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Medicines from the Deep Sea: Exploration of the Gulf of Mexico

Chemists with No Backbones

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 be able to identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds.

Students will be able to describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases.

Students will be able to 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
One or 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
Cardiovascular disease
Cancer
Arthritis
Natural products
Sponge
Tunicate
Ascidian
Bryozoan
Octocorals

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.

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

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

The goal of the 2003 Medicines from the Deep Sea Expedition is to discover new resources with pharmaceutical potential in the Gulf of Mexico. To achieve this goal, the expedition will:

- collect selected benthic invertebrates from deep-water bottom communities in the Gulf of Mexico (sponges, octocorals, molluscs, annelids, echinoderms, tunicates), identify these organisms, and obtain samples of DNA and RNA from the collected organisms;
- isolate and culture microorganisms that live in association with deep-sea marine invertebrates;
- prepare extracts of benthic invertebrates and associated microorganisms, and test these extracts to identify those that may be useful in treatment of cancer, cardiovascular disease, infections, inflammation, and disorders of the central nervous system;
- isolate chemicals from extracts that show pharmacological potential and determine the structure of these chemicals;
- further study the pharmacological properties of active compounds; and
- develop methods for the sustainable use of biomedically important marine resources.

The last objective 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.

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. 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 introduce the objectives of the 2003 Medicines of the Deep Sea Expedition.

2. 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.

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

   sponges
   tunicates
   ascidians
   bryozoans
   octocorals

3. Have students make a brief oral presentation of their research results. Lead a discussion focussing on the role of pharmacologically-active substances to the organisms studied. Students should recognize that all of these species are sessile. Several reasons have been suggested to explain why these particular animals procuce 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 "Chemistry" for resources on drugs from the sea. Click on "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; Chemistry

Evaluation

Written and oral reports provide opportunities for evaluation.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest discoveries of the 2003 Medicines from the Deep Sea Expedition.

Visit http://www.woodrow.org/teachers/bi/1993/ for more activities related to biotechnology from the 1993 Woodrow Wilson Biology Institute.

Resources

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

http://www.fau.edu/hboi/MarineDrugDiscovery/MDDdrugdiscovery.php – An overview article on drugs from the sea

www.nci.nih.gov – Web site of the National Cancer Institute

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

http://www.denniskunkel.com/ – Web site containing hundreds of images taken with light and electron microscopes

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
- Reproduction and heredity
- Diversity and adaptations of organisms

Content Standard F: Science in Personal and Social Perspectives

- Personal health
- Risks and benefits
- Science and technology in society

For More Information

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