The NOAA Ship *Okeanos Explorer*

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Microfriends

(adapted from the 2003 Medicines from the Deep Sea: Exploration of the Gulf of Mexico Expedition)

An essential component of the NOAA Office of Ocean Exploration and Research mission is to enhance understanding of science, technology, engineering, and mathematics used in exploring the ocean, and build interest in careers that support ocean-related work. To help fulfill this mission, the Okeanos Explorer *Education Materials Collection is being developed to encourage educators and students to become personally involved with the voyages and discoveries of the* Okeanos Explorer*—America's first Federal ship dedicated to Ocean Exploration. Leader's Guides for Classroom Explorers focus on three themes: "Why Do We Explore?" (reasons for ocean exploration), "How Do We Explore?" (exploration methods), and "What Do We Expect to Find?" (recent discoveries that give us clues about what we may find in Earth's largely unknown ocean). Each Leader's Guide provides background information, links to resources, and an overview of recommended lesson plans on the Ocean Explorer Web site (*http://oceanexplorer.noaa.gov*). An Initial Inquiry Lesson for each of the three themes leads student inquiries that provide an overview of key topics. A series of lessons for each theme guides student investigations that explore these topics in greater depth. In the future additional guides will be added to the Education Materials Collection to support the involvement of citizen scientists.*

This lesson guides student inquiry into the key topic of Human Health within the "Why Do We Explore?" theme.

Focus

Beneficial microorganisms

Grade Level

5-6 (Life Science)

Focus Question

How may microorganisms benefit humans?

Learning Objectives

- Students will be able to describe at least three ways in which microorganisms benefit humans.
- Students will be able to describe aseptic procedures.
- Students will be able to obtain and culture a bacterial sample on a nutrient medium.

Materials

For each student group:

- Copies of *Microfriends Inquiry Guide*
- Squirt bottle containing household bleach diluted to a 10% solution
- Paper towels
- Sterile cotton swabs (see Learning Procedure), 2 or more
- Culture dish(es) containing nutrient medium (see Learning Procedure), 1 or more
- Wax pencils or permanent markers
- Safety glasses, 1 pair for each student
- Protective disposal gloves

For full class:

- Glo-Germ™ kit (order from Glo-Germ Co., POB 189, Moab, Utah 84532; 800-842-6622; or online at www.glogerm.com), 4 oz.
- Ultraviolet light
- Pressure cooker (not needed if pre-sterilized materials are used; see Learning Procedure)

Audiovisual Materials

- Marker board, blackboard (or digital equivalent), or overhead projector with transparencies for group discussions

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words and Concepts

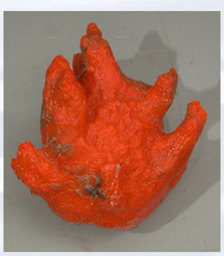
Cardiovascular disease
Cancer
Arthritis
Natural products

Microorganisms
Mutualism
Commensalism
Parasitism
Bacterial culture
Aseptic technique
Symbiosis

Background Information

Despite the many advances of modern medicine, disease is still the leading cause of death in the United States. Cardiovascular disease and cancer together account for more than 1.5 million deaths annually (40% and 25% of all deaths, respectively). In addition, one in six Americans have some form of arthritis, and hospitalized patients are increasingly threatened by infections that are resistant to conventional antibiotics. The cost of these diseases is staggering: $285 billion per year for cardiovascular disease; $107 billion per year for cancer; $65 billion per year for arthritis. Death rates, costs of treatment and lost productivity, and emergence of drug-resistant diseases all point to the need for new and more effective treatments.

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.




Though they may be visually unimpressive, *Forcepia* sponges (left) are the source of the lasonolides and tunicates (right) are the source of ecteinascidin, potential new drugs for treating cancer. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/logs/hirez/lasonolide1_hirez.jpg
http://oceanexplorer.noaa.gov/explorations/03bio/logs/hirez/figure4_hirez.jpg

The list of drugs derived from marine invertebrates includes:

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

Harbor Branch Oceanographic Institution researcher Dr. Shirley Pomponi removes a bright yellow sponge from a rock collected by an underwater robot during the 2003 Medicines from the Deep Sea expedition. Extracts from the sponge were tested for anti-cancer properties. Image credit: Laura Rear, NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/logs/summary/media/10249_bio_600.jpg

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

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

This list reflects an interesting fact about invertebrates that produce pharmacologically active substances: most species are sessile; they are immobile and live all or most of their lives attached to some sort of surface. 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 goal of the 2003 Medicines from the Deep Sea Expedition was to discover new resources with pharmaceutical potential in the Gulf of Mexico. To achieve this goal, the expedition:

- Collected selected benthic invertebrates from deep-water bottom communities in the Gulf of Mexico (sponges, octocorals, molluscs, annelids, echinoderms, tunicates), identified these organisms, and obtained samples of DNA and RNA from the collected organisms;
- Isolated and cultured microorganisms that live in association with deep-sea marine invertebrates;
- Prepared extracts of benthic invertebrates and associated microorganisms, and tested these extracts to identify those that might be useful in treatment of cancer, cardiovascular

disease, infections, inflammation, and disorders of the central nervous system;
- Isolated chemicals from extracts that show pharmacological potential and determined the structure of these chemicals;
- Studied the pharmacological properties of active compounds; and
- Developed methods for the sustainable use of biomedically important marine resources.

The last activity is particularly important, since many potentially useful drugs are present in very small quantities in the animals that produce these drugs. This makes it impossible to obtain useful amounts of the drugs simply by harvesting large numbers of animals from the sea. Some alternatives are chemical synthesis of specific compounds, aquaculture to produce large numbers of productive species, or culture of the cells that produce the drugs.

Notice that in addition to selected benthic invertebrates, scientists on the Medicines from the Deep Sea Expedition were equally interested in associated microorganisms as possible sources of useful pharmaceuticals. Many students assume that most microorganisms are dangerous and cause diseases in humans. This activity is designed to introduce students to some of the ways that humans benefit from microorganisms.

Learning Procedure

[***NOTE:*** Steps 2 – 5 are based, in part, on activities developed during the 1996/1997 teacher internship program of the Center for Engineering Plants for Resistance Against Pathogens at the University of California, Davis. You may want to download a copy of "Microbial World" which has other background information and activities from http://ceprap.ucdavis.edu/acrobat/microkit_00.pdf]

1. To prepare for this lesson:
   - If you have not previously done so, review introductory information on the NOAA Ship *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html. You may also want to consider having students complete some or all of the Initial Inquiry Lesson, *To Boldly Go…* (http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09toboldlygo.pdf).
   - Prepare culture dishes: Petri dishes containing sterile nutrient agar can be purchased from biological supply companies, or you can prepare your own. If you are using nutrient agar, prepare the solution according to

manufacturers' instructions. Sterilize the agar solution in a pressure cooker by placing the agar container in a basket just above the water level. Seal the lid onto the cooker and allow steam to flow freely for 10 minutes. Place the pressure control on the vent and maintain the pressure at 15 pounds for 30 minutes. At the end of this time, let the cooker cool, then pour the agar into sterilized petri dishes, baby food jars, or shallow glass dishes with glass covers.

As an alternative to nutrient agar, you can use unflavored gelatin. Prepare the gelatin according to directions on the package, but substitute beef broth (made from a bouillon cube) for boiling water. Sterilize the gelatin as described above and pour it into sterilized petri dishes or other containers.

Prepare sterile cotton swabs by wrapping one or two swabs in white paper (butcher paper), taping with masking tape, and sterilizing in a pressure cooker as described above. Alternatively, you can buy pre-packaged sterile swabs from a biological supply company.

• Review information that accompanied your Glo-Germ™ kit, or check out educational materials at http://www.glogerm.com/worksheet.html. Decide how much time you want to devote to handwashing activities. Considering emerging issues of pandemics, this portion of the lesson may have the most immediate potential benefit to students and educators. "Infect" student lab stations with Glo-Germ™ powder by rubbing the powder into a few areas on each station and brushing off any excess powder. Check the "infected" areas to be sure the powder shows up when illuminated with ultraviolet light.

2. If you have not previously done so, briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Lead a discussion of reasons that ocean exploration is important, which should include human health.

   Review the importance of finding new drugs for the treatment of cardiovascular disease, cancer, inflammatory diseases, and infections. Describe the potential of marine communities as sources for these drugs, and highlight the fact that new drugs may be found in microorganisms as well as the larger benthic invertebrates with which the microorganisms are associated.

3. Tell students that they are going to culture some bacteria living in your classroom, and that this type of work requires special procedures called aseptic techniques to minimize the risks of contamination. Begin with handwashing exercises, as detailed in the Glo Germ™ worksheets.

   Next, explain that to practice proper aseptic lab procedures, their lab stations have been "infected" with glowing particles that represent bacteria. Show students what an "infected" area looks like under ultraviolet light. Provide students with protective gloves, eye protection, paper towels, and squirt bottles of 10% bleach solution. Have them carefully wipe down the entire lab area with the bleach solution, then inspect the area again with ultraviolet light.

4. Provide each student group with a copy of *Microfriends Inquiry Guide*, and have students complete Part 1 (you may want to assign Part 1 as homework).

5. Provide each student group with one or more culture dishes containing nutrient agar or gelatin, sterile cotton swabs, and wax pencils or markers. Tell students to follow instructions for Part 2 of the *Inquiry Guide*. When Part 2 is completed, have students place their dishes upside down in the incubation area. If an incubator is not used, be sure that the dishes are not placed in direct sunlight or a cold part of the room. Have students clean their lab stations and wash their hands before leaving the lab.

6. After two and four days, students should record their observations on Part 3 of the *Inquiry Guide*.

7. Review students' answers to questions on the worksheet. The following points should be included:
   (1) Bacteria have existed on Earth longer than any other known organism.

   (2) Bacterial cells are structurally simpler than those of other organisms and do not have a nucleus.

   (3) Bacteria are extremely hardy; some can live well below freezing, others survive in boiling water, and others live in solid rock.

   (4) Bacteria are everywhere, and in large numbers; a teaspoon of garden soil contains about ten billion bacteria,

and there are more bacteria in the human mouth than the total number of people who have ever lived.

(5) Virtually all plants and animals live in association with bacteria and other microorganisms; these associations may benefit both organisms (mutualism), benefit one organism without affecting the other (commensalism); or benefit one organism and harm the other (parasitism). Mutualism, commensalism and parasitism are all types of symbiotic relationships.

(6) Most bacteria are not parasitic.

(7) Some benefits provided by bacteria include:
- Bacteria in human intestines aid in the digestion of certain foods;
- Production of cheese, yogurt, and other foods;
- Decomposition and recycling of dead organisms;
- Fixation of nitrogen from the atmosphere into useable nitrogen in soils;
- Production of antibiotics;
- Photosynthetic bacteria produce oxygen; cyanobacteria produced the Earth's oxygen atmosphere 2.45-2.7 billion years ago;
- Bacteria are responsible for the production of fossil fuels;
- Bacteria are used to clean up polluted areas, including oil spills;
- Bacteria produce a variety of chemicals used in many industries, including acetone, butanol, and citric acid;
- Bacteria are used to treat sewage;
- Bacteria are what makes composting work; and
- Bacteria can be used to generate methane gas from sewage waste.

Have each group present their results, and lead a discussion focusing on which parts of the classroom seem to have the most bacteria and why.

8. After completion of the activity, collect the culture dishes, and immerse them in a 10% bleach solution for at least 15 minutes. Drain the excess solution and seal the dishes in a plastic bag for disposal. Alternatively, you may sterilize the dishes for 30 minutes in a pressure cooker at 15 lb pressure.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science" in the navigation menu to the left, then "Human Activities" then "Technology" for resources on biotechnology and drugs from the sea.

The "Me" Connection

Have students write a short essay describing how bacteria affect their own lives on any typical day.

Connections to Other Subjects

English/Language Arts, Physical Science

Assessment

Students' responses to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html to find out more about the Deep Sea Medicines 2003 Expedition.

2. Visit the following web sites for other activities related to microorganisms:
   www.glogerm.com
   http://ceprap.ucdavis.edu/acrobat/microkit_00.pdf
   http://spikesworld.spike-jamie.com/science/index.html
   http://www.umsl.edu/~microbes/

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 12 for interactive multimedia presentations and Learning Activities on Food, Water, and Medicine from the Sea

Other Relevant Lessons from NOAA's Ocean Explorer Program

(The following Lesson Plan is targeted toward grades 5-6)

Chemists with no Backbones
http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/Meds_ChemNoBackbones.pdf
(4 pages, 356k) (from the 2003 Medicines from the Deep Sea: Exploration of the Gulf of Mexico Expedition)

Focus: Benthic invertebrates that produce pharmacologically-active substances (Life Science)

In this activity, students will be able to identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds and will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases. Students will also be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Other 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 – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.umsl.edu/~microbes/pdf/steriletechnique.pdf - Worksheet on sterile technique

http://www.umsl.edu/~microbes/ – Web site of the Science in the Real World: Microbes in Action of the Department of Biology, University of Missouri - St. Louis

www.glogerm.com – Web site of the Glo-Germ Company, with activity ideas related to microorganisms

http://ceprap.ucdavis.edu/acrobat/microkit_00.pdf – Activity manual developed during the 1996/97 teacher internship program of the Center for Engineering Plants for Resistance Against Pathogens at the University of California, Davis

http://spikesworld.spike-jamie.com/science/index.html — Web site with lots of background and activities on multiple science topics, including microorganisms

National Science Education Standards

Content Standard A: Science As Inquiry

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

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal health
- Natural hazards
- Risks and benefits
- Science and technology in societyy

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

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 e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

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 sustain the 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 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, including how you use it in your formal/informal education setting.
Please send your comments to: oceanexeducation@noaa.gov

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Ocean Exploration Program
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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Microfriends Inquiry Guide

Part 1. Background Research

1. How long have bacteria existed on Earth compared to other organisms?

2. How are bacterial cells different from the cells of other organisms?

3. Are bacteria, in general, delicate or hardy?

4. Where are bacteria found? In general, are bacteria rare or abundant?

5. Are bacteria generally absent from healthy plants and animals?

6. Are most bacteria harmful to humans?

7. What are at least three benefits that we may receive from bacteria?

Microfriends Inquiry Guide

Part 2. Grow Some Bacteria!

1. Select an area of your classroom where you think there will be large numbers of bacteria.

2. Sample your selected area by having one student rub the surface with a sterile swab.

3. Have another student raise the top of a culture dish while the student with the sample swab gently streaks the surface of the agar or gelatin with the swab. Be careful not to tear the surface! Do not put the top of the dish on any other surface; just keep the top raised until the streaking is completed, then put the top back onto the dish.

4. After replacing the top, seal the top to the dish with strapping tape and label the dish with the names of students in your group and the collection site where you collected your sample.

5. Place your culture dish in an incubation area as directed by your teacher.

6. Clean your lab station and wash your hands before leaving the lab.

Part 3. Observe

After two days, record your observations on the chart below. Be sure to estimate how many different types of bacteria seem to be present. Repeat your observations after four days. DO NOT REMOVE THE TOPS FROM YOUR CULTURE DISH!

Microfriends Inquiry Observations

Collection Site ______________________________

Description of Colony	# of Colonies observed	Observations in culture dish
After 2 days:		
After 4 days:		