Gel electrophoresis: sort and see the DNA

Description of Activity

Gel Electrophoresis allows students to visualize the process of separating fragments of DNA by gel electrophoresis. Students will construct DNA fingerprints of the Lambda (λ) genome using diverse restriction enzymes.

Learning Outcomes

Students will:

- learn to read and interpret restriction maps.
- understand how DNA fragments are sorted by size with gel electrophoresis.
- work together to construct and compare different DNA fingerprints.
- describe and explain the process of gel electrophoresis.

Assumptions of Prior Knowledge

Students should be familiar with restriction enzymes and their function.

Misconceptions

When viewing the bands of a DNA fingerprint, students often think that one band represents a single DNA fragment of a certain length. Stress that you begin with a large quantity of DNA and each band is in fact many DNA fragments of the same size.

Students often believe in a linear relationship between the size of the DNA fragment and the distance traveled through the gel. They think that if you have two fragments, one that is half the size of the other will travel twice the distance.

Possible misconception question: If you could look at the band of DNA that appears on a gel, what would you notice about the sizes of all the DNA fragments in that band?

Implementing the Lesson

Become familiar with the *DNA Interactive (DNAi)* web site (www.dnai.org) and how to navigate through it. Provide students with information about navigating the site, and how to play animations and video clips.

Before class:

Students should review the section on "cutting and pasting on the *DNAi* web site: **www.dnai.org > Manipulation > Techniques > cutting and pasting**.

Pre-class activity

Make copies of the *Pre-class activity* worksheet for each student. Following the instructions on the student worksheet, they will watch a gel electrophoresis animation at **www.dnai.org > Manipulation > Techniques > sorting and sequencing**. If students do not have Internet access at home, school computer time should be allocated to complete this activity.

Prepare for the in-class activity

You will need:

- card stock.
- liquid laundry detergent that fluoresces under black or UV light (almost all laundry detergents do this e.g. Tide or All).
- a paintbrush or thin sponge.
- a laminating machine (if available).

This activity runs best with students in groups of six. Although each student will be assigned a task, the students in the group of six can assist each other to produce one complete data set.

Make one set of copies of the restriction enzyme fragment sheets on card stock for each group.

Paint over the number and area to the right of the number with the laundry detergent. On the left side of the band, write a letter so that when the fragments are correctly sorted by size and viewed, the name of the restriction enzyme will be spelled out. For *Eco*RI, on the left hand side of the largest band (21,226), you should paint the letter "E". The next largest band of 7,421, you would paint "c" continuing until there are no more letters remaining. For some of the restriction enzymes, you will end up with bands without letters.

For each sheet, cut out the bands and place them in an envelope labeled with the name of the restriction enzyme.

Hints: Laminate sheets after painting so that they can be used with multiple classes. Then cut them into strips. Match the color of the card stock as best you can to the color of the laundry detergent so that the letters and painted areas are concealed.

Make one copy of the *Marker* sheet for each group of six. Paint the sheets completely with the laundry detergent, laminate (if possible), and cut out all the bands.

Make one copy for each student of the following:

DNA fragment size chart (blank);

Restriction maps of the linear λ genome; and

DNA fingerprints (blank).

During class:

Before starting this activity, review how DNA can be cut into fragments using restriction enzymes. To review gel electrophoresis, go over the pre-class activity questions as a group.

Explain that the "DNA" for this activity was isolated from lambda (λ), a bacteriophage (a virus that infects bacteria). It is 48,502 nucleotides long.

Divide the class into groups of six students. Provide each student with a copy of the *Restriction map of the λ genome*. Assign each student a restriction enzyme. Using the restriction map, they will determine the length, in base pairs, of the subsequent DNA fragments after cutting.

Point out that the map shows only the restriction sites, not the fragment sizes. Students will have to subtract the site locations to determine the lengths of the fragments.

The students should list their answers in the *DNA restriction fragment size chart*. Note: Not every cell in the table will be filled. When each student has completed their individual enzyme, have the group share their data. Every student should end up with a completed chart.

Distribute the envelopes containing the DNA fragments that correspond to the students' allocated restriction enzymes. Also provide each group with a set of markers.

Ask the students to demonstrate their understanding of gel electrophoresis by arranging the "DNA fragments" in the envelope. For this simulation, the DNA would be loaded into the gel at a point on a lab table nearest them, and as the gel runs, the fragments move away from them. They should use the marker bands as a guide when laying out the fragments.

Once all of the student groups have created their DNA fingerprint, ask one group to volunteer to tape their "bands" to the blackboard. Shut off the lights in the classroom and shine a UV light or black light over the fingerprints to illuminate the bands.

If the students have created the correct fingerprint the name of the enzyme should appear as you read down the board. A hand held UV light can be used for the bands laid out on tables.

For homework, have students transfer their bands

to the blank "DNA Fingerprint" sheet. They will draw a line in the appropriate position to the nearest marker. Each fragment line should be of the same width.

Further Explorations

Writing

Go to **www.dnai.org > Applications > Human Identification**

Have students review the four parts of the web site (*profiling, family, murder,* and *innocence*). In this activity, each student will play the role of a reporter for the *New York Times* Science section writing a series of articles about the importance of DNA. In these pieces, students should discuss the impact of DNA fingerprinting within the judicial system. They should write news articles about cases not discussed on the web site, referring to any of the three broad topics discussed ie. paternity, crime-solving, and exoneration.

Glossary

Agarose

Bacteriophage

DNA fingerprint

Ethidium bromide

Gel electrophoresis

Lambda (λ) virus

Matrix

Restriction enzymes

Restriction maps

Resources

Web

Access Excellence @The National Health Museum (1994-2003). *ae@nhm: the Site for Health & Bioscience Teachers and Learners*, www.accessexcellence.com

Cold Spring Harbor Laboratory (2002). *DNA From the Beginning: an animated primer on the basics of DNA, genes, and heredity*, www.dnaftb.org

Woodrow Wilson National Fellowship Foundation (2002). *Leadership Program for Teachers: Teacher Resources > Core Websites*, www.woodrow.org/teachers/Teacher_Resources/CORE/core.html

University of Illinois, *Molecular Biology CyberLab* www.life.uiuc.edu/molbio/geldigest/electro.html#run

Books

Micklos, David A., Freyer, Greg A., and Crotty, David A. (2003). *DNA Science: A First Course, (2nd Edition),* Cold Spring Harbor Laboratory Press, New York.

Lesson Pages Include:

Student worksheets: pre-class activity; restriction mapping; restriction fragment chart; and DNA fingerprint.

Answer sheets: pre-class activity; restriction mapping; restriction fragment chart; and DNA fingerprint.

Templates: Fragment sheets with fragment sizes resulting from six different restriction enzymes; and marker sheet with size markers to assist students to compile the DNA fingerprint.

Correlation with U.S. National Science Education Standards.