Teacher's Guide

Supermarket Science: Investigating Genetically Modified Organisms (GMOs)

Grade Level: High or early undergraduate

Subject area(s): Biology, genetics

Time required: (1-2) 55 minute classes

Learning objectives: 1. Learn about GMOs; 2. Learn how gel electrophoresis works; 3; understand the nanoscale size of genetic material.

Summary: In this activity, students will use mock gel electrophoresis data to identify some common organisms that have been genetically modified. Gel electrophoresis is a technique that separates DNA, according to size, using an electric field. Students are introduced to the process by watching a YouTube video on the process. A PowerPoint provides information on what are genetically modified organisms (GMOs).

Lesson Background: Genetically modified organisms (GMOs) are organisms (plants, animals or microorganisms) that contain DNA that has been altered by the intentional introduction of foreign genes. The genes allow the organism to grow faster, have better nutrition, and resist disease. The first genetically modified crops, potatoes and corn, were approved for consumption in the US in 1995[1]. Since their inception, healthier crops and better yields have been obtained[2-4]. In the U.S., there are several crops that have been almost entirely genetically modified. These include corn, soybeans, canola, sugar beets, cotton, papaya and, to a lesser extent, alfalfa. It is important to note that these may not be sold in your local grocery, they are common in our food supply. It is estimated that up to 80% of processed foods contain GMOs[5] With the advent of GMOs, ethical, political, legal, environmental, economic and social concerns have been raised for this technology.

One commonly implanted gene is the Bt gene, which is found in *Bacillus thuringiensis* bacteria[6]. The Bt gene produces proteins that kill insect larvae and plants that have the Bt gene can produce their own pesticide. Currently the only GMO animal product approved for consumption is from AquaBounty[7-8] -- their AquAdvantage Salmon.

For a short but good overview download the article *Genetically Modified Organisms: Transgenic Crops and Recombinant DNA Technology* by Nature Education at: http://www.nature.com/scitable/topicpage/genetically-modified-organisms-gmos-transgenic-crops-and-732. Or have your students read the article before beginning the mock gel electrophoresis activity.

As noted above, students will use **mock** gel electrophoresis data to identify some commonly consumed GMOs. Gel electrophoresis is a technique that separates DNA, according to size, using an electric field. The first step in the procedure is the extraction of DNA from the organism. After extraction of the DNA, the DNA is then copied using polymerase chain reaction (PCR). PCR uses heat, enzymes, and DNA nucleotides bases to rapidly replicate DNA. After running PCR, the DNA exposed to restriction enzymes that cut it into smaller segments. The DNA is loaded into the gel and exposed to an electric field. The migration rate of DNA fragments within the gel is dependent on their size. Shorter fragments migrate faster than larger fragments. At the conclusion of the experiment, the gel is stained and the DNA fragments appear as bands. An example of the results of a gel electrophoresis experiment is shown in Figure 1. Show the students one of the YouTube videos on the procedure as an introduction.

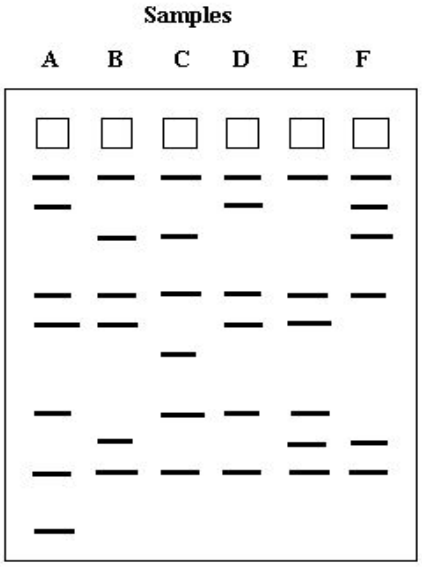

Figure 1: Gel electrophoresis results. The bands represent DNA fragments[9]

DNA and Nanotechnology

Why study DNA for nanotechnology? Nanotechnology is the field of science and engineering that studies and manipulates objects that are 1-100 nm in size in at least one dimension. Nano means one billionth (1 nm= 10^{-9} m). While DNA is 2-3 meters in length (depending on reference source), it is ~2 nm in width, so it is considered to be a nanoscale object. Manipulating DNA has advanced biotechnology and the creation of GMOs is one such example of its use in biotechnology. This lab will show students another application DNA beyond paternity and solving crimes. DNA nanotechnology is a totally different application of DNA in nanoscale science and engineering and should not be confused with altering of genetic information. In this field, scientists and engineers design and manufacture artificial nucleic acid structures for technological uses, e.g., non-biological engineering materials.

References:

1. http://www.gmeducation.org/faqs/p149248-a-brief-history-of-genetic-modification.html

2. http://www.nlm.nih.gov/medlineplus/ency/article/002432.htm
3. http://www.usda.gov/wps/portal/usda/usdahome?contentid=BiotechnologyFAQs.xml&navid=AGRICULTURE
4. http://www.nongmoproject.org/learn-more/what-is-gmo/
5. What are GMOs? Purdue University College of Agriculture: https://ag.purdue.edu/GMOs/Pages/WhatareGMOs.aspx
6. http://www.monsanto.com/newsviews/Pages/gmo-sweet-corn-variety-coming-soon.aspx
7. https://www.marketwatch.com/story/the-first-genetically-modified-animals-approved-for-us-consumption-are-here-2019-06-21
8. AquaBounty: https://aquabounty.com/our-salmon/
9. http://www.fda.gov/animalveterinary/developmentapprovalprocess/geneticengineering/geneticallyengineeredanimals/ucm280853.htm

Pre-requisite Knowledge: Know what DNA and genes are, including base pairs. Some knowledge of heredity.

Materials (For each group of students):

- Chart paper
- Sharpies
- Tape or glue
- Ruler
- Specimen DNA sheet
- Scissors

Safety Information: None

Advance Preparation: Prior to beginning the lab, the teacher should read about genetically modified organisms, gel electrophoresis and polymerase chain reaction (PCR). Listed in the Resource section are numerous links. There is also a link to an online simulation on gel electrophoresis. Students should complete the simulation to gain a better understanding of electrophoresis. Students should also read about PCR and genetically modified crops. See resource section.

Directions for the Activity: See Student Guide with answers.

Resources:
Online electrophoresis simulation: http://learn.genetics.utah.edu/content/labs/gel/
http://www.dnalc.org/resources/animations/gelelectrophoresis.html
http://www.sumanasinc.com/webcontent/animations/content/gelelectrophoresis.html
http://www.pbslearningmedia.org/resource/biot11.sci.life.gen.isolatedna/electrophoresis-and-gel-analysis/

Gel electrophoresis overview:

- Online experiment: https://learn.genetics.utah.edu/content/labs/gel/

- Gel Electrophoresis Kahn Academy: https://www.youtube.com/watch?v=mN5IvS96wNk
- Gel Electrophoresis Amoeba Sisters: https://www.youtube.com/watch?v=ZDZUAleWX78
- Gel Electrophoresis Cold Springs Harbor Lab: Simulation - https://dnalc.cshl.edu/resources/animations/gelelectrophoresis.html

PCR

- PCR Kahn Academy: https://www.khanacademy.org/science/biology/biotech-dna-technology/dna-sequencing-pcr-electrophoresis/a/polymerase-chain-reaction-pcr
- PCR Animation: https://www.youtube.com/watch?v=iQsu3Kz9NYo
- PCR Kahn Academy video: https://www.youtube.com/watch?v=aUBJtHwHASA
- What is PCR? https://www.youtube.com/watch?v=hO3mTqrEeq8

GMO web resources

- Monsanto Innovations: https://monsanto.com/innovations/
- From Corgis to Corn: A brief look at the long history of GMO technology. Harvard University: http://sitn.hms.harvard.edu/flash/2015/from-corgis-to-corn-a-brief-look-at-the-long-history-of-gmo-technology/
- GMO Wikipedia: http://en.wikipedia.org/wiki/Genetically_modified_organism
- Agricultural Biotechnology FDA: https://www.fda.gov/food/consumers/agricultural-biotechnology
- History of GMOs FDA: https://www.fda.gov/food/agricultural-biotechnology/science-and-history-gmos-and-other-food-modification-processes
- GMOs Farmaid: https://www.farmaid.org/issues/gmos/gmos-what-eaters-need-to-know/
- What are GMOs? Purdue Univesity: https://ag.purdue.edu/GMOs/Pages/WhatareGMOs.aspx
- Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA Technology. Nature Education: https://www.nature.com/scitable/topicpage/genetically-modified-organisms-gmos-transgenic-crops-and-732/

Next Generation Science Standards:

HS. Inheritance and Variation of Traits

- LS1.A: Structure and Function
- LS3.A: Inheritance of Traits
- LS3.B: Variation of Traits

HS. Natural Selection and Evolution

- LS4.B: Natural Selection
- LS4.C: Adaptation

HS. Human Sustainability

HS. Engineering Design

- ETS-1 Influence of Science, Engineering, and Technology on Society and the Natural World

Optional: An extension to this activity would have students research the societal and ethical issues of GMOs and create either a PowerPoint or poster to be presented in class.

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Student Worksheet
(with answers in red)

Introduction: Genetically modified organisms (GMOs) are organisms that have DNA that has been altered by the intentional introduction of foreign genes. Food products which contain genetically modified organisms are available in your grocery store. These organisms, mostly plants, have had their DNA manipulated to enhance their growth and nutrition. DNA is a biological nanostructure that measures ~2 nm in width and 2-3 m in length. It is also the organism's genetic blueprint that controls its characteristics, such as height and color.

You are a scientist working at a food science laboratory *SuperGro* and you have been tasked with analyzing several fruit samples to determine if they are genetically modified with the gene *Growfast*. *Growfast* is a 4 base pair gene that is used to replace the plant's normal height growth gene to accelerate its growth.

Directions for the Activity: Your teacher will direct you to an online simulation/animation on gel electrophoresis. This technique is used to estimate the size and separate DNA using an electric field. This simulation will help you prepare for the analysis of your mock data.

Prior to receiving the samples, your assistant extracted the DNA from several fruit samples and amplified the samples using PCR (polymerase chain reaction). PCR is a laboratory technique used to make many copies of a particular region of DNA – it can be any part of the DNA of interest to a scientist. Gel electrophoresis is how the results of a PCR reaction can visualized. It is a technique in which fragments of DNA are pulled through a gel matrix by an electric current that causes the separation of the DNA fragments according to size.

1. Record the samples that you will be testing in the blanks below or in your lab notebook.
    a. Sample 1_____
    b. Sample 2_____
    c. Sample 3_____
    d. Sample 4_____

2. Label your chart paper with the sample names across the top. The sample DNA will be analyzed in the labeled lane. Use Figure 1 as guide for labeling the chart paper.

3. Use the restriction enzyme Cutit to cut your DNA into small fragments. Cutit cuts the DNA sequence after the sequence TAC.

4. Count the number of bases pairs for each fragment.

5. "Run" your gel by organizing your DNA according to size on the chart paper. Remember that short fragments run faster on the gel. Label the number base pairs along the length of the paper. Make sure you keep each sample in the appropriate lane on the gel.

6. Compare the bands of your samples with the controls and determine if your item is genetically modified.

Results

Draw the results of your gel below or in your lab notebook.

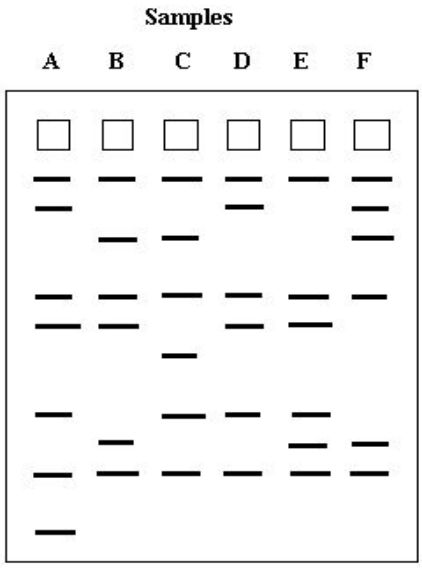

Figure 1: Gel electrophoresis results. The bands represent DNA fragments

Cleanup: Have students discard their chart paper and return supplies

Assessment:

1. Was your organism genetically modified? If so how did you know? The genetically modified organisms are corn and papaya. There was a 4 base pair band that indicates the presence of the Growfast gene.

2. What were the controls for the experiment? Positive and negative GMO controls were used for the experiment. The positive control is a genetically modified organism that has the foreign sequence, while the negative control does not. Both controls are needed to confirm the results. Explain the importance of both controls for the experiment.

3. What are the benefits of creating and using GMOs? GMOs can be engineered to create their own pesticides and herbicides, resist droughts, and grow faster.

4. Why is this lesson connected to nanotechnology? DNA is a nanoscale material because it has a diameter of 2-3 nm. The cutting of the DNA sequence and the insertion of genetic material occurs on the nanoscale.

5. What are some ethical concerns about using GMOs?
   Genetically modified crops can outcompete native crops. They can also result in the herbicide and pesticide-resistant weeds and insects, respectively. Answers will vary depending on the student.

6. Other than plants, what other organisms are manipulated using genetic engineering? Bacteria are manipulated to produce protein therapeutics, such as insulin, for humans. Animals are also manipulated for food and product production.

7. Using the internet or other references explain the steps that a nanobiologist would have to take to insert foreign genes in another organism. References:
http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Projects00/rdna/rdna.html
http://biology.kenyon.edu/courses/biol114/Chap08/Chapter_08a.html

DNA Samples (Red indicates where the restriction enzyme cleaves the DNA after the sequence TAC). The gel with the results is shown on the next page.

Papaya DNA Papaya DNA Papaya DNA Papaya DNA Papaya DNA
TACTAGGATCTACTAGGCCTATAAGCCTATACCGGTGCCTATACCAGC
ATGATCCTAGATGATCCGGATATTCGGATATGGCCACGGATATGGTCG

Organic papaya DNA Organic papaya DNA Organic papaya DNA
TACTAGGATCTACTAGGCCTATAAGCCTATACCGGTGCTTAGCTACAC
ATGATCCTAGATGATCCGGATATTCGGATATGGCCACGAATGGATGTG

Corn DNA Corn DNA Corn DNA Corn DNA Corn DNA Corn DNA
AGCTACCTAGCGTGCCTATACTAGGATCTTACAGGCCTATATACCAGC
TCGATGGATCGCACGGATATGATCCTAGAATGTCCGGATATATGGTCG

Organic corn DNA Organic corn DNA Organic corn DNA Organic corn
AGCTACCTAGGGTGCCTATACTAGGATCTTACTAGGCCGTGCAGCTAT
TCGATGGATCCCACGGATATGATCCTAGAATGATCCGGCACGTCGATA

Strawberry DNA Strawberry DNA Strawberry DNA Strawberry DNA
AGCCTACTACGGTGCCTATAGGATCTTACAATAGGTTGCATACGCTGG
TCGGATGATGCCACGGATATCCTAGAATGTTATCCAACGTATGCGACC

Banana DNA Banana DNA Banana DNA Banana DNA Banana DNA
AGCTACAGGTTACGGTGCCTTACTGCAGCTGGGTACTAGGATCTAATG
TCGATGTCCAATGCCACGGTATGACGTCGACCCATGATCCTAGATTAC

GMO Control GMO Control GMO Control GMO Control GMO Control
AGCTACCTCTGG TTACGCC TATAGGATCTACTAGGCCT ATATACCAGC
TCGATGGAGACCAATGCGGATATCC TAGATGATCCGGATATATGGTCG

non-GMO control non-GMO control non-GMO control non-GMO control
CGGTGAGCTACCTATCTATACTAGATAGATCTACTAGGCCGTGCAGCT
GCCACTCGATGGATAGATATGATCTATCTAGATGATCCGGCACGTCGA

Solution:

The gel with all the bands is shown below. All the plants that have the 4 base pair DNA fragment are genetically modified.