Welcome back to Lecture 13 the genetically modified organisms. This topic was added to the course on request from many students who wanted to learn more about GMOs. I hope you will listen carefully and enjoy the lecture.

The objectives for this lecture are as follows; Define GMOs and describe their impact. List the types and uses of GMOs. We will describe the advantages of using GMOs for food production and promotion of health. We will explain the opposition to GMOs in foods with respect to regulation, safety, and other factors. I will try to explain both side of the GMO lecture where it is appropriate to do so.

One of the most difficult things to do is to define what a GMO is. Some groups consider selectively breed or hybrid crops to be GMOs while other groups do not. This is in fact one of the major problems with labeling GMOs which we will discuss in later slides. For the purpose of our class, a GMO is an organism whose DNA has been altered by genetic engineering. What we mean by altered includes things like upregulating genes or downregulating genes. We might add a gene from a related species. For example, a gene from one type of apple is added to a different type of apple. We might add genes from unrelated species as we will talk about in following slides. We could also delete genes or use techniques well beyond the scope of this class and not discussed here. GMOs could include plants, which are the most common, animals, or microorganisms. The microorganisms are really important because they do things like produce insulin. When we think of GMOs we tend to think of odd things like the picture shown here on the right. This is a Drosophila, or fruit fly, with legs growing from its eye sockets. You might ask yourself why we would do such a thing. The answer is that studies were trying to determine how genes know what to become. In other words, how does one cell know to become your leg while another becomes your arm.
NOTE ON LECTURE

For the purpose of our discussion we are going to talk about some GMO non-food crops. The reason for this is that the birth of GMOs came from some non-food crops such as cotton. The potential use of GMOs in many food groups will be influenced by findings in non-food crops. In other words, what was done in cotton may be used later in foods. A full discussion of ethical/moral/cultural opposition to GMOs is beyond the scope of this lecture/course. Some of these issues will be touched on briefly herein. However, this lecture is focused on the safety of GMOs.

Impact of GMOs

You may be surprised to see how many things on the market really are GMOs. To talk about the impact of GMOs, 1.7 million hectares of crops were GMOs in 1996, but by 2009 that had risen to 134 million hectares. 14 million farmers worldwide grow GM crops. We know of 25 countries that are growing GM crops but many others are looking at the possibilities of doing so. [Note added: recently, some of the countries that have banned GMO crops are reversing those decisions]. 16 of the 25 countries are developing countries and we are going to talk later about why GM crops are so important for developing countries.

Uses of GMOs

What can we do with GMOs? You are probably really familiar with GMO corn. The most common uses of GMOs is what is used in corn; herbicide tolerance and insecticide tolerance. The ones you are less likely to be familiar with are biofortification or the use of GM technology to add nutrients to foods. GM technology can also be used to remove allergens from food, remove toxins from food, and to provide resistance to environmental stresses. GM technology can create crops that can grow in areas of high salt, or low water. There are also random uses of GM technology such as the GloFish shown on the right which were created with GM technology.

GMs

Again the biggest use of GM technology is herbicide resistance and insect resistance. Crops that are herbicide resistant include corn, soy, cotton, canola, rice, alfalfa, beet, and flax. When you read beet you might have pictures soup, but this really refers to sugar beets. A large percentage of sugar comes from these. With insect resistance we see corn, cotton, potato, and tomatoes. There is also the possibility of sterile pollen and we will talk about why that is important later. And finally, virus resistant crops for example papaya. We don’t cover papaya much in this lecture but you should know that a virus was wiping out papaya in Hawaii. It was a GM crop that saved papaya in Hawaii. Many of the GMOs have more than one of the above and this is known as stacked
Another technology used is delayed ripening, especially with tomatoes. We talked earlier in the class about how a huge percentage of food is lost as waste in part due to spoilage. That is the idea here with the tomatoes is to get them to market at their freshest peak without having them go bad immediately. There are also altered oils including canola and soy. The idea here is that nutrition science has changed with regard to which oils are nutritious and which are not. GMO technology can change which oils are present in canola and soy. Altered protein composition is relatively new and the idea is to make corn more nutritious. And of course reduced nicotine has been used with tobacco. On the right you see a common use of green fluorescent protein. In the laboratory we use the green fluorescent protein from jellyfish as a marker for gene expression. In the picture, the gene has made the entire plant grow.

A lot of research goes into using GMO technologies to remove or reduce allergens. The crops in development are always changing but during the time this lecture was written they were soybeans, tomatoes, apples, rice, and peanuts. An allergy free peanut is currently waiting approval. You can imagine how important this would be if you read the story at right. A college freshman died after eating a cookie containing trace amounts of peanut oil. If we used the allergen free peanut, the oil would be harmless. This is a really interesting possible use of GMOs. The ability to remove or reduce toxins in cassava is also really important. Recall that cassava produces that disease known as konzo. If we could remove the toxin, this disease would no longer exist.

The first generation GMOs were produced by very large companies that you may know their names. One of these is Monsanto. Monsanto is one of the companies that people love to hate. I am not interested in defending any company’s practices but there are a few things you should know about Monsanto. One thing is that they are not the biggest GMO company. Bayer and Syngenta are much larger. The second point is that GM is a science, it is not a company. Whether you like or dislike Monsanto should not play a role in your opinion of GM science. The first generation GMO crop was Bt-cotton and it was commercialized in the early 1990s. The cry toxin genes from Bacillus thuringiensis are inserted into cotton. The Bt organism when sprayed on crops acts as a pesticide. Bt organism is one of the most common pesticides used in organic crops. In the case of Bt-cotton, the genes are inserted into the cotton resulted in technology. For example, corn is usually both herbicide and insect resistant.
insect resistance. Therefore you don’t have to spray these crops with insecticide. This provides resistance to pests, the most important of which is bollworms which will actively destroy cotton so this is very important. This cotton has been extensively studied and manipulated to produce crops that are resistant to pests (and to weeds by another mechanisms that is discussed later), and in some cases environmental conditions. Recall that you can use stacked technology in cotton. 90% of all cotton grown in India is Bt-cotton.

Once proof of principle was shown in a non-food crop, it is not surprising that this technology makes its way into food crops. Remember that agriculture is the largest user of pesticides. The GMO here is resistant to glyphosate an herbicide. The idea is that farmers can spray their crops with glyphosate (Roundup) and kill the weeds but not the crops. The hope was to decrease herbicide use. For individual crops this is true, but so many people have adopted the technology and moved to growing corn that herbicide use is actually increasing. There is also an issue with resistance (so called super weeds) but the big 3 companies are already working on solutions. Roundup blocks an enzyme known as EPSP synthase required for growth. Please note that you do not have to memorize plant growth cycles or enzyme metabolism for this course. GMO corn contains a gene to boost EPSP synthase, resulting in resistance to Roundup. It is important to note that humans do not possess this metabolic pathway and do not have receptors for Roundup. Animals and humans can eat these crops with no ill effects. The gene derived from this is that the farmer can spray crops with Roundup and kill weeds but the corn will not die. Just an FYI, several companies are trying to move this into lawn service and create Roundup resistant grass.

I wanted to add a quick lecture note here to tell you that GM crops are largely controlled by a few large companies. Large monopolies controlling any commodity is inherently problematic. Discussing this in detail is outside of this course by large monopolies potentially threaten food sustainability. We really want to focus on the technology here. I would urge you to judge any technology on its scientific merit and not on the company who owns the patents or markets the goods. This is true for GMOs as it is true for “big pharma”. In other words, always argue the science!
When we talk about cotton and corn, the reason to use GM technology is increase yield and make more money. However, there are GM technologies that are specifically designed to promote health. This is one of those, a second generation GMO known as golden rice. It is specifically engineered to produce β-carotene, a precursor to vitamin A. Vitamin A deficiency is a disease of poverty and poor diet. There are about 2 million deaths annually due to vitamin A deficiency. Deaths are preventable by ingesting just a few ounces of Golden Rice daily. Seeds are available free of charge to resource-poor farmers.

We are now talking about a third generation of GMO including this one in which rotavirus antibody is present in rice. Rice has been engineered to contain antibody against rotavirus. Rotavirus is the leading cause of severe diarrhea in infants and young children. It kills around 520,000 children annually. We talked about rotavirus in our virus lecture and discussed that is not a major killer in the US due to the vaccine. What we didn’t mention is that the vaccine isn’t very effective in people who are malnourished. The idea here is to give both the rice and the vaccine to people in developing countries. The two could work together to provide a robust response that can protect against rotavirus and also help with malnutrition. Rice is very stable and can be held for long time periods. Hence the desire to put this in rice as opposed to other foods.

A quick lecture note here. Presented in the following slides are the issues surrounding GMOs from both opposing and supporting viewpoints. When possible, research supporting/refuting claims is presented. This lecture is intended to present the issue as it pertains to Food Safety, the reader is encouraged to make their own choices regarding GMOs.

Let’s being with environmental concerns on GMOs. Genetically altered seeds and pollen can be spread by wind, birds, bugs, etc. Environmental effects may take decades to occur. Early detection of environmental effects may be impossible. You can find a lot of opposition to GMOs and an example is seen on right with Monsanto squishing Mother Nature.
So let’s address the unintentional spread of GM crops. Studies too numerous to list here have demonstrated the spread of GM crops to nearby conventional crops. This creates problems including litigation. GM crops are patented and you are required to pay a fee to use them. You are also required to not save the seeds. You must buy them every year. If you are growing a crop you didn’t pay for, litigation is possible. There is a famous case of a farmer known as Percy Schmeiser. You can Google to learn more but please look at the actual case ruling. People would like you to believe he was sued for growing crops that accidentally blew into his field. In fact, he was sued for saving seeds from those crops and growing them the next year. There are labeling concerns. For example, if you are growing organic crops and GM seeds blow into your fields, do you now have to label your foods as GM? GMs are prohibited in certain areas like in organic foods. Measures are necessary to prevent accidental introduction.

Those supporting GMOs would enter these comments in answer to environmental concerns. They would say that genetic engineering can save threatened species and environments. I mentioned GM technology saved papaya crops in Hawaii. Previously unusable lands can be used for farming. GM crops can grow in areas where there is low water, where herbicide and pesticide use is necessary, and in areas where there is high salt. Genetic engineering for a desired trait is no different from breeding. This is a very controversial idea and something I would like you to research on your own if you are interested to decide if you think this is true or not. Crops can be engineered with sterile pollen and remember I told you two crops were engineered this way. This prevents unwanted spread. GM crops are not new (depending on your definition) some have been used commercially since 1994 with no known ill effects.

This study is included to support the use of GM crops. Rice growth is inhibited in areas of high salinity. A transgenic rice has been produced that tolerates and grows well in areas of high salt. In this study environmental soil studies were performed to see if cultivation of this rice had any ill effect on the environment. In this study no adverse effects were found.
There are also concerns by those opposing GMOs about genetic pollution. The spread of engineered organisms cannot be undone unlike other types of pollution. Although we have looked at pollution of chemicals that cannot be done as well. Pests and diseases can adapt to overtake genetically identical organisms. In other words, GM crops are monocultures. This is a huge problem, monocultures are very susceptible to diseases. However, this is not a problem unique to GM crops, any crop can be a monoculture. Some GM crops can outgrow conventional crops and could replace them. Genes from GM crops could spread to other organisms.

Here is the opposing view to that by those who support GMOs. Organisms are engineered to benefit the environment, not to do harm. GMOs are created that are resistant to pests and diseases and anytime an issue occurs, changes can be made to maintain diversity. This is in defense of GM crops being monocultures. In other words, if crops are susceptible to new pathogens, a new crop will be made in the lab that is resistant. Another point here is that conventional and organic crops can also be monocultures so this problem isn’t unique to GM crops. If we engineer a crop and a bug attacks it, we can just engineer a new crop. Sterile pollen can be engineered to prevent cross-breeding between GM and conventional crops.

Here is a case study of apple scab. Commercial apples were breed with unappetizing related apples to create a variety that is resistant to apple scab. Apple scab is caused by a fungus and can be seen in the picture on the right. It destroys apples. The breeding experiment to create a resistant apple took 85 years! Five years later, the fungus evolved and infected trees again. This was a great idea that quickly failed. To combat the fungus this time, a gene for resistance was added to apples using a “gene gun”. The laboratory was able to create a resistant apple in about 6 months time.
People opposed to GMOs are very concerned about human health as it relates to GMOs. This is the area that is prone to the most pseudoscience. If you decide to research GMOs beware of sites that commonly have information that is not scientifically accurate. Be especially aware of Natural News, GreenMedInfo, Collective Evolution and other conspiracy sites that spread misinformation about GMOs (as well as other topics). Those who oppose GMOs are concerned that studies on the effects of GMOs on humans are lacking. They believe that safety should be a higher priority than potential economic and/or nutritional benefits. Safety testing should occur before products are brought to market. Because GM corn has been in the food supply for more than a decade, human populations are being used without their permission to test GM safety.

Those who support GMOs would counter with the following points. Safety testing is unnecessary because the products are essentially the same as the original foods. Obviously this is a very controversial statement. Those of us who work in genetics would mostly agree with this statement. However, those who are not familiar with pointed/targeted genetics may be very concerned with this. National and international treaties prevent experimentation on humans so how do you test the safety of GMOs? We cannot do studies on humans that is impossible but we can use animals. The studies on animals number in the 1000s and none have demonstrated disease/illness due to eating GMOs. If you find papers that you do think show GMOs are not safe, refutations to those papers are probably also available. Remember that people can publish anything if they are willing to pay for it. GM corn has been in the food supply for 10 years with no known detrimental health effects. Recent meta-analysis of over 1700 papers found no ill effects of GM foods on animals or humans. The science does not support that there is a human safety issue associated with GM foods. This is in terms of direct effect. This doesn’t consider nutrition in which you could argue that a surplus of corn leads to a surplus of corn sugars and directly contributes to obesity. However, nutrition is outside the scope of this course and will not discuss this issue in detail here.

This brings us to groups opposing GMOs concerns on animal safety and testing. These groups will note that there are immunological and histological changes evident in lab animals fed GMOs. For example, some of those studies are shown here. Immune system changes in gut of mice fed GMO corn. Liver function influenced during aging in mice fed GMO soybean. Minimal histological changes in liver/kidney of rats fed GMO corn.
### Slide 26
**Animal Safety/testing – Supporting GMOs**

- Safety testing is unnecessary because the products are essentially the same as the original foods.
- Effects seen in animals are acknowledged but they have no impact on health.
- Animal safety testing because the foods are essentially the same as the original foods.
- Most people would find that controversial and argue that this is not the case. Effects seen in animals are acknowledged but they have no impact on health. For example, similar changes can be seen when you feed animals conventional foods. The effect of GM on non-target animals has been minimal. Lab animals have been fed GMO corn for nearly a decade and no ill effects have been noted. There is a famous paper known as the Serelini paper in which lab animals fed GM corn developed tumors. Most people believe the data was falsified as all lab animals were fed GM corn at the time and no other animals developed tumors.

### Slide 27
**Bt-cotton**

- Bt-cotton grows faster – higher yield.
- Significantly less damage due to bollworms.
- 2013 study demonstrated no adverse effects of Bt-cotton on the arthropod diversity under field conditions. In other words, target animals were not harmed.
- Bollworm on cotton – integrated pest management U. of Missouri – missouri.edu

### Slide 28
**Allergens – Opposing GMOs**

- Genetic engineering could potentially introduce a known allergen into a food.
- Genetic engineering could potentially create a new allergen.
- Genetic engineering could potentially upregulate (increase) the amount of allergen already present in foods.

### Slide 29
**Soybeans – Brazil Nut Allergen**

- Soybeans are nutritionally deficient in methionine (a necessary amino acid).
- Genetic engineering introduced the amino acid using a gene from the Brazil nut.
- Test subjects (those allergic to Brazil nuts) were allergic to the GMO soybean.

This is a case in which genetic engineering did result in an allergen problem. Soybeans are nutritionally deficient in methionine and methionine is a necessary amino acid. Genetic engineering was used to introduce the amino acid using a gene from the Brazil nut. Essentially, a Brazil nut gene was added to soybeans. When they then tested subjects who were allergic to the Brazil nut, they were allergic to the soybean as well. Recall that nut allergies can be fatal! This testing was performed using blood from the allergic people, they were not ingested or injected. Thus, genetic engineering can introduce an allergen and these were tested and never entered the market.
Those who support GMOs would counter that genetic engineering can be used to remove an allergen from foods. This has been successful in rice, soybean, apple, tomato, peanuts and in cassava they can remove the toxins. Proponents would also argue that foods containing allergens are labeled anyway so who cares if you introduce another one. Of course this is very controversial. Research commonly uses newer technologies such as silencing of genes (not introduction of genes from other species).

We see 200 deaths per year in the United States. Transgenic peanuts were produced in which the gene responsible for the allergy was silenced. When tested against sera from allergic patients, no reaction occurred. Potentially we could remove peanut allergies from our food supply.

This slide examines the use of GMOs to provide nutrients. The rationale is that staple foods such as grains, rice, and tubers are deficient in micronutrients. Breeding to increase nutrients is not possible with some plants. For example, bananas, cassava, and potatoes cannot be breed. So there is no other choice if we want to increase nutrients. Genetic modification can easily add nutrients not normally found in foods. Nutrient fortification can prevent unnecessary morbidity and mortality.

We have already discussed Golden Rice but I want to highlight it again here. 1.9-2.8 million preventable deaths annually. Preventable if Golden Rice were available.

One of the hottest topics on GMOs is GMO labeling. If you are a voter in this country, there is a good chance you might find yourself looking at a ballot with this issue on it. This movement is gaining momentum across the United States. [Note added: federal legislators are currently trying to block any state from enacting its own GMO labeling laws]. There is no requirement to label GMOs with the exception of USDA Certified Organic (cannot contain transgenic organisms). Anything labeled USDA Organic is GMO-free. Without labeling, the consumer cannot refuse to
consume GMOs. Without labeling, GMO foods cannot be excluded. Many countries require GMOs to be labeled.

Needless to say, those who support GMOs do not support their labeling. There are many reasons why this is true beginning with issues defining what is a GMO food. In other words, what percentage of the food can come from GMO? For reference, a food can be labeled Organic if it is 95% organic. If it is 100% organic, it can be labeled 100% Organic. How will we define a GMO? A similar system where it is 95% GMO-free? Also, should an animal that is fed GMO corn be considered GMO food? If we feed GMO corn to a cow, does it become a GMO cow? What about the milk from that cow? Biotechnology firms and food producers oppose, and they activity fund opposition to, labeling GMO foods? These companies have poured millions of dollars into preventing GMO labeling. They do this because they do not want to lose their profits. They believe it is unfair that they should lose profits because there is no data demonstrating health risks associated with GMOs. In other words, they are concerned that consumers will read that a food contains GMOs and think they must be worried. However, data doesn’t show this to be true (that GMO cause health risks). There are also costs associated with labeling. Many people think labeling is cheap because it is just ink but that is not true. Once you create a mandatory labeling system, you have to have a system to regulate that. For example, there are costs involved in certifying organic foods and the same would be true of non-GMO foods. Facilities would need to be certified before using the mandatory labels (the 100% GMO free label). Many people have concluded that labeling should not be mandatory, it should be voluntary. Cross pollination of conventional crops can occur as well so a farmer could unwittingly produce a GMO product while trying to do an organic. Current mandatory labeling laws are for nutrition and safety. This is one of the reasons your instructor is not in favor of mandatory labeling of GMO foods. I do believe labeling should be voluntary because GMOs fall under neither mandatory laws for safety nor laws for nutrition. We also have a very robust voluntary system in the US (project GMO Verified). Finally, organic foods do not contain engineered organisms. This is another reason why your instructor is against mandatory labeling, consumers can avoid GM foods by buying organic.
Another big issue for people opposed to GMOs is the use of herbicides and pesticides. The concerns are that overuse of pesticides will occur if crops are resistant. And overuse of pesticides (should really say insecticides) will occur if crops are resistant. And that pesticides produced by an organism cannot be removed by a consumer. Bt-corn produces the cry toxin within its flesh that cannot be removed by washing.

Those persons supporting GMOs would counter with the following. Farmers will not waste expensive pesticides/herbicides. Pesticide production is low compared to application by agricultural workers. Pesticide production is controlled, leading to fewer overdoses. Resistant crops require less pesticide/herbicide. We have seen that data earlier, they do require less insecticide but herbicide is questionable. Pesticides produced by crops such as Bt-corn have no specificity for humans and are therefore harmless if ingested. The whole Bt bacterium is used for organic pesticides. If you are eating organic crops you are likely eating the whole organism. Pesticides required for GM crops are far less environmentally harmful than those commonly used in lesser developed countries such as DDT. If you can get countries using DDT to adapt to GM crops, they have no reason to use DDT.

This brings us to regulation. Those who oppose GMOs are concerned that oversight is run by industry which is driven by profits. They are very concerned about lack of regulation and this fuels public suspicion about GM crops. Newer technologies are not regulated, especially if they don’t use bacterial/viral DNA. There are different requirements for products produced with bacterial/viral DNA versus products produced using genes from related species. In other words if you take a gene from an apple and put it in another apple there are one set of criteria for regulation. However, if you put a gene from a bacterium in an apple, it is a completely different set of regulations.

People who oppose GMOs are very concerned that there are regulation loopholes. FDA regulates substances added to food products as additives: Must differ significantly from what is already present in foods. If you take a gene from an apple and put it in another apple FDA testing is not required. Products genetically engineered for pesticide/herbicide production are regulated by EPA. The EPA is not worried about low production of toxins by GM products and generally this leads to their approval. USDA regulates GM crops only if DNA from pathogens is utilized. If you use DNA not from a pathogen, they don’t care.
Those people who support GMOs would say that government agencies act efficiently in identifying problems as they arise. They would say that agencies are regulating products, and the lack of adverse health effects indicates that new regulations are not necessary. Obviously, this is very controversial and something you should think about. The costs of more regulation would prohibit smaller agricultural labs from developing products. This is true, regulation is so expensive right now that smaller labs cannot get into this field. This is why so many GMOs are produced by very large companies. This prohibits the use of the technology on minor food products. In other words, if you can’t make a profit from it, no one will have the money to study it.

Here we have apple scab again. I wanted to draw your attention to when the breeding experiment took place, there was no regulation required. However, once the gene gun was used, it was regulated. This is because a plant pathogen was used to insert the gene of interest. This is a very common technique. Even though the gene was from a related apple, it was regulated because a pathogen was used in the process. I would say that we have a lot to work to do on the regulation side of GMOs. For example, RNA silencing technology currently isn’t regulated.

This brings us to concerns about profits from those opposing GMOs. There are concerns that GMOs do not improve the socioeconomic situation in developing countries. In fact, they may be disruptive to traditional cultivation systems. There are also concerns about the dominance of multinational companies in biotechnology. There are intellectual property rights and the exploitation of agricultural producers. This is counterproductive for food security and development. I would say this is a very legitimate concern as food security is threatened when large companies have monopolies on foods. Note that this is also a concern for meat products (just a few companies produce most of the meat products) but this is beyond the scope of this lecture. Worldwide opposition to GMOs could decrease exports from producers. Some companies will not import GMOs and that is cutting into profits.

Where there is considerable profit involved, there are often issues with fraud, bribery, etc. Again, don’t make your judgments about the technology because you hate this company or that company but most do have problems. Monsanto was fined $1.5 million for attempting to bribe an official in Indonesia. Bribes were aimed at repealing an Indonesian law that requires an environmental impact study before planting genetically modified cotton.
Profits – Supporting GMOs
• Raise agricultural productivity.
• Save money on insecticides (fewer applications needed).
• Save money on herbicides (fewer applications needed).
• Sizable income gains.
• Crops with higher nutrients could reduce nutrient deficiencies among the poor.

People who support GMOs would argue that profits were the whole point. We are trying to put money in the farmer’s pockets. Raise agricultural productivity. Save money on insecticides (fewer applications needed). Save money on herbicides (fewer applications needed). Sizable income gains which is arguable and depend on where the crops are grown. Crops with higher nutrients could reduce nutrient deficiencies among the poor.

If you are asking why 90% of cotton in India is Bt-cotton, this is why. When they introduced Bt-cotton in India there was a 41% decrease in use of insecticides. That goes directly to costs. It benefits the environment and it benefits the farmer’s health. Remember that there were also changes to pesticides, DDT is out, glyphosate is in for example. This result in 30-45% higher yield in crops and a 89% increase in profits! How would you like an 89% increase in your paycheck?

I did say that ethical/moral/cultural issues were beyond the scope of this class but I wanted to touch on some of the big ones which are concerns of people who oppose GMOs. Genes are being mixed from species that cannot do so naturally. There is concern from various groups that scientists are playing God. Genes from prohibited species may be added to diets. For example, what happens if I grow produce that contains a gene from animals? Would vegetarians and vegans be upset about that? What about the various foods prohibited in Kosher diets? The possibility exists that mixing species could be problematic. There is big concern about interruption of traditional methods of cultivation. That is pretty complex and beyond the scope of this class but very important. There are many other issues but I am sure you have noticed this lecture is already pretty long!

What happens when people oppose GMOs? Unfortunately, they sometimes destroy things. In the Philippines there is what is known as the International Rice Research Institute. When they have new crops, they plant it at the institute and do testing. They test the crops, non-target species, diversity, etc. Protestors destroyed a golden rice test field. Remember that countries such as Indonesia require data from field tests before crops can be planted. This crop was destroyed before that data was obtained. The global scientific community has condemned this action as field tests are required for safety assessment. However, it illustrates that opposition to the technology will sometimes destroy crops.
Ethical/Moral/Cultural Issues – Supporting GMOs
- Preservation of species.
- Food security:
  - Resistant species
  - Low water use
  - Nutrient added
- GM crops provided to resource limited farmers at no cost.
- Traditional methods of dispersal not impacted.
- Once established, crops can be maintained indefinitely.

Those who support GMOs would counter that we have a moral imperative to preserve species. Also, there is a role for GMOs in food security. We can grow resistant species, we can grow in areas where there is no water, and we can add nutrients to foods. All of these contribute to food security. GM crops are provided to resource limited farmers at no cost. Traditional methods of dispersal are not impacted. Cultivation is impacted, but dispersal is not. Once established, crops can be maintained indefinitely. In the case of crops such as golden rice, there are no issues with patents and saving seeds. You can save seeds and keep growing them forever at no cost.

Golden Rice – Predicted Benefit
- Estimated worldwide welfare gains of over $15 billion per year.
- India
- Asia
- Projected 2% growth in national income.
- As many as 2.8 million lives could be saved.
- “Stacked” technology would allow vaccinations to be delivered with the same rice.

This is what a crop like golden rice could really do. It could result in estimated worldwide welfare gain of over $15 billion per year. Especially in countries like India and Asia. In Asia, it could result in a projected 2% growth in national income. As many as 2.8 million lives could be saved. Remember that golden rice could use stacked technology. It already has β-carotene but we could add that rotavirus antibody as well.

Lecture 13 - Summary
- “The hasty transition of the radically new technology of crop transgenics from the research and development stage to commercialization, in which products of the young industry have penetrated global food markets, has resulted in what may turn out to be the largest diet experiment in history.” – Don Lotter
- “Discarding genetic modification as a viable option is definitely not in the interest of human wellbeing” – Peter Beyer, Center for Applied Biosciences, Germany.

Rather than try to summarize this large lecture, I leave you with the two opposing quotes. You are encouraged to do your own research and make your own decisions regarding the consumption of GMOs.