contributed writing to Ethical Analysis and Recommendations
- Contributed to Executive Summary

Jason Cox

- Primary writer and researcher for Chapter 2: Current Research, Emerging Technologies, and Conflict of Interest
- Primary writer for Introduction
- Contributed research section for Ethical Analysis and Recommendations
- Primary writer and organizer for List of Figures and Tables
- Contributed to Executive Summary

Louise Lehman

- Primary writer and researcher for Chapter 3: Business Perspective
- Contributed business section for Ethical Analysis and Recommendations
- Contributed to Introduction and Conclusion
- Contributed to Executive Summary
- Created and helped organize a group forum for project assignments and discussion

Celebration Ferguson

- Primary writer and researcher for Chapter 4: Environmental Analysis
- Contributed environment section for Ethical Analysis and Recommendations
- Contributed to Executive Summary
- Contributed to Conclusion

# LIST OF FIGURES AND TABLES

# INTRODUCTION

For the last few decades, genetically modified organisms (commonly referred to as GMOs) have been an exciting topic of discussion and research among the scientific community.  Ever since 1982, when Monsanto developed the first genetically modified plant with the intention of bring it to market, scientists and entrepreneurs have examined the possibilities of improving the farming of crops and animals, eradicating disease, and even solving world hunger.  Unfortunately, the scientific leaps and bounds have caused some concern for the public.  As the power of GMOs is being realized, people are discovering many ethical issues that, if handled incorrectly, could destroy not only the GMOs industry, but also possibly the human health and the environment.

Fears first became exposed in the late 20th century as Monsanto slowly converted from a chemical company to biotechnology.  Older generations still remember the use of Agent Orange and DDT, both of which were Monsanto products. Even though Monsanto is definitively not the same corporation that it was back in the day, the memories make people wary of unforeseen effects that GMOs could have on both human populations and the environment.

For the people who tend to look towards the future, there are plenty of prospects.  New companies are springing up with valuable ideas such as fast-growing salmon and nutrient-infused pigs.  Advances like these will lead to generally healthier populations and even bring us closer to the ultimate goal of solving world hunger.  Some scientists believe this will finally come about with the introduction of vat-grown meat.  Being able to grow the meat in large quantities without the need to care for animals could drastically improve food supplies and lower prices.  Unfortunately, such science fiction-esque technologies quickly bring us to the ethical issues associated with their use.

Some of these public concerns about GMOs include health risks and environmental consequences. Consuming food that is produced partially by unnatural means causes people to equate genetic modification to chemicals. Some believe that if GMOs are a substitute replacement for pesticides and herbicides, they must be similarly dangerous to human health. Some GMOs have also been shown to unintentionally harm wild plants and animals. Consumers' opinions are important to businesses because the welfare of business directly depends on the demand of consumers. Businesses have to consider costs, efficiencies, and relations with other businesses when deciding whether or not to produce GMO crops. Important factors in GMO production are trade with other nations, how labeling laws could affect businesses' reputations, and how the supply and demand of GMO products could affect price and profit, and safety risks for the environment and humans.  This paper examines these factors and provides analysis for each issue.

# CHAPTER 1: A HISTORY OF GENETIC MODIFICATION

## Genetics and DNA

Humans have been genetically engineering their food since they first domesticated plants and animals.  Organisms such as cows, pigs, sheep, chickens, wheat, and rice are the byproducts of domestication and early techniques in engineering the perfect organisms for food.  At such a time, the techniques for genetically engineering food involved the relatively simple method of artificial selection.  Artificial selection is the act of humans selecting traits they found beneficial or detrimental in certain organisms and breeding the beneficial traits into the next generation while breeding the detrimental traits out.  It was not until much later, however, that the mechanisms of genetics were researched and documented. Since then, the field of genetics, and by extension genetic engineering, has advanced to the point of directly manipulating the DNA of organisms.  Companies such as Monsanto have since commercialized such techniques and the products thereof.

Genetics is the scientific study of genes, heredity, and the variation between organisms that plays a role in selection (Campbell 2005). DNA is a double-helix shaped molecule that can be thought of as the building block of all life. DNA encodes the genetic material that delegates how an organism is built and functions (Campbell 2005). Being encrypted, however, DNA must be read, transported, and translated by RNA, DNA's mirror image. Subsections of DNA are called genes and are passed down to an organism's offspring (Freudenrich 2012).

Gregor Mendel is often considered the father of modern genetics for his pea plant experiments. Mendel's experiments involved the repeated cultivation of pea plants in order to determine the inheritance patterns of specific characteristics in the pea plant such as color (Campbell 2005). His work eventually led him to the development of two generalizations known as the Law of Segregation and the Law of Independent Assortment. The Law of Segregation states that every trait or characteristic possessed by an organism is determined by a pair of alleles and that one of these alleles is copied and passed on to an offspring at random (Campbell 2005). An allele is one of two or more variations of a gene. Usually, there are only two variations of an allele with one variant being dominant over the other. The dominant allele is the one that is physically expressed by the organism. The second generalization, the Law of Independent Assortment, states that genes for separate characteristics are passed to an organism's offspring independently of one another (Campbell 2005).

When an organism produces an offspring sexually, it receives half of its alleles from its mother and a mirror half from its father. The manner in which an organism receives these genes follows the aforementioned generalizations made by Mendel. When the offspring's DNA is read in order to begin its construction, however, there may be issues in the reading, transportation, or translation of genetic material (Freudenrich 2012). This leads to mutations whose effects can range from nothing to a change in the construction of the organism from increased height to an extra limb.

## Selection

Within a population of organisms there is always variation in each individual organism's genetic make up. For some individuals, their genotype, or genetic make up, offers certain advantages for that individual over the rest of the population in survival. For example, a tiger with eyes that allow its pupils to expand more than others will have an advantage when hunting during the night, thereby giving it an advantage in survival. For others, the genotype may provide disadvantages in survival. An example of such would be a gazelle with shorter legs. The gazelle with shorter legs will be unable to run as fast as the rest of the herd and would therefore be more likely to be caught and killed by a predator. For some individuals, however, their genotypes will offer little to no notable advantages or disadvantages over the rest of the population. Natural selection is the process by which nature weeds out the weaker organisms out of a population of organisms in favor of those with stronger, more beneficial traits for survival due to the scarcity of resources and some selecting factor like a predator or disease (Campbell 2005). In the case that the traits are heritable, that is able to be passed onto the individual's offspring, the proportion of the next generation with the aforementioned traits will be greater than that of the previous generation. Natural selection is only one specific case of the selection process.

After generations of selection, populations of organisms change according to their habitat and situation. Biological evolution is the end result of just that. It is a population of organism's adaptation to its environment and stimuli (Campbell 2005). It is important, though, to remember that evolution is a relatively slow process. It can, and often does, take many generations of selection before a significant change to the population's overall gene pool occurs. In organisms such as bacteria, this can occur in a matter of days if not hours. By comparison, evolution in species with much longer life spans can take years, if not decades. In an environment without certain human interactions, natural selection would be the major driving factor in a population's evolution. However, many organism species that are common today exist largely due to human interference in the selection process.

Artificial selection, or selective breeding, is another biological phenomenon affecting a population's evolution. In contrast to natural selection in which the selecting agent is a population's ecosystem, artificial selection's selecting agent is humans. In artificial selection, humans influence the gene pool by deciding which individual organisms are able to breed and with what other individual. Through this method, humans are able to select out undesirable characteristics while propagating the desirable characteristics. Outside of the selecting agent, the mechanisms behind traditional artificial selection and natural selection are exactly the same and as such both lead to the same end results of evolution. Regardless, it is still a very powerful tool, allowing humans to directly influence and, in some cases, dictate the flow of nature. Domesticated organisms are almost all direct results of artificial selection.

Early humans took advantage of the process of artificial selection. In the transition between the hunter-gatherer and a more agricultural-based lifestyle closer to modern society, humans began to domesticate plants, animals, and even bacteria to suit their needs. One of the most popular examples of domesticated organisms is the domesticated dog. The domesticated dog is the result of millennia of artificial selection on prehistoric wolves (Hedges 2009). The exact purpose of the prehistoric domesticated dog is still widely debated; however, it is very likely they were selected for their ability to assist in hunting for food and less for their aesthetics (Hedges 2009). At some point on the road to modern human society, the consensus of desirable characteristics shifted from favoring the ability to assist in hunting to favoring the animal's ability to act like a modern day pet. This has resulted in the modern day domesticated dog that can be seen throughout society.

Another example of a domesticated animal is the cow. In contrast to how the domesticated dog was largely selected upon based on its ability to hunt and then its aesthetics and ability to act as a more docile pet, the cow was selected to be purely as livestock used for their meat, dairy, and leather among other products. The prehistoric ancestor of the modern day cow was the aurochs (Wilkins 2012). The aurochs were, in comparison to modern cows, much larger and much more aggressive animals with large horns (Wilkins 2012). In comparison to wolves, the aurochs were much more dangerous and difficult to domesticate.

One final example of organism domestication is wheat. In terms of ease of domestication, plants are significantly easier than animals simply because plants can't turn around and attack or eat the human trying to capture them. The wild ancestor of modern day wheat had thinner, longer seeds along with a shattering rachis, the steam that holds the seeds together (Hirst 2012). Both of these characteristics, however, were not beneficial to humans as the seeds were smaller in comparison to the seeds of modern wheat and the shattering rachis meant ripe seeds would fall to the ground before they could be harvested (UCBL 2010). In order to engineer a more agriculturally friendly plant, humans had to actively select the wheat plants with the biggest seeds and plant them so that the genes for large seed size would be passed on to the next generation. The genes for non-shattering rachis, however, were selected in a more natural way (UCBL 2010). Wheat plants with a shattering rachis would drop their seeds to the ground when said seeds ripened making it rather difficult to harvest. The non-shattering rachis plants, however, would not drop their seeds after ripening. This made it much easier to harvest the seeds which would in turn increase the proportion of non-shattering plants in the next generation (UCBL 2010). Eventually, with the two different selections occurring at the same time, the wild wheat plant would become domesticated and evolve into its modern form.

These three cases of organism domestication through artificial selection are only a small subset of many others including cats, bees, rice, and certain strains of bacteria. The main point that these three cases exemplify is that humans have been genetically engineering and modifying organisms for their game for millennia. The major difference between now and then is the means by which the ends of genetic engineering is met. These organisms and many others that are similar are prime examples of early human genetic engineering. Since then, society's understanding of the inner workings of genetics has improved vastly and, along with significantly more powerful technology, has allowed for the genetic modification of organisms to reach a whole new level of finesse and precision as can be seen by companies such as Monsanto.

## Monsanto

Monsanto is a massive agricultural biotech corporation founded in 1901 and now located in St. Louis, Missouri (Monsanto 2012). Monsanto is a relatively well known company, being both famous and infamous for its work in the agricultural and biotech industries. Two of its most infamous products are DDT and Agent Orange. Dichlorodiphenyltrichloroethane, or DDT, was a very popular insecticide in the 1940s used as pest control during World War II for agriculture and to protect soldiers from harmful insects like mosquitoes (US EPA 2012). Agent Orange is an herbicide that was used during the Vietnam War as a chemical weapon (US Congress 1978). As time went on, scientists began to note the harmful chain of effects that DDT and Agent Orange had on people and the environment. Due to these past products and other dangerous chemicals it has produced, Monsanto has become a relatively controversial company in spite of its contributions to the biotech and agricultural industry.

## Current Products and Business

Despite its past as a chemical company, Monsanto has begun refocusing its efforts on agriculture and biotech. Monsanto was among the first to genetically modify a plant cell in 1982 (Monsanto 2012). In 1987, Monsanto began some of the first field trails of plants with genetically modified traits in the US (Monsanto 2012). Some of its most important products today are agricultural seeds such as wheat, corn, cotton, canola, and alfalfa among others.

Mosanto's genetically modified crops have become an incredibly large part of its business. These genetically engineered plants come with various genetic benefits to farmers such as drought resistance, insect control, and improved crop yield to name a few. Their newest line of genetically modified crops, called Genuity (Monsanto 2012), can be stacked with multiples of these benefits. For example, their Genuity Smartstax Corn comes with modifications that allow it to produce its own insecticide and increases its harvest yield (Monsanto 2012). Monsanto and other biotech companies in the industry are currently making strides in the fields of genetically modified crops and the research thereof that will likely continue to do so in the future.

# CHAPTER 2: GMOs' CURRENT RESEARCH, ENGINEERING TECHNOLOGIES, AND CONFLICTS OF INTEREST

## GMO Research in the Near Future

Over the past few decades, research in genetically modified organisms has boomed. The immediate future looks bright as the possibilities for genetic modification seem endless. Scientists have found genes in various organisms, both plant and animal, that can benefit the farming industry. In the immediate future, farmers are likely to grow hardier plants and in larger quantities than their naturally-evolved cousins. Further into the distance, science fiction appears to come to life as researchers discuss and test the viability of vat-grown meats. Although not limited to modifying food sources, researchers are focusing most of their efforts on that and related fields because there is already an established market and it brings humanity closer to the elusive problem of solving world hunger.

Unfortunately, chasing after this lofty goal has brought with it a host of problems, misinformation, and uncertainty. Corporations throw large sums of money at lobbying in the hopes that regulation of GMOs (and by extension, food) will be free and unencumbering. But, some groups of consumers oppose genetic modification on the grounds of questioning its safety, both for the environment and for consumption. Other groups, such as farmers have become worried that their livelihood will be dictated by the GMO corporations by being forced to purchase GMO seed every season. Swift and heavy regulations may seem to be the right way to go, but scientists bring up that heavy regulation will also impact scientific research that allows us to better understand the consequences and benefits of modifying the genetics of living things. This multifaceted conflict of interest is a very difficult problem to solve, so first we'll look at what people want from GMO research, how and where it gets its funding, and then discuss each party's view on the subject.

Research in the field of GMOs is expected to yield very exciting results within the next couple decades. Continuing on the theme of Monsanto's entrance into the GMO market, the improvement of crops has been the focus of many scientists in recent years. This can be mostly attributed to the relatively lower cost of gene modification with plants as opposed to animals. With plants, there are a number of well known gene transcription techniques that have been studied in detail. Animals, on the other hand, require a much more complicated process because a fertilized egg must be implanted in a female, and then the transgenic animal must be birthed. These extra steps along with additional care for the animals is quite costly. Most genetic modification in the near future will be concerning plants because of this fact. More specifically, scientists are focusing their efforts on farm crops in an attempt to increase crop yields as well as improving resistances to disease, pests, droughts, and flooding. Monsanto's genetically modified corn is a famous example of engineering a crop to be more resistant to pests by enabling the plant to excrete chemicals that are toxic to the insects.

Looking forward, there are even more possibilities in the world of genetically modified organisms to be realized within this decade. Many GMO enthusiasts are currently watching AquaBounty Technologies, as they are currently looking for FDA approval for a transgenic salmon that grows almost twice as fast as natural salmon. The salmon was preliminarily declared to be safe to eat, but is still undergoing the approval process, which may take many more years to complete (McLure). Being such a healthy source of protein and other nutrients, increasing the output of salmon filets will likely reduce its price and make it available to a larger percentage of the world's population. In a time when many developed countries are worried about processed, low-quality food encompassing a majority of people's diets, looking forward to cheaper healthy food is great news. And not only are scientists looking for ways to produce more of healthy foods, but also to make existing products inherently more healthy. An example is where researchers in China are "already studying transgenic sheep that produce more wool, cows resistant to foot-and-mouth disease, and pigs that contain healthy omega-3 fatty acids in their meat" (McLure).

**GMO Research Beyond a Decade**

A bit further into the future, researchers are looking to turn fiction into reality. Once gene modification is developed into an industrializable technology, it will have more uses than just tweaking existing plants and animals to have favorable qualities. Two particularly exciting technologies being discussed by scientists are in vitro meat production and non-nutritional additions to food sources such as vaccines.

In vitro meat, also called vat-grown meat, is the growing of cell cultures with the intent of producing a consumable meat product. A culture starts as a small group of stem cells from any animal, such as a cow, and is given a carefully calibrated chemical medium to grow in. Once growing to sufficient size, the scientists then coax the stem cells to differentiate into muscle tissue using chemical activators. The final product is a volume of meat that is genetically identical to the original animal. This process is beneficial for a number of reasons. It takes the animal out of the process of food production, not only reducing the need for space, a living environment, and constant care, but it also reduces animal suffering which is one of the main points for some opponents of meat consumption. Additionally, it has the potential to reduce waste products typically associated with the production of meat, including large amounts of waste water, fecal material, and methane. The technology for in vitro meat already exists, however it has problems that need to be addressed before mass production is viable. First, the cell-culture mediums are too small and expensive. Even though research is underway to change that, it could be some time before they technology is viable for industrialization (Siegelbaum). Second, the meat must be grown with "blood" vessels in order to efficiently transport nutrients all throughout the cell mass. Third, the meat must be artificially exercised in order to produce healthy, correctly textured meat. Otherwise, the meat ends up chewy and tasteless (Kelland).

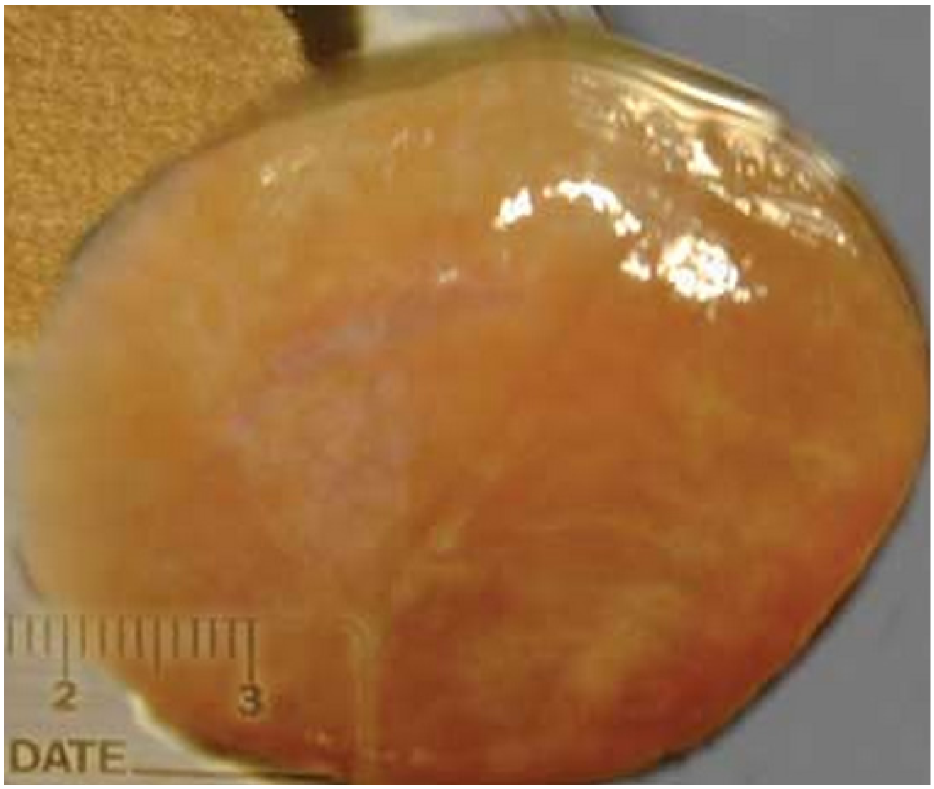


**Figure 2.1** - In vitro meat (Wired). Note the anemic qualities due to lack of vessels and exercise.

Another hot topic among scientists is the possibility of introducing genetic modifications into food that provide benefits other than nutrition. A commonly touted example is adding vaccines to fruits and vegetables such as bananas and tomatoes. Doing so would make vaccination of populations not only much easier, but cheaper as well. Without the need for equipment such as sterile needles, trained personnel are also no longer needed to administer vaccines. With vaccine-infused foods, the dream of eradicating deadly, curable diseases around the world may finally be realized. Charles J. Arntzen, a University of Arizona plant biologist, stated that he is about three years from introducing hepatitis B and diarrhea vaccines into dried fruit. Unfortunately, it would take many more years for safety research to be conducted and for it to be approved by regulatory agencies (Hosansky).

## Sources of GMO Funding

The research conducted to match these visions aren't cheap, so the question sometimes arises concerning who is paying for it all.  In general, there are four main contributing groups: corporate research and development, university research, government sponsorship, and non-profit organizations.  A majority of research (and therefore, funding) is conducted by biotechnology companies with the intent of driving profits with a product that will outcompete their rivals.  Unfortunately, because this research is financed by private money, exact dollar amounts often can't be found as they remain confidential.  In a paper on GMOs in the United States, Vogt and Parish state that "one newspaper reported that Monsanto estimates that research and development time and costs to create a commercial product are about 10 years and about $300 million. For every genetically engineered seed that goes to field trials, 10,000 have failed along the way.  Corporations charge steep prices for this technology, claiming the need to recoup their investment to be able to research the third and fourth wave of products" (Vogt and Parish).

University research in the United States is where most of the early discoveries were made, but eventually they became under threat of being overshadowed by other groups.  In order to stay competitive in introducing new gene transfer methods, the Bayh-Dole Act of 1985 was passed.  This allowed universities to hold more intellectual property rights and accelerated the process of moving research technology into consumer products (Vogt and Parish).  Additionally, due to the nature of university research, there has been encouragement to conduct studies on minor-use crops.  This remains a powerful research niche that universities maintain today.

Although usually conducted at universities or corporate research labs, various governments are well known to finance research through public funds. These studies tend to focus on safety, environmental effects, and other concerns of the public.  For example, the European Union has spent over 200 million Euros between 2001 and 2010 on food, agriculture, and biotechnology all in the context of genetic modification (European Union, 10).  Unfortunately, information concerning the United States isn't as complete because federal food and agricultural biotechnology research isn't listed as a fine item during budget analysis.  As a result, the amount of funding towards GMO research is unclear (Vogt and Parish).  Additional funding that addresses concerns of the public comes from non-profit organizations, but so far that has shown to be mostly ineffective because independent research on currently-marketed transgenic seeds is made difficult by the corporations that produce them.  Monsanto and other agri-biotech companies include statements in their user agreements that prevent the purchasers from publishing studies on the seeds without the corporation's approval (Scientific American).

## Concerns Following GMO Research

Companies like Monsanto have the largest stake in genetic modification of food products.  Naturally, this makes people wonder what sorts of products these companies will produce and how their livelihoods will be affected.  There have been a number of groups identified that could be affected by GMOs (either favorably or adversely): consumers, farmers, scientists, and the corporations themselves.  Consumers, being the largest group that is likely to be affected, are worried about their safety in terms of consumption of genetically modified foods.  It's difficult to know if the modifications scientists are making are safe.  Even more difficult is the actual detection of genetically modified material.  If GMOs were introduced into the market, would most people even know?  These concerns, coupled with the fact that non-profits (the groups that typically support consumers directly) don't have the financial power to compete with corporations, often leaves the consumer powerless and unheard.

Similarly, farmers have had a hard time dealing with the whims of biotechnology corporations.  In order to control GMO crops, one suggestion by scientists was to produce seeds that grow into sterile plants.  This would prevent cross pollination with natural flora and non-GMO farms.  However, this has the side effect of forcing GMO farmers to repurchase 100% of their seed every season. Normally, a significant amount of their fields can be replanted with seed from the harvested crops.

Trying to come up with viable methods of solving the farmers' problems, scientists are having issues of their own.  In the interest of consumers, governments such as the United States and European Union are eyeing legislation that will put GMOs under heavy oversight and regulation.  This significantly slows down scientists' work, increases research expenses, and may impede further developments.  Enacting these laws may also put those countries behind others that don't enforce the same restrictions, putting top scientists behind in their fields due to unrestricted competition.  Already, China is proving to be a strong competitor against western countries.  For example, Origin Agritech Limited, a Chinese agri-biotech company, has made headway with transgenic phytase corn, a particularly useful solution to expense and pollution issues surrounding farm animal feed (Business Wire).

Corporations focus on producing viable products, yet consumers are concerned about safety.  To produce their products effectively, the corporations lobby against government regulation.  Yet, some oversight may be required to keep people safe.  Adding scientists to the mix, we see that they are needed both for developing the biotechnology and demonstrating its safety.  Unfortunately, this amalgamation of conflicting of interests has caused many problems for the development of genetic biotechnology.

# CHAPTER 3: BUSINESS PERSPECTIVE OF GMOs

There is a lot of controversy around the health risks of GMOs, but any preferences for or against them by manufacturers and farmers depends on the business side of GMOs. To the producer of GMOs, as in any successful business, the main concern is making profit, not necessarily producing the healthiest product. For businesses, there are negative and positive effects of using GMOs. They could reduce costs and increase production, but they could also result in international issues in food production domination, exploitation, or trade relations. The means of reducing costs or increasing production involve decisions that relate to animals and the environment - what people mainly think about when they consider GMOs - but they could also affect the entire food production industry in fiscal and legal ways. In deciding how much to produce of GMO versus non-GMO products, businesses take into account the demand of GMO and non-GMO crops, which is entirely dependent on consumers' opinions towards GMOs.

## GMOs and Business: Consumer Concerns

### Consumer Concerns: Health Risks

There is still a lot of controversy between consumers over whether or not they will purchase GM products, specifically food, leaving businesses to make projections of what GMO and non-GMO markets will look like and grow crops based on these projections. Another issue that comes along with GMOs being relatively new to the food market is that little is known about what they are, how they're made, and what health benefits or risks come along with them. Many consumers who are against GMOs are concerned with their health, believing that because GMOs are unnatural there is a higher chance of having bad reactions to them if they are consumed.

However, “advocates say genetically engineering crops are perfectly safe for human consumption” (Hosansky, 2001). Indeed, as of yet, “‘no one has died of eating genetically modified crops,’ notes Peter Day, director of Rutgers University’s Biotechnology Center for Agriculture and the Environment. ‘And people die all the time from eating contaminated food’” (Hosansky, 2001). The spotless track record of GMOs could perhaps be the result of the amount of testing that they go through. Compared to that of non-GMOs, GMOs undergo several tests to determine that they are safe to consume. A likely reason for this is that a bad reaction to GMOs, which is not as common, would probably be more publicized than a bad reaction to food that doesn’t contain GMOs. Additionally, a big portion of the population already associates a negative connotation with GMOs, as depicted in Figure 3.1.


**Figure 3.1:** Negative Consumer View of GMOs

The pictures in the image show what people think GMOs are: monstrous and unnatural, with unexpected dangers depicted by the spider crawling out of the tomato and the extra arm growing out of the man. The image strongly suggests people's fear and hatred for GMOs, but it also shows their ignorance of GMOs. "Biotech companies and food processors say GMOs already undergo stringent testing. 'Biotech foods are actually the most tested foods on grocery shelves,' says Brian Hurley, a spokesman for Monsanto Corp., one of the world's largest agricultural biotechnology companies. 'We've done thousands of field trials, thousands of compositional analyses… The data clearly support that the products are absolutely safe'" (Hosansky, 2001).

**Consumer Concerns: Harm to the Environment**

Another concern for some people who are against GMOs is not the harm that could be done to them in consuming GMOs, but the harm to the environment or other animal species in the cultivation of GMO crops. Unlike the public's health concerns, this environmental concern is more founded since there have been cases that support it. "A 1999 Cornell University study indicated that pesticide-producing corn plants could harm monarch butterflies" (Hosansky, 2001). The corn plants were genetically modified to produce their own pesticides so that they didn't have to be sprayed with chemicals. The corn produced a toxin that protected it from corn pests, but it also produced a contaminated pollen which was "dispersed by the wind, [and] land[ing] on other plants, including milkweed, the exclusive food of monarch caterpillars commonly found around cornfields" (Friedlander, 1999). Some types of modifications can spread through the air to other crops or wild areas instead of staying contained. GMO crops affect their surrounding environment just as natural crops do. As such modifications to them can have consequences for other surrounding plant and animal species.

This also touches on the issue of containment and eradication after spreading occurs. Toxins spreading through the wind, water drainage, or soil, are consequences that are nearly impossible to avoid because they occur by means of natural forces. Once in the wild, because GMOs are engineered to resist pesticides or herbicides, they could be difficult to remove. “Environmental groups like Greenpeace … claim genetically modified organisms (GMOs) could increase resistance to pesticides or transform the genes of wild organisms, creating highly resistant weeds” (Hosansky, 2001). If new tolerances in plants to current pesticides evolve from or are created by GMOs, pests and pathogens could evolve to require a new pesticide to eradicate them. Thus, the genetic arms race could escalate resulting in which new pesticides or types of genetic modifications that are in turn created over and over again leading to food with genes that are radically different from the original and pathogens that are exceedingly strong. A real life case occurred when “bioengineered canola spread into the wild from a northern Canada farm in 1998, where it resisted three herbicides before finally being eradicated by a fourth” (Hosansky, 2001). Developing new pesticides and taking care of the unwanted spreading of toxins from GM crops requires more time and money as the frequency of such events increases and as it gets more difficult to stop the spreading. Environmental issues are not only the concern of the public, but also of those who are not in the business of crop production.

## GMOs and Business: Impact on Trade

### Impact on Trade: Labeling

As genetically modified products are relatively new, consumers have mixed opinions towards them, leaving the markets for GM and non-GM products subject to change. The welfare of businesses depends on what these market looks like. The demand for GMO and non-GMO crops is a reflection of how consumers feel towards GMOs. It has been suggested that, without labeling, organic foods are still prefered by consumers based off of “the estimated 20 percent per year growth in the organic food market in recent years (estimated to total close to a $10 billion market in a March, 2001, report by Solomon Smith Barney)” (Harl, 2003). Currently consumer resistance to GMOs is gaining publicity as labeling laws for GMOs are being debated in some places and put into effect in others. “A country’s decision to impose GMO labeling requirements, or to enforce standards banning importation of some GM products, has immediate implications for international trade and may entail welfare redistribution effects across national boundaries” (Lapan and Moschini, 2002). Only some states in the U.S. have enforced labeling laws for GMOs. In 2012, California voted down Prop 37, which would have required GM foods in California to be labeled and prohibited labeling or advertising GM foods as “natural”. A poll taken in 2001 “indicated that 75 percent of respondents in the United States indicated that they wanted to know if their food contained genetically modified ingredients. About 58 percent reportedly stated that they were opposed to the use of such ingredients in food” (Harl, 2003). It is not known how the markets for GM and non-GM products could change if GM product labeling was more strongly enforced. Labeling in the U.S. might have to be enforced eventually since at least fourty-eight countries have indicated that they will embrace labeling, including countries in Europe and Asia, two important trade areas.

**Impact on Trade: Regulation and Standards of Purity**

It is generally better for businesses if consumer resistance to GM products subsides, rather than if it increases. This is based on what businesses would have to do in order to satisfy consumers in each situation. First of all, local consumers have to have their expectations met. But local producers also export GMO crops to foreign companies, and these foreign companies have to satisfy their local consumers who could have different views on GM products than consumers in the local country. To do this, suppliers in each country have to meet a set of standards when it comes to crop production. “In the EU, the Agriculture Council (comprised of European Union agricultural ministers) agreed in 2002 by a majority decision that food containing more than 0.9 percent genetically modified material would have to be labeled as containing genetically modified organisms” (Harl, 2003). The threshold of 0.9 percent is not universal, though. There could be a higher maximum percentage of GM material allowed in the United States before a food would have to be labeled as containing GMOs. If there are conflicting standards in different countries, they would either have to become equal or the direction of trade from the higher threshold country to the lower would cease. In either case, testing has to be done on the part of the exporting and the importing country, first to label the product as containing GMOs or not, and secondly to check the validity of that determination. This is an inefficient and expensive system. It could become increasingly difficult to qualify food as being GMO-free if both GMO and non-GMO crops are produced together, since “even the 1 percent threshold level proposed by the EU is unusually strict (compared with pre-existing IP [identity preservation] systems) and may be challenging. Hence, it may be very costly and difficult to keep GM and traditional products strictly separated**”** (Lapan and Moschini, 2002). If limiting the amount of GM material in non-GMO products to one percent is strict, this suggests that an even higher percentage of GM material is difficult to avoid when producing GM and non-GM products, and hence, it is very costly to meet the higher standards. In the end, consumers dictate what standards producers in their perspective country have to meet, and producers have to satisfy the standards of local and foreign consumers if they don’t want to harm trade patterns. Therefore, businesses' decisions are a reaction to the demand for GM and non-GM products, which is a reflection of what consumers want.

**Impact on Trade: Reputation**

Reputation is becoming an important factor in trade patterns among countries when it comes to food. There are countries that will not import GM products or seeds for crops because the consumers in that country prefer to buy organic or non-GMO products. It can therefore be very detrimental to the economy of a country which is advertised as not being GMO free in its exports. This was the case for the U.S. when “Brazil’s status as a reliable source of non-genetically modified crops was a key factor in South Korea’s recent decision to import Brazilian, rather than U.S., corn” (Harl, 2003). Countries might become more wary of importing from countries that do not have a good reputation of being GMO free. “U.S. corn and soybean exports to the

EU, and corn exports to Japan have been adversely affected by the inability to assure suppliers of non-genetically modified commodities” (Harl, 2003). This issue could also arise if there are stricter regulations on producing GMO products in the importing country than there are in the exporting country. “A 2003 Iowa State University study by Dr. Robert Wisner concluded that there was a ‘high risk’ that the United States wheat industry would lose 30 percent to 50 percent of its business with foreign markets for spring wheat if genetically modified wheat is released for planting” (Harl, 2003). Planting GMO crops is currently a risky decision because the laws and preferences of importing countries could change in the near future, resulting in unsellable GMO crops.

**Impact on Trade: Possible Future Issue with Monopolies**

There is a great amount of importing and exporting of food and seeds among countries, and not all types of foods are grown in one country. If GM and non-GM products are made and traded around the world, the issue of keeping them adequately segregated could deter producers from producing both. If companies stick to one type, this would reduce the number of producers for each type of GM and non-GM product or crop. Around the year 2002, almost 98 percent of transgenic crops were produced by three countries - the U.S., Canada, and Argentina (Table 3.1).

TABLE 1. Global area of transgenic crops, 1996–2001 hectares (million)

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Percent (2001) |
|---|---|---|---|---|---|---|---|
| By Country | | | | | | | |
| United States | 1.5 | 8.1 | 20.5 | 28.7 | 30.3 | 35.7 | 67.9 |
| Argentina | 0.1 | 1.4 | 4.3 | 6.7 | 10.0 | 11.8 | 22.4 |
| Canada | 0.1 | 1.3 | 2.8 | 4.0 | 3.0 | 3.2 | 6.1 |
| China | ... | < 0.1 | < 0.1 | 0.3 | 0.5 | 1.5 | 2.8 |
| Other | ... | 0.1 | 0.1 | 0.2 | 0.4 | 0.4 | 0.8 |
| World | 1.7 | 11.0 | 27.8 | 39.9 | 44.2 | 52.6 | |
| By Crop | | | | | | | |
| Soybeans | ... | 5.1 | 14.5 | 21.6 | 25.8 | 33.3 | 63.3 |
| Corn | ... | 3.2 | 8.3 | 11.1 | 10.3 | 9.8 | 18.7 |
| Cotton | ... | 1.4 | 2.5 | 3.7 | 5.3 | 6.8 | 12.9 |
| Canola | ... | 1.2 | 2.4 | 3.4 | 2.8 | 2.7 | 5.1 |
| Total | 1.7 | 11.0 | 27.8 | 39.9 | 44.2 | 52.6 | |

*Source*: International Service for the Acquisition of Agri-Biotech Applications (ISAAA).

**Table 3.1**: Global percentage of transgenic crop production.

The fewer producers of a product there are, the higher the possibility of a monopoly. If there is a monopoly on any product, prices could go up for importers of that product.

## GMOs and Business: Economic Relationships

Although there are concerns over health and the environment in relation to GMOs among the public, there is a key aspect that contributes to the future of GMOs that is overlooked by consumers - the economics of it. According to Neil Harl, director of Iowa State University’s Center for International Agricultural Finance, “every group with an interest in the operation of the food system should be aware that the outcome ultimately depends upon the three basic economic relationships” (Harl, 2003). The three relationships he is referring to are the demand, supply, and cost of maintaining, marketing, and developing a handling system for GMO crops compared to that of non-GMO crops. He asserts that the controversy over GM crops will eventually be resolved according to what happens with respect to these three components of the GM market and GM production.

**Economic Relationships: Supply and Demand**

The supply of GMO and non-GMO products is determined by the businesses rather than the consumers because businesses take into account the costs and risks of each type of production. Because "cost decreasing technology, also, ultimately leads to an increase in output," the higher yield in GMO crop production than in non-GMO crop production ultimately leads to a drop in price and profit for the producers based on the basic economic principle that as supply increases, profit decreases (Harl, 2003). According to Neil Harl, there is an "inelastic demand for most agricultural products," (Harl, 2003). Because the supply and demand for inelastic goods is not affected by price changes, the increase in output of a product is met with a "disproportionate drop in price and in profitability" (Harl, 2003). This is understandable, considering agricultural products are a necessary commodity. So even if the price for food changes, the demand will stay constant. If there is a higher supply at the same price, with demand kept constant, a smaller percentage of the food will be sold. If an increase in yield for the same production costs would cause an increase in profit if only one producer was using the technology, "only early adopters benefit economically from output increasing technology" until the other producers catch up and cause a price drop from the overall increase in supply (Harl, 2003). And if one producer is benefitting from GMOs, other producers "have to adopt technology to be competitive but they are rewarded by lower prices and profits if they do" (Harl, 2003).

**Economic Relationships: Maintaining and Producing GMO and non-GMO crops**

The third component of the business side of GMOs is the cost of producing GMO crops along with non-GMO crops. “A major problem faced by the U.S. and other producers of genetically modified crops on a widespread basis is the feasibility and cost of a two track or multi- track marketing and handling system” (Harl, 2003). When a producer has both GMO and non-GMO crops, extensive and expensive measures must be taken to keep the non-GMO crops pure. “Research indicates that the cost of segregation rises exponentially as the tolerance level (amount of GMO germ plasm in non-GMO crops) is reduced” (Harl, 2003). If mistakes are made in terms of keeping GMO and non-GMOs separate, the process of fixing these mistakes can be very expensive and tedious. One case of this was when the genetic modification in corn branded as StarLink, produced by Aventis Crop Science, got into corn advertised as non-GMO.

“Aventis had failed to enforce a suitable IP system to segregate this corn variety. The incident led to the recall of over 300 food products and the implementation of a massive Starlink corn buyback program (led by the USDA), as well as numerous lawsuits, at a cost estimated in the hundreds of millions” (Lapan and Moschini, 2002). Aventis had to compensate growers and those who processed the crops. The presence of GMO in the crops also contaminated the machinery that processed it. “Additional transportation, demurrage and testing costs incurred by a grain elevator because of commingled corn” had to be paid by Aventis as well (Harl, 2003). This mistake also affected other companies and cost the government when "the U.S. Department of Agriculture asked 280 seed companies to test their seed supplies for traces of the StarLinkTM protein and offered to purchase the seed supplies failing the test. Some lots were found to contain StarLinkTM and USDA reportedly set aside $20 million to purchase that seed” (Harl, 2003). Once traces of genetic modification are found in supposedly pure products, testing has to be done of all possibly contaminated products.

## Conclusion for Business

It is incredibly difficult and costly for producers to keep GMO and non-GMO crops separate. Not only do non-GMO products have to be tested at every step for GMO contamination, but the equipment that is used for GMO and non-GMO substances must also be cleared of GMO germ plasm. Even if the GMO and non-GMO products are produced with different equipment, or even by different producers, “if both GM and non-GM goods are produced in a given country, then establishing that a particular output is GM-free entails segregation and verification costs” (Lapan and Moschini, 2002). Gene flow from pollen drift originating from GMO crops can contaminate non-GMO crops, and this is not something that is easy to control by producers. Therefore, there is always the possibility of unintentional contamination. “The introduction of GM production into a region involves an externality that imposes costs on the (verified) output of another good” (Lapan and Moschini, 2002). Non-GMO crops are affected by the introduction of GMO-crops in a country, because non-GMO crops now must test and verify that they are pure. These verification costs are costly and inefficient for production. Furthermore, “verification costs … could induce some (or perhaps even all) exporters to ban production of GM products” simply in order to avoid the costs and inefficiencies (Lapan and Moschini, 2002).

The result of the controversy between GMO advocates and the opposition is what will determine the future of GMO and non-GMO production. Consumers are concerned about their health and the environment. Consumers' opinions influence demand for GMO and non-GMO markets within countries and indirectly influence trade patterns. Things businesses consider in terms of producing GMO and non-GMO products are costs and consequences of labeling, establishing and keeping up a reputation, trade patterns, dangers of monopolies, costs of maintaining, testing, and producing GMO or non-GMO crops, and consumer preferences which determine demand. The consumers and businesses determine the supply and demand for GMO and non-GMO products, and “the outcome [of which type of crop will dominate the market] is almost certain to be resolved on an economic basis,” according to Neil Harl (Harl, 2003).

# CHAPTER 4: ENVIRONMENTAL EFFECTS OF GENETICALLY MODIFIED CROPS

The use of Genetically Modified Organisms in agriculture has the potential to either hurt or help the environment. Some possible environmental benefits that agricultural GMOs may bring include more efficient use of water, reduced tilling and land erosion, a reduced use of harmful chemicals such as pesticides, herbicides, and fertilizers, and an increase in beneficial wild animals such as ladybugs and praying mantises. However, there are also a number of environmental threats associated with GMO agriculture, such as building up populations of pesticide-resistant pests (and consequently also increasing the need for pesticides), creating invasive species of weeds by introducing GMO genes to weed gene pools, harming beneficial wild animals like butterflies and bees, and unbalancing natural ecosystems in unpredictable, potentially harmful ways. In general, if the GMO is designed in an environmentally-conscious way, the associated environmental risks can be satisfyingly reduced or eliminated. GMO engineers, farmers, and society at large have an ethical duty to protect the environment, so we are obligated to further pursue GMO technology for its environmental value. However, the environmental benefits of GMOs are only justified if the technology is developed and used with thorough, careful, environmental safeguarding.

## GMOs’ Effect on Physical Quality of Environment

One of the environmental benefits of GMOs is something that farmers also appreciate greatly: a significantly higher crop yield per acre (Brookes and Barfoot

2010, Mellon 2003), with potential increases as high as nearly 30% per acre (Environmental Protection Agency 2005). The increase in productivity helps make the most of our water resources, which is a particularly important environmental concern in areas suffering from water shortages such as California. Also, GMOs can help reduce pollution from nutrient runoff by increasing the efficiency of fertilizer use. Nutrient-rich runoff from farms is particularly harmful to aquatic life because it causes oxygen-depleting algal blooms, and in many cases, dead zones where fish and other aquatic animals can no longer survive.

GMO crops are commonly designed to be weed-resistant, which reduces the need for weed control plowing and helps reduce soil erosion and the emission of greenhouse gasses (Brooks and Barfoot 2010, Environmental Protection Agency 2005, Pollack 2003). Soil erosion is a major concern for farmers because it can destroy farmland fertility. During the Great Depression, farming practices that did not account for soil erosion very nearly turned the midwestern United States into a barren desert. Tilling also releases greenhouse gasses from the soil and from tractor use. Grahm Brooks and Peter Barfoot, two environmental researchers from PG Economics in Dorchester, UK, reported in their 2010 publication "Global Impact of Biotech Crops: Environmental Effects" that the GMO-related reduction in greenhouse gas emissions from tractor use "was equivalent to removing 8.6 million cars from the roads."

## GMOs' Effect on Wild Plants

### GMOs' Effect on Wild Plants: Herbicide Use and Resistant Weeds

Although they reduce soil erosion and greenhouse gasses, GMOs that are designed to help with weed problems may introduce other complications. Some GMOs are designed to be herbicide resistant so farmers can spray herbicides on GMO crops and kill weeds without harming the crop (Canon 2001, Environmental Protection Agency 2005, Mellon and Rissler 2003). These varieties of GMOs encourage the use of herbicides (Canon 2001, Environmental Protection Agency 2005, Mellon and Rissler 2003, New York Times 2003, Riechers and Simmons 2002). Herbicide overuse promotes the evolution of herbicide-resistant weeds. When herbicides are used extensively, all the weeds that can be killed by the herbicide die off. A few weeds remain because they have genetic traits that make them resistant to the herbicide. These surviving weeds reproduce, creating new generations of herbicide-resistant weeds. If herbicides are used less often, enough non-herbicide-resistant weeds survive to out-compete herbicide-resistant varieties, deterring the evolution of herbicide-resistant super weeds. (Brooks 2010, Canon 2001, Environmental Protection Agency 2005, Riechers and Simmons 2002)

Farmers and researchers have recently been reporting concerns about herbicide-resistant eastern black nightshade (Mellon and Rissler 2003, Riechers and Simmons 2002) and water hemp (Canon 2001, Mellon and Rissler 2003, New York Times 2003), among others (Mellon and Rissler 2003) that appear related to the use of herbicide-resistant GMOs. However, weed resistance and overuse of herbicides are problems common to all non-organic farming (Canon 2001, Riechers and Simmons 2002). So far there has been little research done to prove or disprove that GMOs are the cause of these instances of weed resistance instead of other common causes of weed resistance such as herbicide overuse. For all farms, GMO and non-GMO, the evolution of weed resistance can be avoided if herbicides are used in moderation (Brooks 2010, Canon 2001, Chen 2011, Riechers and Simmons 2002).

### GMOs' Effect on Wild Plants: Wild-GMO Hybrid Plants

Aside from herbicide use, many are concerned that super-weeds will arise from GMO gene transfer to wild plants (Brooks 2010, Mellon and Rissler 2003, Mercer et al 2006, Spencer and Snow 2001, Snow et al 1998). Pollinators like bees and butterflies can transfer GMO genes to wild plants as far as a thousand meters away from the GMO farm (Snow et al 1998). The offspring of plants that have been pollinated with GMO pollen have a mixture of wild and GMO genes and genetic characteristics.

Many are concerned that wild-hybrid plants will have a genetic advantage that would lead them to out-compete purely wild varieties. This could leave us with nothing but wild-hybrid plants, reducing the variety of existing genes and hurting biodiversity (Mellon and Rissler 2003, Mercer et al 2006, Spencer and Snow 2001, Snow et al 1998). There is also concern that wild-hybrid plants will become pesticide-resistant or invasive (Mellon and Rissler 2003, Mercer et al 2006, Spencer and Snow 2001, Snow et al 1998). Invasive plants are harmful to the environment because they overpower other species of wild plants, outcompeting them for sunlight, land, and nutrient resources. Invasive plants also hurt wild animals that depend on the out-competed plant species. Oftentimes invasive species are of little or no value to wild animals with regards to nutrition or shelter, aggravating the negative impact wild-hybrid invasive species would have on the environment.

However, many studies indicate that most GMO traits do not give hybrid wild plants advantages over purely wild ones (Environmental Protection Agency 2005, Godfree et al 2004, Mercer et al 2006, Snow et al 1998). GMO traits in agriculture make crops more edible and harvestable, but these traits do not necessarily translate to better wilderness survival. For example, a number of studies show that GMO traits actually gave wild-hybrid wild sunflowers a disadvantage in nature (Mercer et al 2006, Snow et al 1998). Wild sunflowers are most successful when each plant has many flowers, blooms throughout the year, and produces seeds that wait for favorable conditions before germinating. Domesticated and GMO sunflowers are agriculturally desirable when each plant has a single large flower that blooms once at a specific time of year. This makes harvesting more efficient, but is disadvantageous for wild-hybrid sunflower survival. A number of other studies have also concluded that for the most part, GMO genetics give wild-hybrid plants little, no, or less advantage over purely wild plants (Environmental Protection Agency 2005, Godfree et al 2004, Mercer et al 2006, Snow et al 1998).

The sunflower studies also reported that there was no anticipated threat of hybrid gene transfer eliminating the existence of purely wild genotypes. Firstly, hybrid sunflowers did not have enough of a survival advantage for them to be competitive enough to begin with. Secondly, purely wild sunflowers bloom for long periods of time during the year, but both hybrid and agriculturally-grown sunflowers bloom only at one specific time. This leaves only a small window of opportunity for GMO-wild cross-pollination, and significantly reduces the likelihood of GMOs wiping out all purely wild varieties (Mercer et al 2006, Snow et al 1998). These observations appear to be true for other species of wild-hybrid plants as well (Environmental Protection Agency 2005, Godfree et al 2004).

However, wild-hybrid plants can have a survival advantage if they exhibit GMO disease or pest resistance. (Mercer et al 2006, Snow et al 1998). So far there has been little conclusive research done about whether or not disease and pest-resistant advantages are significant enough to cause concern about hybrids out-competing purely wild varieties or the evolution of super weeds.

## GMOs' Effect on Wild Animals

### GMOs' Effect on Wild Animals: Reduced Pesticide Use

Pesticide use is another important discussion point for the environmental impact of GMOs. Many GMOs are designed to reduce or replace the need for pesticides by having low levels of toxins that kill pests (Brookes 2010, Chen 2011, Environmental Protection Agency 2005, Hui-Lin 2011, Knight). Not surprisingly, runoff from pesticides is harmful to wildlife and can affect areas far from the farm. Typical pesticide application cannot be directed towards any one particular species of animal, killing both target pests and beneficial wildlife such as ladybugs and lacewings. In his 2010 publication "Global Impact of Biotech Crops: Environmental Effects", Grahm Brookes, an agricultural economist from the United Kingdom, reported on the environmental benefits of GMOs with regards to pesticide use. He states that GMO agriculture

> has reduced pesticide spraying by 443 million kg (-9.1%) and, as a result, decreased the environmental impact associated with herbicide and insecticide use on these crops (as measured by the indicator the Environment Impact Quotient (EIQ)) by 17.9%.

The United States Environmental Protection Agency (EPA) also officially recognizes the use of pesticides as a major source of environmental harm. A 2005 report from the EPA's Office of Pesticide  analyzed the risks and benefits of using GMO corn as a pesticide replacement for fighting corn roundworm (CRW) pests, saying

> [a]ll of the major chemicals used for CRW control can cause adverse environmental effects under conditions of normal use. Fifteen products are labeled as "toxic," 6 as "highly toxic," 1 as "very highly toxic," and 14 as "extremely toxic" to birds, fish and other wildlife.

The reduction or elimination of pesticide use from pest-resistant GMOs is considered one of the greatest potential environmental benefits GMOs has to offer (Brookes 2010, Chen 2011, Environmental Protection Agency 2005, Hui-Lin 2011, Smith 2010).

**GMOs' Effect on Wild Animals: Increased Pest Resistance**

Though pest-resistant GMOs could possibly reduce or eliminate pesticide use, one top fears is that overuse of these pest-resistant GMOs will induce the evolution of pesticide-resistant pests (Brookes 2010, Environmental Protection Agency, Knight, Mellon and Rissler 2003). In fields of pest-resistant GMOs, all "normal" pests are eventually killed off, leaving a few genetically resistant survivors to breed many new generations of resistant pests. Like with herbicide-resistant weeds, pesticide-resistant pests are a major concern because their uprising would either devastate crops or require the development and use of more pesticides.

GMO farmers can avoid creating resistant pests if they plant a mixture of both GMO and non-GMO crop together (Environmental Protection Agency, Knight). The non-GMO crop areas provide a safe haven for pests that are not resistant to GMO toxins or pesticides. These pests can then out-compete any pesticide-resistant pests that may have started to evolve in the GMO crop areas. (not clear) This parallels anti-super-weed techniques that involve moderation of herbicide use (as was discussed previously in this chapter). The actual proportion of non-GMO crop to GMO crop that is needed for this method to be effective has recently been debated (Knight). Many are concerned that farmers and the Environmental Protection Agency have not been strict enough with policies preventing the rise of GMO-induced pesticide-resistant pests (Knight).

**GMOs' Effect on Wild Animals: Effect on Non-Target Organisms**

A related concern is that the GMO anti-pest toxins will hurt non-target organisms (NTOs) like butterflies and bees (Dutton et al 2003, Mattila et al 2005, Mellon and Rissler 2003, Perry et al 2010, Prasifka et al 2007). Though in some cases concerns are valid, studies show that most GMOs do not harm beneficial NTOs (Environmental Protection Agency 2005, Hui-Lin 2011).
Well-designed pest-resistant GMOs are harmful only to the target pests and do not affect other animals in the ecosystem even when making direct contact with the GMO or when ingesting prey that consumed GMO material. For example, certain varieties of GMO corn that are designed to be resistant to corn roundworm (CRW) have been proven to be poisonous only to corn roundworms and very closely related species (Environmental Protection Agency, 2005). Standard studies on GMOs effects on NTOs consider both direct contact with and indirect ingestion of GMO proteins. Thorough NTO studies focus on one or two species from every major category of the ecosystem, including first order predators like birds, NTO herbivores like butterflies, higher order predators like hawks, and decomposers like worms. In the CRW study, NTO species were harmed neither from direct contact with GMO proteins nor from indirectly ingesting the proteins (like eating a corn roundworm that had ingested GMO proteins). In fact, many studies have shown that NTO populations are actually higher in areas near GMO farms because they do not suffer the effects of pesticide sprays (Environmental Protection Agency 2005, Hui-Lin 2011). Other GMOs can also be designed, tested, and selected for NTO safety.

Another study examined the effects GMOs have on the monarch butterfly, one of the most spectacular species of endangered butterfly in North America. Many have been concerned that proteins in pest-resistant GMO pollen would drift onto milkweed, poisoning monarch caterpillars that depend on milkweed to grow (Hui-Lin 2011, Mattila et al 2005, Mellon and Rissler 2003, Perry et al 2010, Prasifka et al 2007). A number of research teams have investigated GMOs safety for monarch butterflies (Hui-Lin 2011). Five out of six strains of corn tested in these studies did no significant harm to the butterflies (Hui-Lin 2011). Luckily, the one strain of corn that did hurt monarchs was never widely used to begin with (Hui-Lin 2011). If testing similar to the monarch butterfly and corn roundworm studies are done before commercial release of GMOs, we can help make sure that we only use varieties that are safe for NTO wildlife.

Even with extensive testing, there is still reason to be concerned about GMOs impact on NTOs. Safety testing cannot examine GMO effects on every wild NTO species and must instead select only a few representative species to study (Environmental Protection Agency 2005, Hui-Lin 2011). NTO safety studies may show that a particular strain of GMOs are safe for many NTOs, but there may by chance be an NTO species that was harmed by GMO proteins that the studies did not test for (Environmental Protection Agency 2005, Hui-Lin 2011). The scientific and agricultural community helps to address this issue by advancing environmental monitoring in areas influenced by GMO farms (Environmental Protection Agency 2005). Currently-used GMOs have been used long enough that any catastrophic effect on NTOs would have been seen by now. No such issue happened yet, so we seem to have avoided major NTO-related problems so far (Mellon and Rissler 2003).

## GMOs' Overall Effect on Ecosystems

Even if GMOs do affect the ecosystem in seemingly neutral or beneficial ways, the fact that they are altering the ecosystem in any way could lead to unpredictable, potentially harmful, large-scale changes (Environmental Protection Agency 2005, Mellon and Rissler 2003). For example, although studies may confirm that wild-hybrid weeds won't become highly-invasive super-weeds or contaminate all wild plant genomes, the introduction of GMO genes still influence the ecosystem. In cases where the immediate effects are not dramatic, it is still very difficult to predict long-term effects. The same can be said for other seemingly non-harmful GMO-induced ecosystem changes such as an increase in beneficial predators and other NTOs from the reduced use of pesticides. However, agriculture has always influenced wild ecosystems- this concept is nothing new. With adamant, thorough testing for the environmental safety of GMOs, we can help minimize both the immediate and long-term environmental impact of agriculture.

# ETHICAL SUMMARY, ANALYSIS, AND RECOMMENDATIONS

## Ethical Analysis and Recommendations Concerning Research

Pursuing the most enlightened ethical path for GMO research is going to be difficult. With corporations holding a majority of the financial power compared to governments, universities, and non-profit organizations, their wants and needs will likely be answered first. Considering that profits are a top priority of corporations, people often worry that their safety could be at stake. But, if we simply follow the mantra of "safety always comes first", we put ourselves at a damaging disadvantage when it comes to competing with other countries. Scientists in the United States will be wasting their time and money adhering to regulations while their foreign counterparts are advancing the technology regardless of our government's attempt to restrain the industry. The best solution will likely be a balance of convincing corporations that people's safety is a top priority and keeping regulations from being too burdensome.

This solution can be brought about by addressing a few key issues. First, there needs to be a simple, accessible way for consumers to make their concerns heard. Non-profits often work towards this goal, but corporations need to listen in order for the process to work correctly. I suggest a corporate-sponsored, international consortium on GMO practice. If enough corporations can agree on important topics, change and recognition of consumer worries will proceed much quicker than government oversight. If reduction of regulations can be achieved along with increased awareness and practice of GMO safety, this becomes a win-win situation for everyone. Additionally, this relieves scientists' worries that regulation could destroy their competitive edge against foreign scientists.

A second key issue to address is the worries of farmers being pigeon-holed into purchasing large amounts of seed every season without the hopes of reusing it. Regulation sounds like a simple solution, but it becomes very tricky when laws are only partially enacted within certain regions of the world. When these laws do come into play, they only end up harming the farmers of those regions, while unregulated regions end up with higher quality crops. The solution here is less of a legislative one and more of a social aspect. Increased competition among multiple biotech companies can give farmers more choices, allowing them to pick the best seed for their own purposes. In order to spur this competitive atmosphere, regulations must be kept low (although not eliminated), and government subsidies can encourage varied use of seed types in each unique region.

## Ethical Analysis and Recommendations Concerning Consumers/Business

It is the duty of producers and businesses to perform adequate testing of GMO products and give truthful and correct results of these tests to customers. It is also their duty to not cut costs when it comes to maintaining clean facilities and performing all the tests needed. Businesses also have to appropriately respond to any mistakes in keeping GMO and non-GMO products separate. If non-GMO products are found to be contaminated, the businesses responsible have to admit to their mistake, compensate anyone affected, and fix the cause of the mistake so that it doesn't happen again. In the possible case of market domination, businesses should not take advantage of buyers for personal wealth.

In accordance with utilitarian ethics, businesses should shoulder the costs of

GMO crop production, maintenance, and testing in order to provide poor and nutritionally deprived countries with cheaper, more nutritious foods. Exporters should also not price their foods too high for poorer countries to afford, since these are the people who need the benefits GMOs offer the most.

It is possible to adequately keep GMO and non-GMO crops separate by not cutting corners in testing and cleaning. No cases of dangers to human health have occurred in GMO consumption. Containment of crops is possibly the most uncontrollable aspect of GMO crop production, but with further research or developments, methods for producing GMOs that don't harm NTOs or improved methods of containment can be made. Therefore, the potential benefits of GMOs should be explored and utilized.

### Ethical Analysis and Recommendations Concerning the Environment

It is our human duty to protect the environment, not only for nature's own sake, but also for our own self-preservation. GMOs do have the potential to be very harmful to nature, and it is our responsibility to avoid preventable damage as much as possible. However, it's also our duty to strive towards finding environmentally-friendly alternatives to current agricultural practices. GMOs definitely have the potential to improve agriculture's environmental impact, so it is important that we pursue this opportunity. If done in a careful, safe way, GMO research and development should be pursued, and may someday make environmental improvements worldwide.

Environmental safety may not be a top priority for businesses and researchers whose primary goals are directed towards profit. In order to ensure that environmental safety is taken very seriously, GMO research and development must have strict governmental regulations for design safety and environmental testing. In the USA, the Environmental Protection Agency should take responsibility for creating and enforcing environmental protection regulations on GMO development.

# CONCLUSION

Agricultural use of GMOs has many current and potential benefits. GMO agriculture could help increase worldwide food supply, helping ease world starvation. GMOs could help the environment by reducing the need for pesticides, herbicides, and fossil fuels, increasing water and fertilizer efficiency, and decreasing soil erosion. Some types of genetic modification can increase the nutritional value of foods, helping with vitamin deficiencies in poor countries. Scientists are even developing foods that deliver vaccines, a major benefit for developing countries. Businesses could benefit from increases in crop yields and save money on pesticide, herbicide, and fossil fuel use. Crops could also become resistant to natural disasters such as droughts that would damage both farmers and the economy.

However, GMOs also have many serious risks and complications across the board. GMO agriculture could do severe damage to the environment, be unsafe for human consumption, cause mayhem between businesses and farmers, and open the door to many other serious technical and ethical concerns. Environmental threats include unintentionally harming NTOs, the evolution of super weeds and super pests, the loss of biodiversity, and an overall unbalancing of wild ecosystems. Several costs are incurred by producers of both GMO and non-GMO crops. Keeping crops separate to avoid contamination requires either having separate processing equipment or cleaning and testing equipment used for both types of crops. Testing also has to be done on all products to determine their amount of GMO content for labeling and to verify the purity of non-GMO products. Contrasting acceptable levels of GMO content in certain products among nations could potentially cause drastic changes in trade patterns and the economic welfare of entire countries. These changes would lead to a further imbalance in scientific research where regulated regions of the world will fall behind as under regulated areas thrive. However, unregulated countries would be more likely to produce unsafe GMO strains, endangering everyone.

All major environmental and human health concerns involving GMOs can be greatly reduced or eliminated if the GMOs are carefully designed and thoroughly tested for maximum safety. However, if the GMO industry is left unregulated, corporate interests such as profits and production efficiency can easily conflict with and override measures taken for safety. Strict governmental regulations designed to ensure GMOs' environmental and human safety are recommended. Regulations such as labeling would also establish a better reputation for the U.S. when trading with other countries that have strict regulations on GMO imports. Furthermore, government enforcement of testing would result in less corruption among businesses that would try to cut costs or falsify test results to gain an advantage over competing producers. If GMO research and development is pursued with top priority on safety, we can minimize GMOs adverse effects and maximize GMOs human, environmental, and worldwide benefits.

## GLOSSARY

Agent Orange

a potent herbicide used as part of chemical warfare by the United States during the Vietnam War

CRW - Corn Roundworm

a pest that severely damages corn crop. Some varieties of GMO corn are designed to be resistant to this pest.

DDT - Dichlorodiphenyltrichloroethane

a potent insecticide that was banned for use in the United States in 1972

EPA - Environmental Protection Agency

a governmental agency of the United States in charge of creating and enforcing regulations that protect the environment

FDA - Food and Drug Administration

an agency of the United States Department of Health and Human Services

GMO - Genetically Modified Organism

an organism whose genetic makeup has been artificially altered in order for it to express desirable genetic characteristics

GM - Genetically Modified

NTO - Non-Target Organism

an organism/species that may or may not be inadvertently affected by anti-pest toxins in pest or weed-resistant GMOs. Bees and butterflies are common examples of NTOs, for the toxins in GMOs are intended to be harmful to pests, not beneficial pollinators.

Super Weed/Pest

a variety of weed or pest that has evolved to be highly resistant to herbicides or pesticides

## WORKS CITED


Brookes, G., Barfoot, P., 2010, Global Impact of Biotech Crops: Environmental Effects, 1996-2008; Agbioforum, v. 13, no. 1.

Business Wire Editors. (2009, November 21). Origin Agritech Announces Final Approval of World's First Genetically Modified Phytase Corn. Business Wire. www.businesswire.com/news/home/20091121005009/en/Origin-Agritech-Announces-Final-Approval-World%E2%80%99s-Genetically

Campbell, N, & Reece, J., 2005, Biology 7th edition: San Francisco, CA: Pearson, Education Inc..

Canon, S., 2001, Roundup Ready Soybeans Giving Rise to Superweeds; The Kansas City Star, www.kcstar.com.

Chen, M.,2011, Insect-Resistant Genetically Modified Rice in China: From Research to Commercialization; Annual review of entomology, v. 56, pp. 81-101.

Dutton, A., Klein, H., Romeis, J., Biger, F., 2003, Prey-mediated effects of Bacillus thuringiensis spray on the predator Chrysoperla carnea in maize; Biological Control, v. 26, i. 2, pp. 209-216.

European Union (2010). A decade of EU-funded GMO Research. Belgium. ec.europa.eu/research/biosociety/pdf/a_decade_of_eu-funded_gmo_research.pdf

Environmental Protection Agency, 2005, Bacillus thuringiensis Cry3Bb1 Protein and the Genetic Material Necessary for its Production (Vector XMIR13L) in Event MON863 Corn (006484) Fact Sheet: Office of Pesticide Programs Environmental Protection Agency 1200 Pennsylvania Avenue, NW Washington, D.C. 20460, Environmental Protection Agency, www.epa.gov.

Forbes, Cavallaro, Matt, 2009, The Seeds Of A Monsanto Short Play. [http://www.forbes.com/2009/06/29/monsanto-potash-fertilizer-personal-f

inance-investing-ideas-agrium-mosaic.html; Accessed October 30, 2012].
Freudenrich, Craig, How Stuff Works, How DNA Works.
[http://science.howstuffworks.com/life/cellular-microscopic/dna.htm; Accessed October 14, 2012].
Friedlander, Blaine P. (1999 May 19). “Toxic pollen from widely planted, genetically modified
corn can kill monarch butterflies, Cornell study shows”.
[http://www.news.cornell.edu/releases/May99/Butterflies.bpf.html].
Godfree, Robert C.; Woods, Matthew J.; Young, Andrew G.; Burdon, Jeremy J.; Higgins, T. J. V., 2004, “Growth, fecundity and competitive ability of transgenic Trifolium subterraneum subsp. subterraneum cv. Leura expressing a sunflower seed albumin gene; Hereditas, Vol. 140 Issue 3, p229-244.
Harl, Neil. (2003 April 14). “Biotechnology Policy:  Global Economic and Legal Issues”.
[http://www.econ.iastate.edu/~harl/BiotecnologyPolicy.pdf].
Harl, Neil. (1999 September). "Genetically Modified Crops: Guidelines for Producers".
[http://www.extension.iastate.edu/NR/rdonlyres/3DA758C3-C136-456A-8062-53B08FA0BE00/83014/0010harl1.pdf].
Hedges, Robert E.M., 2009, Fossil dogs and wolves from Palaeolithic sites in Belgium, the Ukraine and Russia: osteometry, ancient DNA and stable isotopes: Journal of Archaeological Science, v. 36, pp. 473-490.
Hirst, Kris K., 2012, Wheat Domestication: The Origins of Wheat.
[http://archaeology.about.com/od/domestications/qt/wheat.htm; Accessed November 18, 2012].
Hosansky, D. (2001, March 30). Biotech foods. CQ Researcher, 11, 249-272.
library.cqpress.com/cqresearcher/document.php?id=cqresrre2001033000
Hui-Lin, Y., 2011, Risk Assessment and Ecological Effects of Transgenic Bacillus thuringiensis Crops on Non-Target Organism; Journal of Integrative Plant Biology, v. 53, i. 7, pp. 520-538.
Kelland, Kate. (2011, November 11). Petri Dish to Dinner Plate, In-Vitro Meat Coming Soon. Reuters.
www.reuters.com/article/2011/11/11/us-science-meat-f-idUSTRE7AA30020

111111
Knight, J., Agency ‘ignoring its advisers’ over Bt maize; Nature, v. 422, i. 6927. pp. 5.
Lapan, Harvey E. and Moschini, GianCarlo. (2002, May). “ Innovation and Trade with Endogenous Market Failure - The Case of Genetically Modified Products”. http://www.card.iastate.edu/publications/DBS/PDFFiles/02wp302.pdf
Mattila H.R., Sears M.K., Duan J.J., 2005, Response of Danaus plexippus to pollen of two new Bt corn events via laboratory bioassay; Entomol. Exp. Appl. v. 116, pp. 31-41.
McLure, Jason. (2012, August 31). Genetically modified food. CQ Researcher, 22, 717-740. [library.cqpress.com/cqresearcher/document.php?id=cqresrre2012083100].
Mellon, M., Rissler, J., 2003, Environmental Effects of Genetically Modified Food Crops – Recent Experiences; Genetically Modified Foods- the American Experience, conference sponsored by the Royal Veterinary and Agricultural University, Copenhagen, Denmark.
Mercer, K.L., Wyse, D.L., Shaw, R.G., Kalisz, S. 2006, Effects of competition on the fitness of wild and crop-wild hybrid sunflower from a diversity of wild populations and crop lines; Evolution, v. 60 i. 10, pp. 2044-2055. New York Times, 2003, Roundup Unready; New York Times, [www.nytimes.com].
Monsanto Company, 2012, Company Website. [http://monsanto.com; Accessed October 20, 2012].
Oxford Journals, 2012, Modern Taurine Cattle descended from small number of Near-Eastern founders. [http://mbe.oxfordjournals.org/content/early/2012/03/14/molbev.mss092; Accessed November 21, 2012].
Perry J.N., Devos Y., Arpaia S., Bartsch D., Gathmann A., Hails R.S., Kiss J., Lheurerx K., Manachini B., Mestdagh S., Neemann G., Ortego F., Schiemann J., Sweet J.B., 2010, A mathematical model of exposure of non-target lepidoptera to Bt-maize pollen expressing Cry1Ab within Europe., Proc.

Biol. Sci., v. 277, pp. 1417-1425.
Pollack, A., 2003, Widely Used Crop Herbicide is Losing Weed Resistance; New York Times.
Prasifka P.L., Hellmich R.L., Prasifka J.R., Lewis L.C., 2007, Effects of Cry1Ab-expressing corn anthers on the movement of monarch butterfly larvae; Environ. Entomol., v. 36, pp. 228-233.
Riechers, D., Simmons, B., 2002, Eastern black nightshade: re-emergence of an old nightmare for soybean growers; University of Illinois Extension, Agronomy Day 2002.
Scientific American Editors. (2009, August 13). Do Seed Companies Control GM Crop Research? Scientific American. www.scientificamerican.com/article.cfm?id=do-seed-companies-control-gm-crop-research
Science on NBCNews, Viegas, Jennifer, 2012, World's First Dog Lived 31,700 Years Ago, Ate Big. [http://www.msnbc.msn.com/id/27240370/; Accessed November 5, 2012].
Siegelbaum, D. J. (2008, April 23). In Search of a Test-Tube Hamburger. Time Magazine. [www.time.com/time/health/article/0,8599,1734630,00.html].
Snow, Allison A.; Moran-Palma, Pedro; Rieseberg, L.H.; Wszelaki, A.; Seiler, G.J., 1998, Fecundity, phenology, and seed dormancy of F1 wild-crop hybrids in sunflower (Helianthus annus, asteracae); American Journal of Botany. v. 85 i. 6, pp. 794.
Spencer, L., Snow, A., 2001, Fecundity of transgenic wild-crop hybrids of Cucurbita pepo (Cucurbitaceae): implications for crop-to-wild gene flow; Heredity, v. 86, i. 6, pp. 694-702.
University of CA-Biomedical Library(UCBL), 2010, Evolution of Domesticated Bread Wheat. [http://www.plantcell.org/content/22/4/993.full; Accessed November 15, 2012].
U.S. Environmental Protection Agency (US EPA), DDT - A Brief History and Status. [http://www.epa.gov/pesticides/factsheets/chemicals/ddt-brief-history-status.htm; Accessed November 17, 2012].

U.S. Congressional Subcommittee on Medical Facilities and Benefits (US Congress), 1978, Herbicide "Agent Orange". [http://www.nal.usda.gov/speccoll/findaids/agentorange/text/05245.pdf; Accessed November 14, 2012].

Vogt, Donna U., Parish, Mickey. (1999, June 2) Food Biotechnology in the United States: Science,
Regulation, and Issues. Downloaded from the National Library for the Environment. [digital.library.unt.edu/ark:/67531/metacrs835/m1/1/high_res_d/RL30198_1999Jun02.htm].

Wilkins, Alasdair, 2012, DNA reveals that cows were almost impossible to domesticate. [http://io9.com/5897169/dna-reveals-that-cows-were-almost-impossible-to-domesticate?tag=archaeology; Accessed November 20, 2012].

Wired. (June 21, 2006). Slideshow: Test Tube Meat Nears Dinner Table. Wired. [http://www.wired.com/science/discoveries/multimedia/2006/06/71201?slide=1&slideView=4].