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The Gulf of Mexico Deepwater Habitats Expedition

C.S.I. on the Deep Reef

(chemotrophic species investigations, that is…)

Focus
Chemotrophic organisms

Grade Level
9-12 (Life Science/Chemistry)

Focus Question
What factors are indicative of chemotrophic nutritional strategies?

Learning Objectives
Students will be able to describe at least three chemotrophic symbioses known from deep-sea habitats.

Students will be able to identify and explain at least three indicators of chemotropic nutrition.

Materials
- ❒ Copies of "C.S.I. (Chemotrophic Species Investigations) Worksheet," one for each student or student group

Audio/Visual Materials
- ❒ Chalkboard, marker board with markers, or overhead transparencies for group discussions

Teaching Time
One or two 45-minute class periods plus time for student research

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Methanotrophic
Methylotrophic
Chemolithoautotrophic
Facultative chemoautotroph
Polytrophic
Symbiosis

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.

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, but instead derive their energy from chemosynthesis. Because natural conditions for deep-reef organisms are hard to recreate in the laboratory and because bottom time in manned submersibles is extremely limited, it is difficult for scientists to make direct observations of nutritional behavior in deep-sea organisms. Instead, scientists rely on a variety of clues that indicate nutritional strategy. In this lesson, students will learn about some of these clues, and about some of the chemotrophic strategies used by deep-sea organisms.

Learning Procedure

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.

2. Briefly review and contrast chemosynthesis with photosynthesis. Be sure students understand the term "chemosynthesis" encompasses a variety of chemical reactions that can provide energy to biological organisms. 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. Provide individual students or student groups with copies of the "C.S.I. (Chemotrophic Species Investigations) Worksheet." Assign each group three of the organisms listed in Part III. Tell students that each group is to submit a written report that will include answers to all of the questions on the worksheet.

4. Lead a discussion of group reports, which should include the following information:

Part I:

Methanotrophic – an organism that obains energy from methane

Methylotrophic – an organism that obains energy from a compound containing the methyl radical

Chemolithoautotrophic – an organism that obtains energy and cellular carbon from inorganic chemicals

Facultative chemoautotroph – an organism that is capable of obtaining food from inorganic sources, but that may also obtain food from other sources as well

Polytrophic – the ability to obtain food from several different sources

Part II:

Symbiosis – an association between two organisms; many chemotrophic relationships in the deep sea involve a symbiosis between a chemotrophic bacterium and another animal

Gram negative bacteria – bacteria that have a negative reaction to the Gram staining procedure; these bacteria have an outer lipoprotein membrane and thin cell walls; all autotrophic bacteria are Gram negative (but all Gram negative bacteria are not autotrophic!)

Lipopolysaccharide – a compound that occurs naturally only in the outer cell walls of Gram negative bacteria

Trophosome – a large organ found in vestimentifera that contains chemosynthetic bacteria

Calvin-Benson cycle – a series of reactions in which carbon dioxide is converted to glucose; occurs only in autotrophic organisms

Ribulose-1,5-bisphosphate carboxylase-oxygenase – the enzyme that catalyzes the first reaction in the Calvin-Benson cycle

Part III:

Riftia pachyptila – giant tubeworm (vestimentiferan) found in the vicinity of hydrothermal vents; no mouth, gut, or anus; trophosome contains large numbers of chemosynthetic bacteria

Alvinella pompejana – polychaete worm found only at hydrothermal vents; epidermis has numerous bacteria, some of which are chemotrophic

***Phallodrilus leukodermatus* (=*Inanidrilus leukodermatus*)** – Oligochaete worm found in reducing sediments; worms are mouthless and gutless; contain subcutaneous chemautotrophic bacteria

Lucinidae – family of bivalves, many of which contain chemautotrophic bacteria in vacuoles in their gills

Bathymodiolus thermophilus – hydrothermal vent mussel; gills contain chemautotrophic bacteria in bacteriocytes

Solemya reidi – gutless bivalve found in anaerobic sediments; gills contain chemautotrophic bacteria

Vesicomyidae – family of deep-sea bivalves, all found in habitats containing sulfide, including hydrothermal vents, saline seeps, and hydrocarbon seeps; contain chemautotrophic bacteria in their large gills

Alviniconcha hessleri – gastropod found near hydrothermal vents; gills contain chemautotrophic bacteria

Part IV:

The absence of a mouth, gut, and anus suggests that the organism is either absorbing nutrient directly from the surrounding water, or that it may be receiving nutrition from a symbiont, perhaps living within the tissues of the new organism. The presence of large quantities of lipopolysaccharides suggests the presence of large numbers of Gram negative bacteria. Large amounts of ribulose-1,5-bisphosphate carboxylase-oxygenase suggest the presence of autotrophic organisms. The term "large" is important here, because the smoothie almost certainly contained many different bacteria; but indications of large number of Gram negative bacteria and autotrophic organisms suggest that the new species may be part of a chemotrophic symbiosis.

Point out that science often involves these kinds of inferences, using a series of clues that together lead to conclusions about processes that cannot be directly observed.

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 investigate whether they have symbiotic bacteria in their own bodies, and write a short essay describing the results of their investigation.

Connections to Other Subjects

English/Language Arts, 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

Fisher, C. R. 1990. Chemautotrophic and Methanotrophic Symbioses in Marine Invertebrates. Rev. Aquat. Sci. 2:399-436

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

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

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

- Chemical reactions

Content Standard C: Life Science

- The cell
- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Geochemical cycles
- Origin and evolution of the Earth system
- Origin and evolution of the universe

Content Standard F: Science in Personal and 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

Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
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Student Handout

C.S.I.
(Chemotrophic Species Investigations)
Worksheet

I. Define:

Methanotrophic – ____

Methylotrophic – ____

Chemolithoautotrophic – ____________________________________

Facultative chemoautotroph – ________________________________

Polytrophic – ____

II. Describe how the following are relevant to chemosynthetic activity:

Symbiosis – ____

Gram negative bacteria – __________________________________

Lipopolysaccharide – _____________________________________

Trophosome – ____

Calvin-Benson cycle – ____________________________________

Ribulose-1,5-bisphosphate carboxylase-oxygenase – ____________________

Student Handout

III. Briefly describe the overall chemosynthetic process in three of the following:

Riftia pachyptila –

Alvinella pompejana –

Phallodrilus leukodermatus (=Inanidrilus leukodermatus) –

Lucinidae –

Bathymodiolus thermophilus –

Solemya reidi –

Vesicomyidae –

Alviniconcha hessleri –

IV. Your CSI team has discovered a new species! Preliminary observations include the following:

- The organism does not appear to have a mouth, gut, or anus.
- A smoothie made by pureeing the organism in a blender contains large quantities of lipopoly saccharides.
- The smoothie also contains unusually large amounts of ribulose-1,5-bisphosphate carboxylase-oxygenase.

What do these observations suggest about the nutritional strategy employed by the new species? Why?