LESSON OVERVIEW:
Plastics are everywhere. We use them in our houses, clothing, cars, etc. Plastics are polymers, which are large molecules consisting of many repeating subunits called monomers. The origin of most plastics used today is fossil fuel such as coal, natural gas and oil. These fossil fuels are nonrenewable resources that cannot be replaced in our lifetime once they have been used. Green, or bio-, plastics, are from a growing field of research that uses the starches (cellulose) in plants to produce a more environmentally friendly plastic. These “green” plastics are more biodegradable than petroleum-based ones and could be an alternative to the use of our limited fossil fuel resources. This could also reduce the amount of plastic in our society.

LESSON OBJECTIVES:
Students will be able to:
1. Produce a starch-based bioplastic.
2. Evaluate data to compare the different peanut compositions.
3. Apply knowledge to a real-world situation.

ESSENTIAL QUESTION:
How can humans use natural resources in a more effective way to reduce our impact on Earth’s systems?

TOPICAL ESSENTIAL QUESTION:
How are starch-based packing peanuts made using common household substances?
STANDARDS:

High School

HS-ESS3-4
Students who demonstrate understanding will be able to: Evaluate or refine a technological solution that reduces the impact of human activities on natural systems.

HS-ESS3-2
Students who demonstrate understanding will be able to: Evaluate competing design solutions for developing, managing and utilizing natural resources based on cost-to-benefit ratios.

HS-LS2-7
Students who demonstrate understanding will be able to: design, evaluate and refine a solution for reducing the impact of human activities on environment biodiversity. (Application: the effects of plastic waste on the health and well-being of organisms.)

Science and Engineering Practices:
1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating and communicating evidence

Crosscutting Concepts:
1. Patterns
2. Cause and Effect: Mechanisms and explanations
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter: Flows, cycles and conservation
6. Structure and Function
7. Stability and Change

KEY VOCABULARY:

Polymer
Starch
Plasticizers
Fossil Fuels
Nonrenewable resources
Sustainable
Monomer
Cellulose

LAB BACKGROUND INFORMATION:

NOTE: This is background information for the teacher to assist in facilitating learning and will be explained to the students after the Explore section.

In 1941, Henry Ford constructed a vehicle which was displayed in Dearborn, Michigan. The frame was steel, and the car had plastic panels made from 70 percent biodegradable cellulose fibers derived from soybean, pine, hemp, sisal, and other plant materials. The actual origin of the plant material is debated. Ford claimed this vehicle to be safer and lighter than other cars. There was also a suggestion the car may have been fueled by a biofuel. In 1925, Ford told The New York Times:

The fuel of the future is going to come from fruit like that sumac out by the road or from apples, weeds,
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Today there are plastic masses floating on the oceans and our landfills are full of excess nondegradable plastics. Plastic trash can also endanger wildlife. Plastic bags are consumed by animals, often resulting in death, and wildlife can become entangled and strangled in six-pack rings. Plastics also leach hormone-like substances which affect the health of both land and marine life. Therefore, scientists are always exploring sustainable methods to reduce our dependence on nonrenewable petroleum-based plastics.

Agricultural Connections

Corn is one of the most abundant agricultural products grown. Corn has many uses, from food sources to bioplastics. Most of the agricultural growth of corn is field corn, which is used for livestock feed, ethanol production, and bio-based, renewable materials for industrial uses such as bioplastics.

OTHER FUN CORN FACTS

● There is one silk for every kernel that grows in an ear of corn.
● The number of kernels per ear can vary from 500 to about 1,200, but a typical ear will have 800 kernels in 16 rows.
● Corn is grown on every continent except Antarctica.
● 1 acre of corn is about the size of a football field.
● A bushel of corn is 56 pounds, about the weight of a large bag of dog food.
● A single corn bushel can sweeten about 400 cans of soda pop.
Bioplastics are composed of long linear polymers like those found in plant starches (see Figure 1). The two most common are amylose and amylopectin, found in cellulose, which are huge polymers composed of many monomers of glucose. Amylopectin has more branches than amylose and is not as efficient a starch source. In mass production, the starch yield can be increased by a technique called acid hydrolysis which uses acid to break apart some of the branching. Other components are plasticizers, such as glycerol which is used in this experiment, which makes the bioplastic more flexible. Simple bioplastics have drawbacks such as poor water resistance, limited strength and the fact that production still requires some nonrenewable resources. Manufacturing companies can overcome some of the drawbacks by making a more sophisticated bioplastic using sugar fermentation to produce polylactic acid (PLA). PLA makes the bioplastics stronger and more water resistant. Some common products made of bioplastics are trash bags, eating utensils, packing peanuts and disposable golf tees.

The production of bioplastics has great potential as an alternative to using nonrenewable resources to make plastic. This could provide packaging materials and containers that can be returned to the earth as fertilizer or harmless byproducts. Fruits and vegetables could be packaged in boxes that do not leach chemicals into landfills. Bioplastics are an exciting step into the future to help with the sustainable use of Earth’s natural resources.
ENGAGE:
To demonstrate the solubility of a petroleum-based (nonrenewable) packing peanut versus a starch-based (renewable) packing peanut:
• Fill two beakers with water and place several packing peanuts of each type into the beakers.
• Stir both beakers and observe what happens.
• Discuss why the phenomenon occurred, what differences there are between the two peanuts, and how this could be beneficial to the environment.
• Ask whether the styrene peanut can be made to dissolve.
• Place a styrene peanut in 100 mL of acetone. The styrene should dissolve into a slimy, sticky goo.

EXPLORE:
Activity 1: Making a Standard Packing Peanut
1. Add 8 g (1 tablespoon) cornstarch to a paper cup.
2. Add 15 mL water to the paper cup.
3. Stir until all of the hard clumps are gone and it becomes watery.
4. Microwave the paper cup for 30 seconds. (Time may vary depending on power of microwave; some froth may be present on top.)
5. Scrape off any froth from the top of the mixture.
6. Remove carefully and allow to cool until you can pick it up comfortably.
7. Peel the cup away from the peanut and examine the texture, elasticity and color.
8. Record observations in Table 1.

Activity 2: Addition of a Plasticizer
1. Add 8 g cornstarch to a paper cup.
2. Add 8 mL of water to the cup.
3. Add 8 mL of glycerol (1%) to the cup.
4. Stir until all of the hard clumps are gone.
5. Microwave 30 seconds. Take the paper cup out and let it cool.
6. Peel the paper cup away from the peanut and compare this peanut to the one from Activity 1.
7. Record data in Table 1.

Activity 3: Adding Air to the Peanut
1. Add 8 g cornstarch to a paper cup.
2. Add 4.6 g (1 teaspoon) baking powder to the cup, and mix the dry ingredients.
3. Add 15 mL of water to the cup.
4. Stir until all of the hard clumps are gone.
5. Microwave 30 seconds. Remove cup from microwave and allow to cool.
6. Peel the paper cup away from the peanut and compare this peanut to the others.

### Table 1: Corny Peanuts Making a Better Packing Peanut

<table>
<thead>
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**EXPLAIN: (SEE LAB BACKGROUND)**

The Lab Background information from the Teacher Guide is repeated in the Explain section of the Student Guide.

**ELABORATE:**

**Optional Extension Activities**

- Students can compare various sources of starch, i.e., potato, carrot, etc., for their effectiveness in producing not only packing peanuts but other plastic pieces.
- Students can quantify the exact percent composition for producing hard plastics, medium flexibility plastics and soft plastics. The opacity can also be studied.
- Students can mold objects out of the final products to solve a specific engineering problem.
- Students can compare protein/starch and agar to pure starch sources.
- Students can test which combination became water resistant and test the length of time for a product to biodegrade.
EVALUATE:
Activity 1: Standard packing peanut
1. Was your packing peanut flexible, brittle or hard? Describe your peanut.
   Answers will vary.
2. Did your packing peanut have holes in it?
   Answers will vary, but students should note that there are very few holes.

Activity 2: Packing peanut with glycerol added
1. What effect did the glycerol have on the packing peanut?
   Glycerol makes the peanut more flexible.
2. What is the name of the additives that increase the flexibility of a bioplastic?
   Plasticizers

Activity 3: Packing peanut with baking soda added
1. What did the baking powder do to the peanut?
   The baking powder fluffed up the peanut.
2. Why do you think this happened?
   Carbon dioxide bubbles were trapped when it cooled because there was a chemical reaction that produced carbon dioxide gas.
3. What benefit would this have on a packing peanut?
   It could absorb the shock of a dropped box.

The Noble Research Institute would like to thank the following people for their contributions to this lesson:
• Quentin Biddy
• Susie Edens
• Kay Gamble
• Janie Herriott
• Fiona McAlister
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ENGAGE:

As you watch the demonstration performed by your teacher, answer the questions below:

1. Describe the phenomenon you see.
2. Describe any differences between the two peanuts.
3. How could this be beneficial to the environment?

EXPLORE:

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