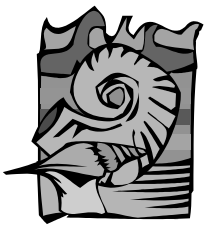
Cold Seeps

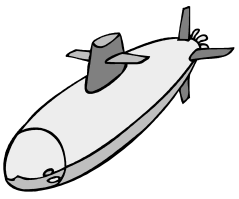
Lesson Objectives: Students will be able to do the following:
- Compare and contrast photosynthesis and chemosynthesis
- Describe the symbiotic relationship between clams and bacteria
- Identify three ways bacteria increase productivity in the cold seep areas

Key concepts: primary producer, photosynthesis, chemosynthesis, symbiosis

Deep Water Discoveries

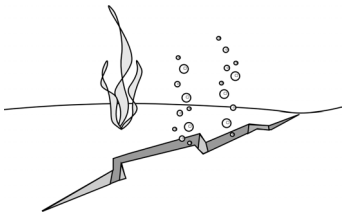


Advances in technology have allowed scientists to study the deep ocean floor. Researchers at the Monterey Bay Aquarium Research Institute (MBARI) have used research vessels and remotely operated vehicles (ROVs) for over a decade to explore these areas. ROVs remain in contact with the onboard scientist through fiber optic cables. These cables act as a **tether** for the vehicle while information is transported between the vehicle and the scientist. One ROV used by these scientists is called Ventana. This vehicle has become their window to the sea allowing them to observe what goes on deep below the surface. This vehicle is equipped with robotic arms, sensors, and a video camera. This allows researchers to collect samples for study from the deep ocean bottom.



Exploration also includes the use of manned underwater **submersibles** such as ALVIN. This technology allows the research scientist to pilot the vehicle and observe first hand the area being explored. These and other advances in technology have helped scientists discover new communities. One of these communities is found on the ocean floor. It is called a “cold seep”.

Cold seeps were first discovered in the late 1980’s in the Monterey Canyon at a depth of 3200 meters. Cold seeps are sites where fluids seep from the sea floor, somewhat like undersea springs, and are often called methane- or sulfide-seeps because the seeping fluids are rich in these compounds. Although the fluids are the same temperature as the surrounding seawater, they are termed “cold seeps” to distinguish them from hydrothermal vents, where extremely hot water is vented from the seafloor. These cold seep areas support life in total darkness and sometimes appear as oases of life in an otherwise desert-like region



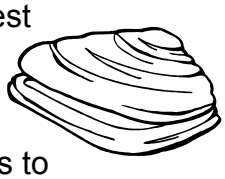
with few other animals. These areas are usually identified by specialized organisms that are abundant in the seeping fluids and carbonate rock formations that form near some seeps. Scientists are not sure where the seeping fluids come from, but they have several hypotheses. Some researchers believe that this fluid may result from rainfall runoff. As rain falls, it seeps through the soil and penetrates holes in the earth's crust. This fluid can then reappear under water in the cold seep areas. Other scientists think that changes in tectonic plate size may cause this fluid to seep through the ocean bottom in these areas.

The cold seep areas are home to some unique organisms. Scientists are taking a closer look at these organisms and how they get their energy.

Ways of Making a Living

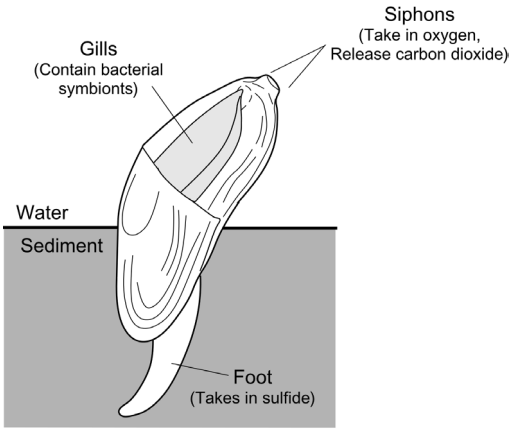
All organisms need energy to live. This energy comes from food. Some organisms make their own food. These organisms are called **autotrophs**. They have a very important job. These organisms are the first members in all **food chains** and **food webs**. Ultimately every organism gets its energy from autotrophs. These organisms are also called primary producers. Most of the world's primary producers are plants or **phytoplankton**. They make food energy through a process called **photosynthesis**. During photosynthesis energy from the sun is used to change carbon dioxide in the air or water into food. This food is usually a sugar called glucose.

Another group of autotrophs make food using chemical energy instead of energy from the sun. These autotrophs are microorganisms that occur mainly in seafloor muds where the right chemical compounds are present. These primary producers include two groups of microorganisms: **bacteria** and archaea. We will focus on the bacteria that use a process called **chemosynthesis** to create food energy. Bacteria harvest the chemical energy from **hydrogen sulfide** or **methane** found in the seep fluids to produce sugars, **proteins**, and other building blocks of **tissues**. These bacteria are fed upon by various heterotrophic animals. Unlike autotrophs, heterotrophic animals do not produce their own food and depend on other organisms for food. Nearly all animals are **heterotrophs**.



Several animals have developed highly specialized relationships with autotrophic bacteria at cold seeps. One of these animals, a clam, obtains its food from the bacteria. How does this happen? The clams

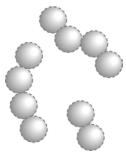
and the bacteria live together and help each other. This is called **symbiosis**. In the cold seep community bacteria make their home inside the clam's **gills**. Clams have a muscular foot that helps them attach to the seafloor. This muscular foot also takes in hydrogen sulfide from the water found at the cold seep area. This hydrogen sulfide is produced by methane-using microbes found in the seep. It is then carried in the clam's blood, just like oxygen is carried in our blood, to the clam's gills where the bacteria are located. The bacteria use the chemical energy found in the hydrogen sulfide to combine carbon dioxide and water to create sugar and other compounds for growth. The bacteria and sugars that it releases become food for the clam.

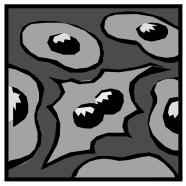


Vesicomyid Clam

Diversity and Research

Scientists have found that clams with symbiotic bacteria make up a large portion of the cold seep community, but other animals live there too. There are several types of bacteria that make their home in this environment. Some of them are **aerobic** or oxygen requiring. Other **anaerobic** bacteria can live without oxygen. All types of bacteria add to the energy flow in this **ecosystem**. The symbiotic, aerobic bacteria found in the gills of the clams produce food for the clams. This food energy can then be used by the clams to carry on life processes such as growing and reproducing. Other free-living, aerobic bacteria depend on hydrogen sulfide, and grow on the surface of the sediment where they form large mats. These mats are grazed upon by snails, crustaceans, and other animals. This enriches the cold seep environment by providing more food for the animals in this area. Otherwise, the animals would have to depend on food that falls through the water column from the surface. A third type of bacteria is found in the sediment. These anaerobic bacteria are thought to produce the methane and sulfide that act as the energy sources for chemosynthesis. Scientists have also found highly specialized tubeworms that use the hydrogen sulfide in the mud as a source of energy. Hydrogen sulfide enters the worm's circulatory system and is carried to the bacteria living in the worm's body through its blood



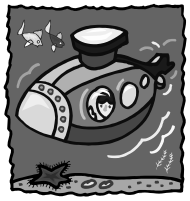


on a hemoglobin molecule, the same compound we use to transport oxygen in our blood. These bacteria use hydrogen sulfide as an energy source for chemosynthesis. Other types of clams use methane in the seep muds for chemosynthesis instead of hydrogen sulfide. They also have symbiotic bacteria, but these bacteria depend on the chemical energy of methane for chemosynthesis.

Scientists are also making comparisons between cold seep communities and hydrothermal vent communities. Hydrothermal vent communities were first discovered in the late nineteen seventies. These communities are also found in deep ocean areas of darkness. In this case the fluids seeping from the ocean floor are hot. The sulfide used in the chemosynthetic process comes from the decay and decomposition of dead organisms rather than from sulfide found in the earth's crust. In these communities, giant tubeworms seem to be the main type of organism present. They also have symbiotic bacteria that provide food for them.

What are scientists still trying to find out? And why? Scientists are continuing to study these deep water environments. Many questions still remain unanswered. They are taking a closer look at the ecology and energy flow through these systems. Scientists are trying to determine what factors influence the type and number of organisms that live in a particular area. They are comparing life forms found in various cold seep communities. They are also interested in learning more about how productivity at this level affects other areas. This information could be helpful to us as we continue to develop management plans to save our natural resources.

Activity: Underwater Exploration



As technology advances, smaller and smaller machines are capable of doing higher precision work in minute spaces. This technology has found a place in marine science as underwater vehicles have advanced from remotely operated vehicles (ROVs) requiring the constant attention of researchers to autonomous underwater vehicles (AUVs). At a fraction of the size of their predecessors, these sleek new models can be programmed and left on the ocean bottom to be recovered at a later date.

Objectives: Participants will experience the challenges facing scientists as they develop technologies to collect specimens found far below the ocean surface.

Materials:

- Markers to designate the playing area
- Items for groups to collect such as inflatables, stuffed animals, balls, or other small objects
- Items to use for collection devices such as sand shovels and tongs
- Paper or index cards and a writing device

Procedure:

1. Explain that microsystems are important components of larger machines. In this activity the participants will become a remotely operated vehicle with microsystem components controlling the collection process.
2. Tell participants that they will be working in groups or teams and each member will be a part of the underwater vehicle.
3. The groups or vehicles for round one will each have four components:
   Brain-will direct the vehicle with verbal commands, will position the arms for collecting, and will carry out the orders of the scientist
   Camera-will survey the collection area and focus on specific collection sites
   Two Manipulator Arms-will collect the desired specimen and will deposit it in the collection receptacle
4. Tell participants that in their group of four, the two participants representing manipulator arms will be visually impaired (not able to see). The only member of the group that may speak is the brain. The brain may only give directional information such as forward, back, up, down, left, or right.
5. Have the participants divide into groups of four.
6. Help groups form their underwater vehicle by positioning people in the following order from front to back: camera, robotic arms, brain. Individuals will be lined up facing the back of the person in front of them with hands on the shoulders of the person in front of them. Give each of the two center people (manipulator arms) a collection device (shovel, tongs, etc.).

7. Have groups navigate by walking onto the playing field. Give the command to "survey". The group walks in unison through the playing field while the camera lens moves back and forth taking pictures of the area.
8. The scientist stops the group in the desired area. (Specimens to be surveyed are placed in the "ocean".)
9. (The scientist gives the brain a card with the name of the item to be collected.) Scientist gives the verbal command to "collect". The brain moves the arms into the collecting mode. (The "arms" are positioned on either side of the camera. Each "arm" has one hand on the shoulder of the camera lens and the other hand holding a collection device.) The brain gives the manipulator arms verbal directional signals. (The brain may not actually help or position the manipulator arms.)
10. The item must be picked up by using both manipulator arms and placed in the collection area.
11. The arms are returned to their "survey" positions.
12. The vehicle receives the command to return to the surface.
13. The specimen is safely deposited in the collection area.
14. Discuss the problems encountered and the solutions. Remind participants that technology is continually improving. How could this technology be improved? (Perhaps by having fewer parts completing the task or better positioning of parts.)
15. Repeat the activity using suggestions from the group. For instance, have the vehicle composed of only two components (people): a combination brain and camera (one person), and a set of manipulator arms working in unison (another person).
16. Discuss how the process became easier and more efficient when the vehicle became smaller. Compare this to the use of MEMS in the newest autonomous underwater vehicles.

Student Information: Deep Ocean Adventures

The deep ocean bottom is an exciting place to explore, but half the fun is getting there. People have designed vehicles that can dive into these totally dark areas and send back pictures to scientists onboard ships. Some of these vehicles are called autonomous underwater vehicles (AUVs), because they are not connected to the ship. Others are called remotely operated vehicles (ROVs), because they are attached to the surface with fiber optic cables. The scientist onboard the ship controls these vehicles as they maneuver through underwater caves and deep canyons taking pictures and collecting samples. Sometimes scientists even get to explore under the water in **submersibles**. The scientists themselves can pilot these machines and get an up-close look at the strange and wondrous world below the ocean's surface.

Some scientists using these machines have discovered new underwater communities in the dark ocean depths. One of these communities is alive with clams that get their food energy from **bacteria**. This "cold seep" **community** is located near cracks in the ocean bottom where fluid is escaping. Some of the compounds found in this fluid are captured by symbiotic bacteria. Symbiotic bacteria live within the gills of the clams. These bacteria then use the chemical energy of compounds found in the seeping fluids to grow and produce food for the clam. This process is called **chemosynthesis**.

Scientists were very surprised to find these communities on the ocean bottom. They didn't think that animals such as clams could live without sunlight. They are now studying how these animals live and what types of adaptations they have. There are still many questions to be answered. Perhaps someday you will be a scientist helping to solve the mysteries of the ocean depths.