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2004 Estuaries to the Abyss Expedition

Superbugs

Focus
Antimicrobial resistance

Grade Level
9-12 (Life Science)

Focus Questions
What are the causes and potential solutions to emergence of antimicrobial resistant organisms?

Learning Objectives
Students will be able to define and explain antimicrobial resistance.

Students will be able to identify and explain at least three human activities that contribute to the emergence of antimicrobial resistance.

Students will be able to explain how research on deep-sea communities may contribute to our knowledge and strategies for dealing with the problem of antimicrobial resistance.

Materials
- ❑ For Part 2 (see Learning Procedure; materials may be ordered from Carolina Biological Supply; following quantities assume ten groups of three students per group, plus 20% allowance for spills, contamination, etc.)
- ❑ *Pseudomonas fluorescens* culture, catalog #AA-15-5255
- ❑ Nutrient broth, catalog #AA-78-5360, to make at least 500 ml
- ❑ Nutrient agar, catalog #AA-78-5300, to make at least 2 l
- ❑ Kanamycin, catalog #AA-21-6881, at least 150 mg
- ❑ 80 petri dishes
- ❑ 40 capped test tubes
- ❑ 30 sterile 1-ml pipets
- ❑ 12 pipet pumps or bulbs
- ❑ 15 glass rod spreaders
- ❑ Bunsen burners
- ❑ Alcohol (for sterilizing the glass spreaders)
- ❑ Facilities for sterilizing and preparing growth media

Audio/Visual Materials
None

Teaching Time
Part 1: Two 45-minute class periods, plus time for student research
Part 2: Five to seven days (see Learning Procedure)

Seating Arrangement
Classroom style or groups of 3-4 students

Maximum Number of Students
30

Key Words
Charleston Bump
Blake Plateau
Antimicrobial resistance
Antibiotics
Microbial cross resistance

Background Information

The Blake Plateau is a large sediment deposit located on the continental slope of the United States off the coasts of Florida, Georgia, South Carolina, and North Carolina. Depths on the plateau range from 400 to 1,250 meters. On the eastern edge of the Plateau, the Blake Ridge extends in a direction roughly perpendicular to the continental rise for more than 500 km to the southwest. To the east of the Ridge, water depths increase sharply to more than 4,000 m. The Blake Ridge has been extensively studied over the past 30 years because of the large deposits of methane hydrate found in the area, (visit http://198.99.247.24/scng/hydrate/about-hydrates/about_hydrates.htm for more information about methane hydrates and why they are important).

About 130 km east of the Georgia-South Carolina coast, a series of rocky scarps, mounds, overhangs, and flat pavements rise from more than 700 m at the surface of the Blake Plateau to within 400 m of the sea surface. This hard-bottom feature is known as the Charleston Bump.

The Charleston Bump was first discovered in the 1970's when scientists noticed an eastward deflection in the Gulf Stream off the coast of South Carolina. The cause of this deflection turned out to be the Charleston Bump, which also produces wave-like oscillations that roll northward toward Cape Hatteras. These waves produce another circulatory feature known as the Charleston Gyre. The Gyre is a reverse circulation that forms in the trough of the first wave downstream of the Charleston Bump, and resembles the dangerous hydraulics that form beneath waterfalls and river rapids (see "Eddies, Gyres, and Drowning Machines" at http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/edu.htm for more information).

In 1979, scientists correlated satellite observations of the Gyre with measurements made from a research ship that showed elevated phytoplankton pigment concentrations within the Gyre, suggesting that this circulation was associated with upwelling currents that bring nutrients to the surface and enhance phytoplankton growth. Despite these observations, and even though waters over the Charleston Bump have been important to commercial fishing for many years, the ecology of the Bump was not studied until very recently. Prior to these studies, it was generally assumed that fisheries were the result of migrations from other areas and/or nutrients carried in from deeper or coastal waters. And although no one had actually looked at the surface of the Charleston Bump, it was assumed that benthic communities were scattered and relatively unproductive. Once scientists actually began exploring the area more thoroughly, they found many diverse and thriving benthic communities.

The 2001 "Islands in the Stream" and 2003 "Investigating the Charleston Bump" Ocean Exploration expeditions found a series of very complex habitats on the Charleston Bump with numerous fishes and invertebrate species involved in communities that we are just beginning to understand. These biological communities offer opportunities to study organisms in relatively pristine environments that may not have been exposed to many of the synthetic chemicals produced by human society. This opportunity is particularly relevant to the emerging problem of bacteria that have developed resistance to many commonly-used antimicrobial drugs. Antimicrobial-resistant bacteria have been isolated from human and veterinary hospitals, and present a potential health risk to anyone involved with these facilities. A study of 50 sharks captured off the coast of Louisiana found that 60% of the fishes harbored bacteria that were resistant to a variety of commonly-used antibiotics. These findings suggest that fishes may be contributing to the problem of antimicrobial resistance, even though they theoretically have never been exposed to the synthetic drugs that induce such resistance. Highly mobile and migratory coastal species may be exposed to antibiotics in runoff from agriculture and aquaculture facilities. Studies of antimicrobial-resistant bacteria in deep-sea demersal fishes may provide a more definitive indication of how widespread this problem has become. One objective of the 2004 Estuaries to the Abyss Ocean Exploration Expedition is to determine whether deep-water fishes from a relatively pristine environment harbor bacteria that are resistant to antibiotics routinely used by medical and veterinary health professionals.

In Part 1 of this activity, students will research causes and implications of antimicrobial resistance. In Part 2, they will complete a portion of a module prepared by the National Institutes of Health in which they investigate the growth of bacteria in the presence of antibiotics and use the results to explain a case of antibiotic-resistant disease.

Learning Procedure:

Part 1

1. Briefly review the location and significance of the Blake Plateau and Charleston Bump. Introduce the problem of antimicrobial resistance and how research in deep-sea habitats may contribute to our knowledge and strategy for dealing with this problem.

2. Have each student group prepare a written report on antimicrobial resistance that includes answers to the following questions:
   - Are most bacteria pathogenic to humans?
   - What is "antimicrobial resistance (AMR)?"
   - How does AMR develop?
   - What is "microbial cross resistance?"
   - What human activities are associate with the development of AMR?
   - What common practices related to the use of antibiotics contribute to development of AMR?
   - How may genetically-modified organisms contribute to spread of AMR organisms?

3. Lead a discussion based on students' research. The following points should emerge during this discussion:
   - Most bacteria are non-pathogenic to humans, and many are directly beneficial. Of the estimated 200,000 species of microbes on Earth, only about 400 are pathogenic. Another concern related to indiscriminate use of antibiotics is the potential impact on beneficial bacteria involved in the global food web.

   - Antimicrobial resistance (AMR) stops or reduces the effectiveness of antimicrobial agents and may adversely impact treatment of human and animal illness. Increasing prevalence of microbial resistance represents a serious public health threat that has the potential to reduce medical defenses against bacterial infections to only a few antimicrobial agents. It is also quite possible that the growth and proliferation of undesirable microorganisms could outpace our ability to control and mitigate their effect on our health and on the health of our environment.

   - Resistance may occur as the result of inherent cellular components of microorganisms, by genetic selection resulting from exposure to an antimicrobial agent, or through the horizontal transfer of resistance genes.

   - The probability that a population of organisms will develop resistance to a given antimicrobial agent increases with length of exposure to that agent.

   - Microbial cross resistance develops when microbes exposed to one drug develop resistance to other antimicrobials of the same drug family.

   - Development of resistance is associated with the use of antimicrobial agents in human medicine, veterinary medicine, animal husbandry, plant agriculture, aquaculture, and with environmental contamination with antimicrobial agents

- Overprescription is an oft-cited contributor to AMR caused by health care professionals who use a "shot-gun" approach to therapy, or who prescribe antibiotics to "treat" viral infections (against which the antibiotics are ineffective) or to treat conditions that typically clear up without treatment. A related problem is the use of 'empirical therapy', in which broad spectrum drugs are prescribed rather than waiting for test results and targeting a particular organism with the most effective narrow-spectrum drug available.

- Prophylactic use of antibiotics in the absence of a specific need can also lead to the development of resistance by creating an environment in which selective pressure favors the proliferation of resistant organisms. This includes unnecessary use of over-the-counter antibiotics, such as topical creams, instead of equally effective disinfecting agents.

- AMR has also been associated with antimicrobial use in veterinary medicine and livestock production. Some reports estimate that US livestock producers use approximately 11.2 million kilograms of antimicrobials for non-therapeutic purposes primarily to promote the growth of cattle, hogs, and poultry, while clinical uses are estimated at only about 10% of total antimicrobial use. The contribution of the aquaculture sector is not expected to be a significant percentage of the non-human use of antimicrobials.

- AMR developed in bacteria found in animals may be transmitted to human pathogens. There is increasing evidence that resistant bacteria are being transferred from farm animals to humans possibly through food, water or direct/indirect contact.

- The impact of antimicrobial use in non-food animals such as companion animals (pets) on the development of AMR is not known. However, there is ample opportunity for exchange of resistance genes between bacteria in companion animals and those in humans.

- There is increasing concern that the use of bactericides, disinfectants and antiseptics in the home, community and health care facilities (in cleaning supplies, personal hygiene products, etc.) and the incorporation of these agents in common household products increases selective pressure on bacteria to develop resistance towards these agents.

- Deliberate release into the environment of genetically-modified organisms (GMOs) containing AMR markers of clinical and veterinary importance may pose a risk of gene transfer from the GMOs and their food products to the gut microorganisms or to other microorganisms in the environment.

Part 2

Have students complete the "Superbugs" activity detailed in the National Institutes of Health module on Emerging and Re-emerging Infectious Diseases (http://science.education.nih.gov/supplements/nih1/diseases/default.htm). In this activity, students investigate the growth of bacteria in the presence of antibiotics and use the results to explain a case of antibiotic-resistant tuberculosis, presented in an Internet-based interview. This activity requires 5 to 7 days to complete.

The BRIDGE Connection

www.vims.edu/BRIDGE/ – Type "bacteria" in the search box for links to information about beneficial bacteria in the marine environment.

The "Me" Connection

Have students write a short essay on what actions they could take to address the problem of antimicrobial resistance.

Connections to Other Subjects

English/Language Arts, Mathematics, Earth Science, Life Science

Evaluation

Written reports prepared in Step 2, and discussions in Step 3 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov to find out more about the 2004 Estuary to the Abyss Expedition and about opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.

2. Visit http://oceanexplorer.noaa.gov/explorations/03bump/background/edu/edu.html for additional education activities related to exploration of the Charleston Bump.

Resources

www.hc-sc.gc.ca/vetdrugs-medsvet/ amr_issue_id_paper_e.html – Background paper on antimicrobial resistance

http://www.bioteach.ubc.ca/Biomedicine/antibioticsagain/ – From Dyes to Peptides: The Evolution of Antibiotic Drugs

www.what-is-cancer.com/ papers/HowToDiminishResistance.html – How to diminish microbial resistance to antibiotics

www.esb.utexas.edu/palmer/bio303/group13/rs.html - Good discussion of microbial resistance mechanisms

http://science.education.nih.gov/supplements/nih1/diseases/default.htm – Educational module on Emerging and Re-emerging Infectious Diseases presented by the National Institutes of Health

oceanexplorer.noaa.gov/explorations/03bump/background/plan/plan.html – Simulated flyover of the Charleston Bump

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

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
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms

Content Standard E: Science and Technology
- Understandings about science & technology

Content Standard F: Science in Personal and Social Perspectives
- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

For More Information

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