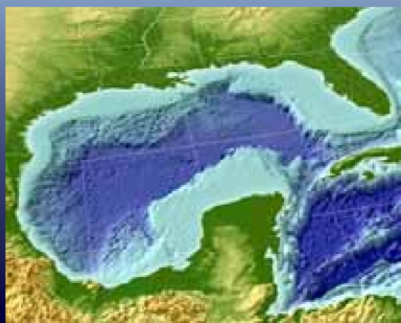


Lessons from the Deep:

Exploring the Gulf of Mexico's Deep-Sea Ecosystems

Education Materials Collection

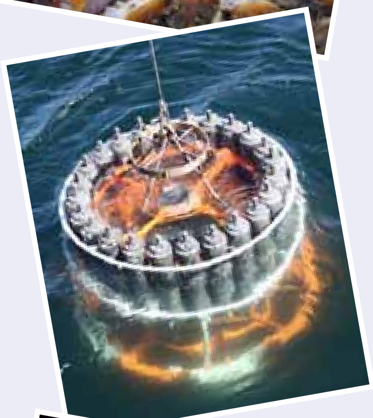


Image captions/credits on Page 2.

lesson plan

Chemists with No Backbones

(adapted from the 2003 Medicines from the Deep-Sea)

Focus
Benthic invertebrates that produce pharmacologically-active substances

Grade Level
5-6 (Life Science)

Focus Question
What groups of marine organisms produce substances that may be helpful in treating human diseases?

Learning Objectives
- Students will identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds.
- Students will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases.
- Students will infer why sessile marine invertebrates appear to be promising sources of new drugs.

Materials
- Marker board, blackboard, or overhead projector with transparencies for group discussions

Audio/Visual Materials
- None

Teaching Time
Two 45-minute class periods, plus time for student research

Seating Arrangement
Classroom style, or groups of 2-3 students

Maximum Number of Students
30

Key Words
Gulf of Mexico
Deep-sea coral
Cold-seep
Natural products

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 for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems that may be important in other ways as well.

Deepwater chemosynthetic communities are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions among 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.

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

Most drugs in use today come from nature. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. To date, almost all of the drugs derived from natural sources come from terrestrial organisms. But recently, systematic searches for new drugs have shown that marine invertebrates produce more antibiotic, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms.

Particularly promising invertebrate groups include sponges, tunicates, ascidians, bryozoans, octocorals, and some molluscs, annelids, and echinoderms. This activity is designed to familiarize students with some of the organisms that produce chemicals that have shown promise for the treatment of human diseases.

Learning Procedure

1. a) To prepare for this lesson, review the following essays:

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

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

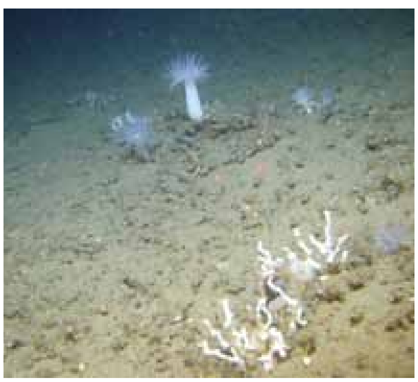
Medicines from the Deep Sea: Discoveries to Date (http://oceanexplorer.noaa.gov/explorations/03bio/background/medicines/medicines.html); and

What is a Natural Product? (http://oceanexplorer.noaa.gov/explorations/03bio/background/products/products.html)

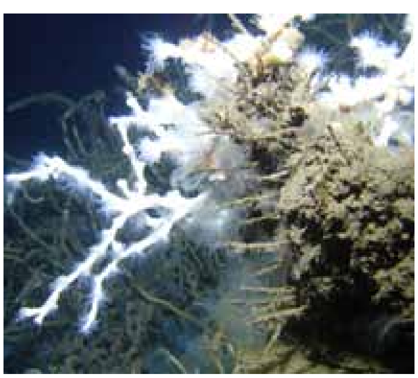
(b) You may also want to review the following visual resources and consider presenting some of these to your students:

- 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)



An example of the Viosca Knoll 906 habitat. In part of this site, there are a series of mounds that appear to be composed primarily of dead *Lophelia pertusa* rubble. Image courtesy of Lophelia II Team 2009, NOAA-OER.
http://oceanexplorer.noaa.gov/explorations/09lophelia/background/plan/media/image_4.html



Lophelia pertusa coral, with opened polyps, attached to an authigenic carbonate rock. Seep-dependent tubeworms are visible behind the coral. Image courtesy of, Lophelia II 2009: Deepwater Coral Expedition: Reefs, Rigs and Wrecks.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug25/media/lophelia_insitu_.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)

2. Briefly introduce the concept of chemosynthetic communities, and describe the two types of deep-sea ecosystems found in the Gulf of Mexico. Discuss the potential of these ecosystems as sources of new drugs for treating of cardiovascular disease, cancer, inflammatory diseases, and infections, as well as other natural products.

3. Tell students that their assignment is to prepare a written report on a marine benthic invertebrate that produces one or more substances having potential for treating human diseases. Reports should include:
   - description of the organism, with pictures if possible;
   - basic life history information about these organisms (where they live, what they eat)
   - students' inferences about how powerful chemicals might be useful to the organism.

   You may also want to ask students to find out about chemicals produced by their assigned organism that may be useful for treating human diseases, and/or other potentially useful natural products from these organisms.

Assign each student or student group one or more of the following organisms:

Sponges
Tunicates
Ascidians
Bryozoans
Octocorals

4. Have students make a brief oral presentation of their research results. Drugs derived from marine invertebrates include:
   Ecteinascidin – Extracted from tunicates; being tested in

humans for treatment of breast and ovarian cancers and other solid tumors

Topsentin – Extracted from the sponges *Topsentia genitrix*, *Hexadella* sp., and *Spongosorites* sp.; anti-inflammatory agent

Lasonolide – Extracted from the sponge *Forcepia* sp.; anti-tumor agent

Discodermalide – Extracted from deep-sea sponges belonging to the genus *Discodermia*; anti-tumor agent

Bryostatin – Extracted from the bryozoan *Bugula neritina*; potential treatment for leukemia and melanoma

Pseudopterosins – Extracted from the octocoral (sea whip) *Pseudopterogorgia elisabethae*; anti-inflammatory and analgesic agents that reduce swelling and skin irritation and accelerate wound healing

w-conotoxin MVIIA – Extracted from the cone snail, *Conus magnus*; potent pain-killer

Microorganisms are proving to be a very promising source for a variety of new natural products. Chemicals from some microorganisms found around hydrothermal vents are promising for the treatment of bone injuries and diseases, while similar chemicals may be useful for treating cardiovascular disease. Other examples of useful products include a protein that can be used to make billions of copies of DNA for scientific studies and crime scene investigations (from the hydrothermal vent microbe *Thermus thermophylus*). Another microorganism (genus *Thermococcus*) produces a type of protein (an enzyme called pullulanase) that can be used to make sweeteners for food additives.

Discuss the role of pharmacologically-active substances in the organisms from which they are obtained. Students should recognize that most of these species are sessile. Several reasons have been suggested to explain why these particular animals produce potent chemicals. One possibility is that they use these chemicals to repel predators, since they are sessile, and thus basically "sitting ducks." Since many of these species are filter feeders, and consequently are exposed to all sorts of parasites and pathogens in the water, they may use powerful chemicals to repel parasites or as antibiotics against disease-causing organisms. Competition for space may explain why some of these invertebrates produce anti-cancer agents: if two species are competing for the same piece of bottom space, it would be helpful to produce a substance that would attack rapidly dividing cells of the competing organism. Since cancer cells often divide more rapidly than normal cells, the same substance might have anti-cancer properties.

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. Click on "Human Activities" then "Technology" for resources on biotechnology.

The "Me" Connection

Have students write a short essay from the viewpoint of a sessile benthic invertebrate, describing the hazards their animal must face in a typical day, and how their animal copes with these dangers.

Connections to Other Subjects

English/Language Arts, Physical Science

Assessment

Written and oral reports provide opportunities for evaluation.

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. Visit http://www.woodrow.org/teachers/bi/1993/ for more activities related to biotechnology from the 1993 Woodrow Wilson Biology Institute.
3. Visit http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html to find out more about the Deep Sea Medicines 2003 Expedition.

Multimedia Discovery Missions

http://www.learningdemo.com/noaa/ 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

Let's Make a Tubeworm! (15 pages, 1946 KB)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/tubeworm.pdf

Focus - Symbiotic relationships in cold-seep communities (Life Science)

Students describe the process of chemosynthesis in general terms, contrast chemosynthesis and photosynthesis, describe major features of cold-seep communities, and list at least five organisms typical of these communities. They will be able to *define symbiosis, describe two examples of symbiosis in cold-seep communities, describe the anatomy of vestimentiferans, and explain how these organisms obtain their food.*

Animals of the Fire Ice (5 pages, 364 KB)

http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/09animalsoffireice.pdf

Focus - Methane hydrate ice worms and hydrate shrimp (Life Science)

Students define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

Cool Lights (7 pages, 220 KB)

http://oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/media/coollights.pdf

Focus - Light-producing processes and organisms in deep-sea environments (Life Science/Physical Science)

Students compare and contrast chemiluminescence, bioluminescence, fluorescence, and phosphorescence. Given observations on materials that emit light under certain conditions, students infer whether the light-producing process is chemiluminescence, fluorescence, or phosphorescence. Students explain three ways in which the ability to produce light may be useful to deep-sea organisms and explain how scientists may be able to use light-producing processes in deep-sea organisms to obtain new observations of these organisms.

Now You See Me, Now You Don't (5 pages, 281 KB)

http://oceanexplorer.noaa.gov/explorations/05deepscope/background/edu/media/now_u_see_me.pdf

Focus - Light, color, and camouflage in the deep ocean (Life Science)

Students explain light in terms of electromagnetic waves, and explain the relationship between color and wavelength; compare and contrast color related to wavelength with color perceived by biological vision systems; and explain how color and light may be important to deepsea organisms, even under conditions of near-total darkness. Students also predict the perceived color of objects when illuminated by light of certain wavelengths.

Microfriends (6 pages, 420 KB)
http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/09microfriends.pdf
Focus - Beneficial microorganisms (Life Science)
Students describe at least three ways in which microorganisms benefit people, describe aseptic procedures, and obtain and culture a bacterial sample on a nutrient medium.

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

Mayer, A. M. S. and K. R. Gustafson. 2003. Marine pharmacology in 2000: Antitumor and cytotoxic compounds. Int. J. Cancer 105:291-299. Available online at http://marinepharmacology.midwestern.edu/docs/MP2000_Anticancer_Mayer_Gustafson.pdf

Tim Batchelder, T. 2001. Natural products from the sea: Ethnopharmacology, nutrition and conservation. Townsend Letter for Doctors and Patients, Feb, 2001. Available online at http://www.findarticles.com/p/articles/mi_m0ISW/is_2001_Feb/ai_70777319/pg_1.

http://www.woodrow.org/teachers/bi/1993/ – Background and activities from the 1993 Woodrow Wilson Biology Institute on biotechnology

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

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

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

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard C: Life Science

- Structure and function in living systems
- Reproduction and heredity
- Diversity and adaptations of organisms

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 3.
The ocean is a major influence on weather and climate.

Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

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

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 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 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

For More Information

Paula Keener, Director, Education Programs
NOAA's Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818 843.762.8737 (fax) paula.keener-chavis@noaa.gov

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