Fossil Fuels and the Carbon Cycle

Activity from The Science of Global Atmospheric Change Teacher’s Guide and for Mr. Slaptail’s Curious Contraption

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Teacher Resources from the Center for Educational Outreach at Baylor College of Medicine

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The sun is the source of Earth’s energy. Every second, approximately five million tons of matter within this relatively small star are converted into energy, which is sent outward into space. We feel part of this energy as heat and see another part as light. Heat and light that we can detect, however, represent only a small portion of the radiation emitted by the sun.

Radiation travels in waves, similar in some ways to waves on the surface of a lake. The distance between the peaks, or crests, of two successive waves is known as the wavelength. The longest wavelengths—between 1 and 1,000 meters—correspond to television and radio signals. The shortest wavelengths, those of cosmic rays, are only 0.000,000,000,001 meters long!

Radiation traveling toward Earth passes through a thin layer of gases called the atmosphere. Without this protective layer, life on Earth would be impossible. Earth’s atmosphere consists primarily of nitrogen and oxygen, along with other argon, carbon dioxide and water vapor. The atmosphere keeps the planet warmer than it would be otherwise; provides oxygen, moisture and carbon dioxide; and prevents most harmful radiation from reaching the surface.

Green plants and algae (related plant-like organisms that usually grow in water) are able to absorb energy from the sun and use it to combine carbon dioxide (CO\textsubscript{2}) from the atmosphere with water to make energy-rich molecules, such as sugars and carbohydrates. Green plants and their products form the base of almost all food webs on Earth. They also are the source of our most common fuels.

Fuels such as wood, coal, oil and natural gas all are composed of matter originally produced by plants and other organisms. Each holds energy, originally trapped during photosynthesis, in the chemical bonds of carbon-containing molecules. When these substances are burned, they release heat energy that can be used for many purposes.

Our use of fossil fuels has grown dramatically since the 1800s. During the Industrial Revolution, coal was used to power steam engines in mines, factories, locomotives and ships. Later, it was used to generate electrical power. The discovery of large deposits of petroleum led to widespread use of fuels for transportation, heating and production of electricity. When fossil fuels are burned, carbon-containing molecules combine rapidly with oxygen. This chemical reaction releases energy in the form of heat. It also releases CO\textsubscript{2} into the air. Many other chemical substances also are produced by the burning or incomplete burning of fossil fuels.
In the United States, more than 75% of the energy used in homes and businesses, and for transportation comes from coal, oil or natural gas. These fuels are known as “fossil” fuels because they are the remnants of ancient plants and other living things buried under intense heat and pressure over millions of years. They are very efficient sources of energy. However, it is important to keep in mind that the energy in fossil fuels originally came from the sun and was trapped by plants and similar organisms during photosynthesis. During this process, plants also consumed carbon dioxide (CO$_2$) from the atmosphere. So when fossil fuels are burned, trapped carbon is released back into the atmosphere, principally as CO$_2$.

- **Petroleum**, or crude oil, is a thick, gooey liquid that can be found within Earth’s crust on land or beneath the sea floor. It was formed principally from tiny marine organisms that were buried in layers of sediment, such as sand. In addition to containing high-energy carbon compounds, petroleum contains varying amounts of substances such as oxygen, sulfur and nitrogen. Crude oil must be heated and distilled to separate it into gasoline, heating oil, diesel oil, asphalt and other materials. Some components of crude oil are used to manufacture industrial chemicals, fertilizers, pesticides, plastics, medicines and other products.

- **Natural gas** is a mixture of methane (CH$_4$) and smaller amounts of related gases. It often is found above deposits of crude oil. Natural gas burns hotter and produces less air pollution than any other fossil fuel. When burned, it also releases less CO$_2$, relative to the amount of energy produced.

- **Coal** is a solid that is formed in several stages. It is a mixture of many different substances, with varying amounts of water, nitrogen and sulphur. Coal is formed from peat—a moist soil substance made of partially decayed plant material. When peat is subjected to intense heat and pressure, it becomes lignite—a brown coal. Lignite will become bituminous coal if it is placed under more heat and pressure. Bituminous coal often is used as fuel because it produces high levels of heat and is abundant. The most desirable form of coal is anthracite, a hard mineral that results from the transformation of bituminous coal under more conditions of very high heat and pressure. Anthracite is a very attractive fuel because it burns cleanly and produces great quantities of heat.
When geologists look for fossil fuels, they often drill deep into Earth. They remove narrow cores of rock and sediments and examine them for clues about the presence of oil and other fuels. This activity lets students explore the layers in a muffin representing Earth’s crust, using a straw to drill “cores.”

**SETUP**

You will need to bake 24 GeoMuffins (see recipe, p. 6) in advance, using two envelopes of prepared bran muffin mix and two envelopes of prepared corn muffin mix, plus ingredients listed on the packages. (Other flavors may be substituted as long as they are different colors and contain no fruit or nuts.) You will need 24 aluminum baking cups on a cookie sheet or 24 paper liners and a muffin pan.

*Note.* Cake mixes usually are less satisfactory because the baked texture is too soft.

Cut straws into 3-in. lengths for students to use.

Students may work individually or in groups.

**PROCEDURE**

1. Show the muffins to the class. Point out that all of the muffins look the same on the surface. Tell students that the muffins are made of layers that look similar to those visible in a cross section of Earth’s crust. Explain that they will be exploring their muffins to discover whether or not the muffins hold petroleum deposits, and where those deposits might be located. Lead the class in a discussion of how fossil fuels were formed under the ground, how they are mined and how they are used.

2. Give a muffin and a “GeoMuffin Observations” sheet to each student or team of students. Ask, *What do you think the inside of the muffin looks like?* Without touching or removing the baking cup, instruct students to draw their predictions on their student sheets. They also should predict whether or not they will find oil (see “Geomuffin Legend,” right).

3. Have students insert a toothpick near the edge of their muffins to represent “North.” Based on what they can observe on the top surface of the muffin, have students identify six places on the muffin to “drill.”

4. Demonstrate the technique to be used. Show the students how to take a core sample by gently twisting a section of plastic drinking straw into a muffin and then pulling it back out. Use a cotton swab to dislodge the core by inserting it in the top of the straw and pushing the core out the bottom.

5. Encourage students to take at least six samples, recording each
sample’s location on their worksheets, and then drawing and coloring the samples in order.

6. Once they have finished sampling, recording and coloring, students should evaluate their information, looking for a pattern. Based on their cores, students should draw an estimate of a side view of the muffin, showing all the layers.

7. Now instruct students to cut through the center of the muffin. They should compare their predictions with their muffins. Ask, Did the core samples give you valuable information? Why or why not? Did you find anything that predicts the presence of oil? Mention that geologists frequently look for certain patterns of layers in the cores. Certain patterns predict or suggest that oil might be present.

8. Have students consider petroleum as a resource. Ask, What happens when we burn products made from oil? Does burning oil produce carbon dioxide? Do you think we could run out of oil? Help students understand that oil and coal are resources that cannot be replaced once they have been “used up.”

9. Initiate a discussion about where oil and other fossil fuels come from. Use the “Carbon Dioxide and the Carbon Cycle” page as an overhead to help students understand how photosynthesis by ancient plants and similar organisms is responsible for the carbon now found in fossil fuels. Challenge students to figure out what happens to the carbon in fossil fuels when the fuels are burned (carbon returns to the atmosphere as carbon dioxide).

VARIATIONS
- Instead of having students cut their muffins in half after making their predictions, challenge them to restore the “landscape” on the top of their muffins before proceeding with the rest of the activity.
- Encourage students to use resources in the library or on the Internet to learn about other important cycles in ecosystems. Nitrogen is another example of an atmospheric gas that cycles through non-living and living parts of ecosystems in many different forms.
- As an alternative to baking, use different colors of clay or modeling dough to make the layered GeoMuffins.

QUESTIONS FOR STUDENTS TO THINK ABOUT
How many different uses of fossil fuels are there? Have students use the library or the Internet to look for answers.

What will happen when we use up the supplies of fossil fuel? Do you think that we can get any more? Why or why not? Are there any good substitutes for fossil fuels?

How much oil and natural gas still are left on Earth? Have students look for answers in the library or on the Internet. What might be done to ensure wise use of these resources?
Carbon Dioxide and the Carbon Cycle

Carbon Dioxide in the Atmosphere

Plants

CO₂ = Carbon Dioxide

Tiny Organisms in Oceans

dissolved CO₂

Deposits

Fires

Animals

CO₂ waste product

Food

People

CO₂ waste product

Food

Vehicles and Industry

Dead Materials Eaten by Decomposers

Millions of Years

Fossil Fuels

CO₂ = Carbon Dioxide
GeoMuffin Baking Instructions

Materials and Ingredients

- 24 aluminum baking cups and a cookie sheet (or 24 paper liners and 2 muffin pans)
- 2 medium-sized mixing bowls
- 2 small mixing bowls
- 2 envelopes of bran muffin mix (plus ingredients listed on package)
- 2 envelopes of corn muffin* mix (plus ingredients listed on package)
- Green and red food coloring

* Note: Other types of muffin mixes without fruit or nuts may be substituted. Do not use cake mixes.

Baking Instructions

1. Preheat oven to temperature specified on the muffin mixes. If different temperatures are given on the two kinds of mixes, set oven to the lower temperature.
2. Set aluminum baking cups on the cookie sheet (or line muffin pans with paper baking cups).
3. Bran muffin mix. Combine both packages of bran muffin mix in one medium-sized bowl and prepare batter by following the instructions on the packages. If the mixture is very stiff, add additional milk or water so that the consistency of the batter is slightly runny.
   - Remove about 1/4 cup of the corn batter to one small mixing bowl and color it deep red.
   - Remove about 1/2 cup of the corn batter to the second small mixing bowl and color it deep green.
5. Add batters in layers to the baking cups in the following order (see illustration, right).
   - Layer 1: 1 Tbs of bran batter spread across bottom of the cup
   - Layer 2: 1/2 tsp of green batter on one side of muffin
     1 tsp of yellow batter next to the green
   - Layer 3: 1/2 tsp of red batter spread over the green batter
     1 tsp of yellow batter next to the red
   - Layer 4: 1/2 tsp of green spread over the red batter
     1 tsp of yellow batter next to the green
   - Layer 5: 1 Tbs of yellow over entire muffin
   - Layer 6: 1 Tbs of bran over entire muffin
6. Bake according to package instructions.
7. Cool before using with students. Muffins are firmer and easier to sample if they are baked a day in advance.

The colored layers in the muffin represent the following.
- RED = Oil
- GREEN = Predicting layer for oil
- YELLOW = Soil or rock layer
- BROWN = Soil or rock layer
GeoMuffin Observations
The Search for Fossil Fuels

Name ________________________________________________

1. Look at your GeoMuffin. Do not peel or eat it. Write a sentence to describe your GeoMuffin.

2. What do you think the GeoMuffin would look like if you cut it in half? Draw a cross section based on what you can observe.

3. Draw a top view of your GeoMuffin. Mark North on your muffin with a toothpick. Starting just right of your North marker, make your first core sample. Push the core out of the straw. Draw the core and color the layers. Mark it Sample Number 1.

4. Make at least 5 more samples. Draw each core in order in the space below.

5. Now, use the information from your core samples to draw what you predict a side view of your GeoMuffin would look like if you cut it in half. Then cut the muffin half and draw what you see. Compare your two drawings.

6. Do you think there is any “oil” in your GeoMuffin? Is there a pattern in the layers that predicts where oil will be?
Bizcochos Geológicos
La Búsqueda para los Combustibles Fósiles

Mi Nombre ____________________________________________

1. Examina tu Bizcocho Geológico sin tocarlo o comerlo. Escribe una oración que describe tu bizcocho.

2. Como piensas que se vería si partieras el bizcocho a la mitad? Dibuja una vista de la mitad del bizcocho basado en lo que puedes observar.


4. Toma por lo menos 5 muestras más. Dibuja cada muestra en el espacio abajo.

5. Ahora, utiliza la información de tus muestras para dibujar lo que piensas sería una vista de tu bizcocho si lo cortaras a la mitad.

6. ¿Piensas que hay “petroleo” en tu bizcocho? ¿Demuestran las capas algunas características que predicen la presencia de petroleo?