

the science of
MICROBES

Microbes Are Everywhere

Activity from *The Science of Microbes: Teacher's Guide*

by

Nancy P. Moreno, Ph.D.

Barbara Z. Tharp, M.S.

Deanne B. Erdmann, M.S.

Sonia Rahmati Clayton, Ph.D.

James P. Denk, M.A.

RESOURCES

Free, online presentations of each activity, downloadable activities in PDF format, and annotated slide sets for classroom use are available at www.BioEdOnline.org or www.k8science.org/.

BCM
Baylor College of Medicine

TEACHER RESOURCES FROM THE CENTER FOR EDUCATIONAL OUTREACH AT BAYLOR COLLEGE OF MEDICINE

The mark "BioEd" is a service mark of Baylor College of Medicine. The information contained in this publication is for educational purposes only and should in no way be taken to be the provision or practice of medical, nursing or professional healthcare advice or services. The information should not be considered complete and should not be used in place of a visit, call, consultation or advice of a physician or other health care provider. Call or see a physician or other health care provider promptly for any health care-related questions.

Development of The Science of Microbes educational materials is supported, in part, by a Science Education Partnership Award from the National Center for Research Resources (NCRR) of the National Institutes of Health (NIH), grant number 5R25 RR018605. The activities described in this book are intended for school-age children under direct supervision of adults. The authors, Baylor College of Medicine (BCM), the NCRR and NIH cannot be responsible for any accidents or injuries that may result from conduct of the activities, from not specifically following directions, or from ignoring cautions contained in the text. The opinions, findings and conclusions expressed in this publication are solely those of the authors and do not necessarily reflect the views of BCM, image contributors or the sponsoring agencies.

Cover images of children and teacher (models) © 2007 PunchStock. Photographs used throughout this guide, whether copyrighted or in the public domain, require contacting original sources to obtain permission to use images outside of this publication. The authors, contributors, and editorial staff have made every effort to contact copyright holders to obtain permission to reproduce copyrighted images. However, if any permissions have been inadvertently overlooked, BCM will be pleased to make all necessary and reasonable arrangements.

Many microscopic images used in this guide, particularly images obtained from the Public Health Image Library of the Centers for Disease Control and Prevention (CDC), are part of an online library containing other images and subject matter that may be unsuitable for children. Caution should be used when directing students to research health topics and images on the Internet. URLs from image source websites are provided in the Source URL list, to the right.

Authors: Nancy P. Moreno, Ph.D., Barbara Z. Tharp, M.S., Deanne B. Erdmann, M.S.,
Sonia Rahmati Clayton, Ph.D., and James P. Denk, M.A.

Creative Director and Editor: Martha S. Young, B.F.A.

Senior Editor: James P. Denk, M.A.

ACKNOWLEDGMENTS

This guide was developed in partnership with the Baylor-UT Houston Center for AIDS Research, an NIH-funded program (AI036211). The authors gratefully acknowledge the support and guidance of Janet Butel, Ph.D., and Betty Slagle, Ph.D., Baylor-UT Houston Center for AIDS Research; and William A. Thomson, Ph.D., BCM Center for Educational Outreach. The authors also sincerely thank Marsha Matyas, Ph.D., and the American Physiological Society for their collaboration in the development and review of this guide; and L. Tony Beck, Ph.D., of NCRR, NIH, for his assistance and support. In addition, we express our appreciation to Amanda Hodgson, B.S., Victor Keasler, Ph.D., and Tadzia GrandPré, Ph.D., who provided content or editorial reviews; and J. Kyle Roberts, Ph.D., and Alana D. Newell, B.A., who guided field test activities and conducted data analyses. We also are grateful to the Houston-area teachers and students who piloted the activities in this guide.

We are indebted to many scientists and microscopists who contributed SEM and TEM images to the CDC's Public Health Image Library, including Janice H. Carr, James D. Gathany, Cynthia S. Goldsmith, M.S., and Elizabeth H. White, M.S. We especially thank Louisa Howard and Charles P. Daghighian, Ph.D., Electron Microscope Facility, Dartmouth College, for providing several of the SEM and TEM images used in this publication. We thank Martha N. Simon, Ph.D., Joseph S. Wall, Ph.D., and James F. Hainfeld, Ph.D., Department of Biology-STEM Facility, Brookhaven National Laboratory; Libero Ajello, Ph.D., Frank Collins, Ph.D., Richard Facklam, Ph.D., Paul M. Feorino, Ph.D., Barry S. Fields, Ph.D., Patricia I. Fields, Ph.D., Collette C. Fitzgerald, Ph.D., Peggy S. Hayes, B.S., William R. McManus, M.S., Mae Melvin, Ph.D., Frederick A. Murphy, D.V.M., Ph.D., E.L. Palmer, Ph.D., Laura J. Rose, M.S., Robert L. Simmons, Joseph Strycharz, Ph.D., Sylvia Whitfield, M.P.H., and Kyong Sup Yoon, Ph.D., CDC; Dee Breger, B.S., Materials Science and Engineering, Drexel University; John Walsh, Micrographia, Australia; Ron Neumeyer, Microimaging Services, Canada; Clifton E. Barry, III, Ph.D., and Elizabeth R. Fischer, National Institute of Allergy and Infectious Diseases, NIH; Mario E. Cerritelli, Ph.D., and Alasdair C. Steven, Ph.D., National Institute of Arthritis and Musculoskeletal and Skin Diseases, NIH; Larry Stauffer, Oregon State Public Health Laboratory-CDC; David R. Caprette, Ph.D., Department of Biochemistry and Cell Biology, Rice University; Alan E. Wheals, Ph.D., Department of Biology and Biochemistry, University of Bath, United Kingdom; Robert H. Mohlenbrock, Ph.D., USDA Natural Resources Conservation Service; and Chuanlun Zhang, Ph.D., Savannah River Ecology Laboratory, University of Georgia, for the use of their images and/or technical assistance.

No part of this book may be reproduced by any mechanical, photographic or electronic process, or in the form of an audio recording; nor may it be stored in a retrieval system, transmitted, or otherwise copied for public or private use without prior written permission of the publisher. Black-line masters reproduced for classroom use are excepted.

Center for Educational Outreach, Baylor College of Medicine
One Baylor Plaza, BCM411, Houston, Texas 77030 | 713-798-8200 | 800-798-8244 | edoutreach@bcm.edu

www.BioEdOnline.org | www.k8science.org | www.bcm.edu/edoutreach

SOURCE URLs

BAYLOR COLLEGE OF MEDICINE

BIOED ONLINE TEACHER RESOURCES

www.BioEdOnline.org | www.k8science.org
p. 3, 6, 10, 14, 26

MOLECULAR VIROLOGY AND MICROBIOLOGY

www.bcm.edu/molvir

p. ii

BROOKHAVEN NATIONAL LABORATORY

BIOLOGY - STEM FACILITY

www.biology.bnl.gov

p. 30

CENTERS FOR DISEASE CONTROL AND PREVENTION

PUBLIC HEALTH IMAGE LIBRARY

www.cdc.gov

http://phil.cdc.gov

Cover, pp. 1, 4, 5, 7, 8, 9, 10, 12, 13, 14, 17, 18, 20, 21,
22, 23, 24, 27, 28, 29, 31, 32, 33, 34, 35, 36, 39, 40, 41,
42, 45, 46, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58

DARTMOUTH COLLEGE

ELECTRON MICROSCOPE FACILITY

www.dartmouth.edu/~emlab/

pp. ii, 28, 35, 54

DREXEL UNIVERSITY

MATERIALS SCIENCE AND ENGINEERING

www.materials.drexel.edu/breger

p. 28

MICROIMAGING SERVICES (Canada)

www.microimaging.ca

pp. 9, 14, 20

MICROGRAPHIA (Australia)

www.micrographia.com

p. 13

NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES, NIH

www.niaid.nih.gov

p. 43

NATIONAL INSTITUTE OF ARTHRITIS AND MUSCULOSKELETAL AND SKIN DISEASES, NIH

www.niams.nih.gov

p. 30

OREGON STATE PUBLIC HEALTH LABORATORY-CDC

www.oregon.gov/dhs/ph/phil

p. 53

RICE UNIVERSITY

BIOCHEMISTRY AND CELL BIOLOGY

www.biochem.rice.edu

p. 26

UNIVERSITY OF BATH

BIOLOGY AND BIOCHEMISTRY

(United Kingdom)

www.bath.ac.uk/bio-sci

p. 15

UNIVERSITY OF GEORGIA

SAVANNAH RIVER ECOLOGY LABORATORY

www.uga.edu/srel/Nevada_Hot_Springs

p. 35

USDA NATURAL RESOURCES CONSERVATION SERVICE

www.plants.usda.gov

p. 11



INTRODUCTION

Microbial Challenges

Infectious diseases have plagued humans throughout history.

Sometimes, they even have shaped history. Ancient plagues, the Black Death of the Middle Ages, and the “Spanish flu” pandemic of 1918 are but a few examples.

Epidemics and pandemics always have had major social and economic impacts on affected populations, but in our current interconnected world, the outcomes can be truly global. Consider the SARS outbreak of early 2003.

This epidemic demonstrated that new infectious diseases are just a plane trip away, as the disease was spread rapidly to Canada, the U.S. and Europe by air travelers. Even though the SARS outbreak was relatively short-lived and geographically contained, fear inspired by the epidemic led to travel restrictions and the closing of schools, stores, factories and airports. The economic loss to Asian countries was estimated at \$18 billion.

The HIV/AIDS viral epidemic, particularly in Africa, illustrates the economic

For an emerging disease to become established, at least two events must occur: 1) the infectious agent has to be introduced into a vulnerable population, and 2) the agent has to have the ability to spread readily from person to person and cause disease. The infection also must be able to sustain itself within the population and continue to infect more people.

and social effects of a prolonged and widespread infection. The disproportionate loss of the most economically productive individuals within the population has reduced workforces and economic growth in many countries, especially those with high infection rates. This affects the health care, education, and political stability of these nations. In the southern regions of Africa, where the infection rate is highest, life

expectancy has plummeted in a single decade, from 62 years in 1990–95 to 48 years in 2000–05. By 2003, 12 million children under the age of 18 were orphaned by HIV/AIDS in this region.

Despite significant advances in infectious disease research and treatment, control and eradication of diseases are slowed by the following challenges.

- The emergence of new infectious diseases
- An increase in the incidence or geographical distribution of old infectious diseases
- The re-emergence of old infectious diseases
- The potential for intentional introduction of infectious agents by bioterrorists
- The increasing resistance of pathogens to current antimicrobial drugs
- Breakdowns in public health systems.



Baylor College of Medicine, Department of Molecular Virology and Microbiology, www.bcm.edu/molvir/.

USING COOPERATIVE GROUPS IN THE CLASSROOM

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result.

The Teaming Up! model* provides an efficient system for cooperative learning. Four “jobs” entail specific duties. Students wear job badges that describe their

duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. Suggested job titles and duties follow.

Principal Investigator

- Reads the directions
- Asks the questions
- Checks the work

Maintenance Director

- Follows the safety rules
- Directs the cleanup
- Asks others to help

Reporter

- Records observations and results
- Explains the results
- Tells the teacher when the group is finished

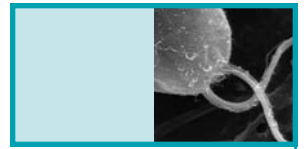
Materials Manager

- Picks up the materials
- Uses the equipment
- Returns the materials

* Jones, R.M. 1990. *Teaming Up!* LaPorte, Texas: ITGROUP.

Overview

Students will grow bacteria and/or fungi from a variety of locations and compare the results. They will learn that microbes are everywhere. Some microbes, such as bacteria and fungi, grow readily on sources of food and water. When provided with the resources they need, microbes can reproduce very rapidly.



Chlamydomonas algae. Dartmouth College/L. Howard, C. Daglian.

TIME

Setup: 30 minutes

Activity: 45 minutes
for first class session

Following 3 days:
15 minutes daily to
observe cultures

M I C R O B E S A R E

Everywhere

Microbes grow and reproduce in habitats where no other organisms can survive. They can be found in hot springs and deep underground veins of water, in volcanic rock beneath the ocean floor, in extremely salty water in the Great Salt Lake and the Dead Sea, and below the ice of Antarctica. Not even radiation or high levels of deadly chemicals, such as lead or sulphur, can kill the hardest of microbes, referred to by scientists as “extremophiles.” Most extremophiles are single-celled organisms similar to bacteria, called Archaea. Many classifications place Archaea (or archaeobacteria) in their own kingdom or domain, instead of with bacteria.

Microbes also are found in more mundane places, such as on our hands, in the air and in soil. This activity is designed to help students understand the diversity of microorganisms present in our immediate surroundings and on our bodies. It also will teach students how to limit the spread of disease-causing microbes. In addition, students will observe examples of bacteria and fungi.

Bacteria are the most numerous living things on Earth. Each bacterium consists of a tiny cell that must be magnified at least 400 times to be visible. Even though individual cells are not visible without the aid of a microscope, bacterial colonies (clumps



Extremophiles include microbes that grow both at or above pH 8 and at or above 60°C. The Three Buddhas geysers in the Nevada Hot Springs is one place where heat-tolerant microbes can be found. University of Georgia, Savannah River Ecology Laboratory/C. Zhang.

of bacteria) grow large enough to be seen clearly.

Yeasts are fungi. They are small, single-celled organisms that can reproduce asexually by producing buds. They are known for their ability to obtain energy from food sources through a process known as fermentation. Fermentation yields alcohol and carbon dioxide gas as byproducts. It is used in the production of alcoholic beverages, such as beer and wine, and in making bread and other baked goods.

Molds, which also are fungi, consist of long, tangled filaments. Hair-like masses of molds often contaminate bread and cheese. They also are important, but usually unnoticed components of soil.

Continued

SCIENCE EDUCATION CONTENT STANDARDS

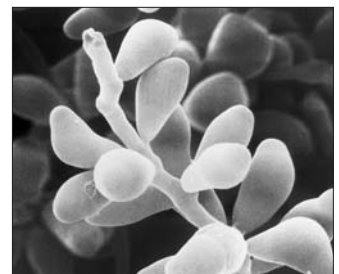
Grades 5–8

Inquiry

- Identify questions that can be answered through scientific investigations.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.

Life Science

- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Some diseases are the result of damage by infection by other organisms.
- Populations of organisms can be categorized by the function they serve in an ecosystem.



Curvularia geniculata is a fungus in soil that causes disease, primarily in plants. CDC\204 J. Carr, R. Simmons.



MICROBES IN SOIL

Normal soils are full of microbes. One gram of soil may contain hundreds of millions of different microorganisms, including various types of bacteria, fungi, algae and protozoans.

Microbes help improve the texture of soil and make nutrients for plants from dead organisms and waste. Special kinds of bacteria convert nitrogen gas from the atmosphere into chemical forms that can be used by plants (nitrogen fixation).

MATERIALS OPTIONS

- For convenience, commercially prepared Petri dishes may be purchased with agar already added.
- Slices of cooked potatoes can be used as an alternative to nutrient agar. Boil whole potatoes until almost soft. Using a clean, dry knife, cut potatoes into 1/4-in. slices. Place each slice in a Petri dish or a clean, resealable, plastic bag.

To safely discard potatoes in the bags after the activity, pour about 20 mL of a 10% bleach solution into each bag. Seal and discard the bags.

In some instances, infections by bacteria or fungi can cause disease. Contamination by these organisms also can make food unsafe to eat. The slime found on food that has been in the refrigerator too long is made of clumps of bacteria and sometimes fungi. Eating spoiled food can make humans and other animals sick.

Bacteria can be transferred to food when people do not wash their hands after using the restroom, changing diapers or playing with a pet. Some foods, especially meats and poultry, can have bacteria on their surfaces that can be transferred to other foods if utensils and cutting boards are not washed with soap and hot water after each use.

In the laboratory, bacteria are grown on substances called culture media. The medium usually contains an energy source, such as a sugar dissolved in water, plus other nutrients, such as nitrogen. Culture media can be in liquid form (usually called a broth) or gelatin-like (called a gel).

In this activity, students will grow microbes on a semisolid gel refined from algae, a medium often referred to as nutrient agar.

MATERIALS

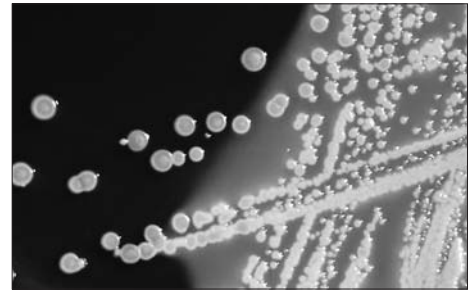
Teacher (see Setup)

Read Materials Options (left sidebar).

- 750 mL of nutrient agar (purchase as powder or bottled agar gel)
- 33 100-mm sterile, disposable Petri dishes (to prepare 30 dishes with agar and 3 dishes for templates for student drawings)
- 36 small, resealable plastic bags
- Chlorine bleach solution
- Cotton swabs, 100-count box
- Disinfectant (liquid soap or spray)
- Hot pads or pot holders
- Paper towels
- Resealable plastic bag, medium-size

Per Group of Students

- 5 prepared Petri dishes (one dish is the control)



These are colonies of *Escherichia coli* bacteria grown on an agar plate medium. *E. coli* are commonly found in the large intestines of healthy individuals. Most strains are harmless, but a few kinds can cause disease. Some forms of *E. coli* cause “travelers diarrhea” and other intestinal infections. Harmful strains of *E. coli* are spread by food or water contaminated with animal or human waste. Poor hygiene, especially not washing hands, also contributes to the spread of *E. coli* microbes. CDC\6676.

- 4 sterile cotton swabs in a resealable plastic bag
- Clean, empty Petri lid or dish (for use as a drawing template)
- Container of distilled or boiled water
- Magnifiers or low power microscopes
- Masking tape
- Permanent marker or wax pencil
- Colored pencils or markers
- 12 sheets of white paper for observations (3 per student)
- Graph or plain paper
- Group concept map (ongoing)

SETUP

Place four sterile, cotton-tipped swabs in a resealable plastic bag for each group.

If not using pre-poured Petri dishes, prepare the dishes in advance (one hour to one day before conducting the activity). Mix powdered nutrient agar following package directions. If using bottled agar gel, completely loosen the cap on the bottle of agar, set the bottle in a pan of boiling water or in a microwave oven, and warm it until the agar melts (about 60°C).

If using a microwave oven, heat the bottle on high for 30 seconds. Use a hot pad to remove the bottle and swirl to mix the agar. Heat and swirl at 10 second intervals until the agar is



completely melted. To avoid condensation in the Petri dishes, let the agar cool slightly before pouring it into the dishes.

Open each Petri dish slightly, pour in enough agar to cover the bottom, (approximately 1/8 in.), and immediately replace the cover. Let the agar cool and solidify, and then store the dishes upside down to prevent condensation.

During the activity, store sealed Petri dishes upside down in a dark, warm place (at or about 37°C or 98.6°F).

Have students work in groups of four.

SAFETY ISSUES

See sidebar, right.

PROCEDURE

Session 1: Getting Started

1. Ask students to share what they already have learned about where microbes might live and grow. Follow by asking, *Do you think there are any microbes in this room? Where might they be?* List students' ideas on the board or overhead.
2. Follow by asking, *How could we find out if any microbes are present in these places?* Encourage students to share their ideas, reminding them of the activity in which they observed bacteria growing in yogurt. If not mentioned by students, suggest that the class could collect samples from different places, provide opportunities for microbes from the samples to develop, and observe the results.
3. Have each group of students select four places (or more, depending on the number of Petri dishes available) that they would like to test for the presence of microbes. Possibilities include the floor, a doorknob, unwashed hands, etc.
4. Have each group create a table with two columns: "Location Sampled" and "Predicted Results." Students should record information on this chart as they collect samples. For example, a group might predict that a sample from the doorknob will have more microbes than a sample from the surface of the door.
5. Review Safety Issues with students (right sidebar). Then, give each group five Petri dishes. One dish will be a control. The remaining four dishes will be used to grow cultures (one per student). Have students label the bottom of all five dishes using masking tape and a marker, or by writing directly on the dishes using a permanent marker or wax pencil. (You may grow more than one culture per dish. Simply divide each dish in half or quarters, drawing lines on the outside with a permanent marker.)
6. Have students use a different clean cotton swab dipped in boiled or distilled water for each sample. You may want to have students think about why the water needs to be boiled or distilled. (Otherwise, the water may contain microbes.) Have students rub the moist swab several times over the area to be tested.
7. Instruct students to open the Petri dishes only enough to swab the gel surface. Tell them to rub the swab *gently* in a zigzag pattern over the surface of the nutrient agar *without breaking the surface of the agar gel*. Students may repeat the pattern in another direction. Have students close and seal the dishes by taping around the edges. Tell students that they will not be able to see streaks on the plate after swabbing. Have students rub (inoculate) the control dish with a clean, moist swab.
8. Collect used swabs from students and discard as instructed in Safety

Continued

SAFETY ISSUES

Most bacteria are harmless to healthy people. However, because some kinds of bacteria can cause disease, it is important that the Petri dishes remain closed after students have started the cultures.

Students should not collect or test saliva, tears or other body fluids.

Dispose of used cotton swabs by placing them in a resealable plastic bag. Cover swabs with a 10% bleach solution (10 mL chlorine bleach mixed with 90 mL water). Seal the bag and discard.

Dispose of cultures immediately after the activity. Carefully remove the tape used to seal each dish and place each closed Petri dish in a separate, resealable plastic bag. Pour about 20 mL of a 10% bleach solution in the plastic bag. Seal the bag. Through the sides of the closed bag, loosen the cover of the Petri dish enough to allow the bleach solution to move inside and completely cover the contents of the dish. Dispose of the plastic bag and its contents in the trash.

Follow all district and school science laboratory safety procedures. It is good laboratory practice to have students wash hands before and after any laboratory activity. Clean work areas with disinfectant.





EXTENSIONS

- Have students design additional experiments to test for the presence of microbes. They might examine water from different sources, compare washed vs. unwashed hands, or see which kinds of food grow the most kinds of microbes or spoil most quickly.
- Have students investigate what happens when similar samples are grown at room temperature and in the refrigerator. Based on their results, conduct a discussion about the importance of refrigerating leftover food.

Issues. Clean all work areas with paper towels and disinfectant.

9. Collect and store sealed Petri dishes.

Sessions 2–4: Follow-up

1. Distribute clean Petri lids or dishes. Have each student use a dish as a template to draw three separate circles, labeled “Day 1,” “Day 2” and “Day 3.” Have each group member observe and draw one of the group’s cultures each day. Ask one group member to prepare an additional sheet for observing the control. Students should take turns making control observations.
2. Have students observe the cultures daily for 1 to 3 days. If possible, have them use a low power microscope to observe the cultures through the lids of the dishes. *Do not allow students to open the Petri dishes.*
3. Conduct a class discussion. Ask, *What has changed inside the Petri dishes?* (Bacteria will discolor the surface of the culture medium and form smooth, wrinkly or slimy circular blotches, called “colonies,” of different colors. Molds, which form fuzzy or felt-like colonies, also may be present.)
4. Have students decide how many different kinds of organisms might be growing on their gels, based on differences they can observe. *Do not allow students to open the dishes.*
Some common microorganisms that might be present include fuzzy green *Penicillium* mold, black fuzzy or hairy bread mold, or various circular white, dark or colored colonies of bacteria. Yeast colonies usually are white. It is not important for students to be able to name all the microbes.
5. On Day 3, have students count the number of colonies, or measure and compare diameters of the colonies on their observation sheets. Have students decide which sample sources had the most microbes. Students’ drawings from all three days also can be used to estimate microbial growth by reviewing changes in the number or size of the colonies over time.
6. Have each group prepare a brief summary comparing its observations with its chart of sample locations and predicted results. Have groups share their summaries with the rest of the class.
7. Based on these reports, have students answer the question posed at the beginning of the activity: *Are there any microbes in the room? If so, where are they?* Promote discussion by asking questions, such as, *If there are microbes all around us, why aren’t we all sick? Relate students’ findings to the activity, “What Do You Know About Microbes?”* in which fluorescent powder was used to simulate microbes on students’ hands.
8. Also, discuss the multiple roles of microbes in the environment. Ask, *Have you ever seen any colonies of microbes (particularly bacteria and molds) growing on food, on damp surfaces, or in natural environments? What do you think is happening when microbes grow on something?* (The microbes are using the substance as a food source.) Discuss the important roles of microorganisms as decomposers of dead organic material in ecosystems.
9. Allow students time to add to their concept maps. 