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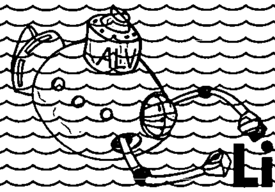
ABSTRACT

This activity is designed to teach about hydrothermal vent ecology. Students are expected to describe how hydrothermal vents are formed and characterize the physical conditions at these sites, explain chemosynthesis and contrast this process with photosynthesis, identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities, and describe common food pathways between organisms typically found in hydrothermal vent communities. The activity provides learning objectives, a list of needed materials, key vocabulary words, background information, day-to-day procedures, internet connections, career ideas, integrated subject areas, evaluation tips, extension ideas, and National Science Education Standards connections. (KHR)

Living with the Heat

Submarine Ring of Fire – Grades 5-6
Hydrothermal Vent Ecology

National Oceanic and Atmospheric Administration
U.S. Department of Commerce



Living with the Heat

Focus
Hydrothermal vent ecology

Grade Level
5-6

Focus Question
How is energy transferred between organisms that live close to hydrothermal vents?

Learning Objectives
Students will be able to describe how hydrothermal vents are formed and characterize the physical conditions at these sites.

Students will be able to explain what chemosynthesis is and contrast this process with photosynthesis.

Students will be able to identify autotrophic bacteria as the basis for food webs in hydrothermal vent communities.

Students will be able to describe common food pathways between organisms typically found in hydrothermal vent communities.

Materials
- ❒ Copies of "Hydrothermal Vent Communities Worksheet," one copy for each student or student group
- ❒ (Optional) Handouts or visual materials from NOAA's vent website (http://www.pmel.noaa.gov/vents/home.html)

Audio/Visual Materials
None, unless needed for optional materials

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom-style or groups of two to four students

Maximum Number of Students
30

Key Words
Hydrothermal vent
Autotroph
Chemosynthesis
Hydrogen sulfide
Magma
Vent plume
Symbiosis

Background
The Ring of Fire is an arc of active volcanoes and earthquake sites that partially encircles the Pacific Ocean Basin. The location of the Ring of Fire coincides with the location of oceanic trenches and volcanic island arcs that result from the movement of large plates of rock that comprise the outer shell of the Earth (called the lithosphere). There are about a dozen of these plates (called tectonic plates) that consist of a crust about 5 km thick, and the upper 60 - 75 km of the Earth's mantle. The plates that make up the lithosphere move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). These convection currents cause the tectonic

plates to move.

Plates may slide horizontally past each other at transform plate boundaries where the motion of the plates sets up huge stresses that can cause portions of the rock to break, resulting in earthquakes. At divergent plate boundaries, magma (molten rock) rises from deep within the Earth and erupts to form new crust on the lithosphere. Most divergent plates boundaries are underwater (Iceland is an exception), and form submarine mountain ranges called oceanic spreading ridges. At convergent plate boundaries, tectonic plates are being pushed together, and one of the converging plates moves beneath the other (a process called subduction). Deep trenches are often formed where tectonic plates are being subducted, and earthquakes are common. As the sinking plate moves deeper into the mantle, fluids are released from the rock causing the overlying mantle to partially melt. The new magma rises and may erupt violently to form volcanoes, often forming arcs of islands along the convergent boundary.

In 1977, scientists in the submersible Alvin made the first visit to an oceanic spreading ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. In the middle of deep, cold ocean waters, they found warm springs rising from areas where hot magma was forming new crustal material; and around those springs they found large numbers of animals that had never been seen before.

These hot springs, called hydrothermal vents, are the result of seawater penetrating cracks in the seafloor crust near magma-containing chambers beneath a spreading ridge. When the intruding water encounters the molten rock, a variety of chemical changes take place as the water is warmed. Oxygen in the water is virtually eliminated, while many substances from the rocks become dissolved in the water. The heated water becomes less dense, and rises upward, forming a hydrothermal vent. When the heated vent fluid (the "plume") is cooled by the cold deep ocean water, many dissolved materials quickly precipitate, and form shimmering blue or smoke-like clouds and chimneys of rock-like deposits.

Hydrothermal vents were surprising to the scientists in the Alvin, but finding large numbers of animals around the vents was an even greater surprise. This is because conditions near the vents are "extreme" when compared to places that we normally think of as being suitable for living species. Water emerging from hydrothermal vents may be as hot as 400 °C, is highly acidic, and usually contains large amounts of hydrogen sulfide which is highly toxic to many animals. Moreover, these vents occur more than a mile beneath the ocean surface, far too deep for photosynthesis which was assumed to be essential to all major biological communities. The fact that hydrothermal vents are home to thriving communities of previously unknown animals suggests that we should not be too quick to use our own needs as a basis for judging whether conditions are "acceptable" or "extreme" for all other forms of life.

The foundation for hydrothermal vent communities are bacteria that can use chemicals in the vent plume (particularly hydrogen sulfide or methane) to produce simple sugars in a process called chemosynthesis. This process closely resembles photosynthesis in which green plants use energy from sunlight to combine carbon dioxide and water to form simple sugars that are the basis for most familiar food chains. The key difference is that in chemosynthesis, energy to produce the sugars is obtained from chemical bonds in hydrogen sulfide (or another compound, such as methane) instead of from sunlight. Both green plants and chemosynthetic organisms are called autotrophs (meaning they feed themselves).

In vent communities, chemosynthesis takes place in the cells of certain bacteria, where oxygen reacts to release energy from chemical bonds in hydrogen sulfide, and the energy is used to create simple sugars from carbon dioxide and water. These chemosynthetic bacteria are specially adapted to life in hydrothermal plumes, and thrive at temperatures exceeding 110° C.

Chemosynthetic bacteria are the base of a food web that includes many types of animals. In one of the most direct relationships, the bacteria live inside the tissues of giant tubeworms and clams. The animals' blood carries carbon dioxide, oxygen, and hydrogen sulfide to the bacteria and receives nourishment from the sugars produced by the bacteria. This is a true symbiosis (a mutually beneficial relationship between organisms) because the bacteria also benefit from having a sheltered environment inside the clams and tubeworms that provides protection from sudden changes in temperature and chemical composition of the vent fluid. Tubeworms have no mouth or gut; they depend entirely upon their symbiotic bacteria for survival.

Most pathways in vent food webs do not involve this type of symbiosis. Some chemosynthetic bacteria float freely in the vent plume, and provide a food source for plankton. Organic materials, including the remains of bacteria and plankton, float in the cooler water beneath the plume and are a food source for filter-feeding organisms such as mussels and a species of limpet (another mollusc). Other chemosynthetic bacteria form mats on hard surfaces, and are grazed by snails. All of these animals may become food for predators such as polychaete worms, crabs, fishes, and octopi. Some of these predators may spend most of their time outside the vent community, and visit only briefly to find food. Most species found in vent communities, though, are not found anywhere else. Many new species of animals have been found as more hydrothermal vents are explored. In fact, every time a new vent is explored, there is a good chance of finding animals that have previously been unknown to science.

This possibility is particularly exciting to scientists participating in the 2002 Submarine Ring of Fire Expedition. Part of this expedition will focus on the divergent boundary of the Juan de Fuca tectonic plate off the coast of western North America. This boundary is organized along three ridges: Gorda Ridge, Juan de Fuca Ridge, and Explorer Ridge. While Gorda and Juan de Fuca Ridges have been intensively studied, Explorer Ridge is virtually unexplored. What new species may be discovered there by the Ring of Fire Expedition?

Learning Procedure

1. Review the concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, and why these boundaries are often the site of volcanic activity. Describe hydrothermal vents, and the types of animals that are found there. Describe how animals acquire their nutrition, but do not discuss details of vent food webs. You may want to use resources from NOAA's hydrothermal vent web site (http://www.pmel.noaa.gov/vents/home.html) to supplement this discussion. Be sure students understand that conditions around vents can be very unpredictable, and that animals may be killed by sudden releases of very hot fluid and toxic chemicals or the eruption of magma from the spreading ridge.

   Discuss chemosynthesis and contrast this process with photosynthesis. Be sure students recognize that energy is required to synthesize simple sugars; simply bringing carbon dioxide and water together will not get the job done! You might ask them to predict whether sugars are formed when dry ice (frozen carbon dioxide) bubbles through water. If dry ice is available, you could test their hypothesis. The key difference between photosynthesis and chemosynthesis is where the energy comes from.

   You may also want to mention and discuss the idea that chemosynthetic bacteria may be one of the earliest forms of life. See http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/rock_eaters9_12.pdf for a discussion of this concept.

2. Distribute copies of "Hydrothermal Vent Communities Worksheet" to each student or student group. Have each group discuss and predict what types of feeding paths may exist among the animals described on the worksheet. Tabulate each group's results, and lead a discussion of the reasoning behind their conclusions. If you want to use this exercise for evaluation, collect the worksheets before discussion.

The BRIDGE Connection

www.vims.edu/bridge – Select Ocean Science Topics, then select Ecology, then Deep Sea

The "Me" Connection

Have students write a first-hand account of life near a hydrothermal vent, describing what conditions are like, and what adaptations are needed to live there. The students may write their story from the standpoint of an explorer in a submersible, or from the perspective of an animal living in a vent community.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

The worksheet may be used to evaluate students' understanding of the concepts presented. Students also may be asked to define key words, and/or describe one or more nutritional strategies used by animals living in a vent community.

Extensions

Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Ring of Fire Expedition discoveries.

Have students research a hydrothermal vent animal on the Internet, and write a report about its life habits and relationships with other organisms.

Discuss the idea that chemosynthetic bacteria were the first life forms on Earth (see http://ocean-explorer.noaa.gov/explorations/02alaska/background/edu/media/rock_eaters9_12.pdf for more information).

Resources

http://oceanexplorer.noaa.gov – Follow the Ring of Fire Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at this site.

http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html – Links to many other web sites with information about hydrothermal vents

Tunnicliffe, V., 1992. Hydrothermal-vent communities of the deep sea. *American Scientist* 80:336-349.

Corliss, J. B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane, and T.H. Andel, 1979. Submarine thermal springs on the Galapagos Rift. *Science* 203:1073-1083. – Scientific journal article describing the first submersible visit to a hydrothermal vent community

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
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Hydrothermal Vent Communities Worksheet

Organism	Feeding Adaptations	Potential Food Source(s)
Autotrophic Bacteria	chemosynthesis	______________________
Zooplankton	particle feeding	______________________
Clams	filter feeding, may be symbiotic with bacteria	______________________
Mussels	filter feeding	______________________
Bacterial mats	chemosynthesis	______________________
Snails	grazing	______________________
Tubeworms	symbiiotic with bacteria	______________________
Ploychete Worms	strong jaws	______________________
Crabs	strong jaws and claws	______________________
Octopus	powerful suctiondiscs on "arms;" strong jaws ("beak")	______________________