An Evaluation of Genetically Modified Organisms

NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are designed to facilitate adaptation in a variety of settings. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section. The modules also contain other sections which contain additional supporting information such as a “Glossary” and “Suggested Resources”.

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An Evaluation of Genetically Modified Organisms - Module Description

This module examines the production of genetically modified organisms as an environmental issue. Potential environmental impacts of genetically modified crops are emphasized, although human health concerns are also addressed. Our current state of knowledge and the viewpoints held by the various stakeholders are described in video and print resources. Students evaluate these viewpoints and formulate their own opinions based on an analysis of the issue. The module includes a detailed outline of a video production, student handouts, a key to the activity, a glossary and citations for print, video and web-based resources. The activity was developed for use in introductory courses in environmental science, general biology and natural resources and is designed to be completed in a single three-hour laboratory session.

An Evaluation of Genetically Modified Organisms

Introduction

With the development of the ability to manipulate DNA through genetic engineering, humans now have the capacity to alter life as we know it. Scientists have developed ways to transfer genes from one individual to another, and even from one species to another. This new technology has provided humans with untold benefits such as the ability to diagnose human disease, to mass produce rare drugs and to genetically improve crops. In addition, the potential for developing new vaccines and even curing genetic diseases holds great promise. As with most new technologies, however, the development of genetically modified organisms (GMOs) has not been without controversy.

The development of genetically modified foods, for example, provides an interesting case study. Advocates contend that growing GM foods has less impact on the environment than traditional agriculture and that GM foods are perfectly safe to eat. In addition, GM foods may provide an answer to how we provide food for a growing world population. Detractors claim that GM crops pose new risks to the environment and human health for which we are not yet prepared.

In today's lab we will examine what is known about the environmental and human health risks associated with growing and consuming genetically modified foods. Be aware that the scientific research in this area is in its infancy. As a result, there are many unknowns and you will be asked (as society is being asked) to develop opinions based on incomplete information.

Objectives

Upon successful completion of this module, students should be able to:

- Describe how and why genetically modified organisms (GMOs) are produced
- Identify and evaluate the various viewpoints held by stakeholders in the GMO issue
- Develop their own opinions on the issue
- Describe potential environmental and human health impacts of GMOs

Notes to Instructors

How are Genetically Modified Organisms Produced?

Good descriptions of genetic engineering techniques are now widely available. The following is a brief overview. Instructors who would like a more detailed description should consult any General Biology textbook.

Using genetic engineering techniques, genes can now be deliberately transferred from one organism to another. This is accomplished by isolating the gene of interest and then inserting the gene into a different species. The resulting organism is called a genetically modified organism (GMO). One commonly used technique that is used to transfer genes from one organism to another involves the use of plasmids – small, circular molecules of DNA that are naturally found in bacteria. The gene of interest is first spliced into the plasmid. Since plasmids have the ability to move freely from one cell to another, they can serve as vectors for this new genetic information. The resulting genetically altered cells can then be cultured and, for many species, complete genetically modified individuals can be generated.

Detailed Video Outline: Harvest of Fear

This section includes detailed notes from the video production and is designed for instructor use. Numbers in the left margin indicate the approximate elapsed time in the video (hours:minutes). Since the entire production is two hours long, most instructors will probably choose to show only portions of the video. Recommendations of sections that should be omitted, resulting in an activity that emphasizes environmental aspects of the issue, are indicated with the word "OPTIONAL" at the start of that section.

Instructors should be aware that the evaluation of GMOs is a rapidly evolving issue. Although relevant updates have been included with this module, instructors are encouraged to supplement this video with more recent information. Citations of additional resources are provided at the end of the module with this purpose in mind.

Harvest of Fear a NOVA/FRONTLINE production

120 minutes; aired November 2001

See *Suggested Resources* for ordering information

Introduction and overview

0:00 - 0:05 Introduction and overview (OPTIONAL)

0:06- 0:12 Papaya example in Hawaii is used to illustrate potential usefulness of GMOs. Ringspot virus devastated the $45 million/year industry in early 1990's.
Mechanism for development of transgenic papaya (papaya w/ viral gene that provides resistance to ringspot virus) is described. These transgenics were tested by subjecting papayas to ringspot virus and were found to have resistance to the disease.

0:13- 0:19 Other transgenic examples include inserting a firefly gene into a tomato (fluorescence as an indicator of drought stress) and a flounder gene into a strawberry (to protect against freezing).

Monsanto (an agricultural biotech company) made a decision to stop all investment in pesticides in favor of biotechnology. Traditionally, corn is sprayed with non-specific pesticide for European corn borer. By genetically engineering corn with a bacterial (B.t.) gene that produces a toxin that kills European corn borers, environmental impacts of pesticides could be reduced.

0:20-0:24 European concerns over genetically modified organisms (GMOs) result in protests by consumers. Greenpeace called for no import of GMOs and labeling requirements. However, by 1996 GMOs were treated as a traditional crop. Meanwhile in the U.S. most Americans were unaware that they had been consuming GMOs for 5 years.

Concerns

Concerns were based on the following questions:

1. Are GMOs safe to eat?
2. Are scientists "tampering with nature?"
3. Will GMOs harm the environment?

0:25

How do we know that GMOs are safe to eat?

"Safety" cannot be proven but we can test for toxicity in animal experiments in which doses 1000 times what humans would be subjected to are tested. To date there is no evidence of harm.

There are very small differences between GMOs and traditional foods (hence, they are considered "substantial equivalents" by regulatory agencies). Primary concern centers around the potential for allergic reactions since the differences that do exist are differences in proteins, some of which may be allergens.

Food allergies to traditional foods certainly exist (e.g., peanuts), but as a result of labeling requirements, consumers can chose to avoid these foods. With GMOs, consumers are unable to screen since there are no labeling requirements. For example, a Brazil nut gene has been spliced into soybean creating a potential for a dangerous allergic reaction.

Union of Concerned Scientists (UCS) asks, "How do we know that GMOs cause no harm to those who consume them if there is no way to track them?"

0:31

Case study in *StarLink* Corn

StarLink corn (developed by *Aventis* - a competitor of *Monsanto*) is a GMO that makes Cry9C, a bacterial toxin with a long breakdown time in human digestive systems. It therefore, has a higher potential for inducing allergic reactions and was approved only for animal feed. Corn-based products available for sale to consumers were tested by an environmental group and *Taco Bell* taco shells were shown to contain this protein (Cry9C). This was later confirmed by tests conducted by the FDA and the issue was well-publicized in the mainstream media.

How did this product approved only for animal feed get into the food supply? The event called into question the safeguards in place for protecting the public against GMOs. *Aventis* removed GMO corn from the market, but only after worldwide contamination.

0:38

Are we "tampering with nature?" (OPTIONAL)

Some supporters claim that GMOs are not fundamentally different from organisms that have resulted from selective breeding, cross breeding and other more traditional practices. These practices are not without risks either (e.g., glycoalkaloids in some potatoes, toxins in celery.)

There is, however, one difference between traditional breeding techniques and genetic modification. In selective breeding, only genetic information from genetically similar organisms can be combined; transgenic techniques allow combination of very different organisms (e.g., strawberries and flounders) producing transgenic life forms.

However, a transgenic organism with a single gene from another organism is still fundamentally the same as the original organism and considered to be substantially equivalent by regulators.

Safeguards in place for GMOs include approval by USDA, FDA and EPA all of which were met for GM papaya in 1997. However, the patent issue remained a barrier. *Monsanto* held intellectual property rights. Biotech companies appear to want it both ways - they state that GMOs are not significantly different from other plant strains BUT they want patents on these "un-unique" GMOs.

Monsanto gave approval because it was distracted by larger issues in U.S. concerning impacts of GMOs on environment.

0:51

Do GMOs harm the environment?

GMO - Monarch butterfly issue - Does pollen from *Bacillus thuringiensis* corn (a GMO corn that produces its own pesticide and thereby gains protection from corn borers) harm non-target species?

Lab-based experiments conducted by John Losey (Cornell University entomologist) exposed Monarch butterfly caterpillars to:

B.t. corn pollen → 40% mortality
Normal corn pollen → 0% mortality
No pollen → 0% mortality

Results raised public awareness of potential unintended consequences of GMOs. It is impossible to retrieve genes once they are released into the environment.

This case was followed by tests that showed GMOs in Gerber's baby food. Other food companies were targeted by stunts, demonstrations and protests.

How much science was behind the Monarch butterfly findings? The following issues were raised by critics:

- *B.t.* corn pollen does not travel very far from corn field, so if there is an impact it would be very limited
- Milkweed (the primary food for Monarch caterpillars) is a weed eliminated by farmers, so there should not be many Monarch caterpillars in or adjacent to corn fields
- Monarchs may not eat enough *B.t.* corn pollen in a field situation to harm the caterpillars
- The use of *B.t.* corn is less environmentally harmful than pesticides that are used currently

Each of these concerns is addressed by researchers and some continue to be studied.
Cotton farming is a logical target for GMO development since traditional cotton requires eight applications of pesticide compared to only one with GMO cotton.

1:13

Union of Concerned Scientists claims that "We are not farming the right way."

What is the relationship between organic farming and GMOs?

Organic farming - farming that uses more natural processes to grow crops; chemical herbicides and fertilizers are not used but rather composting, crop rotation, animal manures, biological control of pests, etc.

Organic farming accounts for less than 2% of food production in the U.S., but amounts are growing. (NOTE: Since 1990, U.S. organic food production has increased by about 20% per year. Organic food products generate approximately $15 billion in sales in the U.S.)

Organic farming uses *B.t.* as a natural toxin against some lepidopteran pests (caterpillars). Organic farmers fear that they will lose *B.t.* as a tool as resistant strains of insects develop. This process is described nicely with graphics in the video.

Monsanto's response to concerns over resistance is that they have identified other genes for use once resistant strains develop. This is a similar marketing strategy to that taken with pesticides.

For now, the EPA mandates a "refuge system" in which a strip of non-GM corn is required to be planted around the GM corn. This refuge serves as a reservoir for non-resistant forms of the insect pests. Growers are required to self-police and there are concerns about compliance.

Pollen drift is also a threat to organic farmers.

Organic farming is unlikely to ever be a major concern in wheat and corn belt of the U.S. California is more likely due to its varied climate, soils and customer base.

Norman Borlaug (agricultural researcher at Texas A&M University) was one of the originators of the Green Revolution and opposes organic farming as a way to “feed the world.”

1:24

Do we need GMOs to feed the growing human population? (OPTIONAL)

Subsistence agriculture in sub-Saharan Africa where soils are poor is described:
- production has been increased using biotechnology (genetically-modified sweet potato)
- test established to see if GMO would grow without disease

Fundamental question: "What is role of GMOs in sustainable agriculture?"
Aluminum toxicity in soils harms roots of plants. This has been addressed by GM corn which binds aluminum, allowing for better root growth and yield. The advantage of GMOs over other ways to address this problem is its simplicity – the GMO is packaged in the seed.

Environmental groups reject the claim that we need GMOs to produce more food in the developing world and claim that malnutrition is a food distribution problem, not a food production problem. Others claim that this is not true in Africa and, therefore, GMOs should not be denied to developing countries. They claim that biotechnology and agro-ecology will feed Africa's growing population.

1:36

Michigan State University arson case (with Catherine Ives , MSU researcher) is described:
- Earth Liberation Front (ELF) claimed responsibility
- Does this kind of action help or hurt their cause?
- test plots of corn targeted

Return to Hawaii for celebration of final approval for GMO papaya and general success for the project.

1:43

What does the future hold?

Prince Edward Island, Canada salmon farming is described as an alternative to harvest of wild fish (*AquaBounty Farm* is producing GM Atlantic salmon). Salmon are genetically engineered to grow four times faster than normal salmon. This is accomplished in transgenic salmon by adding an ocean pout gene and a salmon growth hormone gene.

Environmental concerns include:

- escape into wild and competition with native species
- salmon population declines (perhaps resulting in effects at other trophic levels) due to larger, but less fit, individuals mating

Computer model and laboratory experiment developed by Purdue University scientist are described. Results from this study indicate that large fish get all the matings, but few of their offspring survive and, as a result, population declines. Therefore, in this case at least, “bigger is not necessarily better.”

Environmental concerns related to GM salmon are being addressed by:

- pens located off-shore
- all penned salmon are female
- most are sterile

But, new genes could be spread large distances very rapidly, spreading the impact.

1:54

Off-shore penned salmon ruling expected by end of 2002 in U.S.

Edible vaccines may be available in 2007. Charles Arntzen at Cornell University is developing GM bananas.

Golden rice contains vitamin A which prevents blindness in vitamin deficient individuals. Patent issues for GMOs have not been fully resolved. *Monsanto's* support for developing and distributing golden rice is brought into question. Is it a "gift to the world," as they claim, or a "PR stunt?"

What about labeling? Industry claims that by labeling there is an underlying assumption that there is something to fear. At this point, Europe will not accept GMO foods. Surveys suggest that support for GMOs from consumers increases if labeling is required. It's all about choice.

It is clear that, "just having the technology, is not enough!" There are many other issues to deal with.

2:00 END

Student Handout

An Evaluation of Genetically Modified Organisms

With the development of the ability to manipulate DNA through genetic engineering, humans now have the capacity to alter life as we know it. This new technology has provided humans with untold benefits such as the ability to diagnose human disease, to mass produce rare drugs and to genetically improve crops. In addition, the potential for developing new vaccines and even curing genetic diseases holds great promise. As with most new technologies, however, the development of genetically modified organisms (GMOs) has not been without controversy.

The development of genetically modified foods, for example, provides an interesting case study. Advocates contend that growing GM foods has less impact on the environment than traditional agriculture and that GM foods are perfectly safe to eat. In addition, GM foods may provide an answer to how we provide food for a growing world population. Detractors claim that GM crops pose new risks to the environment and human health for which we are not yet prepared.

In today's lab we will examine what is known about the environmental and human health risks associated with growing and consuming genetically modified foods. Be aware that the scientific research in this area is in its infancy. As a result, there are many unknowns and you will be asked (as society is being asked) to develop opinions based on incomplete information.

After viewing the videotape, *Harvest of Fear* (a NOVA/FRONTLINE production), please respond to the following questions:

1. Describe the viewpoints of each of the following groups towards genetically modified foods. Include in your answer a description of what stake (if any) each has in the success or failure of genetically modified foods in the marketplace.

Radical environmental groups (e.g., Greenpeace, Earth Liberation Front)

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Industrial-scale farmers

Organic farmers

Agricultural biotech companies (e.g., *Monsanto, Aventis*)

Federal agencies (USDA, FDA, EPA)

Retail food companies (represented by the *Grocery Manufacturers of America*)

American consumers

2. In the space below, create a chart that summarizes the "pros" and "cons" of GM foods.

PROS	CONS

3. After evaluating your answers to #1 and #2 describe your view on genetically modified foods. Do you think GMOs should be included in the foods that we purchase to eat? Why or why not?

4. On what grounds do agricultural biotech companies object to GMO labeling? What is your view? What do you think the consequences of labeling would be?

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5. What are the potential environmental impacts of GMOs such as *B.t.* corn and transgenic Atlantic salmon on the environment?

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6. Concerns over the environmental impacts of GMOs reached a peak in 2000 when a published report by an entomologist at Cornell University documented impacts of *B.t.* corn on Monarch butterfly larvae.

Describe the design and results of the lab-based experiment that raised these concerns.

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What issues were raised by critics of these studies?

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How was each of these concerns addressed by the researchers at Cornell?

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7. In your view, how should environmental concerns related to GMOs be addressed?

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Glossary

You should be familiar with the following terms mentioned in the videotape, *Harvest of Fear*:

Biotechnology - the manipulation of the genetic material of living organisms to produce goods and services desired by humans

Genetic engineering - a method used in biotechnology that involves the manipulation (splicing, altering, combining, copying) of an organism's genetic material for the purpose of changing one or more of its characteristics

Transgenic organism - an organism that contains one or more genes that have been transferred from an unrelated organism using genetic engineering technology (e.g., transgenic strawberries that contain an anti-freezing gene from a flounder)

Pesticide - a chemical that is applied to kill various agricultural pests such as insects and mites

Herbicide - a chemical that is applied to kill unwanted vegetation (weeds)

***Bacillus thuringiensis* (*B.t.*)** - a naturally-occurring bacterium that targets caterpillars and beetle larvae and can be used in agricultural environments to control these pests. Genes from *B.t.* can be incorporated into some crops (e.g., corn) through genetic engineering so they essentially produce their own pesticide.

Cry9C - a bacterial toxin found in genetically modified corn (*StarLink*) developed by Aventis, Inc. Cry9C has a long breakdown time in human digestive systems and therefore, has a high potential for inducing allergic reactions. For this reason, GM corn that produces Cry9C has been approved only for animal feed

Organic farming - farming that uses natural products and processes to grow crops rather than agrochemicals such as herbicides and chemical fertilizers; processes such as composting, crop rotation and biological control of pests are used to maintain soil fertility and control pests

Green Revolution - the development and widespread use of agricultural chemicals (fertilizers, pesticides, herbicides) and improved genetic strains of crops in the 1950's. This resulted in a much higher yield per acre and greater accessibility to food throughout much of the world.

Sustainable agriculture - economically viable, environmentally sound and socially acceptable food production. Sustainable agriculture meets society's needs for safe and nutritious food while conserving natural resources and the quality of the environment for future generations.

Assessment

An Evaluation of Genetically Modified Organisms

Students are assessed in this module by evaluating their ability to understand the various viewpoints represented in the GMO issue and to use a variety of resources to develop their own opinions. A student handout is included with this module that guides students through this process. Students may work in small groups or individually and should use all available resources to respond to the following questions. Some suggested responses are included in the key below.

As an alternative, since the module examines a complex issue with several different stakeholders and viewpoints, the module also lends itself to assessment that uses a "town meeting" format. Please refer to the NCSR module entitled, "Town Meeting: An Approach to Exploring Environmental Issues," for a description of this approach.

1. Describe the viewpoints of each of the following groups towards genetically modified foods. Include in your answer a description of what stake (if any) each has in the success or failure of genetically modified foods in the marketplace.

Radical environmental groups (e.g., Greenpeace, Earth Liberation Front)

Those groups shown in the video are opposed to the development, cultivation and sale of genetically modified organisms, particularly those designed for human consumption. They refer to GM crops as "Frankenfoods" and have staged protests and stunts in the U.S. and Europe to voice their opposition. They would appear to have no particular <u>financial</u> stake in the issue; their primary motivation seems to be to inform the public and to increase awareness. However, some would argue that if their fears are ultimately shown to be justified, this may result in an increase in their credibility and perhaps an increase in donations being sent their way.

Industrial-scale farmers

American farmers engaged in modern, large-scale farming would appear to be heavily invested in the success of GM crops and generally support their development. A large and growing percentage of crops, such as soybean, cotton and canola that are grown in the U.S., are genetically modified. Many of these GM crops result in increased yields and decreased amounts of agrochemicals that must be purchased and applied. This should result in greater profits for farmers, reduced exposure to dangerous chemicals and potential environmental benefits. As a result, traditional farmers have a great stake in the success of GMOs.

Organic farmers

Organic farmers are generally opposed to GMOs for several reasons. Genetically modified crops cannot be certified and sold as organic. Therefore, organic farmers have concerns about genetic contamination of their crops as a result of cross-pollination or pollen drift, which may result in their crops losing certification. They are also concerned that "super-weeds" or "super-bugs" may develop and escape, and for which they have no means of control. Finally, they are concerned that GM crops such as B.t. *corn capitalize on all of the benefits that could be achieved by application of* B.t. *over a very short period of time. Should resistant strains develop, organic farmers would lose an important tool to control insect pests. Consequently, organic farmers have a financial stake in the success of GMOs and may be harmed by their widespread use. Many probably also object to GMOs on philosophical grounds.*

Agricultural biotech companies (e.g., *Monsanto, Aventis*)

Large biotechnology companies such as these have invested tremendous amounts of research and development dollars into the development of genetically modified organisms. Some, such as Monsanto*, have abandoned research in new pesticides and other agrochemicals in favor of these new technologies. They also have a readily accessible customer base with whom they have a long history and one would assume a significant amount of trust. As a result, companies like* Monsanto *and* Aventis *are heavily invested in the success of GMOs, which have the potential for generating large profits.*

Federal agencies (USDA, FDA, EPA)

Each has a role in the regulation of GMOs. The U.S. Department of Agriculture assures that GMOs are safe to grow, the Food and Drug Administration assures that they are safe to eat, and the Environmental Protection Agency regulates the release of any toxins that are produced by GMOs and are released into the environment. The credibility of these agencies with the American public (which is currently quite high) is at stake here. If GMOs were shown to have a negative impact on human health or the environment, this credibility would erode very quickly, hampering the ability of these agencies to operate. Some anti-GMO groups take a somewhat cynical view of the relationship between large biotech companies and these federal agencies. They claim that the relationship is a "bit too cozy" and the agencies are approving GMOs without sufficient scrutiny.

Retail food companies (represented by the *Grocery Manufacturers of America*)

Large grocery retailers are reluctant to comment on GMOs because they do not want to be singled out. In the video they were represented by an umbrella trade group, the Grocery Manufacturers of America. Although reluctant to comment, retail food companies are probably supportive of GMOs since increased production probably translates into lower wholesale prices and greater availability of the goods they sell. GM foods and ingredients are already common on grocery store shelves and one must assume that as long as consumers are not concerned about making a distinction between GM and non-GM foods, this will continue. Should consumer confidence be shaken by some change of events, all of this could change very quickly.

American consumers

American consumers are largely unaware that they have been purchasing GM foods for quite some time and when they find out, many are angry. This attitude prevails despite the fact that concerns about health-related effects of consuming GM foods (with the exception of the potential for food allergies) are largely unfounded. Ultimately the health of American consumers is at stake and some feel that they have been used as "GMO guinea pigs." Assuming that higher production levels of GM crops ultimately results in lower retail prices and greater availability of some foods, the consumer does reap some financial benefit from the success of GMOs.

2. In the space below, create a chart that summarizes the "pros" and "cons" of GM foods.

PROS	CONS
Increased yields and profits for farmers and Bio-tech companies	*Unknown human health effects*
Potential for less pesticide use	*Potential for food allergies*
Redefines and potentially expands "arable land"	*Production of "super-weeds" and pesticide resistant pests*
Helps to address food production in developing world	*GMOs competing with native species*
	Population declines of native species due to "genetic swamping" by GMOs
	Impacts on organic farming
	Potential for <u>more</u> herbicide use (e.g., Roundup-ready *alfalfa)*

3. After evaluating your answers to #1 and #2 describe <u>your</u> view on genetically modified foods. Do you think GMOs should be included in the foods that we purchase to eat? Why or why not?

Students should clearly state their opinion and substantiate with reasonable logic.

4. On what grounds do agricultural biotech companies object to GMO labeling? What is your view? What do you think the consequences of labeling would be?

These companies object to labeling requirements, claiming that they are "substantial equivalents" to non-GMOs and consequently should not be labeled as unique. If labeling were required, there would probably be some initial cost in doing so. However, the underlying and most important concern is that, if labeled, GMOs may be perceived by the American consumer as being "dangerous" or "harmful" in some way, resulting in a decrease in sales and market share.

Students should also clearly state their opinion on GMO labeling. Most consumers support labeling so that they have a choice in the matter.

Most industrialized countries including those in the European Union now require the labeling of GMOs. The United States and Canada, however have been reluctant to do so. An examination of the arguments for and against GMO labeling provides a useful extension for this activity.

5. What are the potential environmental impacts of GMOs such as *B.t.* corn and transgenic Atlantic salmon on the environment?

The potential environmental impacts of genetically modified organisms include the following:

- *Each insecticide-producing plant is now a pesticide factory releasing large amounts of these chemicals into the environment*
- *Insect pests may become resistant to these GMOs much in the same way that insects have become resistant to chemical pesticides, requiring additional spraying or development of new GMOs*
- *Herbicide-resistant GMOs may interbreed with closely related native weeds, conferring upon them some degree of herbicide resistance ("super-weeds")*
- *GMOs (bacteria, plant or animal) may escape into natural environments and outcompete native species (This is a newer version of the invasive species problem, which is at present the second most common cause for the loss of native biodiversity.)*
- *For animal species (e.g., transgenic salmon), escaped GMOs may breed at a higher rate than non-transgenic individuals, despite having lower overall fitness. This may result in a genetic swamping of native species, resulting population declines and, ultimately, extinction.*
- *Once GMOs escape into natural habitats and reproduce successfully, it is nearly impossible to retrieve them*
- *Negative impacts on non-target organisms (e.g., Monarch butterflies)*

6. Concerns over the environmental impacts of GMOs reached a peak in 2000 when a published report by an entomologist at Cornell University documented impacts of *B.t.* corn on Monarch butterfly larvae.

Describe the design and results of the lab-based experiment that raised these concerns.

Monarch butterfly larvae were raised on milkweed leaves that were exposed to three different treatments.

Treatments	*Percent mortality (%)*
1. dusted with non-GMO corn pollen	*0*
2. dusted with GMO corn pollen	*44*
3. no pollen (control)	*0*

Larvae were monitored after exposure and high mortality was measured only in the GMO pollen treatment. This was presented as evidence that GMO crops have the potential to harm non-target organisms.

What issues were raised by critics of these studies?

Other scientists made the following criticisms of the study:

- *Milkweed is actively removed from corn fields by farmers, so Monarchs are unlikely to be exposed to corn pollen*
- *Corn pollen is heavy and does not travel far; so, Monarch exposure to pollen is probably minimal*
- *The amount of corn pollen used in the laboratory experiments is not representative of what actually happens in the field*

For more details on the Cornell monarch butterfly study, see:

Toxic pollen from widely planted, genetically modified corn can kill monarch butterflies, Cornell study shows.
Cornell News. 19 May 1999.
http://www.news.cornell.edu/releases/May99/Butterflies.bpf.html

How were each of these concerns addressed by the researchers at Cornell?

- *Further study demonstrated that milkweed is indeed found in great abundance in corn fields (so, there is potential for contact between Monarch butterflies and B.t. corn pollen).*
- *Corn pollen indeed does not travel more than a few meters away from the corn field. However, since milkweed is common in and around corn fields there is still opportunity for exposure.*
- *The amounts of pollen that Monarchs are exposed to in the field are currently under study.*

NOTE: After publication of the Cornell study, the USDA sponsored research by a group of scientists to investigate this final question (Are Monarch butterflies exposed to toxic levels of B.t. *under field conditions?). These studies, published in 2001 in the* Proceedings of the National Academy of Science*, found that only one of several* B.t. *corn varieties (*Event 176*) approved for use and planted in the U.S. produced sufficiently high levels of B.t. toxin in pollen to be lethal to Monarch butterfly larvae. Of the several* B.t. *corn varieties, this one, fortunately, was not particularly popular with farmers and was not planted widely. Pollen from the two most widely planted varieties of* B.t. *corn (*Mon 810 *and* B.t. 11*) was shown to pose neglibile risk to Monarch larvae.*

7. In your view, how should environmental concerns related to GMOs be addressed?

Students should clearly state their opinion here. Further research including monitoring of GMOs in the environment would seem warranted.

Suggested Resources

Print Resources

Brown, K. 2001. Seeds of concern. *Scientific American* April 2001: 52-57.

Crawley, M.J., et al. 2001. Transgenic crops in natural habitats. *Nature* 409:682-683.

Lappe, M. and B. Bailey. 2002. Engineering the farm: The social and ethical aspects of agricultural biotechnology. Island Press. 200 pp.

Liang, G.H. and D.Z. Skinner. 2004. Genetically modified crops: Their development, uses and risks. Haworth Press, NY. 380 pp.

Losey, J.E., L.S. Rayor and M.E. Carter. 1999. Transgenic pollen harms monarch larvae. Nature 399: 214.

Paoletti, M.G. and D. Pimental. 1996. Genetic engineering in agriculture and the environment. *BioScience* 46(9):665-673.

Stewart, C.N. 2004. Genetically modified planet: Environmental impacts of genetically engineered plants. Oxford Univ. Press, Inc., New York. 163 pp.

Thomson, J.A. 2007. Seeds for the future: The impact of genetically modified crops on the environment. Cornell Univ. Press, Ithaca, NY. 51 pp.

Wolfenbarger, L.L. and P.R. Phifer. 2000. The ecological risks and benefits of genetically engineered plants. *Science* 290:2088-2093.

Wu, F. 2004. The future of genetically modified crops: Lessons from the Green Revolution. RAND Corp., 102 pp.

Video Resources

Harvest of Fear. 2001. Public Broadcasting Service, NOVA/FRONTLINE, WGBH Educational Foundation, Boston, MA, PBS Video. 120 min.

Order Video from:
http://www.shoppbs.org/product/index.jsp?productId=2560393&cp&kw=a+harvest+of+fear&origkw=%22A+Harvest+of+Fear%22&sr=1#Details or via phone (1-800-531-4727)

This PBS production examines all aspects of the GMO issue and forms the basis for this module. Its content is described in detail above in "Notes to Instructors"

Genetically Modified Food: Panacea or Poison. 2005. Ufo Central Home Video, Ufo Video, Inc. 60 min.

A somewhat one-sided examination of GM crops that is built on the premise that GM foods may not be safe for humans or the environment.

The Future of Food. 2004. Lily Films, Directed, written and produced by Deborah Koons Garcia, 60 min. www.thefutureoffood.com 2 DVD set, order at www.futureoffoodstore.com or 1-800-981-7870 ($25)

This documentary examines the business and political forces that have resulted in the prominent position of GMOs in the American marketplace and diets. Descriptions of farming practices and the viewpoints of farmers from Canada, Mexico and the United States are included. The film generally takes a dim view of GMOs and promotes sustainable agriculture as an attractive alternative to large scale industrial agriculture.

Web Resources

Ag BioWorld
www.agbioworld.org/

This non-profit organization based in Auburn, Alabama is supportive of GMOs, promotes the development of GMO crops and provides science-based information related to agricultural biotechnology. The AgBioWorld web site provides a number of links, fact sheets, reports and position papers supporting GMO crops that instructors may find useful as resources to support that point of view. To see how this group responds to many of the criticisms against GMOs, for example, see the reports entitled, "31 Critical Questions in Agricultural Technology" and "Response to GM food myths."

Union of Concerned Scientists
www.ucsusa.org/food_and_environment/genetic_engineering/

The Union of Concerned Scientists (UCS) is a science-based nonprofit group that addresses environmental and safety concerns through independent scientific research and citizen action. Based at the Massachusetts Institute of Technology since 1969, the group uses independent scientific analyses to seek practical solutions to societal problems such as global warming, vehicle pollution and the risks of genetically engineered food crops. UCS generally opposes the development and widespread cultivation of GMOs. See, for example, the report entitled "*Environmental effects of genetically modified food crops*" by Margaret Mellon and Jane Rissler.

Information Systems for Biotechnology
www.isb.vt.edu

This USDA – funded site based at Virginia Tech provides resources that support the environmentally responsible use of genetically modified organisms. Documents and searchable databases related to the development, testing and regulatory review of GMOs are available.

Human Genome Project
http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml

This single-page fact sheet provides a useful overview of the issues concerning GMOs. Links to other resources are also provided for additional information.

GMO Compass
http://www.gmo-compass.org/eng/home/

This non-technical site provides an international perspective on all aspects of the GMO issue.