Cell Wall Recipe: A Lesson on Biofuels

Grades: 5-8

Topic: Biomass

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By Daniel Steever

Grade Level/Subject

Middle School Life Science

Relevant Curriculum Standards

CONTENT STANDARD A:
As a result of activities in grades 5-8, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD C:
As a result of their activities in grades 5-8, all students should develop understanding of:

- Structure and function in living systems
- Reproduction and heredity
- Regulation and behavior
- Populations and ecosystems
- Diversity and adaptations of organisms

CONTENT STANDARD E:
As a result of activities in grades 5-8, all students should develop:

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F:
As a result of activities in grades 5-8, all students should develop understanding of:

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

CONTENT STANDARD G:
As a result of activities in grades 5-8, all students should develop understanding of:

- Science as a human endeavor
- Nature of science
- History of science

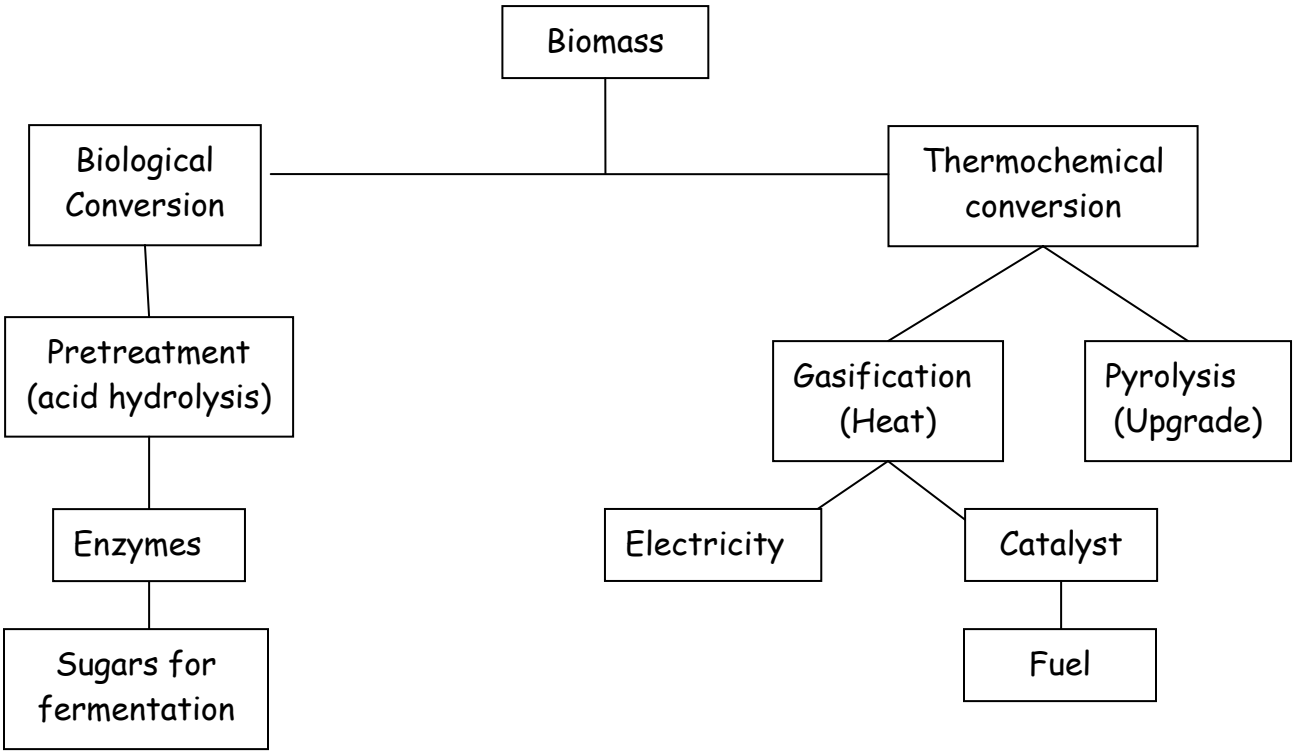
Teacher Overview:

In this activity, students will investigate how changes in the DNA sequence that codes for cell wall formation can have a favorable outcome in producing plants that have higher levels of cellulose than the parent plant. It is the yield of cellulose that is most important in the production of ethanol, and the greater the amount of cellulose there is within in the cell wall, the greater the amount of ethanol that can be produced. To engage students, the first part of this lesson has students participating in a discovery activity where they will extract DNA from wheat germ. This activity is simple and, in my experience, has worked great in the 7th grade science classroom. Following this, students will be given 3 strips of paper at random with different symbols on them; these strips are the DNA strands. While each strip has four symbols, only three symbols represent a gene (a codon, to be specific) and students will read the strips from left to right. By having four symbols per strip, students will have a variety of possible combinations as they lay out their strips to be decoded. Students will look at the key provided and build their cell walls based on the genetic code they were given. Students can make adjustments in their code if they have a fatal mutation or they did not get a gene for cellulose, lignin, or hemicellulose. Once students have built their cell walls they will evaluate the codes that would be most favorable in producing cell walls with a high percentage of cellulose and low percentages of lignin and hemicellulose. This module can be used as part of a whole unit or as an activity in understanding cell wall structure and function, DNA and genetics, evolution, technology, or science and society.

Relevance: This unit was inspired by the research conducted at NREL on cell wall mutations and the development of higher cellulose-yielding feedstock for ethanol production.

Background:

Biomass refers to any organic substance and can range from vegetable or trees to solid wastes such as paper and food based trash. This biomass can be converted to fuel by two main processes: biological conversion and thermochemical conversion. Below is a diagram that highlights the major steps to fuel conversion.



In biological conversion, the biomass is first treated using acid hydrolysis. The purpose of this step is to break up the lignin and hemicellulose within the cell walls, which interfere with the enzymes' ability to work on the cellulose. The enzymes break up the cellulose into sugars that can be used in fermentation. After fermentation the ethanol produced is distilled and can be used as fuel.

In a thermochemical conversion, the biomass can be gasified or used in pyrolysis. Gasification creates heat that can be used to generate electricity or heat a home. Pyrolysis requires burning at high temperatures and pressure in the absence of oxygen. The product then needs to be upgraded to a more useful fuel.

Unfortunately, as of 2006 the production of biofuels is not a cost competitive alternative to fossil fuels. Improvements that must be made start with the biomass itself and follow through the various stages of biological conversion and

thermochemical conversion. This activity looks at ways scientists are trying to "improve" the biomass in organisms such as corn, switch grass, and other plants.

Scientists have mapped the genome of maize (corn plants) and are genetically modifying the maize such that the cell walls contain higher amounts of cellulose than they have in the past. The challenge scientists face is figuring out what genes are involved in producing a cellulose-rich cell wall and how they can create a healthy plant with this high cellulose cell wall and a reduction in lignin and hemicellulose.

Learning Objectives:

1. Students will be able to list the 4 nitrogenous bases associated with DNA.
2. Students will be able to "decode" a hypothetical strand of DNA.
3. Students will be able to list the 3 major building blocks of a cell wall.
4. Students will be able to articulate the structure of their cell walls.
5. Students will be able to create a flowchart illustrating ethanol production from planting through distillation in 5 steps.
6. Students will be able to improve their "cell wall" by making at least one genetic modification through collaboration with peers.
7. Students will be able to articulate 2 challenges facing scientists who are working on biofuels and 2 possible solutions.
8. Students will be able to articulate what a genetic modification is.

Time Allotted: Four 50 minute class periods.

Vocabulary:

Biofuel	Hemicellulose	Enzyme
Ethanol	DNA	Fermentation
Cell	Genetics	mutation
Cell Wall	Modification	
Lignin	Biomass	
Cellulose	Gene	

Wheat Germ DNA Extraction Lab

Background:

Remember that the four basic biological molecules that make up cells are nucleic acids, proteins, carbohydrates, and lipids. We can actually separate these molecules here in the 7th grade lab using regular household products. Our task for today is to extract DNA from the nucleus of wheat germ cells. Sounds tricky, but in fact if we follow the procedure carefully we can do this.

We will be using a combination of household products to accomplish this. We will be using hot water to speed up reactions and to assist in breaking up the biological molecules. We will also be using a mild soap (Dawn or Ivory) to break up membranes. Remember that membranes are made of lipids, commonly called fat, and Dawn "cuts grease out of your way." Unfortunately, we do not have a centrifuge in the classroom to "spin down" heavy molecules such as proteins and carbohydrates so we will use a 70% mixture of rubbing alcohol to separate the nucleic acids from the solution. The alcohol will create a precipitate with the DNA and after about 5 minutes the precipitate will float on top bringing the DNA to the surface. The DNA will appear white and stringy. So why would we want to do such a thing? Well DNA extraction is the first step to DNA "finger printing" or just about anything else involving DNA experimentation.

Materials:

Wheat germ	Rubbing alcohol
Hotplate*	Thermometer
50 ml conical test tubes*	Mild dish soap
Straws (for stirring)*	Paper clips

*These items can be substituted with anything available that can serve the same function.

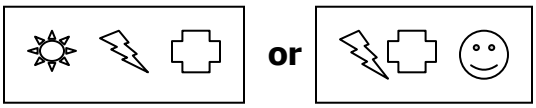
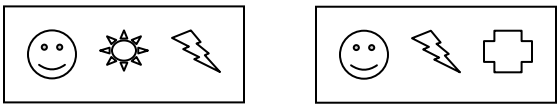
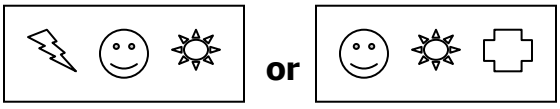
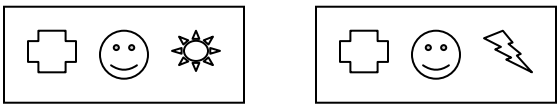
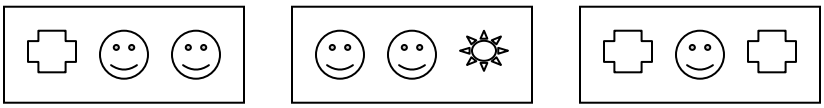
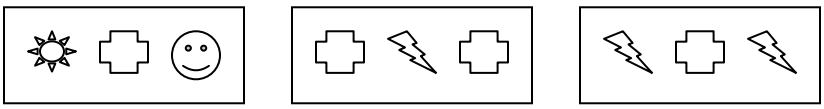
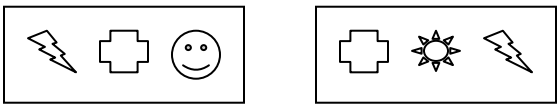
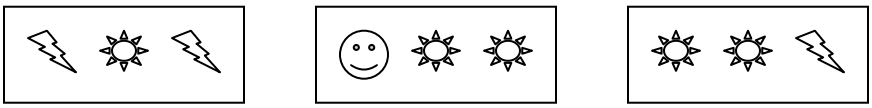
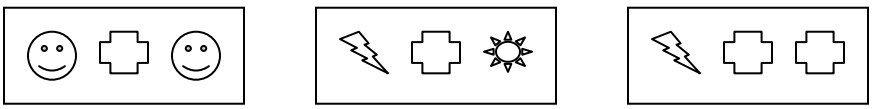
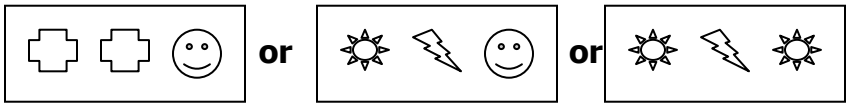
Procedure:

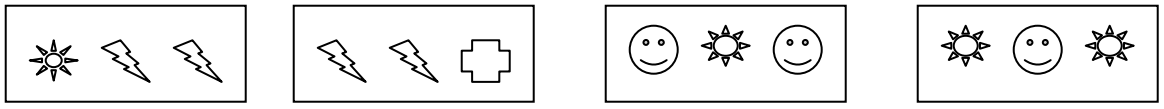
1. Obtain a 50ml conical test tube.
2. Add 1 teaspoon of wheat germ to the test tube.
3. Mix 20ml of hot water (50-60 degrees C) and mix by stirring with a paper clip for 3-4 minutes.
4. Gently mix 1 ml (3 drops) of detergent for about 5 minutes. **Keep foaming to a minimum by not stirring vigorously!**
5. Remove any foam that arises with the pipette.
6. Hold the tube at an angle. Slowly pour 14ml of alcohol down the side of the test tube. It should form a layer on top of the mixture since it has a lower density. **Do not mix.** Return the tube to an upright position.
7. After letting the tube sit for several minutes, DNA should appear where the water and alcohol layers touch. DNA is the stringy white material that is seen. After 15 minutes, the DNA should float on top of the alcohol.
8. Remove the DNA from the solution with a "modified" paper clip and place the DNA in the test tube containing 70% alcohol at the front of the room.

Analysis Questions:

1. What did the DNA look like?
2. Where would you likely find DNA in an organism?
3. What do you think was the specific purpose of adding each of the following:
   (a) detergent (b) alcohol
4. Why might it be important to be able to isolate DNA in the lab?

DNA Decoder

Cell Wall Composition	Possible "genes"
Low % cellulose:	 **or**
Medium % cellulose:	
High % cellulose:	 **or**
Low % Lignin:	
Medium % Lignin:	
High % Lignin:	
Low % Hemicellulose	
Medium % Hemicellulose	
High % Hemicellulose	
Fatal mutations:	 **or** **or**



Resources and Materials:

Literature on biofuels can be found at NREL's website: www.nrel.gov.

Material List:

Strips of construction paper (3 different colors)	Glue
DNA strips (included)	DNA decoder (included)
Scissors	Poster board or butcher paper

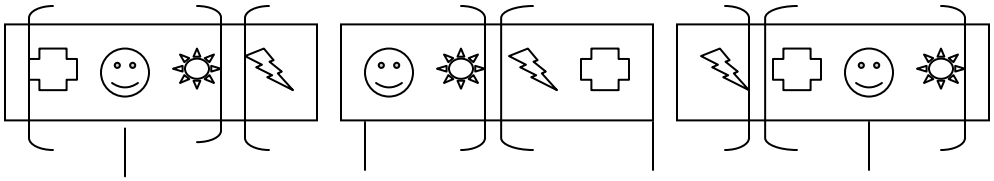
Prerequisite knowledge:

- Understanding of energy and energy conversion.
- Understanding of what DNA is and what genes are.
- Plant cell anatomy.

Main Activities:

1. Engage students on day 1 by doing the Wheat Germ DNA Extraction Lab.
2. Mini-lecture on biofuels and plant biology (Plant biology should be a review.)
3. Tell students that they are genetic engineers and that they will be constructing a cell wall based on a genetic code they have picked out with the DNA strips.
4. Distribute the DNA decoder sheet.
5. Have DNA strips cut out and placed in some sort of container and mix the strips up such that the strips will be picked buy students randomly.
6. Have students choose 3 DNA strips from the container at random.
7. Students will now arrange the 3 strips to form a chain such that the 3 strips give 12 symbols in a row.
8. Tell students that every 3 symbols represents a gene and to use the decoder to figure out what their DNA strand codes for.
9. Remind students what a genetic mutation is and review dominant and recessive genes.

Example:



Gene #1 Gene #2 Gene #3 Gene #4

Low lignin High Cellulose Medium Hemicellulose Low Lignin

10. Students can arrange their strips in anyway they wish. The target is to get low lignin and hemicellulose and high cellulose. The first time it is fine if the student does not get the desired combination, but students should work on arranging their DNA in the best possible combination. You may allow students to switch out strips as many times as they wish to get the desired outcome. However, the desired outcome is statistically based and the student may spend a great deal of time trying to get the "correct" combination.

    Issues:

    If the student can't get three genes for the three components of a cell wall they must "throw out" one strip and replace it with something different from the DNA container and then find another combination.

    If the student gets a fatal mutation they must rearrange their strips or replace it with another. (Many mutations scientists create to improve cell walls are fatal.)

    If the student gets 2 genes for the same component (lignin, hemicellulose, or cellulose) the student uses the gene that is most desirable.

11. Have students "build" their cell walls using strips of construction paper. Students should glue the strips down in a way that cellulose is glued first, hemicellulose second, and lignin third. Students should use a crisscross pattern so that all three layers are visible. The number of strips for low, medium, and high are determined by the teacher. Suggestions: 3 strips = low, 6 = medium, 9 = high.

12. Now have students "improve" their cell wall buy changing the code. They can draw the new code or pick out the same strips as before, cut out individual symbols and glue them down as their new code. Repeat step 10 for the new code.
13. Students can display their work; do a write up, etc.

Assessment: Students will be asked to present their "cell walls" to the teacher one on one as a "show and tell".

Students will be asked to articulate the following:

1. What are the 3 principle components of plant cell walls?
2. How did you read your genetic code? Did you have to manipulate anything?
3. What was the ideal composition of the cell wall?
4. Why are high amounts of cellulose desirable?
5. What genetic modifications did you make to improve your cell wall?
6. Describe the process of converting biomass into ethanol in 5 steps.
7. What is a genetically modified organism?
8. How can biofuels help our society and environment?

DNA Strips: