oceanexplorer.noaa.gov

Submarine Ring of Fire Expedition

Candy Chemosynthesis

Focus
Biochemistry of hydrothermal vents

Grade Level
9-12

Focus Questions
What chemicals are used by autotrophs in extreme environments in the deep ocean?

How are these chemicals different from those used by terrestrial autotrophs?

Learning Objectives
Students will differentiate between requirements for life in extreme environments and other environments.

Students will use models to create a visual image of chemicals involved in autotrophic nutrition.

Additional Information for Teachers of Deaf Students
In addition to the words listed as Key Words, the following words should be part of the list.

Magma
Conversion
Ecosystems
In situ
Derive
Black smoker
Hydrothermal vents
Chemosynthesis

The words listed as Key Words should be introduced prior to the activity. There are no formal signs in American Sign Language for any of these words and many are difficult to lip-read.

These words are integral to the unit but come will be very difficult to introduce prior to the activity. They are really the material of the lesson. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful.

The initial part of the Background Information that shows the chemicals, compounds, and equations that will be used should be written up as a handout for the students. They will need it as a reference later on. It would also be helpful to include the paragraph later on that discusses chemosynthesis. If some of this information has not already been covered in your class, you may need to add an additional class period to teach vocabulary and teach some of the Background Information to the students prior to the activity.

During the "lab" itself, the teacher should begin by demonstrating the development of a model that will represent an equation. The activity itself is very visual and is easily followed by most deaf students once the concepts have been explained.

Materials
- ❒ A clean working environment-students will be able to eat their models
- ❒ Clean-handed students
- ❒ One tablecloth per group
- ❒ Napkins as needed
- ❒ One tube of decorator's icing per class. Do not

pass this out until the final phase of modeling (Note: glue is a much less fun option for this aspect of the lab)
- ❒ 50 soft candies per group of two students (100 per group of four)
- ❒ 20 toothpicks per group of two students (40 per group of four)
- ❒ 5 small paper plates per group of two, for sorting candies (10 per group of four)
- ❒ 1 sheet of poster paper per group of four
- ❒ 1 non-toxic colored marker per group of four

Teaching Time
Two 45-minute class periods

Seating Arrangement
Students should work in groups of four so that they can "pair share" the information they learn and models they create.

Key Words
Autotrophs
Chemoautotrophs
Food Chains
Chemosynthesis
Food Webs
Photosynthesis
Molecules
Terrestrial
Heterotrophs
Aquatic

Background Information
Teachers may wish to read this aloud with students and/or provide groups with their own copies.

The chemicals that will be used in this lab activity are as follows:

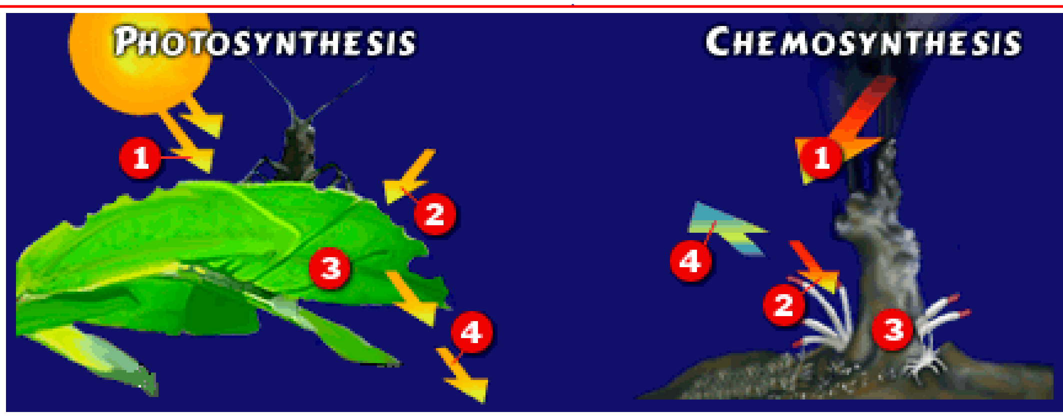
Sulfur: S	Oxygen: O
Hydrogen: H	Carbon: C

The compounds that will be used in this lab activity are as follows:

CO_2: Carbon Dioxide
H_2S: Hydrogen Sulfide
O_2: Oxygen gas
H_2SO_4 Sulfuric Acid
$C_6H_{12}O_6$: Simple sugar
H_2O: Water

The equations that will be used in this lab activity are as follows:

Bacteria
Chemosynthesis:
$6CO_2 + 6H_2O + 3 H_2S > C_6H_{12}O_6 + 3H_2SO_4$



Instead of photosynthesis, vent ecosystems derive their energy from chemicals in a process called "chemosynthesis." Both methods involve an energy source (1), carbon dioxide (2), and water to produce sugars (3). Photosynthesis gives off oxygen gas as a byproduct, while chemosynthesis produces sulfur (4). Image courtesy Woods Hole Oceanographic Institution.
Graphic from: http://science.nasa.gov/headlines/y2001/ast13apr_1.htm

Left: A variety of animals live near these hydrothermal vents, including the shrimps, crab, and anenome in this picture taken at the Indian Ocean vent. So far, the hallmark red and white tubeworms have not been spotted at this vent. (*Image courtesy of Woods Hole Oceanographic Institution*.)

In the above reaction, hydrogen sulfide supplies the energy to convert carbon dioxide and water to glucose and hydrogen sulfide.

Sunlight

Photosynthesis:

$6CO_2 + H_2O > C_6H_{12}O_6 + 6O_2$

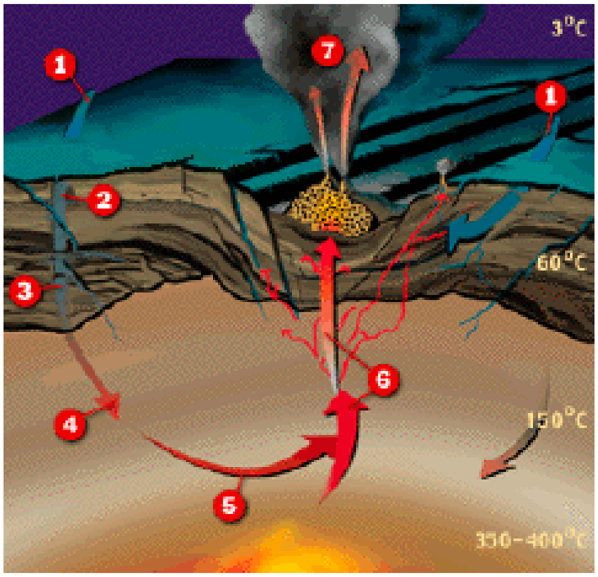
In the above reaction, sunlight supplies the energy to convert carbon dioxide and water to glucose and oxygen.

Hydrothermal vents, which are hot springs on the sea floor, support exotic chemical-based ecosystems. Some scientists think the vents are modern-day examples of environments where life began on Earth billions of years ago. The vents might also hold clues to life on other planets.

The thriving communities of life that surround these hydrothermal vents shocked the scientific world when the first vent was observed *in situ* by humans on the deep ocean floor in 1977. Before 1977, scientists believed that all forms of life ultimately depended on the sun for energy. For all ecosystems then known to exist, plants or photosynthetic microbes (also known as autotrophs) constituted the base of the food chain. In contrast, these vent ecosystems depend on microbes that tap into the chemical energy in the hot spring water that billows out from the sea floor-energy that originates within the Earth itself. Since they depend upon chemicals for energy instead of the sun, these special kinds of autotrophic vent-dwelling microbes are known specifically as chemoautotrophs.

The following Background Material is adapted from the Woods Hole Oceanographic Institution's website, www.divediscover.whoi.edu The images are courtesy of Dive and Discover. Funded by Woods Hole Oceanographic Institution, National Science Foundation, Ohio's Center of Science and Industry (COSI). Image courtesy of shipboard scientists from College of William and Mary, Harvard University, Monterey Bay Aquarium Research Institute, University of New Hampshire, Oregon State University, Portland State University, University of Washington, Woods Hole Oceanographic Institution.

Hydrothermal vents form along mid-ocean ridges, in places where the sea floor moves apart very slowly (6 to 18 cm per year) as magma wells up from below. (This is the engine that drives Earth's tectonic plates apart, moving continents and causing volcanic eruptions and earthquakes.) When cold ocean water seeps through cracks in the sea floor to hot spots below, hydrothermal vents belch a mineral-rich broth of scalding water. Sometimes, in very hot vents, the emerging fluid turns black, creating a "black smoker," because dissolved sulfides of metals (iron, copper, and several heavy metals)



The chemistry of a "black smoker." After seawater seeps into the crust (1), oxygen and potassium (2) and then calcium, sulfate, and magnesium (3) are removed from the water. As the water begins to heat up (4), sodium, potassium, and calcium dissolve from the crust. Magma superheats the water, dissolving iron, zinc, copper, and sulfur (5). The water then rises back to the surface (6), where it mixes with the cold seawater, forming black metal-sulfide compounds (7). (*Image courtesy of Woods Hole Oceanographic Institution.*)

instantaneously precipitate out of solution when they mix with the cold surrounding seawater.

Unlike plants that rely on sunlight, bacteria living in and around the dark vents extract their energy from hydrogen sulfide (HS) and other molecules that billow out of the seafloor. Just like plants, the bacteria use their energy to build sugars out of carbon dioxide and water. Sugars then provide fuel and raw material for the rest of the microbes' activities.

Why is chemosynthesis important?

Chemosynthetic deep-sea bacteria form the base of a varied food web that includes shrimp, tubeworms, clams, fish, crabs, and octopi. All of these animals must be adapted to endure the extreme environment of the vents—complete darkness; water temperatures ranging from 2°C (in ambient seawater) to about 400°C (at the vent openings); pressures hundreds of times that at sea level; and high concentrations of sulfides and other noxious chemicals.

Why is photosynthesis important?

Aquatic and terrestrial plants form the base of varied food webs that may include small fish and crabs, larger fish, and eventually, humans.

Learning Procedure

1. Students should examine and discuss the two chemical equations for chemosynthesis and photosynthesis (see Student Lab Report). Each group of four should decide which pair will model each of the two equations and record that on their lab report sheets.

2. Students should draw a line down the center of the poster board and write "Photosynthesis" on one half and "Chemosynthesis" on the other half. If desired, they can decorate their half with representative autotrophs that undergo each type of nutrition, such as phytoplankton on the "Photosynthesis" side and vent bacteria on the "Chemosynthesis" side. Important: Students should leave a small area of their poster board for the legend. Once completed, they should set the poster board aside.

3. Working cooperatively, all four students should determine which candies will represent each element involved in both of the two formulas. For example, if green gummy bears are chosen to represent oxygen, each set of student pairs should use the green gummy bears to represent oxygen in the creation of both chemical equations.

4. Once candy representatives are chosen, students will record them as a legend on their lab report. This should be the same for all four of the students, with the exception of sulfur, which will be missing from the photosynthesis model equation.

5. Students should then work with their partner to create a model for the equation they have selected. They should insert toothpicks into the proper soft candy chosen to represent each element until all of the components of their equation are created. They should check with the teacher before proceeding to the "gluing" phase.

6. Using the equations on their lab report sheets as a guide, all four students should discuss placement of their chemical compound models on their poster board in the appropriate locations. Once the group has devised a way to represent the two equations that make sense to them, they are ready for the "gluing." If this project is to be edible, students should ask their teacher for the decorator's icing which will be used to fasten the candy model equations and their legend candies to the poster board.

7. Once candies are "glued" to the poster board, students should use their markers to add in "+" symbols and "-->" in the appropriate locations. Each pair should share information about their models with each other, discussing similarities and differences between the two equations. They should select one representative from each pair to present the models to the class.

8. Students should complete the Student Lab Report.

9. Student model equations can be displayed and/or photographed.

The BRIDGE Connection

www.vims.edu/bridge, click on Ocean Science Topics, Ecology, Deep Sea, and scroll down to Ocean Planet: Far from Sunlight, Sulfur Supports Strange Life Forms

The "Me" Connection

Ask students how their lives would be affected if there were no autotrophs? Would they be able to survive? Would other organisms be able to survive? Have them make a list of "pros" and "cons" to being an autotroph and a heterotroph.
Ask students if they could be any autotroph, which one would they be? Why?

Connections to Other Subjects

Art/Design, Mathematics, English/Language Arts, Life Sciences, Physical Sciences

Evaluation

Use Student Evaluation Sheet

Extensions

Hold a round-table discussion and/or debate based on what students learned in this lesson using the following statement: Some scientists believe in the possibility that Earth itself might have started in the sulfurous cauldron around hydrothermal vents. Vent environments minimize oxygen and radiation, which can damage primitive molecules. They believe that many of the primordial molecules needed to jump-start life could have formed in the subsurface of the ocean floor from the interaction of rock and circulating hot water driven by hydrothermal systems.

For students who are older, advanced or seek an academic challenge, use this lesson as a lead in to discuss how to balance chemical equations. Illustrate the difference between structural and molecular formulas.

Visit the Ocean Explorer Web Site at
http://oceanexplorer.noaa.gov

National Science Education Standards

Content Standard A – Science as Inquiry

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

Content Standard B – Physical Science

- Understand properties and changes of properties in matter
- Understand the transfer of energy

Content Standard C – Life Science

- Populations and ecosystems
- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard D – Earth and Space Science

- Structure of the Earth system

For More Information

Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818 843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson plan was developed byKimberly Williams, Miller Place High School, Long Island, NY for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov

Problem links updated May 2011.

Student Handout

Candy Chemosynthesis
Student Lab Report

1) Examine these formulas:

Bacteria

Chemosynthesis: $6CO_2 + 6H_2O + 3 H_2S > C_6H_{12}O_6 + 3H_2SO_4$

Sunlight

Photosynthesis: $6CO_2 + H_2O > C_6H_{12}O_6 + 6O_2$

2) What similarities and differences do you notice?

3) List the two people who will model the chemosynthesis equation.

List the two people who will model the photosynthesis equation.

4) Describe your legend of each candy and which chemical element it represents.

Student Handout

5) Describe the equation that you have modeled. Tell why this process is important to both autotrophic and heterotrophic organisms.

6) Did other groups in the class model the same way you did? If another group's model equations were different than yours, how were they different?

7) What did you learn by modeling your equation? How does this process affect your life?

8) Imagine what it must have been like to be a marine chemist discovering the existence of chemosynthesis. On a separate sheet, write a journal entry that you imagine might have appeared in that scientist's journal.

Teacher Answer Key-Candy Chemosynthesis
Evaluation of Student Lab Report

1) Examine these formulas:

Bacteria

Chemosynthesis: $6CO_2 + 6H_2O + 3 H_2S > C_6H_{12}O_6 + 3H_2SO_4$

Sunlight

Photosynthesis: $6CO_2 + H_2O > C_6H_{12}O_6 + 6O_2$

2. What similarities and differences do you notice?

Answers may include:

Chemosynthesis uses hydrogen sulfide, sulfur, bacteria instead of sunlight

3. List the two people who will model the chemosynthesis equation.
List the two people who will model the photosynthesis equation.

4. Describe your legend of each candy and which chemical element it represents.

Check against completed student models for accuracy in reporting.

5) In words, describe the equation that you have modeled. Tell why this process is important to both autotrophic and heterotrophic organisms.

Students should describe what each equation represents:

Chemosynthesis – hydrogen sulfide supplies the energy to convert carbon dioxide and water to glucose and hydrogen sulfide.

or

Photosynthesis - sunlight supplies the energy to convert carbon dioxide and water to glucose and oxygen.

These equations represent the mechanisms by which autotrophs create their own energy. These processes are important to heterotrophs because the heterotrophs rely upon the autotrophs for energy.

6) Did other groups in the class model the same way you did? If another group's model equations were different than yours, how were they different?

Students will probably notice that due to uniqueness of individuals in their class, no two groups will create exactly the same model. Celebrate their acknowledgement of class diversity and creativity!

7) What did you learn by modeling your equation? How does this process affect your life?

Students should say something about being able to visualize the differences between chemosynthesis and photosynthesis, autotrophic nutrition, and heterotrophic nutrition.

This affects their lives because as heterotrophs, they are ultimately dependent upon autotrophs for nutrition. Also, students may recognize that humans produce the waste gas, carbon dioxide, and that autotrophs help us by removing carbon dioxide.

8) Imagine what it must have been like to be a marine chemist discovering the existence of chemosynthesis. On a separate sheet, write a journal entry that you imagine might have appeared in that scientist's journal.

Enjoy your students' creativity!