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*

Section 5: Key Topic – Human Health

Microfriends

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

Focus

Beneficial microorganisms

Grade Level

5-6 (Life Science)

Focus Question

How may microorganisms benefit humans?

Learning Objectives

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

Materials

For each student group:

- Copies of *Microfriends Investigation 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), one or more
- Wax pencils or permanent markers
- Safety glasses, one 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

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

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.

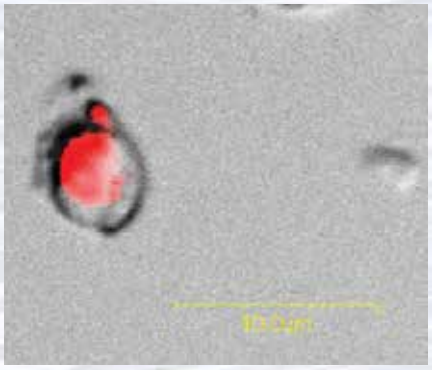
Most drugs in use today are produced from compounds that come from nature. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. To date, almost all of the drugs derived from natural sources come from 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.

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; acts by blocking transcription of DNA

The deepwater sponge *Discodermia* is now in clinical trials for the treatment of cancer. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/background/plan/media/discodermia.html

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



Autofluorescent microorganism from a sponge cell suspension. Transmitted light and Krypton laser. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/logs/sept18/media/microorg.html

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

Topsentin – Extracted from the sponges *Topsentia genitrix*, *Hexadella* sp., and *Spongosorites* sp.; anti-inflammatory agent; mode of action not certain

Lasonolide – Extracted from the sponge *Forcepia* sp.; anti-tumor agent; acts by binding with DNA

Discodermalide – Extracted from deep-sea sponges belonging to the genus *Discodermia*; anti-tumor agent; acts by interfering with microtubule networks

Bryostatin – Extracted from the bryozoan *Bugula neritina*; potential treatment for leukemia and melanoma; acts as a differentiating agent, forcing cancer cells to mature and thus halting uncontrolled cell division

Pseudopterosins – Extracted from the octocoral *Pseudopterogorgia elisabethae* (sea whip); anti-inflammatory and analgesic agents that reduce swelling and skin irritation and accelerate wound healing; acts as an inhibitor of phospholipase A, which is a key enzyme in inflammatory reactions

ω-conotoxin MVIIA – Extracted from the cone snail *Conus magnus*; potent pain-killer; acts by interfering with calcium ion flux, thereby reducing the release of neurotransmitters

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, because they are sessile, and are 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 deepwater 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 compounds found in animals are present in very small quantities. This makes it impossible to

obtain useful amounts of the substances simply by harvesting large numbers of animals from the sea. Some alternatives are chemical synthesis of specific products, aquaculture to produce large numbers of productive species, or culture of the cells that produce the desired compounds.

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/index.php?option=com_content&view=article&id=56&Itemid=138* - Click on "Microbe Laboratories" and it will automatically download.]

1. To prepare for this lesson:
   - 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 lesson, *To Boldly Go….*

   - 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

An agar plate with microorganisms isolated from a deepwater sponge. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/background/microbiology/media/figure_03.html

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, 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 Investigation 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 *Investigation 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 *Investigation 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 usable 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 *Investigation 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/index.php?option=com_content&view=article&id=56&Itemid=138 - Click on "Microbe Laboratories" and it will automatically download

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 Lesson Plans from NOAA's Ocean Explorer Program

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

Chemists with no Backbones

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

http://oceanexplorer.noaa.gov/explorations/03bio/background/edu/media/meds_chemnobackbones.pdf

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

Students will 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 infer why sessile marine invertebrates appear to be promising sources of new drugs.

Other Resources

See page 217 for Other Resources.

Next Generation Science Standards

Lesson plans developed for Volume 1 are correlated with *Ocean Literacy Essential Principles and Fundamental Concepts* as indicated in the back of this book. Additionally, a separate online document illustrates individual lesson support for the Performance Expectations and three dimensions of the Next Generation Science Standards and associated Common Core State Standards for Mathematics and for English Language Arts & Literacy. This information is provided to educators as a context or point of departure for addressing particular standards and does not necessarily mean that any lesson fully develops a particular standard, principle or concept. Please see: *http://oceanexplorer.noaa.gov/okeanos/edu/collection/wdwe_ngss.pdf.*

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings. Please send your comments to:
oceanexeducation@noaa.gov

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Microfriends Investigation 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?

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 Observations

Collection Site _____

Description of Colony	# of Colonies Observed	Observations in Culture Dish
After 2 days:		
After 4 days:		

Notes: