OCEAN EXPLORATION & RESEARCH

Lessons from the Deep:

Exploring the Gulf of Mexico's Deep-Sea Ecosystems

Education Materials Collection

Image captions/credits on Page 2.

lesson plan

Chemosynthesis for the Classroom

(adapted from the Expedition to the Deep Slope 2006)

Focus

Chemosynthetic bacteria

Grade Level

9-12 (Chemistry/Biology)

Focus Question

What changes affect succession in the development of chemosynthetic bacterial communities?

Learning Objectives

- Students will observe the development of chemosynthetic bacterial communities.
- Students will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive.
- Students will be able to explain the process of chemosynthesis.
- Students will be able to explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Materials

- *Directions for Setting Up Winogradsky Columns*, one copy for each student group

Materials for Winogradsky columns for each student group:

- 2 1-liter plastic soda bottles
- 1 Liter black mud from a local river, lake, or estuary
- 1 Liter water from each mud/sand location used
- 1 Small bucket
- 1 500 ml plastic beaker
- 1 Paint stirrer or large spoon
- 1 Sheet of newspaper

- 1 Tablespoon powdered chalk (see Learning Procedure, Step 1d)
- 1 Crushed multivitamin pill
- Calcium sulfate (Plaster of Paris), approximately 80 g
- 1 Plastic teaspoon
- Aluminum foil or plastic wrap
- Rubber bands
- Source of artificial light
- Tape and markers for labeling cylinders
- Flashlight with red cellophane over lens
- Optional: microscopes and materials for making wet mounts

Audio/Visual Materials

- None

Teaching Time

One 45-minute class period to set up columns, approximately 15 minutes at weekly intervals for six weeks to make observations, and one 45-minute class period for presentation and discussion of results

Seating Arrangement

Groups of four students

Maximum Number of Students

24

Key Words

Gulf of Mexico
Hard bottom
Cold seep
Chemosynthesis
Winogradsky

Background Information

Deepwater ecosystems in the Gulf of Mexico are often associated with rocky substrates or "hardgrounds." Most of these hard bottom areas are found in locations called cold seeps where hydrocarbons are seeping through the seafloor. Microorganisms are the connection between hardgrounds and cold seeps. When microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. Two types of ecosystems are typically associated with deepwater hardgrounds in the Gulf of Mexico: chemosynthetic communities and deep-sea coral communities. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, so the presence of these ecosystems may indicate potential sites

Images from Page 1 top to bottom:

A close-up mussel aggregation with *Chirodota heheva* sea cucumbers. Image courtesy of Expedition to the Deep Slope 2007.
http://oceanexplorer.noaa.gov/explorations/07mexico/logs/july3/media/cuke_600.html

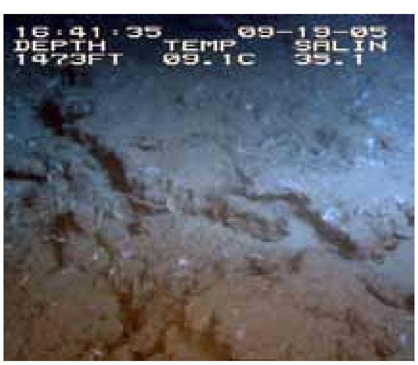
A CTD rosette being recovered at the end of a cast. Note that the stoppers on the sample bottles are all closed. Image courtesy of INSPIRE: Chile Margin 2010.
http://oceanexplorer.noaa.gov/explorations/10chile/logs/summary/media/2summary.html

A methane hydrate mound on the seafloor; bubbles show that methane is continuously leaking out of features like this. If bottom waters warmed, this entire feature may be destabilized and leak methane at a higher rate.
http://oceanexplorer.noaa.gov/explorations/10chile/background/methane/media/methane4.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon. Image courtesy of Chuck Fisher.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

Viosca Knoll is an elevated salt dome with dormant and active chemo-seeps. Where hydrocarbons are actively escaping from the substrate, dense clusters of tightly entwined vestimentiferan tubeworms grow. As the submersible approaches, it disturbs a blackbelly rosefish (*Helicolenus dactylopterus*), and a conger eel (*Conger oceanicus*). Image courtesy Ken Sulak USGS 2004-2006 *Lophelia* program Chief Scientist.
http://fl.biology.usgs.gov/images/pictures/CHEMO_TUBEWORM_BUSH.jpg

These methane mussels (*Bathymodiolus childressi*) live at the edge of Brine Pool NR1 at 650 m depth in the Gulf of Mexico. The pool of brine in the foreground is nearly four times as salty as seawater and is so dense that the submersible can float on the pool to take pictures such as this. Image courtesy Stephane Hourdez.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/mussels_600.html



Areas of active, if subdued, hydrocarbon seeps are notably devoid of large sessile invertebrates. A fluffy gray biofilm coats the underlying rock, dotted with small white patches of the cold-seep-associated bacteria *Beggatoia*. Image courtesy Ken Sulak USGS 2004-2006 *Lophelia* program Chief Scientist.
http://fl.biology.usgs.gov/images/pictures/CHEMO_SEEP_BIOTOPE.jpg

for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems whose full importance is presently unknown.

The first chemosynthetic communities were discovered in 1977 near the Galapagos Islands in the vicinity of underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates (visit http://www.pmel.noaa.gov/vents/ for more information and activities on hydrothermal vent communities). Chemosynthetic communities in the Gulf of Mexico were found by accident in 1984. These communities are similar in that they are based upon energy produced by chemosynthesis; but while energy for the Galapagos communities is derived from underwater hot springs, deep-sea chemosynthetic communities in the Gulf of Mexico are found in the vicinity of cold seeps. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychaete worms and shrimp. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

Deepwater chemosynthetic communities are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions between species found in these communities. These species include some of the most primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Many species are new to science, and may prove to be important sources of unique drugs for the treatment of human diseases. Organisms from hydrothermal vent communities have proven to be useful in a variety of ways, including treatment of bone injuries and cardiovascular disease, copying DNA for scientific studies and crime scene investigations, and making sweeteners for food additives. Because their potential importance is not yet known, it is critical to protect deepwater chemosynthetic ecosystems from adverse impacts caused by human activities.

This activity focuses on chemosynthetic bacteria similar to those that are the base of food chains in cold-seep communities. Black mud from a local water body is incubated in a glass cylinder (called a Winogradsky column) with a source of chemical energy (calcium sulfate) and organic material (straw or filter paper) to grow a succession of chemosynthetic bacteria over a period of six weeks. The following directions are adapted from a NASA Quest lesson, "Mysteries of Microbes: Fascinating Fieldwork" from NASA Quest. You can review the entire lesson at http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/ed.html#lesson.

Learning Procedure

1.To prepare for this lesson:

(a) Review the following essays:

Chemosynthetic Communities in the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/communities.html); and

The Ecology of Gulf of Mexico Deep-Sea Hardground Communities (http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html).

Geological Setting (http://oceanexplorer.noaa.gov/explorations/02mexico/background/geology/geology.html)

(b) You may also want to review the following visual resources and consider presenting some of these to your students:

- Image collections from Sulak, *et al.* (2008). Master Appendix D of this large report contains many images of deep-water coral communities. Download the PDF files "Master Appendix D - Megafaunal Invertebrates of Viosca Knoll, *Lophelia* Community Investigation," and "Key to Plates in Master Appendix D" from http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

- Video showing some of the extraordinary biological diversity of the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/03mex/logs/summary/media/ngom_biodiversity_cm3.html)

- Videos of deepwater corals and coral communities (http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html)

- Virtual tour of a cold-seep community (http://www.bio.psu.edu/cold_seeps)

- Slideshow of highlights from Expedition to the Deep Slope 2006 (http://oceanexplorer.noaa.gov/explorations/06mexico/background/media/slideshow/slideshow.html)

- Slideshow of images from the Expedition to the Deep Slope 2007 (http://oceanexplorer.noaa.gov/explorations/07mexico/logs/summary/media/slideshow/html_slideshow.html)

(c) Copy *Directions for Setting Up Winogradsky Columns*, one copy for each student group. These directions are adapted from a NASA Quest lesson, "Mysteries of Microbes: Fascinating Fieldwork" from NASA Quest. You can review the entire lesson at http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/ed.html#lesson. The PDF file for setting up Winogradsky columns can be downloaded from: http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/lessons/Winogradsky_5_8.pdf. A video demonstrating these procedures is here: http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/lessons/demo.html.

(d) Prepare materials for constructing Winogradsky columns:
(1) Gather mud and water from a forest, garden, lake, pond, marsh, or ocean.
(2) Cut off the tops of the 1-liter bottles to use as funnels.
(3) Powder the chalk. This can be done with a mortar and pestle, but much more easily with a large-capacity pencil sharpener. Alternatively, you may choose to have students prepare the chalk themselves.

2. Lead a discussion about deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis: In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Point out that there are a variety of chemical reactions that can provide this kind of energy. Discuss the importance of the Gulf of Mexico to U.S. petroleum resources, as well as the potential importance of deep-sea biological communities that might be adversely affected by exploration and development of petroleum resources. Ask students to brainstorm steps that might be taken to avoid adverse impacts.

3. Have each student group follow procedures for setting up two Winogradsky columns using locally collected black mud. Cover each column tightly with plastic wrap and secure with rubber bands. One column should be placed in a darkened area and the other column near a light source (but not in direct sunlight). Students should observe their columns weekly, and record their observations. You may have them make wet mounts for microscopic examination at the end of three and six weeks. Use appropriate safety precautions when making wet mounts, including gloves, antibacterial solution for disposing of slides, and hand washing following completion of the activity.

4. Have each group present and discuss their results. Students should have observed a series of changes in the appearance of the mud in the columns caused by a succession of bacterial species. They should infer that changes caused by one species (for example, the production of waste products) create opportunities for other species. Similarly, changes in the chemical composition

of the mud, such as formation of hydrogen sulfide, alter the environment in ways that may favor the growth of other bacterial species. The processes observed in the Winogradsky columns roughly model the development of deep-sea chemosynthetic communities. Ask the students to speculate about what other organisms might appear in the community if these processes were taking place in the area from which the mud was collected.

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Habitats," then "Deep Sea" for resources on deep-sea communities.

The "Me" Connection

Have students write a short essay on why cold seeps might be directly important to their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Reports and class discussions provide opportunities for assessment.

Extensions

1. See the "Resources" section of *Lessons from the Deep: Exploring the Gulf of Mexico's Deep-sea Ecosystem Education Materials Collection Educators Guide* for additional information, activities, and media resources about deepwater ecosystems in the Gulf of Mexico.

2. Have students investigate more about ancient bacteria and recent findings about physical conditions on some of Jupiter's moons, and report on the implications of chemosynthetic bacteria for the origins of life on Earth and extraterrestrial life (http://www.ocean.udel.edu/deepsea/level-2/chemistry/bacteria.html, the January-February, 2002 issue of the American Scientist and the October, 1999 and February, 2000 issues of Scientific American are useful for this).

3. See http://www.woodrow.org/teachers/bi/2000/Winogradsky_Column/winogradsky_column.html for additional discussion about using Winogradsky columns for classroom investigations of bacteria.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, 6, and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Deep-Sea Benthos, and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

From the Gulf of Mexico to the Moons of Jupiter (6 pages, 207 KB)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_moons.pdf

Focus - Adaptations to unique or "extreme" environments (Earth Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and will be able to compare physical conditions in deep-sea "extreme" environments to conditions thought to exist on selected moons of Jupiter. Students will also discuss the relevance of chemosynthetic processes in cold seep communities to the possibility of life on other planetary bodies.

Biochemistry Detectives (8 pages, 480 K)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus - Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

This Old Tubeworm (10 pages, 484 KB)

http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus - Growth rate and age of species in cold-seep communities (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age specific growth in individuals of the same species.

C.S.I. on the Deep Reef (Chemotrophic Species Investigations, That Is) (6 pages, 444 KB)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_csi.pdf
Focus: Chemotrophic organisms (Life Science/Chemistry)
In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

Gellin (4 pages, 372 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_gellin.pdf
Focus - DNA analysis (Life Science)
In this activity, students will explain and carry out a simple process for separating DNA from tissue samples, explain and carry out a simple process for separating complex mixtures, and explain the process of restriction enzyme analysis.

Hot Food (4 pages, 372 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf
Focus - Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)
In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

How Does Your (Coral) Garden Grow? (6 pages, 456 KB)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf
Focus - Growth rate estimates based on isotope ratios (Life Science/Chemistry)
In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

What's the Difference? (20 pages, 300 kb)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf
Focus - Identification of biological communities from survey data (Life Science)

In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

The Big Burp: Where's the Proof? (5 pages, 364 KB)

http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/burp.pdf

Focus - Potential role of methane hydrates in global warming (Earth Science)

In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global warming. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/ – Ocean Explorer Web site

Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). 2008. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - *Lophelia* Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

Fisher, C., H. Roberts, E. Cordes, and B. Bernard. 2007. Cold seeps and associated communities of the Gulf of Mexico. Oceanography 20:118-129; available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/maincontent.htm – Web site for the National Methane Hydrate Research and Development Program

http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html – Gas (Methane) Hydrates—A New Frontier; Web page from the U.S. Geological Survey's Marine and Coastal Geology Program

Van Dover, C.L., P. Aharon, J.M. Bernhard, E. Caylord, M. Doerriesa, W. Flickinger, W. Gilhooly, S.K. Goffredi, K.E. Knick, S.A. Macko, S. Rapoport, E.C. Raulfs, C. Ruppel, J.L. Salerno, R.D. Seitz, B.K. Sen Gupta, T. Shank, M. Turnipseed, R. Vrijenhoek. 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.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

MacDonald, I. and S. Joye. 1997. Lair of the "Ice Worm." Quarterdeck 5(3); http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html; article on cold-seep communities and ice worms

Siegel, L. J. 2001. Café Methane. http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86; article on cold-seep communities and ice worms from NASA's Astrobiology Institute

Kirschvink, J. L. and T. D. Raub. 2003. A methane fuse for the Cambrian explosion: carbon cycles and true polar wander. Comptes Rendus Geoscience 335:65-78. Journal article on the possible role of methane release in rapid diversification of animal groups. Also available on-line at http://www.gps.caltech.edu/users/jkirschvink/pdfs/KirschvinkRaubComptesRendus.pdf

Simpson, S. 2000. Methane fever. *Scientific American* (Feb. 2000) pp 24-27. Article about role of methane release in the Paleocene extinction event

http://www.piersystem.com/go/site/2931/ – Main Unified Command Deepwater Horizon response site

http://response.restoration.noaa.gov/deepwaterhorizon – NOAA Web site on Deepwater Horizon Oil Spill Response

http://docs.lib.noaa.gov/noaa_documents/NESDIS/NODC/LISD/Central_Library/current_references/current_references_2010_2.pdf – Resources on Oil Spills, Response, and Restoration: a Selected Bibliography; document from NOAA Central Library to aid those seeking information concerning the Deepwater Horizon oil spill disaster in the Gulf of Mexico and information on previous spills and associated remedial actions; includes media products (web, video, printed and online documents) selected from resources available via the online NOAA Library and Information Network Catalog (NOAALINC)

http://www.gulfallianceeducation.org/ – Extensive list of publications and other resources from the Gulf of Mexico Alliance; click "Gulf States Information & Contacts for BP Oil Spill" to download the Word document

http://rucool.marine.rutgers.edu/deepwater/ – Deepwater Horizon Oil Spill Portal from the Integrated Ocean Observing System at Rutgers University

http://www.darrp.noaa.gov/southeast/deepwater_horizon/ index.html – Information about damage assessments being conducted by NOAA's Damage Assessment Remediation and Restoration Program

http://response.restoration.noaa.gov/ – Click "Students and Teachers" in the column on the left for information, fact sheets, and activities about oil emergencies, habitats, and other ocean issues

http://www.noaa.gov/sciencemissions/bpoilspill.html – Web page with links to NOAA Science Missions & Data relevant to the Deepwater Horizon/BP Oil Spill

http://ecowatch.ncddc.noaa.gov/jag/data.html – Data Links page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://ecowatch.ncddc.noaa.gov/jag/reports.html – Reports page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html - "Gulf Oil Spill" Web page from NOAA Office of Education with links to multimedia resources, lessons & activities, data, and background information

http://www.geoplatform.gov/gulfresponse/ - Web page for GeoPlatform.gov/gulfresponse—an online map-based tool developed by NOAA with the EPA, U.S. Coast Guard, and the Department of Interior to provide a "one-stop shop" for spill response information; includes oil spill trajectory, fishery area closures, wildlife data, locations of oiled shoreline and positions of deployed research ships

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard B: Physical Science

- Chemical reactions
- Interactions of energy and matter

Content Standard C: Life Science

- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Origin and evolution of the Earth system

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 4.
The ocean makes Earth habitable.

Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustainthe ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please e-mail your comments to: oceanexeducation@noaa.gov

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Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Design/layout by Coastal Images Graphic Design, Mount Pleasant, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

Directions for Setting Up Winogradsky Columns

(adapted from the NASA Quest Lesson, "Mysteries of Microbes: Fascinating Fieldwork;" http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/ed.html#lesson)

1. Add 1 liter of mud or sand to a small bucket. Remove any sticks, leaves, or rocks.
2. Stirring the mud or sand with a large spoon or paint stirrer, slowly add water until the mixture is like thick cream. Be careful not to add too much water.
3. Shred a full sheet of newspaper into very small pieces. Add the newspaper shreddings to the mixture.
4. Add 1 tablespoon of powdered chalk to the mixture.
5. Add 1 teaspoon of calcium sulfate to the mixture.
6. Add one crushed multivitamin pill to the mixture.
7. Stir the mixture gently using a large spoon or paint stirrer. If necessary, add more water so that the mixture is fluid enough to flow through the funnel.
8. Label your soda bottle with the names of the students in your group, date that the column was set up, and the source of the mud or sand.
9. Set the funnel into the mouth of the bottle. Have a group member hold the funnel in place.
10. Using the plastic beaker, scoop a small amount of the mixture from the bucket and pour it through the funnel into the base of the bottle.
11. Place your hand over the top of the bottle and tap the bottom of the bottle firmly on the table. This helps the mixture settle and removes oxygen that is trapped in the mixture.
12. Repeat the two previous steps of adding a small amount of mixture and settling the mixture until the top of the mixture is about 3 cm below the top of the bottle.
13. Gently stir the mixture in the bottle to remove any air bubbles.
14. Let the bottle sit for 30 minutes. The water that settles on top of the mixture should be about 2 cm deep. Add/remove the water in your bottle as needed.
15. Cover the bottle with foil or plastic wrap and secure it with a rubber band to prevent the water from evaporating.
16. Repeat Steps 8 through 15 to set up a second column.
17. Place one column in a darkened area and the other column near a light source as directed by your teacher.
18. Observe your columns once each week, and record your observations. Use a flashlight with red cellophane over the lens when observing the column that is in the dark.