Windows to the Deep Exploration

Life is Weird!

Focus
Biological organisms in cold seep communities

Grade Level
7-8 (Life Science)

Focus Question
What organisms are typically found in cold seep communities, and how do these organisms interact?

Learning Objectives
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 infer probable trophic relationships among organisms typical of cold-seep communities and the surrounding deep-sea environment.

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

Materials
- ❒ 5 x 7 index cards
- ❒ Drawing materials
- ❒ Corkboard, flip chart, or large poster board

Audio/Visual Materials
None

Teaching Time
Two 45-minute class periods, plus time for individual group research

Seating Arrangement
Groups of four students

Maximum Number of Students
30

Key Words
Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Polychaete worms
Chemosynthetic
Methanotrophic
Thiotrophic
Xenophyophores
Anthozoa
Turbellaria
Polychaete worm
Sipunculida
Mussel
Clam
Octopus
Crustacean
Alvinocaris
Nematoda
Sea urchin
Sea cucumber
Brittle star
Sea star

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. 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 foul-smelling 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. Methane and hydrogen sulfide are produced by the breakdown of organic matter deposited in the sediments. Archea and bacteria gain energy by oxidizing methane (methanotrophs) or hydrogen sulfide (thiotrophs), 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 (for example, living in close association with mussels and clams).

Where hydrogen sulfide is present, large tubeworms (phylum Pogonophora) known as vestimentiferans are often found, sometimes growing in clusters of millions of individuals. These unusual animals do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome that contains chemosynthetic bacteria. Vestimentiferans have tentacles that extend into the water. The tentacles are bright red due to the presence of hemoglobin which can absorb hydrogen sulfide and oxygen which are transported to the bacteria in the trophosome. The bacteria produce organic molecules that provide nutrition to the tube worm. A similar symbiotic relationship is found in clams and mussels that have chemosynthetic bacteria living in their gills. Bacteria are also found living independently from other organisms in large bacterial mats.

The Blake Ridge is a large sediment deposit located approximately 400 km east of Charleston, South Carolina on the continental slope and rise of the United States. The crest of the ridge extends in a direction that is roughly perpendicular to the continental rise for more than 500 km to the southwest from water depths of 2000 to 4800 m. Over the past 30 years, the Blake Ridge has been extensively studied because of the large deposits of methane hydrate found in the area. Methane hydrate is a type of clathrate, a chemical substance in which the molecules of one material (water, in this case) form an open lattice that encloses molecules of another material (methane) without actually forming chemical bonds between the two materials. These deposits are significant for several reasons:

- The U. S. Geological Survey has estimated that on a global scale, methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined.
- Methane hydrates can decompose to release large amounts of methane which is a greenhouse gas that could have (and may already have had) major consequences to the Earth's climate.
- Sudden release of pressurized methane gas may cause submarine landslides which in turn can trigger can trigger catastrophic tsunamis.
- Methane hydrates are associated with unusual and possibly unique biological communities containing previously unknown species that may be sources of beneficial pharmaceutical materials.

In September, 2001, the Ocean Exploration Deep East expedition conducted four DSV Alvin dives to explore chemosynthetically-based communities on the crest of the Blake Ridge at a depth of 2,154 m. The expedition recovered some of the largest mussels (up to 364 mm) ever discovered, observed shrimp that appeared to be feeding directly on methane hydrate ices, and documented 16 other numerically abundant groups of invertebrates.

This activity focuses on relationships between some inhabitants of cold-seep communities on the Blake Ridge.

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. Point out that there are a variety of chemical reactions that can provide this kind of energy. 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 in the Gulf of Mexico.

   Review the concepts of food chains and food webs, including the concept of trophic levels (primary producer, primary consumer, secondary consumer, and tertiary consumer).

2. Assign each student group one or more of the following groups to research:
   Methanotrophic bacteria
   Thiotrophic bacteria
   Xenophyophores (see also genus *Syringammina*)
   Anthozoa (sea anemones)
   Turbellaria (a flatworm of the genus *Platyhelminthes*)
   Nautiliniella (a genus of polychaetes)
   Maldanidae (a family of polychaetes)
   Chaetopteridae (a family of polychaetes)
   Capitellidae (a family of polychaetes)
   Sipunculida (peanut worms)
   Bathymodiolus heckerae (a species of mussel)
   Vesicomya (a genus of clams)
   Octopoda (octopus)
   Munidopsis (a genus of crustacean)
   Alvinocaris (a genus of crustacean)
   Nematoda (a round worm)
   Sarsiaster greigi (a species of sea urchin)
   Chiridota (a genus of sea cucumber)
   Ophioctenella (a genus of brittle star)
   Brisingia (a genus of sea star)

   In addition to written reference materials (encyclopedia, periodicals, and books on the deep sea), the following websites contain useful information:
   http://www.bio.psu.edu/cold_seeps
   http://biodidac.bio.uottawa.ca/
   http://www.fishbase.org/search.cfm
   http://www.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.pdf (this document also contains a food web model for the Blake Ridge, so you may want to provide only selected portions of this reference!)

   Each student group should try to determine the energy (food) source(s) of their assigned organisms. It may not be possible to precisely determine specific foods for all groups, but students should be able to draw reasonable inferences from information about related organisms and anatomical features that may give clues about what the animals eat. Students should prepare a 5 x 7 index card for each organism with an illustration of the organism (photocopies from reference material, downloaded internet pictures, or their own sketches), notes on where the organism is found, approximate size of the organism, and its trophic level (whether it is a primary producer, primary consumer, secondary consumer, or tertiary consumer).

3. Have each student group orally present their research results to the entire class. On a corkboard, flip chart, or piece of poster board, arrange the cards to show organisms that inhabit cold-seep communities, organisms from deep-sea environments outside cold-seep communities, and the trophic (feeding) relationships between these organisms. You may want to arrange the organisms by habitat first, then draw lines indicating which organisms probably provide an energy source (food) for other organisms. Painting tape or sticky notes can be used to temporarily anchor the cards until you have decided on the best arrangement, then tape or glue the cards in place.

4. Lead a discussion of the food web the students have created. Which groups show the greatest variety of anatomical types and feeding strategies? Which groups are responsible for primary production? What would the students infer about the relative abundance of each trophic level? In the simplest analysis, organisms at lower trophic levels (primary producers and primary consumers) must be more abundant than those on higher trophic levels. If this does not appear to be true, then there must be additional energy sources for the higher trophic levels.

The BRIDGE Connection

www.vims.edu/bridge/ - Click on "Biology" in the navigation menu to the left, then "Plankton," then "Phytoplankton" for resources on ocean food webs. Click on "Ecology" then "Deep Sea" for resources on deep sea communities.

The "Me" Connection

Have students write a short essay on their favorite deep-sea or cold-seep community organism, stating why they like it and at least three interesting facts about it. Have students discuss how deep sea communities such as those found on Blake Ridge may someday affect their lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

Results and presentation of the research component of this activity provide a basis for group evaluation. In addition, individual written interpretations of the pooled results may be required prior to Step 4 to provide a means of individual assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest Blake Ridge Expedition discoveries, and to find out what researchers are learning about cold-seep communities.

Resources

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

Van Dover, C.L., et al. 2003. Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically based ecosystem. Deep-Sea Research Part I 50:281-300. (available as a PDF file at http://www.geomar.de/projekte/sfb_574/abstracts/vanDover_et_al_2003.pdf)

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

http://ridge2000.bio.psu.edu/nonsciencelinks.htm – 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.geol.ucsb.edu/faculty/valentine/Valentine%202002.pdf – Review of methane-based chemosynthetic processes

http://www.accessexcellence.org/BF/bf01/arp/bf01p1.html – Verbatim transcript of a slide show on coping with toxic sulfide environments

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

For More Information

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