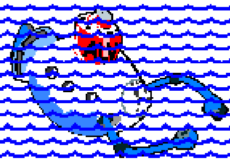
STUDENT ACTIVITIES

Two student activities start on the next page. They can be found at http://oceanexplorer.noaa.gov. Go to the Bridge for these, as well as other, student lesson plans. The titles of these activities are *InVENT a Deep-Sea Invetebrate* and *Yo-Yos, Tow-Yos and pH, Oh My!.*



InVENT a Deep-Sea Invertebrate

Focus
Galapagos Rift Ecosystem - Structure and Function in Living Systems

Grade Level
Grade 5-6

Learning Objectives
Students will design an invertebrate capable of living near deep-sea hydrothermal vents, and in doing so, will learn about the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

Additional Information for Teachers of Deaf Students
The key words are integral to the unit but will be very difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lip-read. If some of this information has not already been covered in your class, you may need to add an additional class period to teach vocabulary and teach some of the background information to the students prior to the activity. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful.

Materials:
- ❒ Reference materials such as encyclopedias, life science textbooks, Internet sites
- ❒ Colored pencils or markers (one pack per student group)
- ❒ Animal Adaptation Chart (one copy per pair of students)
- ❒ Chart paper

Teaching Time
Two 45-minute sessions

Seating Arrangement:
Students will work in pairs for research.

Key Words
Benthic
Adaptations
Hydrothermal vent
Chemosynthesis
Photosynthesis
Plates
Carbohydrates
Ecosystems
Tubeworm
Invertebrate
Amphipod
Sessile
Organism
Deposition
Molten
Magma
Precipitate
Endosymbionts
Genetically

Background Information:
Twenty-five years ago, Jack Corliss, Robert Ballard, and other Woods Hole Oceanographic Institution oceanographers first observed *in situ* the hydrothermal vent system off the coast of the Galapagos Islands on the Galapagos Rift. The year was 1977. They amazed the world with the discovery of communities of organisms that were incredibly unique. But even more incredible was the discovery that these organisms could obtain sugar compounds through chemosynthesis rather than photosynthesis. In fact, chemosynthesis was the basis of the food

web (*Ballard, 2000*). Since this discovery, there have been numerous hydrothermal vent systems discovered in the Pacific, Atlantic, and Indian Oceans.

Hydrothermal vents are areas in which seawater percolates back up through the cracks between plates of the Earth. Fresh lava flows are often found in these areas, but the hydrothermal vents are a product of deposition of chemical reactions created by the circulation of water in these cracks. As seawater is percolated deep down into the oceanic crust, it returns to the ocean through other openings in the crust after being heated to temperatures as high as 400°C. The ocean water to which it returns is often at 2°C and is under extreme pressure, since these areas exist over a mile beneath the surface of the ocean.

As this water passes through channels in the rock near molten magma beneath the oceanic crust, it takes up metal ions of iron, magnesium, copper, and zinc. Hydrogen and hydrogen sulfides are released from the plumes of the hydrothermal vents, along with metallic ions and metallic salts. The metals precipitate from the water to form the chimneys of the vents. Often hydrogen sulfides precipitate within the latticework of the vents (*Baker and Walker, 2000*). The hydrogen sulfides are combined with water and oxygen by chemosynthetic bacteria to form carbohydrates, or sugars. These sugars form the basis of the food web in the vent ecosystems. The chemosynthetic bacteria may exist freely or as endosymbionts within organisms of the vent communities.

Although the organisms in these systems must be able to withstand extreme temperatures, pH, pressure, and total darkness, there is an abundance of different life forms found in vent communities. The organisms of the vent communities are amazing life forms that are highly adapted to these vent environments. Adaptations are genetically-controlled characteristics that aid organisms in surviving and reproducing in their environments. Because of the wide diversity of habitats in the ocean, we see amazing degrees of adaptations in body form and function among marine organisms—and the organisms found living in hydrothermal vent communities are no exception. In fact, probably some of the most amazing adaptations for life on Earth can be found in these strange and beautiful creatures.

Why do these organisms look the way they do? What do they eat and how do they get their food? How do they protect themselves? How do they move and what do their young look like? How long do the adults live? How do they withstand the extreme pressure and heat in this extreme environment?

Organisms adapt to their environment in the following ways:

1) They need to be a certain shape, or form, depending on where they live.
2) They may or may not need to move around. Some organisms are sessile, or immobile. They only move in their larval stage. Once they reach their adult phase they stay in one place. They need some sort of adaptation to stay in that place. Other organisms move about. They need an adaptation to help them move.
3) All organisms need to feed in one way or

another. Some organisms filter food through gills, while others take in food through a mouth. They also need to get rid of wastes.
4) All organisms need protection from predators and environmental stress. This protection may be camouflage, special body parts, a heavy, protective outer layer, and/or some form of locomotion, or a metabolic process to handle stress.
5) All organisms need to reproduce, and their young often look very different from the adults.

Scientists have discovered over 300 new species of organisms associated with vent communities around the world. Probably the most notable are the giant tubeworms, which can reach 6 feet in length. These are the fastest growing invertebrates known to mankind. Other worms, such as the Jericho worm, are about the size of a pencil and live in tubes that look like accordions. Another type of worm, named Alvinellids by scientists, was also discovered at vent communities. These worms were named after the Woods Hole Oceanographic Institution's manned submersible, Alvin.

Other organisms that have adapted to life near vents include clams, mussels, and shrimp. Amphipods, small lobsters, sea anemones, fish, and octopi have also been found in these extreme environments.

The discoveries of scientists as they continue to explore the ocean depths at hydrothermal vents continue to intrigue the scientific community and the world. Jack Corliss, one of the first observers of hydrothermal vents, has proposed that life evolved from hydrothermal vent communities over 3 billion years ago (Hoyt, 2001). As scientists begin to explore new rift system communities around hydrothermal vents, they continue to discover new species of organisms. The rich data provided by these hydrothermal vent systems will continue to produce intense speculation about the origins of life on Earth.

Learning Procedure

1. Discuss the Background Information, as appropriate, with your students. Have them brainstorm what they think it might be like to live in the deep sea near hydrothermal vents and record their answers on chart paper. Students need to remember the parameters of the ecosystem, such as extremely cold water, extremely hot water rising from the vents, no light, and the presence of chemosynthetic bacteria. Further brainstorm with your students about the kinds of adaptations that organisms might need to live in the extreme conditions associated with hydrothermal vent ecosystems. Record these answers on chart paper.
2. Ask each student pair to research, using available references (Internet, encyclopedias, and/or textbooks), organisms found near hydrothermal vent communities. Each pair should be directed to www.divediscover.whoi.edu
3. Distribute one copy of the Animal Adaptation Chart for each pair of students.
4. Ask each student pair to design and draw an invertebrate capable of living near a hydrothermal vent ecosystem. Each invertebrate must exhibit adaptations in body form (for both young and adult stages),

locomotion, feeding, and protection. The pair should name their "new" organism, and describe to the class as they display their drawing what their organism's body shape is and why it is shaped that way, how it moves, how it feeds, how it protects itself, and what its young look like and why they look the way they do.

The BRIDGE Connection:

http://www.vims.edu/bridge/vents.html
Go to this site for a BRIDGE Ocean AdVENTure on hydrothermal vents.

The "Me" Connection

Ask students to think about what types of adaptations they would have to have as humans if the temperature of the air were to rise such that desert conditions existed everywhere on Earth.

Connection to Other Subjects

Art, English/Language Arts

Evaluation

Adaptation Charts from each student pair may be evaluated for completeness and student drawings may be evaluated for understanding of adaptations.

Extensions

Have your students visit http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu with a member of their family each day to keep up to date with the latest Galapagos Rift Expedition discoveries.

Have students write a story about "A Day in the Life of..." for the animal they chose to design. They should explain the unique adaptations of the animal within the story.

The student pairs could get together with other student pairs to form a food web that incorporates several of the animals they designed.

Students should research the animals that actually live in hydrothermal vent communities.

Resources

http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu - Follow the Galapagos Rift Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of resource information can also be found at both of these sites.

National Science Education Standards:

Life Science Content Standard C:

- Structure and Function in Living Systems
- Reproduction and Heredity
- Regulation and Behavior
- Populations and Ecosystems
- Diversity and Adaptations of Organisms

Activity adapted from Design a Deep Sea Invertebrate, developed by Robin Sheek and Donna Ouzts, Laing Middle School, Charleston County School District, Deep East 2001 Educators Guide

Student Sheet
Animal Adaptation Chart

Directions:
Use references provided to complete the following chart for your invertebrate.

Draw a picture of your animal:

Describe its body form: ______________________________

____

____

Describe how it moves: ______________________________

____

____

Describe how it feeds: ______________________________

____

____

Describe how it protects itself: ______________________________

____

____

Describe what its young look like: ______________________________

____

____

Yo-Yos, Tow-Yos and pH, Oh My!

Focus

Galapagos Rift Expedition - Locating Hydrothermal Vents

Grade Level

7-8

Focus Questions

What are hydrothermal vents and where are they found?

What is a CTD and how is it used?

How can pH be used as an indicator of hydrothermal vent activity?

Learning Objectives

Students will learn how hydrothermal vents are formed and where they are located on the ocean floor.

Students will learn how scientists use CTDs to locate hydrothermal vents.

Students will learn how to determine the pH of a water sample and how this variable can be used to detect hydrothermal vent activity.

Additional Information for Teachers of Deaf Students

There are no formal signs in American Sign Language for any of these words and many are difficult to lip-read. This activity is really designed to teach pH. You can start with that part of the activity (# 6 in the procedures), then go back and discuss how scientists would sample water if it was not easily accessible to them. You can then introduce CTD's as a way to collect this information. The third part of the lesson can then be discussion of hydrothermal vents and their properties. A reflection could be looking back at the pH and temperature lab and answering the final two questions regarding which sample was taken near a hydrothermal vent and how the data supports this hypothesis. That would be a good time to make the "white smoker" discussed in Step 16. Depending on the background of the students, their knowledge of chemistry, and the depth to which you wish to go into this material, it may take two lessons to accomplish this activity.

Materials

- ❒ One yo-yo
- ❒ One chart showing where spreading ridges are located in the ocean floor
- ❒ National Geographic Video entitled "Dive to the Edge of Creation," if available
- ❒ Pictures of hydrothermal vents from website: http://www.divediscover.whoi.edu
- ❒ Pictures of animals that live near hydrothermal vents from website: http://www.divediscover.whoi.edu
- ❒ Picture of CTD frame and sampling bottles from website: http://www.divediscover.whoi.edu
- ❒ One gallon of water, chilled in a refrigerator
- ❒ Vinegar
- ❒ A heat source (microwave oven or hot plate)
- ❒ One eyedropper
- ❒ One tablespoon
- ❒ One data record sheet per student

Per group of four students:

- ❒ Five beakers labeled A, B, C, D and E
- ❒ One Alka-seltzer tablet (optional)
- ❒ Four thermometers
- ❒ 20 strips of pH paper and one color indicator scale

Audio/Visual Materials

TV/VCR the National Geographic Video "Dive to the Edge of Creation" is available

Teaching Time

45 minutes

Seating Arrangement

Groups of four students

Maximum Number of Students

36 students

Key Words

Tow-yo
Conductivity
Salinity
CTD
Sampling bottle
pH
Acidic
Basic
Hydrothermal vent
Galapagos Islands
Plumes
Hydrothermal
White smokers
Black smokers
Vents
Molten
Crust
Ionization

Background Information

Hydrothermal vents were first found by scientists using towed cameras back in 1976 along the coast of the Galapagos Islands. One year later, scientists traveled over 2,900 meters below the surface of the ocean using the manned submersible, Alvin, for the first *in situ* human observations of these newly-found structures on the deep sea floor. Scientists were very surprised and excited to find towering plumes of black smoke rising from the seafloor, but had no idea then what they were.

Scientists now know that the black smoke was not smoke at all; it was a hydrothermal fluid that was so hot that it could melt metal. The hot fluid carries dissolved metals from beneath the surface of the seafloor out to cold ocean water. When the hot fluid mixes with seawater, the metals combine with sulfur and this combination forms small black particles. The black particles provide the effect of smoke! There are also white smokers. The fluid coming out of white smokers is generally cooler than the black smokers and flows more slowly. The white color comes from minerals (which lack metals) that mix with the surrounding seawater.

Vents occur in areas where warm water flows into the ocean from chimney-like structures on the ocean floor. These vents form in places where there is volcanic activity. Volcanic activity occurs in places around the Earth called ocean ridges where ocean plates are moving away from one another. Erupting lava creates new seafloor.

Near vents, water travels through cracks in the seafloor and is heated by hot, molten rock far below the ocean crust. Temperatures can reach as high as 400°C. As the water heats up, it reacts with the rocks in the ocean crust. These chemical reactions remove all of the oxygen from the water and, therefore, the water becomes acidic. The hot water rises to the surface of the seafloor and spews out of the vent openings. The pH of this fluid varies from roughly 3 to 5. This hydrothermal fluid carries with it dissolved metals and other chemicals from deep beneath the ocean floor. The water around a hydrothermal vent is more acidic, is higher in salinity and temperature, and is less clear than water from similar depths nearby that lack vents. Scientists must sample very close to hydrothermal vents to detect high temperatures as the cold surrounding water of the deep sea at 2 degrees Celsius rapidly absorbs the heat generated from the vents.

Scientists note the location of hydrothermal vents carefully when they find them so that they are able to return to the area for future observations of vent activity. However, finding new areas of hydrothermal vent activity can be quite challenging. One of the tools scientists use to find vents is a CTD sensor (a conductivity, temperature and depth sensor). The CTD frame can also carry water-sampling bottles that look like long skinny bottles with a cap on the end. Scientists on board a research vessel drop the CTD frame with sampling bottles attached over the side and down to a specific water depth. They are able to send an electronic current down the cable and the current causes the cap on the sampling bottle to open. Water from that depth rushes into the sampling bottle, the cap closes, and the scientists then pull the sensor up through the water column back to the research vessel. Because scientists continually send the CTD frame down to a predetermined depth and then bring it back to the research vessel, this type of sampling can be thought to resemble the up and down movement of a "yo-yo." Since the CTD is towed behind a research vessel as it goes up and down, scientists bestowed the name of this type of sampling as a "tow-yo."

The CTD's "job" is to measure conductivity and temperature of the seawater at various depths, and in some cases, it can collect water samples from various depths for scientists to study on board the ship. Using data sent up the conducting cable that connects the CTD to the ship, scientists map hydrothermal signals detected in the water column above the seafloor. Once a hydrothermal plume is detected, they send an electrical pulse down the cable. That triggers a sample bottle on the CTD frame to collect a water sample.

When the CTD and water sample bottles are hauled back on the ship, the researchers take the water samples and transfer them the ship's laboratory. There they perform analyses to identify hydrothermal chemicals such as iron, manganese, methane, and hydrogen. If scientists detect significant amounts of hydrogen in a water sample (a low pH), then this can be an indicator of proximity to high-temperature vents.

A water molecule, H_2O, is composed of two hydrogen atoms and one oxygen atom. When water dissociates or separates, it forms H^+ and OH^-. This process is known as ionization. The hydrogen ion, H^+, has a positive charge because it lost an electron, while the hydroxide ion, OH^-, has a negative charge due to its gaining an electron. When another substance that ionizes is added, acids and bases are formed. An acid is created when excess hydrogen ions are present, while a base is formed when excess hydroxide ions are present. To determine if a substance is acidic or basic, the pH should be determined.

pH is a measure of the hydronium (H_30^+) concentration in a water solution. The pH scale ranges from 0 to 14. If the solution contains more H^+ ions, it is acidic while one containing more OH^- ions is basic. A neutral solution will have a pH of 7.

0--------------------------7------------------------14
most acidic neutral most basic
($H^+ > OH^-$) ($H^+ < OH^-$)

pH can be measured using a variety of methods. pH paper is often used and is simple and inexpensive. There are indicators like phenolphthalein and methyl red, as well as foods that change colors in the presence of acids and bases. A variety of household items can be used as examples of acids or bases. Lemon juice, orange juice, soda, and vinegar are acids. Humans also have a very strong acid—hydrochloric acid—inside their stomachs to aid digestion. The lining of the human stomach is designed to protect the stomach from the strong acid, however those people with holes in the lining of their stomachs (ulcers) often suffer very painful results. Examples of bases include bleach and baking soda. Solutions that have very low pHs or very high pHs can do tremendous damage to the human body.

The pH is one attribute that determines the biotic characteristics of a body of water. Most plants can tolerate a pH range of 6.5 to 13 while a large variety of animals prefer 6.5 to 7.5. For this reason, the low pH found around hydrothermal vents creates a harsh environment in which only uniquely-adapted organisms can survive.

Learning Procedure

Prior to class:

1. Chill one gallon of water overnight in a refrigerator.
2. For each group of four students, fill five 100ml beakers with chilled water and label each with an A, B, C, D or E.
3. Heat the water in all beakers labeled D for 60 seconds in the microwave oven shortly before the start of class.
4. Add 3 drops of vinegar to all beakers labeled C and E and stir.
5. Add one tablespoon of vinegar to all beakers labeled D and stir.
6. Practice your yo-yo skills!

During class:

1. Divide the class into groups of four.
2. Provide each student with a data worksheet.
3. Discuss the characteristics of hydrothermal vents with students. Explain where they are located and what they are.
4. Get out your yo-yo and begin to move the yo-yo up and down along the string. Once you have their attention, explain to students the design and function of a CTD. You can take a step forward with each downward movement of the yo-yo and tell students that scientists use a CTD

in a similar manner; they travel "forward" by research vessel and sample the water below with each downward cast of the CTD.

5. Explain that sampling bottles are attached to the CTD and explain how sampling bottles function.
6. Explain the concept of pH. Provide examples of common acids and bases. Explain why the water around a hydrothermal vent is acidic.
7. Explain to students that they are about to conduct an experiment to determine which sample was taken (using a CTD frame and sampling bottle) from a location very near a hydrothermal vent.
8. Provide sample A, B, C, D and E to each group of four students.
9. Provide two thermometers to each group of four students.
10. Provide 20 strips of pH paper to each group of four students with at least one pH color indicator chart per group.
11. Explain that each student will need to record the temperature and pH of each sample on their data worksheet.
12. Model the correct way to measure pH with a pH strip.
13. Ask the group, as a whole, to come up with a hypothesis as to which sample was collected near a hydrothermal vent. Require that they be able to support their hypothesis using the data they have collected.
14. Provide 20 minutes for the groups to complete their experiments, fill out their worksheets, and form their hypotheses.
15. Ask the groups to report their hypotheses.
16. Optional: for any group that correctly identifies sample D as the sample taken very near a hydrothermal vent, provide the group with an Alka-Seltzer to place in sample D. The fizzing looks similar to a white smoker on a hydrothermal vent.

The Bridge Connection

www.vims.edu/bridge

Choose Data Port from the sidebar on the left, then On-line Data, and then go to General Sources, then to the Digital Library for Earth Systems Education. Once you reach this site, conduct a search using the term "hydrothermal vents."

The "Me" Connection

Have students do research to determine three similarities and three differences between the land-based geyser called "Old Faithful" at Yellowstone National Park and a deep sea hydrothermal vent.

Connections to Other Subjects

Biology, English/Language Arts

Evaluation

Provide students with the following hypothetical situation: there is a local citizens group that is concerned about the health of a lake in their area. Twenty years ago, someone threw several canisters of a strong acid into the lake. The canisters have rusted and now have begun leaking. Have students write a letter to the citizen group explaining how they could use a CTD with a water sampling bottle and pH paper to pinpoint where in the lake the canisters have begun to leak.

Extensions

Have your students visit http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu with a member of their family each day to keep up to date with the latest Galapagos Rift Expedition discoveries.

Build your own sampling bottle. Let students tape nails or weights to the outside of a small bottle so that it will sink when placed in water. Twist a screw eye into a cork that fits the mouth of the bottle. Mark a string or nylon cord at six inch intervals and tie it to the screw eye. Now tie another 12-inch piece of string from the screw eye around the neck of the bottle. Let this 12-inch piece of string hang loosely. Insert the cork just tightly enough so that it will stay in place when the bottle is lifted by the first string. Carefully, lower the bottle into the water to a depth from which a sample is to be obtained. Next, jerk the string to remove the cork, wait for bubbles to stop rising to the surface and then pull the bottle up (From *The Everyday Science Source-book*, Dale Seymour Publications, 1985).

Have students read and summarize any of the following articles from past issues of *National Geographic:*

- Oases of Life in the Cold Abyss
  October, 1977
- Return to the Oases of the Deep
  November, 1979
- Light in the Abyss Reveals Life
  November, 1994
- Rebirth of a Deep-sea Vent
  November, 1994
- Life at the Bottom, May, 1998
- Deep-sea Geysers of the Atlantic
  October, 1992
- Deep Sea Vents: Science at the Extreme
  October, 2000

Resources

http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu - Follow the Galapagos Rift Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of resource information can also be found at both of these sites.

http://www.pmel.noaa.gov/vents/nemo/
http://www.divediscover.whoi.edu
http://www.nationalgeographic.com
http://www.marine.whoi.edu/ships/alvin/alvin.htm
http://www.ocean.udel.edu/deepsea

Gordon, David George. "Explosions from the Deep." *National Geographic World*, June 2000, 18-21.

Haymon, Rachel and Richard A. Lutz. "Rebirth of a Deep-Sea Vent." *National Geographic*, Nov. 1994, 114-126.

Rona, Peter A. "Deep-Sea Geysers of the Atlantic." *National Geographic*, October 1992, 105-109.

Van Dover, Cindy Lee. "The Ecology of Deep-Sea Hydrothermal Vents." Princeton University Press, 2000.

Van Dover, Cindy Lee. "The Octopus's Garden: Hydrothermal Vents and Other Mysteries of the Deep Sea." Perseus Press, 1996.

Woodman, Nancy. "Sea-Fari Deep." National Geographic Books, 1999.

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

- Properties and changes of properties in matter

Content Standard D: Earth and Space Science

- Structure of the earth system

Content Standard E: Science and Technology

- Abilities of technological design

Activity developed by Stacia Fletcher, South Carolina Aquarium

Student Data Sheet

Name: ______________________________

Sample Data

Sample	Temperature	pH
A		
B		
C		
D		
E		

Which sample do you think was taken near a hydrothermal vent? ____________

How does your data support this hypothesis? ______________________________