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Gulf of Mexico Exploration

Let's Make a Tube Worm!

Focus
Symbiotic relationships in cold-seep communities

Grade Level
5-6 Life Science

Focus Question
How are deep-sea tubeworms adapted for a symbiotic relationship that allows them to survive?

Learning Objectives
Students will be able to describe the process of chemosynthesis in general terms, and will be able to contrast chemosynthesis and photosynthesis.

Students will be able to describe major features of cold seep communities, and list at least five organisms typical of these communities.

Students will be able to define symbiosis and will be able to describe two examples of symbiosis in cold seep communities.

Students will be able to describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.

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.
Photosynthesis
Symbiosis
Hydrothermal vent
Hydrocarbon
Sediments
Polychaete worm
Bacteria
Symbiotic
Trophosome
Hemoglobin
Organic

The words listed as key words are integral to the unit. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. Also give the list as a handout to the students to refer to after the lesson.

Taking some time to introduce some of the Background Information will be of great use later as the students attempt to complete the activity in Part 4. Have the students act as one group for Parts 3 and 4. An alternative to the written report, which might be difficult or time consuming, is to have the students make a video or oral presentation.

Materials
- ❒ (If posters are to be made) poster materials (bristol board, markers)
- ❒ (If models are to be made) cardboard tubes (mailing tube or paper towel roll), colored markers, pipe cleaners (to simulate tentacles), modelling clay, paper and glue (to make a model trophosome)

Audio/Visual Materials
None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of four students

Maximum Number of Students

30

Key Words

Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Vestimentifera
Trophosome
Plume
Vestimentum
Trunk
Tube
Opisthosome

Background Information

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 (in contrast to photosynthesis in which sunlight is the basic energy source). 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. These bacteria obtain energy by oxidizing hydrogen sulfide to sulfur:

$CO_2 + 4H_2S + O_2 > CH_2O + 4S + 3H_2O$

(carbon dioxide plus sulfur dioxide plus oxygen yields organic matter, sulfur, and water). Visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities.

Other deep-sea chemosynthetic communities are found in areas where hydrocarbon gases (often methane and hydrogen sulfide) 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. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychete worms. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

As is the case with hydrothermal vents, chemosynthetic bacteria are also the base of the food web in cold seep communities. Bacteria may form thick bacterial mats, or may live in close association with other organisms. These associations are examples of symbiotic relationships in which both organisms benefit from the association (in contrast to parasitic relationships in which one organism benefits and the other is harmed). One of the most interesting and unusual symbiotic relationships exists between chemosynthetic bacteria and large tubeworms that belong to the group Vestimentifera (formerly classified within the phylum Pogonophora; recently Pogonophora and Vestimentifera have been included in the phylum Annelida). Pogonophora means "beard bearing," and refers to the fact that many species in this phylum have one or more tentacles at their anterior end. Tubeworms that live in the vicinity of hydrothermal vents and cold seeps are called vestimentiferans, and their tentacles are bright red because they contain hemoglobin (like our own red blood cells). Vestimentiferans can grow to more than 10 feet long, sometimes in clusters of millions of individuals, and are believed to live for more than 100 years. They do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome, that contains chemosynthetic bacteria. Hemoglobin in the tubeworm's blood absorbs hydrogen sulfide and oxygen from the water around the tentacles, and then

transports these raw materials to bacteria living in the trophosome. The bacteria produce organic molecules that provide nutrition to the tubeworm.

Similar symbiotic relationships are found in clams and mussels that have chemosynthetic bacteria living in their gills. A variety of other organisms are also found in cold seep communities, and probably use tubeworms, clams, mussels, and bacterial mats as sources of food. These organisms include snails, eels, sea stars, crabs, lobsters, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.

The Gulf of Mexico contains the largest reservoir of fossil fuel in the continental U.S., and the geology of the area has been intensively studied for more than 50 years. While cold seep communities were discovered in the Gulf in 1984, the biology of these communities has been studied at only three sites less than 20 km apart. Exploring for new cold seep sites and studying the biology and ecology of the organisms that live there is the focus of the Ocean Exploration 2002 Gulf of Mexico Expedition.

This activity focuses on the unusual anatomy and ecology of vestimentiferans.

Learning Procedure

1. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis: In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Contrast hydrothermal vent communities with cold-seep communities. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community, including several images of tubeworms.

2. Have students visit http://www.cham.montefiore.org/links/pbs/wgbh/nova/abyss/life/tubewormsans.html to find an illustration of tubeworm anatomy and explanations of what each body part does.

3. Have each student group create a poster or three-dimensional model of a tubeworm. A portion of the poster or model should be in cut-away form so that internal structures can be seen. The following structures should be included:
   - Plume (including red color to indicate hemoglobin)
   - Vestimentum
   - Trophosome (including symbiotic bacteria)
   - Trunk
   - Tube
   - Opisthosome

4. Have each group prepare a written report that includes:
   - A description of the function of each of the organs or structures listed above;
   - A description of the symbiotic relationship between the tubeworm and chemosynthetic bacteria;
   - An explanation of how the tubeworm obtains its food
   - A discussion of how this symbiotic relationship supports other organisms in the cold seep food web, and what some of these organisms might be.

The BRIDGE Connection

www.vims.edu/BRIDGE/vents.html

The "Me" Connection

Have students write a short essay on symbiotic relationships that are important in their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

Models or posters and the accompanying written reports can be evaluated on the basis of the extent to which the required elements are included and upon the quality of the written discussions.

Extensions

Have students draw a cold seep food web that

includes at least six organisms representing primary producers and consumers.

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Mexico Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm – Web site for the principal investigator on the Gulf of Mexico expedition

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

http://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

http://www.cham.montefiore.org/links/pbs/wgbh/nova/abyss/life/tubewormsans.html

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
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

For More Information

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