Genetically Modified Crops

Purpose: While many view genetically modified crops as a promising innovation, there is much controversy surrounding their use. This lesson aims to give students a brief overview of the technology to equip them to evaluate the social, environmental, and economic arguments for and against genetically modified crops.

Level: 9-12

Materials:

- Corn Utilization poster
- Genetic Modification Slide Presentation
- Computers with internet access
- Overview of Crop Genetic Engineering from University of Nebraska-Lincoln's Institute of Agriculture and Natural Resources http://croptechnology.unl.edu/pages/animation.php?a=overview_genetic_engineering.swf&b=990818777
- Materials for students to make posters – paper, markers, etc.
- Articles - links and/or pdfs found on page 7 of this lesson
- Reading Guide – 1 per student
- A variety of food packages that are likely to contain genetically modified ingredients and some that advertise that they contain no genetically modified ingredients (these can often be found in organic or natural foods sections of grocery stores)

Minnesota Science Standards and Benchmarks

9.1.2.1.2 Recognize that risk analysis is used to determine the potential positive and negative consequences of using a new technology or design, including the evaluation of causes and effects of failures.

9.4.4.1.1 Describe the social, economic and ecological risks and benefits of biotechnology in agriculture and medicine.

9.4.4.1.2 Describe the social, economic and ecological risks and benefits of changing a natural ecosystem as a result of human activity.

Background

Genetically modified organisms are defined by the United Nations Food and Agriculture Organization as "any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology."[1] The first genetically engineered plant cell was made in 1983, and since that time, novel genes have been inserted into many crop plants.[2] Most modified crops are engineered to increase yield through resistance to pesticides (such as Roundup Ready crops) or pests (such as Bt crops), but the technology is also used to create new foods (such as golden rice or the forthcoming Arctic apple).

While many view genetically modified crops as a promising innovation, there is much controversy surrounding their use. This lesson aims to give students a brief overview of the technology to equip them to evaluate the social, environmental, and economic arguments for and against genetically modified crops. Students experience the promise of genetic engineering by designing their own genetically engineered product, and evaluate risks and benefits by reading primary source articles on four controversial topics. Finally, students use their knowledge of the risks and benefits to decide whether genetically modified foods should be labeled, which is currently a topic of debate in Minnesota and the US. This lesson is not intended as an in-depth treatment of the process of genetic engineering, so students should be familiar with DNA. It is intended to be flexible, so teachers can select from the activities to suit their students' needs. Suggestions for adaptations, extensions, and further resources are given at the end.

[1] http://www.fao.org/docrep/006/y4955e/y4955e03.htm
[2] http://www.nature.com/news/fields-of-gold-1.12897

Vocabulary

European corn borer: An insect native to Europe that damages corn. In its caterpillar stage, it chews through stalks and ears of corn plants, which can cause the plants to fall over.

Bt: Bacillus thuringiensis is a bacteria present in soil that produces a protein toxic to many insects, including European corn borer.

Cry protein: Crystalline proteins produced by *Bacillus thuringiensis* that kill insects by disrupting intestinal cell membranes.

Genetic Engineering (GE)/ Genetic Modification (GM): The process of directly modifying an organism's genes using biotechnology to produce desired traits.

GMO: Genetically modified organism.

Transgenic: Containing a gene that has been transferred from one organism to another. A synonym for genetically modified.

Enzyme: Protein that catalyzes a biochemical reaction. In genetic engineering, enzymes are used to cut DNA, allowing scientists to isolate the gene they would like to insert into another organism.

Gene: A region of the DNA that encodes a protein or part of a protein.

Clone: To isolate and make copies of a single gene, such as the gene for Cry protein.

Agrobacterium: A bacteria that is a natural plant pathogen, able to transfer genes to plants by invading through wounds and inserting DNA into the chromosomes. This is used in genetic engineering to get the gene of interest into the target organism.

Transformation: When foreign DNA is inserted into the host, such as the Bt Cry protein gene into the corn DNA.

Backcross: The process of breeding genetically modified plants that contain the gene of interest with plants that have other desirable traits, such as high yields.

Roundup/ glyphosate: A chemical that kills plants by inhibiting an enzyme responsible for amino acid synthesis. Roundup is the Monsanto trademark.

Procedure

Activity 1: An Introduction to Genetic Engineering
What is genetic engineering and why does it matter?

1. To get students to recognize the importance of agriculture in their lives, ask them if they have eaten any corn today. Students may not recognize that corn is an ingredient in many of the foods that they eat. List a few food items that contain corn. Examples are included below, but you can modify this list to suit your class:

Doritos/ Tortilla Chips	*Chicken Nuggets*
Popcorn	*French Fries*
Pop	*Salad Dressing*
Pop Tarts	*Ketchup*
Takis	*Many cereals, breads, cakes, etc.*

   Display or pass out copies of the Corn Utilization poster (Genetic Modification Slide Presentation slide 1). Ask students to identify which uses of corn surprise them.
2. Display the state corn production map (presentation slide 2). Tell students that Minnesota ranks 4th in corn production in the US and produces nearly $6 billion worth of corn annually.[3]
3. Introduce the problem of the European corn borer. The corn borer larvae damage corn plants by burrowing into the stalks and causing them to become hollow, which can lead to breakage. Show the images of the damage from the borer (presentation slide 3). Tell students that losses resulting from corn borer damage and pest control costs exceed $1 billion in the US each year.[4] Ask students what ideas they can think of to control this insect infestation.
4. Introduce *Bacillus thuringiensis* (Bt) (presentation slide 4). This bacterium lives in soil throughout the world and naturally produces a protein called Cry that is toxic to the European corn borer larvae. When corn borers eat enough of the Cry proteins, their digestive systems stop working and they die. Farmers have used this property to their advantage since the 1950s, when pesticides containing Bt were introduced for sale. However, Bt pesticide sprays have limited use because they degrade in sunlight and it is hard to get enough spray coating the stalk, where the corn borer does most of its damage.[5] Ask students what they would change to make the Bt pesticide more effective.
5. Ask students if they have heard of genetic engineering and what they think it means. Explain that scientists have used genetic engineering

[3] Minnesota Agricultural Facts and Stats, prepared by Sue Ye, MDA (Jan. 2013)
[4] http://www.extension.umn.edu/distribution/cropsystems/dc7055.html#ch1
[5] http://www.ext.colostate.edu/pubs/insect/05556.html

to create corn plants that produce the Cry protein. This genetically engineered (GE) or genetically modified (GM) corn is called Bt corn.

6. Review the following vocabulary terms as a class: enzyme, gene, agrobacterium, clone, transformation, backcross. Then, present the Overview of Crop Genetic Engineering animation from the University of Nebraska-Lincoln's Institute of Agriculture and Natural Resources. The animation gives 5 general steps for genetically modifying a crop plant. As you watch with students, pause to review the 5 steps. After watching the animation, ask students to explain to a partner how these 5 steps are applied to create Bt corn. After students have shared with a partner, randomly call on students to explain each step.
7. Ask students how the process of genetic engineering of plants differs from traditional plant breeding. Have them write down 2 differences on their own, and then construct a T-chart using student ideas (see example). Students should understand that the major difference is that genes from different species can be expressed in plants through genetic engineering (such as the bacterial Cry protein expression in Bt corn), while traditional plant breeding can only modify traits that already exist in the species.

T-Chart Example:

Traditional Plant Breeding	Genetic Engineering
Combine DNA from plants of the same species	Can combine DNA from different species
Select plants that have desirable traits and cross them	Select a desirable trait from another species and isolate the gene
Large parts of genome changed	Can select a single gene
Genes introduced via pollination	Genes introduced via a plasmid

Activity 2: Designing a GE Product

How can genetic engineering address needs in agriculture?

1. Brainstorm issues that need to be addressed in order to successfully grow and market agricultural products. Make sure to consider environmental conditions, processing, and consumer desires. Possible factors include:
    - *Weather*
    - *Damage During shipping*
    - *Climate/Growing season*
    - *Spoilage during storage*
    - *Yield*
    - *Ease of processing*
    - *Desire for fresh food year-round*
    - *Desire for convenient foods*
    - *Desire for certain flavor, texture*

2. Give other examples of GE crops that have already been developed to address some of these needs (presentation slides 5-7).
    - Glyphosate resistant (also known as Roundup Ready) crops were engineered to address the problem of weeds competing with crops in farmers' fields. They are able to tolerate the herbicide glyphosate, so farmers can spray their fields to control weeds without killing their crops, thus reducing the need for tilling. Glyphosate works by inhibiting an enzyme necessary for amino acid synthesis in many plants. Roundup Ready crops contain a gene for a bacterial form of the enzyme that resists the inhibition.
    - Golden rice was engineered to address the problem of vitamin A deficiency, which is a major cause of blindness in many parts of the world. Golden rice contains the beta-carotene gene of the daffodil plant, giving it its golden color, and beta-carotene is broken down to form vitamin A in the body.
    - Arctic Apples were engineered to have reduced expression of polyphenol oxidase, which causes the apples to brown when you cut or bite into them. This apple modification was designed to appeal to consumer desires and is projected to be available in a few years.
3. Have groups of 2-4 students design a new GE product and make a poster to show their product. The product and poster must:
    - address a problem in agriculture or consumer desires (students should refer to the class brainstorming list for ideas).
    - be realistic; it must result from the transfer of one gene from one species into another species. For example, scientists can make a glowing rabbit using a gene for a fluorescent protein from a jellyfish, but cannot make a rabbit-jellyfish hybrid.
    - explain the process of how the product was engineered, using the 5 steps from the animation as a guide.
4. (Optional) Students will share their GE product proposals from Activity 2 in a gallery walk. Each student group will display their poster while other students are free to view the posters and ask questions. Encourage students to ask their peers about potential risks of the new products, and how those concerns might be addressed. By viewing other students' products after they have learned about some of the concerns about GM crops, they will be able to apply the ideas and risk analysis to their peers' work.

Activity 3: Assessing the Risks and Benefits

What are the risks and benefits of Genetically Modified crops?

1. Display the statistics about GM crops grown around the world and GM corn and soy grown in MN in 2012 (presentation slides 8-9)[6].

[6] http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx#.UbOIBvac63A

- Corn in MN:
  - 19% Bt only
  - 22% Herbicide-tolerant only (Example = Roundup Ready)
  - 47% Stacked (contains both modifications)
  - 88% of all corn grown in MN in 2012 was genetically modified
- Soybeans in MN:
  - 91% of all soybeans grown in MN in 2012 were genetically modified

Clearly, most farmers in MN are planting genetically engineered crops because they have many benefits. Prompt the class by asking, "Are there any risks to growing these newly developed crops?"

2. As a class, brainstorm possible benefits and risks of growing genetically engineered crops. It may be useful to begin by having the class identify possible stakeholders who would benefit or be harmed by GE crops. Possible stakeholders may include:

   - *Biotech companies*
   - *government/regulators*
   - *scientists*
   - *grocers*
   - *farmers*
   - *environmental organizations*
   - *consumers*
   - *international aid organizations*

   Have the class identify the possible benefits and risks that would be faced by each of these stakeholders. For example, biotech companies might benefit from sales of a new product, while grocers might face a risk that people won't want to buy GE foods. Show images of the controversy surrounding GM crops (presentation slide #10).
3. Students will learn about concerns about GM crops through a jigsaw activity. Divide the class into home groups of four students. The number of groups you have will depend on the number of students in the class. Assign each student in the home group one of the four GE topics below and have them read the corresponding set of articles, taking notes on the questions in the Reading Guide. When students have finished reading the articles, have them meet in expert groups of students who read the same article. Expert groups should discuss their Reading Guide answers and prepare to report back to their home groups. Then each student reports to their home group on the issue they read about, while the other students in the home group take notes on the Reading Guide and ask questions of the experts.

Note: Articles with links can be retrieved from the internet. Articles without links are provided.

Do GM crops harm monarch butterflies?

- "Transgenic pollen harms monarch larvae"
  Losey, J.E., Raynor, L.S., & Carter, M.E. *Nature* 399, 214 (1999).
  http://www.nature.com/scitable/content/transgenic-pollen-harms-monarch-larvae-97961
  doi:10.1038/20338

- "Monarchs safe from Bt"
  Clark, T. *Nature* (2001).
  http://www.nature.com/news/2001/010912/full/news010913-12.html
  doi:10.1038/news010913-12

Do GM crops benefit the environment?

- "Potential Benefits for the Environment" in "Weighing the GMO arguments: for" Food and Agriculture Organization of the United Nations, 2003.
- "Case studies: A hard look at GM crops" – sections on Superweeds and Transgenes
  Gilbert, N. *Nature* 497, 24-46 (2013).
  http://www.nature.com/news/case-studies-a-hard-look-at-gm-crops-1.12907
  doi:10.1038/497024a

Are GM crops safe to eat?

- "Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods" American Association for the Advancement of Science, 2012.
  http://www.aaas.org/sites/default/files/AAAS_GM_statement.pdf
- "Uncertain Safety" in "Genetically Engineered Food: An Overview" Food & Water Watch, 2012.

Is patenting seeds harmful?

- "Why Does Monsanto Patent Seeds?" Freeman, E., 2008.
- "GM Crops Should Not Be Patented"

Activity 4: GM Labeling - A Current Controversy

Should GM foods be labeled?

1. Ask students if they have eaten genetically modified food. Ask students how they know if a food is genetically modified or non-genetically modified. If given a choice between genetically modified food and non-genetically modified food, which would the student choose? Pass out examples of food products and have students work in pairs to discuss whether they can identify foods that contain genetically modified ingredients. Some packages will say that they don't contain GMOs, but on the others it will be impossible to tell. Ask students to report out about the packages they examined.

2. Inform students that food producers are not currently required to label genetically modified foods, but that it is very likely that if they eat foods containing corn, soy, canola, sugar beets, or cottonseed oil, that they do eat genetically modified foods[7].
3. Display the map of genetically modified labeling laws (presentation slide 11). There is a movement in individual states to require labeling of genetically modified foods. Engage students in a discussion of labeling rules. Who are the stakeholders? Some examples include consumers, grocers, food companies, biotech companies, and government organizations who would oversee labeling. Consider the costs and the risks and benefits you learned about in Activity 3, such as the concern that genetically modified foods could cause allergies in some people, or that consumers might want to avoid buying genetically modified foods because the crops they are made from could harm non-target organisms.
4. Have students write an essay telling why they do or do not believe that genetically modified foods should be labeled in Minnesota. They must support their opinion with evidence, referencing at least five risks and benefits of genetically modified crops. Remind students that there is no correct answer.

Adaptations and Extensions:

- For more advanced students, you may wish to use this more complex animation from Nova for Activity 1. http://www.pbs.org/wgbh/harvest/engineer/transgen.html
- Learning about controversies surrounding GM crops is a great opportunity for more advanced students to read primary literature. The original 1999 Losey, Raynor, and Carter article is included here, but many other articles on the topic would be accessible to students.
- Use PCR to detect GM proteins in food samples - many kits are available.
- Engineer your own fluorescent bacteria with a from Bio-Rad.
- For further study, you could delve more deeply into how Roundup Ready crops work by enzyme inhibition.
- Several of the print resources suggested here also have audio versions, such as this *Nature* podcast http://www.nature.com/news/case-studies-a-hard-look-at-gm-crops-1.12907

Resources:

- NSTA lessons http://www.enviroliteracy.org/nsfmod/GM-Crops.pdf
- Bt Corn & European Corn Borer - University of Minnesota Extension (http://www.extension.umn.edu/distribution/cropsystems/dc7055.html#ch1)

[7] http://www.cspinet.org/biotech/faq.html

Name_____

Hour_____

Genetically Modified Crops Reading Guide

Topic 1_____

You will read the articles individually and discuss them with your team. Be prepared to share what you learn with other students who have not read these articles. As you read, take notes to answer the following:

- What is the source of the information?

- What are the three main concerns brought up in the article?

- What is the evidence for these concerns?

- How would you evaluate the risks? What additional information would you like to have?

- What do you think is likely to happen with this issue in the near future?

Use this space to write down notes about the other genetically modified crop concerns. Make sure you can describe at least three concerns and evidence for and against them.

Topic 2 _____

Topic 3 _____

Topic 4_____