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Windows to the Deep Exploration

Giants of the Protozoa

Focus
Xenophyophores

Grade Level
7-8 (Life Science)

Focus Question
What are xenophyophores and how do they interact with other species?

Learning Objectives
Students will be able to define and describe xenophyophores.

Students will be able to describe processes of feeding and locomotion in xenophyophores.

Students will be able to infer how xenophyophores may interact with other species in the biological communities of which they are part.

Materials
❒ Materials for constructing a model xenophyophore (styrofoam, modeling clay, gumdrops, toothpicks, stiff wire, etc.)

Audio/Visual Materials
None

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

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Cold seeps
Methane hydrate
Clathrate
Xenophyophore
Protoctista

Background Information
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 2,000 to 4,800 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 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.

The expedition also observed a group of organisms called xenophyophores (pronounced zee-no-FIE-oh-fors) that are neither animals nor plants, but are members of the kingdom Protoctista [Note: We are using the five-kingdom scheme for classifying living organisms rather than the three-domain, multi-kingdom scheme for reasons explained by Margulis and Schwartz (see Resources, below)]. Almost all Protoctists are microscopic in size, but xenophyophores may be more than 20 cm in diameter—yet they are composed of only one cell! Although xenophyophores are found throughout the world's oceans, they are most abundant in very deep waters beneath nutrient-rich surface water. Xenophyophores are easily damaged during collection and have not been cultured, so knowledge about them is very limited. There are few internet sites that mention the phylum Xenophyophora (see References, below). The most detailed description of these organisms is a monograph by Tendal (1972), but the discussion by Margulis and Schwartz (1998) is the most readily available. Some encyclopedias also mention these organisms.

Like other protoctists, xenophyophores are believed to have evolved from symbiotic relationships between at least two different kinds of bacteria. The overall anatomy of xenophyophores consists of masses of cytoplasm with multiple nuclei, surrounded by a branched tube system called a granellare which is made of a cement-like organic substance. Strings of fecal pellets, called stercomes, hang outside the granellare in masses called stercomares. The granellare and stercomares are surrounded by a shell-like structure called a test that is made of bits of minerals and the microscopic skeletons of other organisms (e.g., sponges, forams, radiolarians). It is this foreign matter that gives xenophyophores their name: xenophyae ("stranger particles") + phore ("bearer") = "bearer of stranger particles."

Xenophyophores can occur in densities of more than 2,000 individuals per 100 m^2, and are the dominant organism in some bottom communities. Their habit of stirring up bottom sediments to form their tests may be important to maintaining diversity. Another yet-to-be-explained observation is that xenophyophores are often found in close association with ophiuroid echinoderms (brittle stars). The 2001 Ocean Exploration Deep East expedition recovered live xenophyophores from the edge of the cold seep community on the Blake Ridge. Because xenophyophores have not been extensively studied, their importance to deep-sea biological communities is not known—but this is not the same as "unimportant!"

In this activity, students will gather information on xenophyophores, make a model based on their research, and develop hypotheses about the role of these organisms in deep-sea bottom communities.

Learning Procedure

1. Visit **http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/oct1/oct1.html** and **http://oceanexplorer.noaa.gov/explorations/03windows/welcome.html** for background on the 2001 Ocean Exploration Deep East Expedition and

the 2003 Windows to the Deep Expedition to the Blake Ridge. Lead an introductory discussion about these expeditions. You may also want to visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community in the Gulf of Mexico.

2. Tell students that expeditions to deep-sea communities often lead to discoveries of new and unusual types of living organisms. Remind them about the giant tubeworms of hydrothermal vent communities which were completely unknown until scientists visited them in person (visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities). Tell students that among the organisms found near cold seep communities on the Blake Ridge in 2001 were large (about 5 cm diameter) xenophyophores. Ask how many students have ever heard of xenophyophores. Tell students that although these are fairly common deep-sea organisms throughout the world's oceans, very little is known about them. Tell students that they are going to find out as much as they can about xenophyophores, and develop their own hypotheses about the role of these organisms in deep-sea bottom communities.

3. Have each student group prepare:

a. A written report on xenophyophores that will (at the minimum) include
   - Explanation of what xenophyophores are
   - Description of xenophyophores
   - Explanation of how xenophyophores feed and move around
   - Description of interactions between xenophyophores and other species in deep-sea bottom communities
   - One or more hypotheses about the role of xenophyophores in deep-sea bottom communities

   [Note: An alternative to a traditional written report is to have students create a travel brochure for a xenophyophore. Visit "Travel Brochure for a Cell" by Mark Porter at www.accessexcellence.org/AE/AEC/ AEF/1995/porter_cell.html for a full description of this activity.]

b. A model of a xenophyophore illustrating what they have been able to learn about these organisms. [Note: You may want to visit "String Cells" by Marlys McCurdy at www.accessexcellence.org/AE/AEC/ AEF/1995/mccurdy_string.html for an alternative approach to constructing a cell model.]

Have student groups begin their research by looking for information on xenophyophores in reference books (such as encyclopedias and biology textbooks), as well as through keyword searches on the internet. Suggest the following keywords:

xenophyophore
protoctista
podia
plasmodia

You may want to direct students to the following websites, or allow them to discover these sites on their own:

- levin.ucsd.edu/current_research/JMBAUK%20-%202001.pdf
- www.microscopy-uk.org.uk/mag/artnov98/xeno1.html
- www.ngo.grida.no/wwfneap/Projects/Reports/ Offshore_Features/xenophyophores.pdf

If students have trouble coming up with hypotheses, have them read "Dressing up for the deep: agglutinated protists adorn an irregular urchin" [available online at levin.ucsd.edu/current_research/JMBAUK%20-%202001.pdf]. This may give them some ideas, but they should understand that xenophyophores may have many functions in their communities; at this point, we just don't know.

4. Lead a discussion of what is known about xenophyophores. Have each student group present their hypotheses about the role of xenophyophores in deep-sea bottom com-

munities, how these hypotheses are consistent with current knowledge of these organisms, and what sort of investigations might be carried out to test their hypotheses. Ask students whether they think it is worthwhile to study organisms like xenophyophores. Encourage pro and con discussion of this question, but be sure to challenge students to defend their positions. At some point in this discussion, ask students whether "unknown" is the same as "unimportant." You may want to cite examples in which obscure species proved to be directly important to humans (such as the Madagascar periwinkle that provides a powerful cancer treatment).

The Bridge Connection

www.vims.edu/bridge/ – Enter "cold seep" in the "Search" box, then click "Search" to display entries on the BRIDGE website for cold seep communities.

The "Me" Connection

Have students write a short essay on how little-known or undiscovered organisms could be important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

Written group reports and xenophyophore models provide opportunities for assessment. In addition, you may want to have students write individual hypotheses about the role of xenophyophores in deep-sea bottom communities prior to the group discussion in Step 4.

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 explorers 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)

Margulis, L. and K. V. Schwartz. 1998. Five Kingdoms. W. H. Freeman, New York.

Tendal, Ø. S. 1972. A monograph of the xenophyophoria. Galathea Report 12:7-103.

Levin, L.. A., A. J. Gooday, and D. W. James. 2001. Dressing up for the deep: agglutinated protists adorn an irregular urchin. Journal of the Marine Biological Association of the United Kingdom 81:881-882. [available online at levin.ucsd.edu/current_research/JMBAUK%20-%202001.pdf]

www.microscopy-uk.org.uk/mag/artnov98/xeno1.html – A short summary of facts about xenophyophores, with a few references

www.ngo.grida.no/wwfneap/Projects/Reports/ Offshore_Features/xenophyophores.pdf – Part of a report that includes a discussion of xenophyophores in British waters

http://www.resa.net/nasa/ocean_methane.htm — Links to other sites with information about methane hydrates and associated communities

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard C: Life Science

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

For More Information

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