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The Gulf of Mexico Deepwater Habitats Expedition

Hot Food

Focus

Energy content of hydrocarbon substrates in chemosynthesis

Grade Level

9-12 (Chemistry)

Focus Question

What is the relative energy content of light hydrocarbons that might serve as substrates for chemosynthesis in deep-water coral communities?

Learning Objectives

Students will be able compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities.

Given information on molecular structure of two or more substances, students will be able to make inferences about the relative amount of energy that could be provided by the substances.

Students will be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

Materials

- ❒ Erlenmeyer flask, 250 ml; one for each student group
- ❒ Thermometer, 0° – 100° C; one for each student group
- ❒ Alcohol burner; one for each student group
- ❒ Ring stand with clamps to hold Erlenmeyer flask and thermometer
- ❒ Graduated cylinder, 100 ml; one for each student group
- ❒ Methyl alcohol, ethyl alcohol, propyl alcohol, butyl alcohol; approximately 100 ml of each for each student group
- ❒ Balance, triple beam, 0 – 500 g, accurate to 0.1 g
- ❒ Safety glasses, one pair for each student
- ❒ Copies of "Comparing the heat energy produced by combustion of various alcohols;" download from http://www.chemsoc.org/networks/learnnet/classic_exp.htm; choose "PDF files 81 to 90," and make copies of #85; please see note at "Learning Procedure"

Audio/Visual Materials

- ❒ Chalkboard, marker board with markers, or overhead transparencies for group discussions

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

30

Key Words

Lophelia pertusa
Chemosynthesis
Photosynthesis

Background Information

Deep-water coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, but very little is known about the ecology of these communities or the basic biology of the corals that produce them. In contrast, deep-water coral reefs near the coasts of Europe have been intensively studied, and scientists have found a great abundance and variety of species associated with these communities. *Lophelia pertusa* is the dominant coral species in these communities. Technically, *Lophelia* is ahermatypic (non-reef-building), but branches of living coral grow on mounds of dead coral branches that can be several meters deep and hundreds of meters long. Unlike hermatypic corals that produce reefs in shallower waters, *Lophelia* does not have symbiotic algae and receives nutrition from plankton and particulate material captured by its polyps from the surrounding water. *Lophelia* mounds alter the flow of currents and provide habitats for a variety of filter feeders. Several commercially-important species are associated with *Lophelia* reefs in European waters, and scientists suspect that the same may be true for deep-water reefs in the Gulf of Mexico. But they don't know for sure, because most of these communities are almost entirely unexplored.

Most reports of *Lophelia* reefs in the Gulf of Mexico were the result of investigations directed toward hydrocarbon seepage and/or chemosynthetic communities. Scientists studying deep-water reefs on the Norwegian continental shelf have found that many large *Lophelia* banks occur at sites where there were relatively high levels of light hydrocarbons present in the sediments. The reason for this correlation is not known, nor is it known whether a similar correlation exists in the hydrocarbon-rich Gulf of Mexico.

As scientists have begun to learn more about *Lophelia* reefs, there is increasing concern that these reefs and their associated resources may be in serious danger. Many investigations have reported large-scale damage due to commercial fishing trawlers, and there is also concern about damage that might result from exploration and extraction of fossil fuels. The primary objectives of the Gulf of Mexico Deepwater Habitats Expedition are:

- to locate deep-water coral reefs in the Gulf of Mexico
- to describe biological communities and geological features associated with these reefs; and
- to improve our understanding of the ecology of *Lophelia* and deep-water reef communities.

In this activity, students will investigate the energy content of hydrocarbons that might serve as substrates for chemosynthetic processes in deep-water coral communities.

Learning Procedure

{NOTE: This activity uses a lesson developed by the U. K. Royal Society of Chemistry. The Society allows free classroom use of resources that are available in pdf format, and requests that colleagues be directed to the website (http://www.chemsoc.org/networks/learnnet/classic_exp.htm_ so they can benefit fully from all materials available.]

1. Briefly review Background Information on the Gulf of Mexico Deepwater Habitats Expedition, and deep-water reefs. Be sure students understand that these reefs have a high diversity of species and large number of individual organisms like coral reefs in shallower water, but are virtually unexplored in the Gulf of Mexico. Compare and contrast deep-water reef corals (e.g., *Lophelia pertusa*) with reef-building corals in shallow water. Visit http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_Lophelia.html for more background on *Lophelia* reefs. Tell students that Norwegian scientists have found large *Lophelia* banks at sites where relatively high levels of light hydrocarbons are present in the sediments, and that one objective of the Gulf of Mexico Deepwater Habitats Expedition is to investigate possible correlations between hydrocarbon seepage and the occurrence of deep-water corals.

2. Lead a discussion of deep-sea chemosynthetic communities. Tell students that one of the major scientific discoveries of the last 100 years is the presence of extensive deep sea communities that do not depend upon sunlight as their primary

source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis. Contrast chemosynthesis with photosynthesis, and be sure students understand that there are a variety of chemical reactions that can provide this kind of energy. Some chemosynthetic communities have been found near underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food chain.

Other deep sea chemosynthetic communities are found in areas where hydrocarbon gases and oil seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth. Methane and hydrogen sulfide are produced by the breakdown of organic matter deposited in the sediments. Archea and bacteria gain energy by oxidizing methane and hydrogen sulfide, and then become the base for a "chemosynthetic" food chain, in some cases by being grazed and filtered out of the water and in other cases by functioning as symbionts.

Point out that until recently it was well-accepted that photosynthesis was the basis of all major biological communities on Earth. Recognition of these communities has changed this view dramatically; indeed, many biologists now favor the idea that life on Earth may have begun in chemosynthetic communities like those found near hydrothermal vents and cold seeps. (You may want to visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities; http://www.bio.psu.edu/cold_seeps and http://www.bio.psu.edu/hotvents offer virtual tours of cold seep and hydrothermal vent communities.)

3. Tell students that they are to investigate the relative amount of energy available from four hydrocarbons, and use the results of their investigations to make inferences about light hydrocarbons as a potential source of energy for deep-water coral reef communities.

   Provide each student group with a copy of "Comparing the heat energy produced by combustion of various alcohols." Have each group follow procedures described under "What to do," and record their results in the table provided. Students should use approximately 100 ml of each alcohol to be tested, and empty the burner completely before testing another type of alcohol.

   Each group should prepare a written report that includes:
   - experimental results;
   - conclusions about the relative energy available from the substances tested; and
   - inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

4. Lead a group discussion of students' results. Begin with structural formulas for the four alchohols tested. Students should recognize that substances having more carbon-carbon bonds yield greater thermal energy than those with fewer bonds. Ask students to make inferences about the light hydrocarbons as a potential source of energy for deep-water coral reef communities. Understanding that methane is a known energy source for some deep-sea communities, students should infer that hydrocarbons with two or more carbon-carbon bonds offer even more energy that is potentially useful to chemosynthetic organisms. Based on knowledge of other chemosynthetically-based deep-sea communities, students may also infer that organisms capable of using light hydrocarbons as an energy source are likely to be bacteria.

The BRIDGE Connection

http://www.vims.edu/bridge/reef.html; www.vims.edu/bridge/vents.html; and www.vims.edu/bridge/geology.html

The "Me" Connection

Have students write a short essay describing how chemosynthetic processes affect their own lives (if they are stumped, have them consider the word "fermentation").

Connections to Other Subjects

English/Language Arts, Biology, Earth Science

Evaluation

Written reports prepared in Step 3 provide an opportunity for assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up with the latest Gulf of Mexico Deepwater Habitats Expedition discoveries, and to find out what explorers are learning about deep-water coral communities

Resources

http://oceanica.cofc.edu/activities.htm – Project Oceanica website, with a variety of resources on ocean exploration topics

http://www.chemsoc.org/networks/learnnet/classic_exp.htm – Collection of 100 classic chemistry experiments developed by the U. K. Royal Society of Chemistry

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/uploads/oceana_coral_report.pdf — Background on deep-water coral reefs

http://www.geol.ucsb.edu/faculty/valentine/Valentine%202002.pdf – Review of methane-based chemosynthetic processes

http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities

http://www.ridge.oce.orst.edu/links/edlinks.html – links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – links to other ocean-related web sites

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – early report on cold seep communities.

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
- Structure of atoms
- Structure and properties of matter
- Chemical reactions

Content Standard C: Life Science
- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard F: Science in Personal & Social Perspectives
- Natural resources

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338 843.740.1329 (fax)
paula.keener-chavis@noaa.gov

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