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To accompany the peer-reviewed article by Trudy M. Wassenaar, Ph.D.:
"Bacteria: More Than Pathogens" (July 2002)
http://www.actionbioscience.org/biodiversity/wassenaar.html

Bacteria: Friend or Foe? (January 2003)

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Grades & Levels:

- **Handout 1:** middle school – high school (general-advanced)
- **Handout 2:** high school (advanced/AP) – undergraduate (year 1)

Time Recommendations:

- 1-2 class periods for article review and background research
- 2-5 class periods for lab activity (Part B of either handout)
- up to 3 weeks for group projects and Bacteria Quiz

NSES (USA) Content Standards, 5-8 & 9-12:

- NSES 1.2. Unifying Concepts & Processes: evidence, models, and explanation
- NSES 2.1. Science as Inquiry: abilities necessary to do scientific inquiry
- NSES 2.2. Science as Inquiry: understanding about scientific inquiry
- NSES 4.1. Life Science: the cell
- NSES 4.4. Life Science: interdependence of organisms
- NSES 5.2. Earth & Space Science: geochemical cycles
- NSES 7.1. Science in Personal & Social Perspectives: personal and community health
- NSES 7.4. Science in Personal & Social Perspectives: environmental quality
- NSES 7.5. Science in Personal & Social Perspectives: natural and human-induced hazards

Note: View the NSES content standards on this site to choose other curricular applications for additional activities at: http://www.actionbioscience.org/educators/correlationcharts.html

Learning Objectives: Students will…

- examine a variety of environmental and industrial roles of bacteria
- explore where bacteria can be found in everyday life
- describe what distinguishes bacteria from other organisms

Key Words Include:
aerobic, anaerobic, antibiotics, bacteria, bacteriophage, biomass, disease, ecosystem, eukaryote, fermentation, heterotrophic, immune system, intestinal flora, microbes, nitrogen fixation, pathogen, prokaryote, symbiosis, virus

Preparation

Article Discussion:

- Distribute or ask students to download and read Wassenaar's article at http://www.actionbioscience.org/biodiversity/wassenaar.html
- Follow the reading with questions about the article. Suggested questions are listed on page 2. Students can answer questions orally in class, brainstorm answers in groups, or complete content questions and/or extension questions as a written assignment.

Bacteria Quiz:

This activity may be suitable to middle school and high school grades and so it may accompany either Handout 1 or 2. Research may be required to complete the quiz.

Student Handout 1 or 2:

- Distribute Student Handout 1 for middle - high school (general - advanced) activities or Student Handout 2 for high school (advanced/AP) - undergraduate (year 1) activities.
- Part A of each handout lists several non-lab activities for group assignment.
- Part B of each handout provides a lab experiment (sampling activity) involving growing bacteria on nutrient agar plates, and while it is extremely unlikely that students will grow anything potentially pathogenic, it is important to observe and to teach students standard sterile protocol. If unfamiliar with this, see Micklos & Freyer's *DNA Science* (1990). The experiments are designed for teams of 3 to 4 students and the materials are readily available from any commercial science supplier.
- Refer students to "Useful Links" in the *Educator Resources* section at the end of the Wassenaar article. These links help students with their activities and provide a source for research information.

For Educators: Article Discussion

About the article by Trudy M. Wassenaar, Ph.D.: "Bacteria: More Than Pathogens"
http://www.actionbioscience.org/biodiversity/wassenaar.html

Content Questions:

1. What are bacteria and how are they different from other organisms?
2. Why are most bacteria unable to live in our bodies?
3. Where do beneficial bacteria live in our bodies?
4. What role(s) do they play in our bodies?
5. What impact do antibiotics have on the beneficial bacteria that live in our bodies?
6. What are some examples of how we use bacteria for commercial purposes?
7. Where on the earth do bacteria live?

Extension Questions:

1. Wassenaar mentions that antimicrobial agents are added to a wide variety of commercial products (soaps, plastics, etc.). Besides bacteria, what other kinds of microscopic organisms are these chemical agents intended to retard the growth of? When might that be especially useful?
2. Why do you think better hygiene led to a decrease in child mortality?
3. What kinds of niches do you think bacteria might occupy in the ecosystem?
4. Why do you think bacteria are so successful at living almost anywhere on Earth?
5. What impact might the use of antimicrobial substances have on the bacteria populations that come into contact regularly with humans?
6. Wassenaar mentions a number of ways your body defends itself against bacterial invasion; what do you think are some other ways your body prevents infection?
7. Biologists can now manipulate the genetic code of many bacteria, engineering them to perform tasks they might not otherwise be able to do; what are some useful purposes to which you think science might put these "designer" bacteria?

BACTERIA QUIZ *Circle the correct answer(s). Some questions have more than one answer.*

1. Which type of bacteria cannot thrive in oxygen?
a) cyanobacteria b) aerobic c) anaerobic d) antibiotic

2. To which group do bacteria belong?
a) eukaryotes b) prokaryotes c) protists d) algae

3. What color are gram-positive bacteria?
a) red b) green c) white d) purple

4. What is the whip-like appendage called on some bacteria?
a) flagellum b) chlorophyll c) ribosome d) filament

5. What are hair-like structures on the body of certain bacteria called?
a) pili b) fungi c) fimbriae d) polymerase

6. How do most bacteria reproduce?
a) DNA transfer b) binary fission c) conjugation d) translocation

7. What is the small DNA segment in a bacterium called?
a) nucleoid b) capsule c) peptidoglycan d) plasmid

8. Where in the human body will you find *E. coli*?
a) mouth b) heart c) gut d) blood

9. Which of these products does not involve a bacterial process?
a) yogurt b) wine c) vitamin C d) sourdough bread

10. What are rod-shaped bacteria called?
a) cocci b) spirilla c) eubacteria d) bacilli

11. How do heterotrophic bacteria get their energy?
a) transduction b) from sunlight c) oxidation d) feed on organisms

12. What is the jelly-like substance in which the bacteria's DNA is suspended?
a) membrane b) cytoplasm c) endospore d) cosmid

13. What does a bacteriophage do?
a) infects bacteria b) destroys viruses c) makes antibodies d) invades human cells

14. How far back, approximately, have scientists dated cyanobacteria fossils?
a) 10,000 years b) 3 billion years c) 1.5 billion years d) 650 million years

15. What bacteria caused the infamous Black Plague of the 14th century?
a) *lactobacilli* b) *Vibrio cholerae* c) *Y. pestis* d) *A. Escherichia coli*

16. What are microbes called that can survive in extreme environments?
a) halophiles b) autotrophs c) pseudomonae d) extremophiles

Bacteria: Friend or Foe?
Student Handout 1

A. GROUP PROJECTS

1. Bacteria Fan Club
There's a public health exhibit in your town. The exhibitors are giving bacteria a bad rap. Create a presentation for the exhibit that tells the "good" story about these microorganisms. Research the basic cellular structures and functions of bacteria. Then choose one of the following topics (additional research will be required) regarding bacteria in:

- food preparation
- nitrogen fixation and plant fertilization
- genetic engineering
- hot springs and/or undersea thermal vents

2. The Wanted List
Create flyers for a gallery of "Most Wanted" (beneficial bacteria) and "Least Wanted" (pathogenic bacteria). For each flyer:

- provide a mug shot (picture) of the bacterium
- name the bacterium (you can add humor, e.g., Sly the *Salmonella typhi*)
- indicate where it might be found (its natural hangout)
- specify it's crime (e.g., poison suspect) or benefit (e.g., yogurt helper)

3. Bacteria at Work
Your eco-friendly team will design an experiment to show why composting is a good idea in your school. There are a few basic requirements for composting, so research the topic on the Internet.

- First, design and conduct 3 to 5 trials during a one-week period, using small jars/pails as composters, to determine what conditions help or hinder decomposition. Keep a journal of daily observations about the color, texture, and events occurring in each container.
- Then, make a list of the benefits of composting that could be posted in the school cafeteria.

4. Virus vs. Bacterium
Write a funny skit about a virus and a bacterium debating which one is better. Include comments about their appearance (structure, size, etc.), abilities (good and/or bad), and anything else that they can boast about. Present the skit in class or record it on audiotape.

B. EXPERIMENT: BACTERIA EVERYWHERE

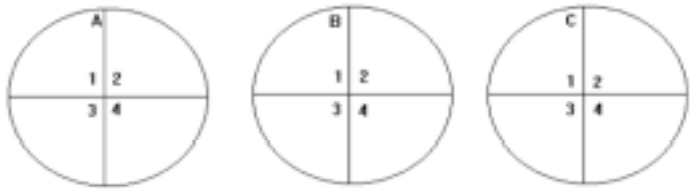
Bacteria are the most common organisms on the face of the earth. From the inside of our intestines to the boiling mud baths of Yellowstone National Park, they are everywhere and affect almost every aspect of our lives. Some consume the oil on our faces (and occasionally create pimples as a result); while others produce the yogurt and cheese we eat. To see just how prevalent bacteria are in our world, let's go hunting!

Instructions

1. Collect three petri dishes with nutrient agar from your teacher. Label them A, B, & C and draw quadrants on them (as shown on top of next page). Prepare a journal to keep a record of your experiment.

Student Handout 1 (cont'd)

Quadrant labeling for petri dishes containing nutrient agar:



2. In plate A, you are going to examine the bacteria that live on your skin. Use fingers from each team member to touch the nutrient agar on the petri plate separately in each quadrant.

3. In the remaining two plates, use sterile cotton swabs to place samples of various materials or surfaces that you want to test for bacteria onto the nutrient agar of plates B & C. You have eight quadrants; so, you can test eight samples. Be sure to document in your journal what you tested for bacterial growth in each quadrant.

4. Place your petri plates in the incubator at 37°C overnight; then, on the next day, record your observations of what grew and where. Do not open any of your petri plates and be sure to follow all safety instructions given by your teacher.

Analysis & Conclusions for the Bacterial Growth Lab

1. Look at each petri dish and answer the following questions:
    a) Was there any growth in each quadrant?
    b) How were you able to tell which sections had growth and which sections did not?
    c) Which quadrants had more growth on them? Why do you think this is the case?
    d) What does the information gained from this experiment tell you about human hygiene?

2. Based on the evidence, which objects or locations in your everyday life have bacteria on them?

3. What role or purpose do you think these bacteria serve living where they do?

4. With all these bacteria growing, why do you think people aren't more sick or sick more often?

Bacteria: Friend or Foe?
Student Handout 2

A. GROUP PROJECTS

1. Plant-It-All Nursery
The Plant-It-All Nursery needs your help. They hired you to create a flyer for their customers about the importance of soil microecology (how bacteria influence the ecology of soils). To produce the flyer, you will need to:

- research the role bacteria play in the various biogeochemical cycles
- find out about their relationship with plants growing in the soil

2. Campus Composter
Your team is concerned about the lack of waste recycling at your campus. Create a proposal for a composter that can use food waste from your cafeteria. There are a few basic requirements for composting methods, so research the topic on the Internet. Your proposal should include:

- design(s) for a composter that is inexpensive and easy to assemble
- a list of food scraps readily available in the cafeteria (you may need to conduct a survey) and useable for the project
- a list of benefits of the composter to the school and the environment

3. Outbreak!
You are sent out as part of a news team to cover the story of an outbreak of a disease caused by a bacterium. Choose a bacterium appropriate to the location where the outbreak originated, e.g., cholera outbreak at a campground by a river. Your research should include:

- research the disease – its causes, symptoms, and treatment
- research the location of the outbreak and its possible connection to the outbreak
- identify cases (since this is a hypothetical case, your cases will exhibit classic characteristics)
- develop a hypothesis of why the outbreak occurred
- suggest ways that the outbreak may have been prevented

Write a news story that summarizes all of your findings.

B. EXPERIMENT: SOIL ECOLOGY

Examine how the school's management of the campus grounds is affecting one of the most critical components of any ecosystem: the soil. Specifically, you will look at the bacteria that inhabit the soil and determine the ecological "health" of the lawns, playing fields, and woodlands. On the next page is a list of "Research Topics" (possible problems and research questions) that your team can choose to pursue. Pick one and:

- narrow it down to your specific question
- use the research techniques for determining bacterial population densities and identification, listed below under "Soil Ecology Protocols"
- design an experiment solution to your question and to test your hypothesis

Student Handout 2 (*cont'd*)

Research Topics

1. What is the population density of bacteria in the soil in various areas of the campus?
2. What is the population density of bacteria at different soil depths?
3. What is the level of biodiversity of bacteria in the soil in various areas of the campus?
4. What is the level of biodiversity of bacteria at different soil depths?
5. How do any of the following properties of soil impact the population density and/or biodiversity of bacteria?
   a. texture
   b. water dynamics
   c. bulk density
   d. pH

Soil Ecology Protocols

I. Serial Dilutions for Bacteria Counts

1. Place 1 cc of your soil sample into a culture tube containing 10 ml of sterile water; cap the tube and shake vigorously.
2. Using a serological pipette, remove 1 ml of the soil/water mixture and place into a fresh culture tube.
3. Add 9 ml of fresh sterile water to this second tube; cap and shake vigorously.
4. Repeat step 2 using the second diluted tube and then repeat step 3 with the third tube.
5. Continue step 4 with each additional tube until you have diluted the original soil/water mixture a minimum of four times (a 10^{-4} dilution). You should now have a total of five culture tubes.
6. Place 100 microliter samples from the 4^{th} and 5^{th} tubes (dilutions 10^{-3} & 10^{-4}) onto their own separate petri plates filled with nutrient agar. Allow the plates to incubate at room temperature overnight.
7. Examine each of the two plates for individual bacteria colonies and choose the plate with the fewest colonies to make your estimates of the number of bacteria in the original 1 cc soil sample (# of colonies on plate x 10^2 = # of bacteria in dilution tube; # of bacteria in dilution tube x $10^{[\#\text{ of dilutions}]}$ = # of bacteria in original sample tube). Document your findings on the # of bacteria/cc of soil.
8. If there are not individual colonies but still a "lawn" at the 10^{-4} dilution, repeat steps 1-6, adding a 5^{th} dilution, 6^{th} dilution, etc. as necessary until individual colonies are observed.

II. Bacterial Identification

There are two ways to examine & identify your bacteria colonies:

1. Use a sterile cotton swab to apply a thin smear of bacteria to a microscope slide and then use the standard protocol for preparing a Gram +/- slide to observe under the microscope; sort by shape into rod (bacillus), sphere (coccus), or spiral (spirillum).
2. Examine the color of the colonies and sort by pigmentation; while not as precise as Gram staining, it will allow you to sort your bacteria into general family groups.