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Galapagos Rift Expedition

Survivors on the Ocean Ridge

Focus
Inheritance of genetic traits and the effect of environmental pressures on the expressed traits

Grade Level
9-12

Focus Question
Will new hydrothermal vent shrimp species be discovered at new sites along ocean ridges in the Pacific, Atlantic, or Indian Oceans?

Learning Objectives
Students will investigate the history of explorations of the hydrothermal vent systems.

Students will design a new shrimp species based on the introduction of a new gene form from migrating shrimp populations along the rift systems.

Students will assess the viability of the new shrimp species.

Students will develop a model for the establishment of a population of a new species of shrimp.

Additional Information for Teachers of Deaf Students
The words listed as key words should be introduced prior to the activity. There are no formal signs in American Sign Language for any of these words and many are difficult to lip-read. If some of these topics have 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.

For Part II, you may want to divide the students into two groups. As a class you can do the first DNA activity to allow the students to become familiar with all the vocabulary and what the task entails. Each group can take one sheet to work on as a team.

Materials:
Part I:
Students in groups of 2 or 3
- ❐ Computers connected to the Internet
- ❐ Overhead or Board

Part II:
Materials Needed for Each Student Group
(Groups of 3 students)
- ❐ Student Activity Sheet
- ❐ Colored pencils
- ❐ Biology textbook

Classroom Materials:
- ❐ Two pictures of *Rimicaris exoculata* (included in this activity)
- ❐ Sets of Newly-inherited Gene Form 1, Newly-inherited Gene Form 2, and Newly-inherited Gene Form 3 cards (enough for each student to get one Newly-inherited Gene Form card)

Teaching Time
Part I: 45 minutes
Part II: 60 - 90 minutes

Seating Arrangement
Part I: 1-2 students per computer
Part II: Desks arranged in groups of 3

Maximum Number of Students

35

Key Words

Hydrothermal vent
Galapagos Rift
Ocean ridge
Rimicaris exoculata
Endosymbiotic
Chemosynthetic
Dorsal eye
Cephalothorax
Population
Species
Phenotype
Viable
Phenotype
Photosynthesis
Percolates
Molten magma
Plumes
Carbohydrates
Exoculata
Dorsal
Carapace
Dormant
Seeping
DNA
Inherited

Background Information

Twenty-five years ago, Jack Corliss, Robert Ballard, and other Woods Hole Oceanogra-phic Institution oceanographers were the first to observe, *in situ*, hydrothermal vent systems off the coast of the Galapagos Islands on the Galapagos Rift. The year was 1977. They amazed the world with human observations 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 underwater geysers that are found on the new oceanic crust formed by the rifts in the ocean floor. The thin, new ocean crust has cracks in it through which ocean water can seep down to the hotter mantle below. As the ocean water comes in contact with the magma of the mantle, the energy of the magma is transferred to the water, which becomes superheated. The heated water molecules are less dense than the cool ocean water, and will begin to rise. The underground water also dissolves minerals from the surrounding magma and rock. As the water rises, it carries the minerals from the magma with it. When the heated minerals come in contact with cooler water again, the energy from them is transferred out and the minerals precipitate and settle to the ocean floor. As the minerals settle they form structures that resemble chimneys with the hydrothermal vent geyser in the middle. Thus, the transfer of energy between magma and water creates new ocean floor structures.

Hydrogen and hydrogen sulfides are released from the plumes of the hydrothermal vents along with metallic ions and metallic salts. 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. In the giant tubeworms, *Riftia*, the bacteria are endosymbionts that fill a large sac found inside the worm. These bacteria provide the worm with nourishment. The giant tubeworms have no mouth, gut, or anus.

Although the organisms in these systems must be able to withstand extreme temperatures, pH, and pressure, 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. In the Eastern Pacific vent communities, *Riftia*, the giant tubeworms, clams, and mussels dominate the vent communities. In the Atlantic vent communities, the shrimp species, *Rimicaris exoculata*, dominates the vent communities. *Rimicaris exoculata* also visually dominates in two vent communities that have been extensively studied in the Indian Ocean. There are approximately 15 different species of shrimp found at hydrothermal vents (Shank et al., 1999). About half live in the Pacific and half live in the Atlantic.

In 1985, Dr. Peter Rona and his colleagues were the first scientists to discover hot springs in the

Atlantic Ocean and were the first to collect shrimp from these areas. One of the shrimp species collected, a previously undescribed species, was named *Rimicaris exoculata* by Dr. Rona and Dr. Austin Williams. *Rimicaris exoculata* does not have normal anterior eyes and eyestalks as most shrimp with which we are familiar do. The Latin word *exoculata* means "without eyes." Dr. Cindy Lee Van Dover and Dr. Steve Chamberlain looked closely at specimens of *Rimicaris exoculata* and found an unusual white patch on the dorsal side of the shrimp's cephalothorax, just underneath the carapace (Pelli and Chamberlain, 1989). Further examination revealed that this structure was connected to the shrimp's brain via a large nerve cord, and she speculated that the organ might serve a function similar to primitive eyes. Although this "dorsal eye" had no lenses (Cone, 2001), light-sensitive cells, or photoreceptors, were discovered in it. Scientists believe that the shrimp may use their dorsal eyes to detect the light outside the visible spectrum emitted from a hydrothermal vent (White and Chave, 1998), as the structure of the dorsal eye looks like it has been modified to sense low light levels (Tim Shank, pers. comm.) Does the dorsal eye enable an individual of *Rimicaris exoculata* to seek the vents out for chemosynthetic bacteria from which the shrimp derive carbohydrates (Kunzig, 2001), or does it enable the shrimp to avoid extremely high temperature fluids emerging from the vents, or both? Some individuals have been found to have what appear to be scorched feet and bodies, but scientists are not sure whether or not these individuals have been burned by the heated water emerging from the vents or whether this "burned" appearance is the result of a disease.

As one hydrothermal vent becomes dormant, another area along the ridge becomes active and almost immediately, hydrothermal vent organisms colonize these active areas. Scientists speculate that the larval forms of shrimp and other vent organisms may move for a period of time with the plumes from the hydrothermal vents as vents shut down and others are formed. The larvae may not have to move over large distances as was previously thought, because of the amount of activity that continues to occur close to vents that are essentially shut down.

Populations of organisms that become separated from their parent species may evolve into a new species. This may have been the pathway for *Rimicaris exoculata*. When populations are isolated, the gene pool is isolated and a new form of a gene may become dominant in the population. After many generations of reproduction within this population, the environmental pressures may have caused the population to change significantly such that a new species, or a subspecies, evolves.

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

Part I:

In a computer lab, ask the students to go to www.divediscover.whoi.edu/ and click on New Expedition. This will take them to the Expedition 6 Introduction web page. On the right hand side of this page is a picture of a black hydrothermal vent labeled Hydrothermal Vents. Click on this picture. At the bottom of the newly opened window will be a white box that reads "Introduction" and if the pointer is held on the arrow part of this window, a selection appears. Select the "Video" portion of the selections. It will take about 15 minutes for this to download.

While the video is downloading, the teacher should ask students what the air looks like in August over an asphalt road. Lead the students to answer that they can see the shimmering heat waves rising above the street. They know that these are heat waves because they have probably tried to walk barefoot across asphalt in the summer! They may have also seen movies showing heat waves coming up from streets with wavering images over a hot summer road. Let the students watch the video from the Dive and Discover Expedition 6 Introduction web page.

Ask the students if they see the same heat coming up in between the black smoke from the chimney of the vent. They may look at the video numerous times just by clicking on the left arrow. (There are videos by National Geographic which show vent organisms. Also, www.pmel.noaa.gov is a web site with videos to download showing the black smokers of hydrothermal vents.)

Let the students explore all the areas of the Hydrothermal Vent and Vent Biology portions of this Expedition 6 web page. Make sure they read about the shrimp in the Vent Biology section.

After they have had sufficient time to explore, ask them to write a few paragraphs in response to the following statement:
You are a water molecule seeping down into the oceanic crust near a hydrothermal vent. What are some images you will see as you go through the crust and back out a hydrothermal vent?

The main ideas they should convey are given in examples below, but may vary depending on the organisms they prefer. (Asking students to write the original response alone and then to share their responses in small groups could be a variation on sharing with the whole group. Sharing in small groups before sharing with the whole group enables all students to share with someone. This gives them time to further process the information and check their understanding.)

Some of the areas they should cover include:
1. Percolating into the oceanic crust because of high pressure.
2. Meeting very hot areas near hot magma.
3. Seeing ions like iron and zinc and magnesium dissolving in them!
4. Exiting the hydrothermal vent with some hydrogen sulfide and entering a giant tubeworm.
5. Once in the tubeworm, noticing bacteria that are consuming the hydrogen sulfide.
6. Exiting the tubeworm (yuck!) and seeing numerous organisms like octopi and shrimp.

(Ask students to load the Hydrothermal Vent video for the next class.)

Part II:
Shrimp Survivor
In this activity, students will simulate, on a very general scale, the inheritance of genes and the effect the environment can have on the selection of the phenotype of certain individuals as a viable member of a population. Students will be given one gene of *Rimicaris exoculata* and will randomly be given the complimentary gene form. The new individual and others like it are separated and isolated at a new hydrothermal vent. Students are given a description of the new phenotypic expression of the gene form they acquired through reproduction. They write a paragraph explaining if their population will become a successful new species or not based on the viability of this new gene form.

Introduction to Students:
Begin passing around the pictures of *Rimicaris exoculata*. Say to the students: "*Rimicaris exoculata* have been discovered since 1985 in the Atlantic Ocean along the Mid-Atlantic Ridge in hydrothermal vent ecosystems. They swarm the hydrothermal vents. These shrimp do not have normal anterior compound eyes like the shrimp we eat. They instead have a white patch underneath their cephalothorax, called a dorsal eye, that scientists believe may be used to detect infrared radiation that is emitted from the vents. These shrimp depend

on chemosynthetic bacteria found at the vent for food."

Tell the students that in this activity, each group member will get a gene that is common to all *Rimicaris exoculata* (please note for yourself and later to the students that this is only a simulation and that this strand of DNA is not the actual sequence of nucleotides in *Rimicaris exoculata*). Ask the students to look at the top of their Student Activity Sheets to see which Shrimp Survivor number they have been given, either Shrimp Survivor 1, 2, or 3. One member of each group of students will go to the front of the room to pick up Newly-inherited Gene Form Cards for each member of their group. Instructions for this task are found on the Student Activity Sheets.

The instructions on the Student Activity Sheets also tell the students the following:

- DNA of Gene Form 1 causes the shrimp to retain the dorsal eye, but the rest of the body changes to an orange color. The dorsal eye continues to function as before. If this shrimp and others like it were isolated reproductively at another hydrothermal vent area, would it survive? Defend your answer.
- DNA of Gene Form 2 will cause the shrimp to lose its dorsal eye and revert to an anterior eye. Ditto for the survival question and defending the answer. (If shrimp anatomy has not been discussed, refer students to pictures of anterior shrimp eyestalks in their biology text.)
- DNA of Gene Form 3 will not change the phenotype. Again, the students will defend the response to whether the shrimp would survive and be reproductively viable if isolated.

From the background information, we know that both shrimp with dorsal eyes will survive despite the orange color of one. Scientists are still asking questions about the function of the dorsal eye. Although it is used as a photoreceptor to detect the infrared radiation being emitted from the hydrothermal vent chimney, the visual pigment, rhodopsin, has also been found in the dorsal eye. The shrimp with the anterior eye may or may not survive. In this scenario, the students can decide whether or not the anterior eye is a useful adaptation for their new shrimp species. This part of the activity is a good open-ended inquiry for you and your students to contemplate.

This part of the activity should provide the students with a simple model for speciation by isolated populations. Relate this example to Darwin's finches, which are found on the Galapagos Islands, and evolved from a common ancestor on the mainland in Ecuador. Also, explain to the students that an orange-colored shrimp specimen with dorsal eyes was found in the Galapagos region near vents and scientists originally suspected that this was another species. Further investigation showed that the orange-colored specimens were, in fact, juveniles of *Rimicaris exoculata*!

The " Me" Connection

What adaptations might humans develop over time to deal with high temperatures that would result from extreme global warming on Earth? If humans were required to move to different planets that were separated forever, would the human species change into different forms on the different planets?

Evaluation

The paragraphs defending the survival of each shrimp species and ensuing discussion will be an excellent informal evaluation of this activity.

The BRIDGE Connection

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

Extensions

Have students develop a timeline of ocean exploration in hydrothermal vents using major discoveries of different vent areas.

Using the timeline, ask students to identify the major hydrothermal vent areas on a map of the oceans.

Ask students to investigate career opportunities as biogeographers, geochemists, and submersible pilots. Visit www.marinecareers.net and http://oceanexplorer.noaa.gov

Read The Panda's Thumb by Stephen Jay Gould and discuss punctuated equilibrium as a mechanism for evolution.

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 Galapagos Rift Expedition discoveries.

Resources

http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu

Follow the Galapagos Rift Expedition explorers 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 Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Content Standard C: Life Science

- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- The behavior of organisms

Content Standard F: Science in Personal and Social Perspectives

- Science and technology in local, national, and global challenges
- History and nature of science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

For More Information

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Student Handout

Shrimp Survivor 1
Student Activity Sheet

Scenario

Rimicaris exoculata was discovered in1985 in the Atlantic Ocean along the Mid-Atlantic Ridge in hydrothermal vent ecosystems. They swarm the hydrothermal vent chimneys like bees covering a hive. They have a white patch underneath their cephalothorax, called a dorsal eye. This dorsal eye functions as a photoreceptor and can detect infrared radiation being emitted from the vents. These shrimp depend on the chemosynthetic bacteria found at the vent for food. *Rimicaris exoculata* does not have normal anterior compound eyes like the shrimp we are most familiar with.

One gene of your *Rimicaris exoculata* shrimp is listed below. Look at the top of this activity sheet to locate the Shrimp Survivor Number that has been given to you randomly. It will either be Shrimp Survivor 1, Shrimp Survivor 2, or Shrimp Survivor 3. These numbers represent the new gene form of a gene that your shrimp is about to inherit as two *Rimicaris exoculata* shrimp reproduce new offspring. In this simulation, the Newly-inherited Gene Form (1, 2, or 3) will determine the phenotype of the shrimp. Have one member of your team go to the front of the room to pick up your Newly-inherited Gene Form Card that corresponds to your Shrimp Survivor Number located at the top of this sheet. The description of the phenotypic expression of your new shrimp can be found on your Newly-inherited Gene Form Card.

Common gene for *Rimicaris exoculata* below:

A-T
C-G
G-C
A-T
T-A

Student Handout

Shrimp Survivor 2
Student Activity Sheet

Scenario

Rimicaris exoculata was discovered in1985 in the Atlantic Ocean along the Mid-Atlantic Ridge in hydrothermal vent ecosystems. They swarm the hydrothermal vent chimneys like bees covering a hive. They have a white patch underneath their cephalothorax, called a dorsal eye. This dorsal eye functions as a photoreceptor and can detect infrared radiation being emitted from the vents. These shrimp depend on the chemosynthetic bacteria found at the vent for food. *Rimicaris exoculata* do not have normal anterior compound eyes like the shrimp we are most familiar with.

One gene of your *Rimicaris exoculata* shrimp is listed below. Look at the top of this activity sheet to locate the Shrimp Survivor Number that has been given to you randomly. It will either be Shrimp Survivor 1, Shrimp Survivor 2, or Shrimp Survivor 3. These numbers represent the new form of a gene your shrimp is about to inherit as two *Rimicaris exoculata* shrimp reproduce new offspring. In this simulation, the Newly-inherited Gene Form (1, 2, or 3) will determine the phenotype of the shrimp. Have one member of your team go to the front of the room to pick up your Newly-inherited Gene Form Card that corresponds to your Shrimp Survivor Number located at the top of this sheet. The description of the phenotypic expression of your new shrimp can be found on your Newly-inherited Gene Form Card.

Common gene for *Rimicaris exoculata* below:
A-T
C-G
G-C
A-T
T-A

Student Handout

Shrimp Survivor 3
Student Activity Sheet

Scenario

Rimicaris exoculata was discovered in1985 in the Atlantic Ocean along the Mid-Atlantic Ridge in hydrothermal vent ecosystems. They swarm the hydrothermal vent chimneys like bees covering a hive. They have a white patch underneath their cephalothorax, called a dorsal eye. This dorsal eye functions as a photoreceptor and can detect infrared radiation being emitted from the vents. These shrimp depend on the chemosynthetic bacteria found at the vent for food. *Rimicaris exoculata* do not have normal anterior compound eyes like the shrimp we are most familiar with.

One gene of your *Rimicaris exoculata* shrimp is listed below. Look at the top of this activity sheet to locate the Shrimp Survivor Number that has been given to you randomly. It will either be Shrimp Survivor 1, Shrimp Survivor 2, or Shrimp Survivor 3. These numbers represent the new form of a gene your shrimp is about to inherit as two *Rimicaris exoculata* shrimp reproduce new offspring. In this simulation, the Newly-inherited Gene Form (1, 2, or 3) will determine the phenotype of the shrimp. Have one member of your team go to the front of the room to pick up your Newly-inherited Gene Form Card that corresponds to your Shrimp Survivor Number located at the top of this sheet. The description of the phenotypic expression of your new shrimp can be found on your Newly-inherited Gene Form Card.

Common gene for *Rimicaris exoculata* below:
A-T
C-G
G-C
A-T
T-A

Student Handout

Newly-Inherited Gene Form 1:
T-A
C-G
C-G
C-G
A-T

Phenotypic Expression: This complimentary gene form will cause your new *Rimicaris exoculata* to retain its white dorsal eye, but the rest of its body will have an orange coloration. Draw a picture of your new shrimp below. If this shrimp and others like it were isolated reproductively at a new hydrothermal vent, would they survive? Defend your answer and prepare to explain your answer to the class.

Student Handout

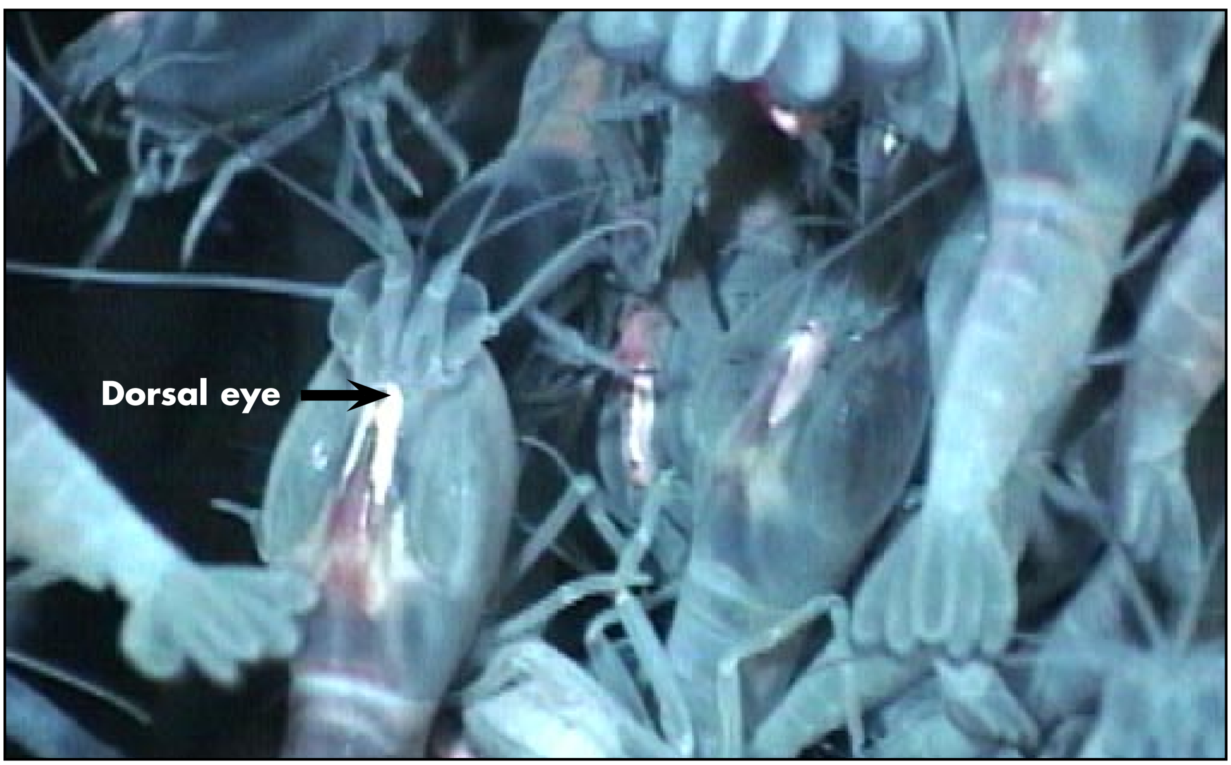
Newly-Inherited Gene Form 2:
T-A
T-A
C-G
C-G
A-T

Phenotypic Expression: This complimentary gene form will cause your new *Rimicaris exoculata* to have anterior compound eyes and no dorsal eye. Draw a picture of your new shrimp below. If this shrimp and others like it were isolated reproductively at a new hydrothermal vent, would they survive? Defend your answer and prepare to explain your answer to the class.

Student Handout

Newly-Inherited Gene Form 3:
C-G
C-G
A-T
T-A
G-C

Phenotypic Expression: This complimentary gene form will cause your *Rimicaris* exoculata to look exactly like the parent generation. It will have a dorsal eye and have the coloration of the original parent generation. Draw a picture of your new shrimp below. If this shrimp and others like it were isolated reproductively at a new hydrothermal vent, would they survive? Defend your answer and prepare to explain your answer to the class.



Courtesy of Dive and Discover (http://www.divediscover.whoi.edu). Images courtesy of shipboard scientists from College of William and Mary, Harvard University, Oregon State University, Portland Sate University, University of Washington, Woods Hole Oceanographic Institution.