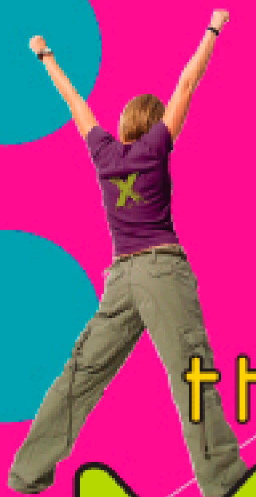
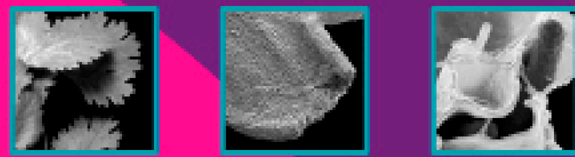
BioEd℠





the science of MICROBES

Teacher's Guide

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.

BCM
Baylor College of Medicine

BioEd[SM]

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., and 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

Printed in the United States of America

ISBN-13: 978-1-888997-54-5
ISBN-10: 1-888997-54-0

BioEd℠

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

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.

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 endebted 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. Daghlian, 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.

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

BCM® Baylor College of Medicine

CFAR CENTER FOR AIDS RESEARCH Baylor-UT Houston

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
Supported by the National Center for Research Resources, a part of the National Institutes of Health

SOURCE URLs

BAYLOR COLLEGE OF MEDICINE
BIOED ONLINE | K8 SCIENCE
www.bioedonline.org | www.k8science.org
p. 3, 6, 10, 14, 26
BAYLOR-UT CENTER FOR AIDS RESEARCH
www.bcm.edu/cfar
p. ii
MOLECULAR VIROLOGY AND MICROBIOLOGY
www.bcm.edu/molvir
p. ii
BAYLOR-UT CENTER FOR AIDS RESEARCH
www.bcm.edu/cfar
p. 25

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, p. 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
p. ii, 28, 35, 54

DREXEL UNIVERSITY
MATERIALS SCIENCE AND ENGINEERING
www.materials.drexel.edu
p. 28

MICROBIAL LIFE EDUCATIONAL RESOURCES
SCIENCE EDUCATION RESEARCH CENTER AT CARLETON COLLAGE
http://serc.carleton.edu/microbelife
p. 35

MICROIMAGING SERVICES (Canada)
www.microimaging.ca
p. 9, 14, 20

MICROGRAPHIA (Australia)
www.micrographia.com
p. 13

NATIONAL CENTER FOR RESEARCH RESOURCES, NIH
www.ncrr.nih.gov
p. 25, 43
SCIENCE EDUCATION PARTNERSHIP AWARD (SEPA)
www.ncrrsepa.org
p. ii

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

NATIONAL INSTITUTES OF HEALTH (NIH)
www.nih.gov
p. ii, 30, 39, 43

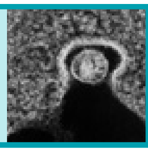
OREGON HEALTH AUTHORITY PUBLIC HEALTH-CDC
http://public.health.oregon.gov/laboratoryservices
p. 53

RICE UNIVERSITY
BIOCHEMISTRY AND CELL BIOLOGY
www.biochem.rice.edu
p. 26

UNIVERSITY OF BATH (United Kingdom)
BIOLOGY AND BIOCHEMISTRY
www.bath.ac.uk/bio-sci
p. 15

USDA NATURAL RESOURCES CONSERVATION SERVICE
www.plants.usda.gov
p. 11

Contents



HIV virus particle. L. Howard, C. Daghlian, Dartmouth College.

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 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.

> 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.

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

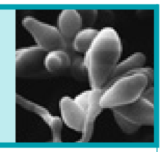
Materials Manager
- Picks up the materials
- Uses the equipment
- Returns the materials

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

Overview: Pre-Assessment

To evaluate their current understanding of microbes, students will complete a pre-assessment, estimate the mass of microbes in the human body, and then begin group concept maps. Completed preassessments will be used again at the conclusion of the unit as part of the post-assessment (see Answer Key, right sidebar). Groups will add to their concept maps regularly throughout the unit.

1



Curvularia geniculata fungus. CDC\203 J. Carr, R. Simmons.

TIME

Setup: 10 minutes
Activity: 45 minutes

WHAT DO YOU KNOW

About Microbes?

Microbiologists study organisms consisting of a single cell or a cluster of a few similar cells. Known as microbes or microorganisms, these organisms usually cannot be observed with the naked eye. The term "microbe" was coined by Charles Sedillot, a French scientist. It means any living thing that must be magnified to be visible.

MICROSCOPIC refers to something that is too small to be seen with the naked eye. The prefix "micro" is derived from the Greek micros, which means "small."

MACROSCOPIC refers to something that is large enough to be visible to the naked eye. The prefix "macro" comes from the Greek for "long" or "large" and "to look at."

Microbes are the most prevalent organisms on our planet, both in mass and number. They comprise a diverse group and include bacteria, microscopic algae, yeast cells, and even protozoa. Most biologists also consider viruses to be microbes, even though according to many definitions, viruses are not true "living" organisms. In this guide, we focus primarily on microbes directly related to health: bacteria, fungi, protists and viruses.

Microbes produce most of the Earth's oxygen and are essential parts of all ecosystems. Although some microbes cause illness, others play a role in digestion, disease resistance and other vital human functions. Microbes also are involved in the production of common foods, including sandwich bread and yogurt.

This activity allows students to share their knowledge about microbes. It also allows you, the teacher, to assess student knowledge before beginning the unit.

MATERIALS

Teacher (See Setup)

- Glo Germ™ kit (includes a black light) available for purchase online at www.glogerm.com or www.sciencekit.com
- Graduated cylinder, beaker or other means to measure one liter of water accurately
- Sturdy plastic bag large enough to hold a one-liter size bottle

Per Group of Students

- 8 small sticky notes (2 per student)
- 4 hand lenses
- 4 pairs of safety goggles
- 4 small paper clips
- Access to a balance or spring scale (2,000 gm capacity)
- Capped plastic bottle, pre-filled with one liter (measured) of water
- Markers

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

- Some diseases are the result of damage by infection or by other organisms.
- Populations of organisms can be categorized by the function they serve in an ecosystem.

ANSWER KEY

Answers to the Pre- and Post-Assessments are as follow.

1. d	11. a
2. c	12. a
3. a	13. a
4. d	14. b
5. a	15. d
6. b	16. c
7. d	17. d
8. a	18. a
9. b	19. d
10. a	20. d

CITATIONS

Image citations, including source URLs, are available at the front of this guide.

BLACK LIGHTS

A black light gives off light (electromagnetic radiation) in the near ultraviolet range (close to 370 nm). To the human eye, light from a black light looks violet.

EXTENSION

Ask students, *How long do you need to wash your hands to make sure they are clean and free of harmful microbes?* Write students' estimates on the board. OR give each student a sticky note on which to write the number of seconds he or she thinks people must wash their hands to be sure they are clean. Have students create another class bar graph with their estimates.

Then, allow students to develop their own experiments to investigate the effectiveness of hand washing techniques or times. Students should examine their hands under the black light before beginning their experiments. Have students devise a uniform strategy for dipping their hands in the Glow Germ™ powder, and then examining their hands under the black lights after washing. Students also should think about other variables, such as water temperature and type of soap used (anti-bacterial, for example).

- Large sheet of poster board or large sheet of paper
- Stopwatch or clock with second hand (for Extension, left sidebar)

Per Student

- Copy of *What About Microbes?* student sheet (p. 4; see Answer Key, p. 1, sidebar)

SETUP

Make copies of the student sheet (one per student).

Fill water bottles with one liter of water (measure) and replace the caps. Dry any excess water from the outside of the bottles.

Place 1 cup Glo Germ™ powder in the plastic bag. Coat the outside of each bottle with powder by placing it in the bag and shaking gently. The bottles will look dusty, but the powder will glow only under a black light. The specks of powder represent microbes in this activity.

After each student has completed the pre-assessment questionnaire, have students work in groups of four.

SAFETY ISSUES

Have students wash hands with soap and water after handling Glo Germ™ powder. Students should avoid contact with eyes and mouth while handling the powder. Students also may wear safety goggles.

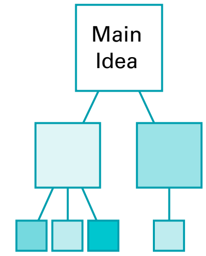
PROCEDURE

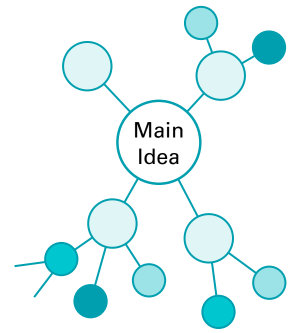
1. Explain to students that they will be learning about the most numerous organisms on Earth—microbes. However, before starting the unit, they will complete a pre-assessment activity. The pre-assessment questions will require students to reflect upon what they already know about microbes. At the end of the unit, students will answer the same questions on the post-assessment.
2. Distribute copies of *What About Microbes?* Have students complete the questions on their own. Tell students to answer each question using their existing knowledge and experiences.
3. Collect the student sheets. Ask, *Does anyone think he or she knew all the answers? Does anyone have questions or observations?* Record questions on chart paper to revisit at the end of the unit. Do not discuss answers to the preassessment questions. Students will have an opportunity to review their answers as part of the last activity of this guide.
4. Give each student a paper clip. Tell students that the mass (weight) of the clip is approximately one gram (gm). If time allows, have students estimate the mass (weight) of different objects in grams. Have students use a balance or scale to compare their estimates to actual measurements.
5. Next, have the materials manager of each group pick up a water bottle that you have treated with Glo Germ™ powder. Ask, *What is the mass of the bottle and its contents, in grams?* Each member of the group should hold the bottle and estimate (predict) the total mass of the bottle (weight of contents plus weight of the container), in grams.

A kilogram (kg) is a measure of mass that represents one liter of water under standard conditions. One kilogram is equivalent to 35.3 ounces, or 2.2 pounds.

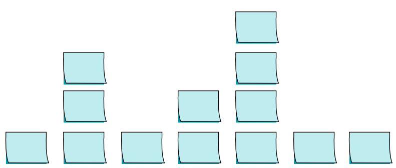
CONCEPT MAPS are web-like representations of knowledge, concepts and ideas. Concepts are expressed as words or phrases, and are connected by lines or arrows, and by linking words that describe relationships between two concepts.

Shown to the right are two different approaches to creating concept maps. Students may use sticky notes to position and reposition concepts on their maps as they learn. Computer-based graphics software also may be used to create concept maps.





6. After everyone has held the bottle, ask students to write their estimates on sticky notes. Create a class bar graph by lining up the notes according to increasing weight in a row across the wall or chalkboard. Stack notes with about the same weights above or below each other in vertical columns.

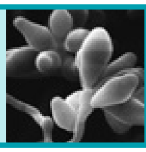


7. Tell students the bottle weighs about as much as the microbes in a person's body—slightly more than 1,000 grams (gm), or 1 kilogram (kg).
8. Review the graph and discuss students' estimates. Ask, *Was anyone close to the correct weight? Why was it difficult to estimate?* At this time, you may want to discuss metric measures and standard equivalents.
9. Next, ask students to examine their hands, first with the naked eye and then with the hand lens. Ask, *Can you see anything?*
10. Bring out the black light(s) and have students examine their hands again under the light. Ask, *What do you see? Was it there before? Why couldn't it be seen?* Explain that the glowing material on their hands is a harmless powder that spreads by contact, just as many microbes spread. The powder, however, becomes visible under special lighting conditions. Microbes cannot be observed in the same way.
11. Ask, *What do you know about microbes or microorganisms? Why do you think they are important?* (Microbes are organisms too small to be seen without magnification. They are the most prevalent life forms on earth, both in mass and number. Most cannot be seen without a microscope, yet microbes influence every person's life. Some students may be able to name a few examples, such as bacteria. Students may think all microbes are harmful, but this is not true.)

    Ask, *Why do you think you were taught always to wash your hands before eating and after using the restroom?* OR *Have you noticed signs in almost all public restrooms stating that all employees must wash their hands before returning to work? Why might this be?* Allow students to discuss their ideas.
12. Finally, have students discuss what they know about microbes or microorganisms, and ask each group to begin a concept map (see illustrations, upper right), that demonstrates its collective knowledge of microbes. Tell students that while they may not have much information now, they will be adding to their concept maps throughout the unit. Display the concept maps around the room.

TEACHING 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.

1 

Curvularia geniculata fungus. CDC\203 J. Carr, R. Simmons.

PRE-ASSESSMENT

What About Microbes?

Name ________________________________

Circle the best response to each question.

1. Microbes usually are
   a. germs.
   b. bad.
   c. good.
   d. microscopic.

2. A microbe does NOT cause
   a. polio.
   b. HIV/AIDS.
   c. asthma.
   d. malaria.

3. One way to prevent the spread of disease is to
   a. wash your hands with soap and water.
   b. not ever get sick.
   c. wear a jacket.
   d. take aspirin.

4. Diseases caused by viruses can be cured with
   a. antibiotics.
   b. anesthetics.
   c. vitamin C.
   d. none of the above.

5. Flu is caused by a
   a. virus.
   b. bacterium.
   c. fungus.
   d. protist.

6. Most bacteria are
   a. harmful.
   b. helpful.
   c. viral.
   d. disease-causing.

7. A paramecium is an example of a
   a. virus.
   b. bacterium.
   c. fungus.
   d. protist.

8. Microbes are an important part of the environment because they
   a. break down waste.
   b. cause the water cycle.
   c. protect the ozone layer.
   d. block global warming.

9. The incubation period of a disease is the length of time
   a. it takes to get over a disease.
   b. between being exposed and showing the symptoms of a disease.
   c. it takes for the eggs to hatch.
   d. between showing the symptoms of a disease and getting well.

10. In order for bacteria to grow, they need
   a. a source of energy.
   b. a source of young viruses.
   c. specialized equipment.
   d. someone to cough or sneeze.

11 Infectious diseases can spread
   a. from one person to another.
   b. by eating only fresh fruit.
   c. from washing your hands.
   d. by inheritance.

12. Most diseases caused by bacteria can be cured with
   a. antibiotics.
   b. anesthetics.
   c. vitamin C.
   d. none of the above.

13. One of the most common microbes used in food production is a
   a. fungus.
   b. protist.
   c. virus.
   d. micron.

14. Scientific advances depend on all of the following, EXCEPT
   a. being curious about what is observed.
   b. always being successful.
   c. appropriate tools and methods.
   d. work by other scientists.

15. The large structure you can often see inside of a cell is called
   a. protein.
   b. flagella.
   c. the cell wall.
   d. the nucleus.

16. Antibiotic resistance is
   a. beneficial for most humans.
   b. caused, in part, by lack of antibiotics.
   c. caused, in part, by overuse of antibiotics.
   d. caused, in part, by overuse of vaccines.

17. A worldwide spread of infectious disease is called a/an
   a. anemic.
   b. epidemic.
   c. systemic.
   d. pandemic.

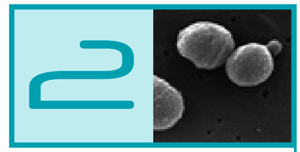
18. It is possible to catch HIV/AIDS from
   a. body piercing.
   b. saliva.
   c. sweat.
   d. mosquito bites.

19. A way to protect yourself from some diseases is called
   a. polarization.
   b. fertilization.
   c. constipation.
   d. vaccination.

20. Microorganisms often are measured in
   a. decimeters.
   b. centimeters.
   c. millimeters.
   d. micrometers.

Overview

Students will use water drops and hand lenses to begin the exploration of magnification, and will be introduced to the microscope.



Streptococcus pneumoniae bacteria. CDC\9996 J. Carr, R. Facklam.

TIME

Setup: 10 minutes

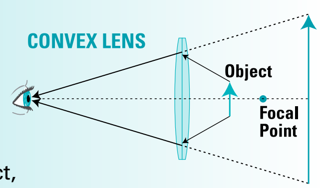
Activity: 45 minutes

T O O L S O F

Magnification

Scientific progress often is tied to the development of new tools and technologies. For example, until magnifying lenses were developed, people were able to see only as much of the world as their naked eyes would allow. The development of high quality magnifiers and microscopes opened up the world of cells and microorganisms for exploration by generations of scientists.

With an object closer to a lens than the focal point, the light rays diverge, giving the viewer the illusion that he or she is seeing a larger object, farther away, in the same orientation.



The word "lens" comes from the Latin word for lentil, because early magnifiers resembled lentil beans in shape.

Lenses are made of transparent materials and have one or two curved surfaces. They work by refraction, which means that the pathway of light is altered as it passes from one clear material, such as air, into another, such as glass. Magnifying glasses are single lenses that are convex on both sides. The compound light, or optical, microscope uses two magnifying lenses in series to make things appear much larger to the eye than would be possible with a single lens. The simplest compound microscopes consist of tubes with lenses at each end. Objects can be magnified up to 2,000 times using a high quality compound microscope.

The invention of the transmission electron microscope (TEM) in the mid-20th Century made it possible to view objects even tinier than cells, such as viruses. This type of microscope magnifies objects up to two million times by passing a beam of electrons through a very thin specimen and recording changes in the electron beam.

Zacharias Janssen is credited with developing the first compound microscope around 1595. But in 1665, scientist Robert Hooke was the first to use such an instrument to observe the division of plant tissues into tiny compartments, which he termed "cellulae," or cells. Inspired by the work of Hooke, Anton van Leeuwenhoek, a Dutch inventor, used simple (one lens) microscopes to describe bacteria and protists. Van Leeuwenhoek's well-made microscopes magnified objects more than 200 times and allowed him to make very detailed observations.

MATERIALS

Per Group of Students (see Setup)

- 4 hand lenses or magnifiers
- 4 index cards (or similarly sized sections of cardstock)
- 4 pairs of scissors
- 4 pieces of newsprint, about 2 cm x 10 cm each. Select pieces that have newsprint on one side only so that print will not show through under the microscope.

Continued

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

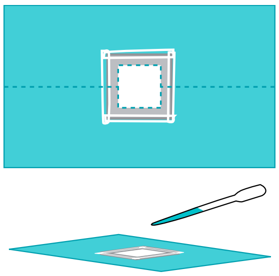
- Use appropriate tools and techniques to gather, analyze and interpret data.

Science and Technology

- Science and technology are reciprocal. Technology provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable.

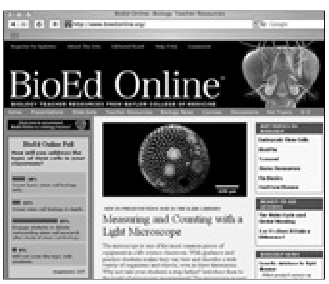
Cynthia Goldsmith, M.S., a CDC research biologist, is shown working at a transmission electron microscope (TEM). Ms. Goldsmith's work has repeatedly played a key role in the rapid identification of emerging disease-causing microbes, including hantavirus, Nipah virus, and SARS coronavirus. CDC\3511 J. Gathany.

WATER DROP MAGNIFIER



Students will create a magnifier by placing a drop of water over a small square of wax paper.

TEACHING RESOURCES



Further information about magnification, refraction, microscopes and microscopy, including free, downloadable PowerPoint slides for classroom use, is available at www.BioEdOnline.org/. Look under the Presentations and Slide Sets pull-down menus for Lab Techniques on Light Microscopy.

EXTENSION

Allow students to bring in their own samples of materials to observe using wet mounts under the microscope.

- 4 pipettes or droppers
- 4 plastic cover slips
- 4 plastic or glass microscope slides
- 4 rulers (measurements in cm)
- Microscope (any kind)
- Other objects to observe, such as a leaf, coin, dollar bill, etc.
- Set of colored pencils or markers
- Sheet of wax paper (6 cm in length)
- Small container of tap water
- Transparent tape

Per Student

- Copies of the stuudent sheets (p. 8–9)

SETUP

Make copies of the student sheets. Place materials for each group on trays in a central location.

Before allowing students to carry microscopes to their work areas, demonstrate how to hold a microscope by placing one hand on the microscope stand (arm) and the other under the base (foot).

Have students work in groups of four.

SAFETY ISSUES

Follow all district and school science laboratory safety procedures. It is good laboratory practice to have students wash hands before and after any investigations.

PROCEDURE

Part 1. Lenses & Magnification

1. Hold up a magnifier or hand lens. Ask students, *How many of you have used something like this? What can it be used for?* (Lenses can be used to focus light on a single point, and also are used in eyeglasses, cameras, etc.) Tell students they will be using hand lenses to make observations.
2. Distribute materials to each team of students. Direct students to observe each item on the tray using the hand lens. Ask, *Did you observe anything on any of the objects that you have never noticed before?* Let students report their observations informally.
3. Tell students to use a hand lens to observe the newsprint and draw what they observe on their student sheets.
4. Next, have each student make a magnifier following these steps.
   - Fold index cards in half lengthwise (see Water Drop Magnifier, left sidebar).
   - Cut an opening about 2 cm long and 1 cm wide in the center of the card. Open the card (opening will be 2 cm x 2 cm).
   - Cut a 3-cm x 3-cm square of wax paper.
   - Place wax paper over the opening and secure it with tape.
5. Direct students to observe the newsprint through the wax paper window. Next, have students place a single drop of water (using a pipette or dropper) in the center of the wax paper window, and observe the newsprint through the water drop. Have students draw their observations as before.
6. Discuss students' observations. Ask, *What happened when you looked at the newsprint through wax paper?* (no change) *Through the water drop?* (print was magnified) *Are there any similarities between the magnifier and the drop?* (clear, transparent, curved surface) Help students understand that the magnifier lens and the water drop shared similar characteristics. If students need additional clarification, have them observe the newsprint through a glass or plastic slide, which is flat. The slide will not magnify (or shrink) the image, because the surface is not curved.

Part 2. Microscopes

1. Ask, *What could we use to magnify the materials further?* Distribute the microscopes and allow groups to examine them for a few minutes. Then ask, *Where is the lens? Is there more than one lens?* (yes, in the eyepiece and at the bases of the objectives) Ask, *What do you notice*

about the lenses? Students should note the curvature of the lens and the "X" markings on the sides of the eyepiece and objective. Ask, *What does "X" usually mean in mathematics?* (multiplication or "times") Explain that the bottom lens number (on the objective in use) and the top lens number (on the eyepiece) are multiplied to indicate the total number of times a specimen is magnified when observed. For example, an eyepiece of 10x with an objective of 4x will magnify an image 40 times (10 x 4 = 40).

2. If students are not familiar with microscopes, help them locate the basic parts. For example, tell students, *One part of the microscope is called the stage. It is similar to a stage for a performance. Can you find it? What about the arm?* Have students use *The Compound Microscope* sheet to find the eyepiece, objectives, coarse and fine focus knobs, arm, stage, and light source of their microscopes.

   Many microscopes also have a condenser to intensify the light and a diaphragm aperture to adjust the amount of light passing from the light source up through the object. Encourage students to examine the microscope and propose the function of each part.

3. Finally, have students create a temporary slide, called a "wet mount." Instruct students to cut out a 1-cm x 1-cm piece of newsprint, and to put the piece of newsprint in the center of a clean microscope slide. Have students place a drop of water on the paper, cover the drop gently with a cover slip and then place the slide on the microscope stage. If the stage has clips, have students place the clips over the slide to hold it in place.

   If the microscope has a light source, make sure the light is aimed up through the paper. Initially, the diaphragm should be adjusted to its largest opening. If the image is too bright (seems "washed out") when viewed, help students reduce the amount of light by partially closing the diaphragm.

   Note: Low-power "dissecting-type" microscopes may not have a light source below the stage.

4. Direct students to move the lowest power objective into place above the print material (not all microscopes have multiple objectives) and to use the coarse focus knob to lower the tip of the objective until it is just above the coverslip. Students should look through the eyepiece and use the coarse focus knob (depending on the microscope) to move the objective gradually upwards until the printing on the paper comes into view.

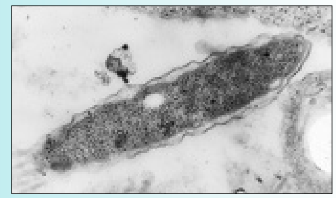
   Remind students that the object sample will come into focus when the objective is very close to the stage. Tell students to use the fine focus knob to sharpen the appearance of the image, and use caution not to break the coverslip. Each student should have an opportunity to adjust and focus the microscope.

5. Have students draw their observations of the newsprint on the *Magnification Observations* sheet. Some students may wish to study the newsprint at a higher magnification by first centering the object in the field of view, then gently rotating the middle objective into position and adjusting the focus using the fine focus knob only.

6. Discuss students' observations or have them answer the following questions in their science notebooks. Ask, *Which tool provided the greatest magnification? What did all of the tools have in common? What were the differences between each of the tools?*

SPECIAL MICROSCOPES

Scientists use a variety of high-powered microscopes to study the surface and internal structure of a sample, and to measure the size of things too tiny to see with light microscopes.



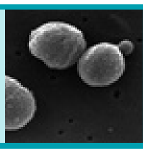
TEM image of *Legionella pneumophila* bacterium (causes Legionnaire's disease). CDC/7306.

A transmission electron microscope (TEM) uses an electron beam that passes through a specimen, enabling the interior of an object to be observed (see image above).

A scanning electron microscope (SEM) uses electrons to image the surface of an object (see image below).

SEM image of *Legionella pneumophila*. CDC\6640 B. Fields.

For more information, see "A Powerful Tool," (p. 28).



Streptococcus pneumoniae bacteria. CDC\9996 J. Carr, R. Facklam.

2 Magnification Observations

Observation 1

Tool Used ________ Magnification (if known) ________

Notes and Observations ________

Observation 2

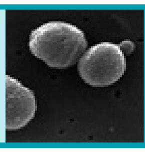
Tool Used ________ Magnification (if known) ________

Notes and Observations ________

Observation 3

Tool Used ________ Magnification (if known) ________

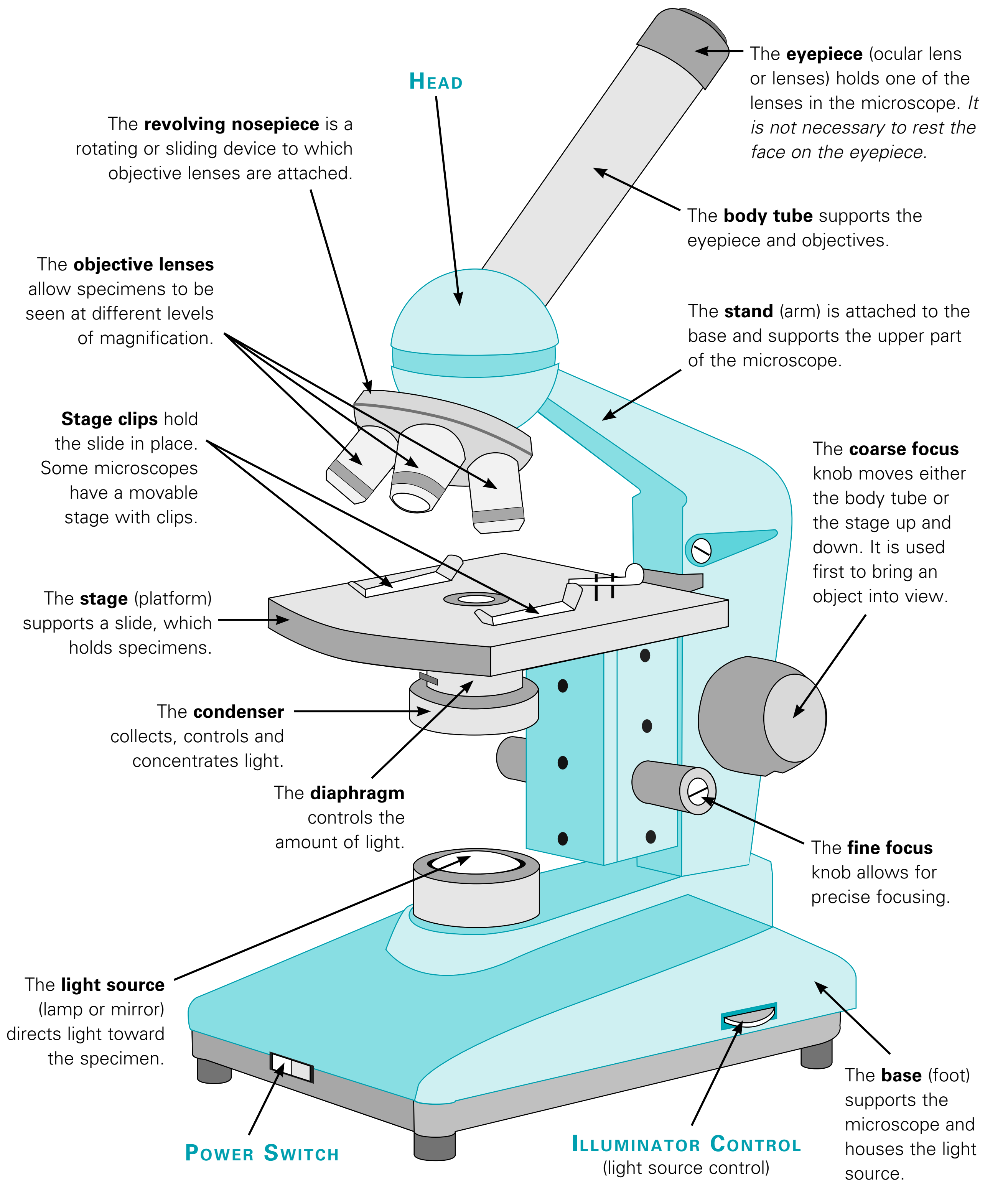
Notes and Observations ________



Streptococcus pneumoniae bacteria. CDC\9996 J. Carr, R. Facklam.

2 The Compound Microscope

When you look through a microscope, lenses make what you are looking at appear larger. For example, a 10-power lens (10x) makes objects appear ten times larger than their actual size. With the right combination of lenses, a very good compound light microscope can magnify objects as much as 2,000 times (2000x).



Text from Ron Neumeyer © MicroImaging Services, www.microimaging.ca/.

3

Smallpox virus particle. CDC\1849 F. Murphy, S. Whitfield.

TIME

Setup: 20 minutes

Activity: 45–60 minutes

Overview

Students will learn that all organisms are composed of cells, the building blocks of life. Most cells are microscopic and must be magnified to be observed. Students will make slides of cells from an onion skin and *Elodea* (American or Canadian waterweed) to observe under a microscope.

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.
- Develop descriptions, explanations, predictions, and models using evidence.
- Use appropriate tools and techniques to gather, analyze, and interpret data.

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Cells carry on many functions needed to sustain life.

TEACHING RESOURCES

Color versions of the "Magnifying Cells" page, as well as other color images of cells used in this guide may be viewed or downloaded from the BioEd Online website at www.BioEdOnline.org.

MAGNIFYING AND Observing Cells

Every living thing is composed of cells, the microscopic building blocks of life. In fact, most life forms exist as single cells that carry out all functions needed for their own independent existence. Examples of common single-celled organisms are bacteria (tiny organisms found in almost every habitat on Earth), diatoms (algae that are common components of phytoplankton), and yeast (a kind of fungus). Multicellular organisms consist of several to many cells. Single-celled and small multicellular organisms, which must be magnified to be observed, are called microbes or microorganisms.

Plants and animals are examples of multicellular organisms visible to the naked eye. These macroscopic multicellular organisms can have up to trillions of cells that carry out specialized functions.

This activity uses plant cells, because many of these are relatively easy to see. Students will observe onion cells (in the thin membrane around each onion "ring") and a leaf from *Elodea*. With these examples, students will be able to see basic parts of cells, including the nucleus (structure in the center of the cell that holds hereditary information), cytoplasm (gel that fills the cell), cell wall (rigid outer boundary of plant and other kinds of cells), and chloroplasts (large green structures in which photosynthesis occurs).

MATERIALS

Teacher (see Setup)

- 6 sheets of card stock
- Overhead projector
- Pair of scissors or a paper cutter
- Safety goggles
- Sharp knife
- Transparency of *Magnifying Cells* sheet (p. 13)

Per Group of Students

- 4 pairs of safety goggles
- 2 plastic cover slips
- 2 plastic microscope slides
- 2 pairs of forceps
- 1/6 of an onion, vertical slice
- Small stalk of *Elodea* leaves
- Iodine solution and pipette (dropper)
- Water and pipette (dropper)
- Microscope (one or more per group)
- Science notebooks or drawing paper
- Set of *Preparing & Viewing Slides* cards (p. 12)
- Group concept map (ongoing)

SETUP

Make copies of the *Preparing & Viewing Slides* page on cardstock, and cut out one set of cards per group.

Make a transparency of *Magnifying Cells* page or download images (see Teaching Resources, left sidebar).

Prepare a tray for each group with all materials listed above and place trays in a central location.

Have students work in groups of two or four, depending on resources.

Optional: If *Elodea* is not available, new growth celery leaves may be substituted. As an alternative to science notebooks or drawing paper, make and distribute clean copies (one per group) of the *Magnification Observations* student sheet (p. 8).

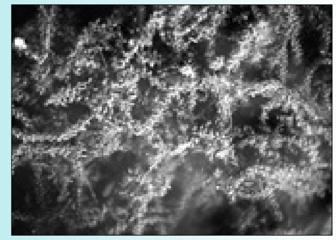
SAFETY ISSUES

See sidebar, right.

PROCEDURE

1. Begin by showing students a transparency of the *Magnifying Cells* sheet. Explain that the structures visible in each frame cannot be seen without magnification. Let students ask questions about what is visible in the images. Tell students that they will be making their own slides to observe the tiny structures, called "cells."
2. Point out the labeled parts of the cells on the transparency. Help students understand that they will look for similar structures in their specimens.
3. If necessary, review microscope use with all students (Activity 2). If available, use a micro projector or video attachment on a microscope to demonstrate how to view cells, change magnifications and make observations.
4. Have students work in groups. Tell them to follow the instructions on their *Preparing & Viewing Slides* cards to prepare their slides.
5. After each group has created both slides, have students take turns observing and drawing their specimens (noting the magnification being used). Have students first examine the cells using low power and then refocus using a higher power objective. Instruct students to make detailed drawings and to label any cell parts that are recognizable. Tell students that some parts of a cell may not be visible when viewed under a microscope. Allow 10–20 minutes for this step.

   Note: Have students determine the total magnification by multiplying the power stamped on the eyepiece (for example, 10x) by the power of the objective.
6. Students usually will be able to observe the cell nuclei in the stained onion skin cells. They also should be able to observe cell walls and cytoplasm in both kinds of cells, and to identify chloroplasts in the *Elodea* cells.
7. Display the *Magnifying Cells* transparency for students. Encourage groups to discuss among themselves what they observed. Ask, *Are all the cells about the same size? Could you see a dot* (nucleus) *inside all the cells? If not, why?*
8. Explain the names and functions of the cell structures that students observed and drew.
9. As an assessment, ask students, *What are the major parts of the cells you observed?* (Structures most likely to be identified include cell wall, nucleus, chloroplasts and cytoplasm.) You also might ask, *What similarities and differences did you observe between the two kinds of cells?* Students can record responses in their science notebooks or turn in their answers as assignments. You also may question each group individually.
10. Allow students time to add information to their concept maps. Explain that while the class has examined some cell structures of multicelled organisms, many organisms consist of only one cell. Students will have opportunities to learn more about single-celled microorganisms in later activities.



Canadian waterweed (*Elodea),* is an important part of lake ecosystems. It provides a good habitat for many aquatic organisms, and is an important food source for waterfowl. It also is a hardy aquarium plant. USDA Natural Resources Conservation Service\R. Mohlenbrock © PLANTS Database.

SAFETY ISSUES

Have students wear goggles when working with iodine, which is poisonous if ingested and will stain clothing permanently. Some students may be allergic to iodine. Methylene blue may be used instead of iodine, but it also can cause skin or eye irritation and should not be ingested. If skin is exposed to either stain, wash with soap and water. If stain gets into the eyes, rinse eyes with water for at least 15 minutes.

Have students wash their hands before and after any lab activity.

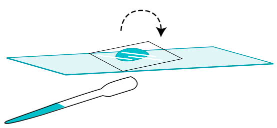
Smallpox virus particle. CDC\1849 F. Murphy, S. Whitfield.

3 Preparing & Viewing Slides

Onion Skin

A. Follow steps 1–3 below to prepare the slide for viewing.

1. Using a pipette or dropper, place one drop each of water and iodine in the center of a slide.
2. Carefully remove a small, thin, transparent section of skin from the onion's inside layer. Use forceps to place the skin on top of the drops.



3. Slowly place the cover slip over the skin and drops, trying not to squeeze any liquid out from under the cover slip.

B. To examine the onion skin with a compound microscope, follow the steps below.

1. Place the slide on the microscope stage.
2. Focus the low-power objective to find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
3. Once you have found a section with onion skin, examine the cells. Center the object in the field of view. Rotate to the medium-power or high-power objective.
4. Refocus the microscope using just the fine adjustment.

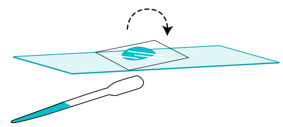
C. Draw what you observe and label any parts you recognize.

D. Record the magnification at which you made your observations.

Elodea Leaf

A. Follow steps 1–3 below to prepare the slide for viewing.

1. Using a pipette or dropper, place one drop of water in the center of a slide.
2. Carefully remove a small, thin leaf from the plant. Use forceps to place the leaf on top of the drop.



3. Slowly place the cover slip over the leaf and drop, trying not to squeeze any liquid out from under the cover slip.

B. To examine the leaf using the microscope, follow the steps below.

1. Place the slide on the microscope stage.
2. Focus the low-power objective to find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
3. Once you have found a section with leaf sample, examine the cells. Center the object in the field of view. Rotate to the medium-power or high-power objective.
4. Refocus the microscope using just the fine adjustment.

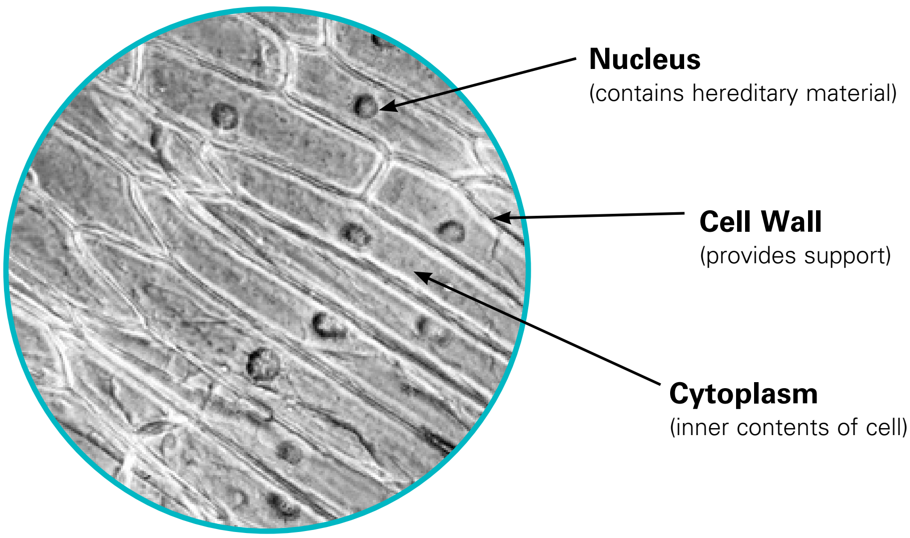
C. Draw what you observe and label any parts you recognize. (**Note:** The *Elodea* leaf has two layers that can be observed separately by slowly changing the focus, using the fine adjustment knob.)

D. Record the magnification at which you made your observations.

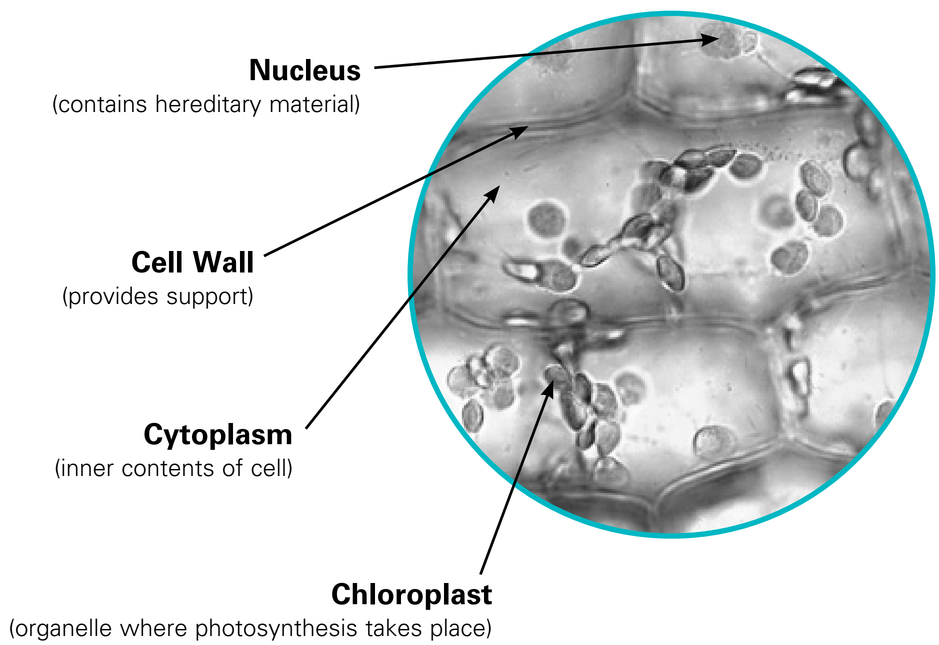
Smallpox virus particle. CDC\1849 F. Murphy, S. Whitfield.

Magnifying Cells

Onion Skin

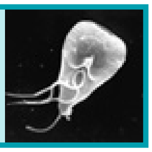


Elodea Leaf



John Walsh © Micrographia, www.micrographia.com/.

4



Giardia lamblia protist. CDC\8698 J. Carr.

TIME

Setup: 20 minutes
Activity: 45–60 minutes

Overview

Students will use a microscope to examine three different microbes: bacteria, yeast and paramecia.

OBSERVING DIFFERENT Microbes

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.
- Develop descriptions, explanations, predictions, and models using evidence.
- Use appropriate tools and techniques to gather, analyze, and interpret data.

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Cells carry on many functions needed to sustain life.

ACCESS TO COLOR IMAGES

If students do not have access to microscopes, color images of the cells used in this activity can be viewed online or downloaded from the BioEd Online website at www.BioEdOnline.org/.

Microbes are organisms too small to be seen with the naked eye. There are enormous variations in the kinds and sizes of microbes. This activity allows students to observe representatives of three different groups of microbes—bacteria, fungi and protists—first hand.

First, students will observe bacterial cells in yogurt, which will be visible only as tiny rods. (Rod-shaped bacteria are called bacilli.) Yogurt is created when milk is fermented by *Lactobacillus* and other kinds of bacteria. It has a slightly sour taste, is acidic, and stays fresh longer than milk. A yogurt recipe is included as an extension to this activity.

> ***SACCHAROMYCES CEREVISIAE*** **is more commonly known as baker's yeast. Members of this group of fungi are used in making wine, bread, beer, and medicines.**

Students also will observe yeast, which are single-celled fungi. This group also includes organisms like mushrooms and molds. Fungi are not able to trap energy through photosynthesis and must feed on other organisms. Many fungi are important decomposers within ecosystems. Yeasts have numerous applications in food production, such as leavening in bread and fermentation for alcoholic beverages. Some kinds of yeast also cause diseases, such as diaper rash or thrush (a painful infection of the mouth and throat).

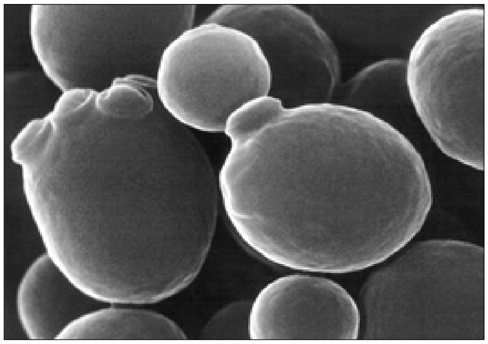
A light microscope image reveals the inner structure of a paramecium. Ron Neumeyer © MicroImaging Services.

Finally, students will observe a paramecium. "Slipper-shaped" paramecia are among the largest microorganisms in the protozoan group, which are considered to be protists. Most of the 40,000 species of protozoa are found in aquatic environments or in moist soil. A few are parasites. Protozoa do not have rigid cell walls (such as those in the onion skin cells). Paramecia take in particles of food through an "oral groove" located on one side of the organism, and they use tiny hairs, called cilia, to propel themselves through water.

MATERIALS

Teacher (See Setup)

- For paramecia, order a culture in advance, collect pond water, or make your own (see sidebar, p. 15).
- For yeast mixture (prepare one day in advance):
  - 250-mL container
  - 150 mL of warm water



Advances in technology allow us to see microbes with more clarity. A scanning electronic microscope (SEM) image shows the detail of the outer surface of common baker's yeast, *Saccharomyces cerevisiae*. Alan E. Wheals, Ph.D. © University of Bath.

- Package of dry baker's yeast
- Teaspoon of sugar

- 6–8 oz of plain, unflavored yogurt
- 6 sheets of cardstock (to make *Slide Preparation* cards)
- Small dropper bottle of glycerin (one drop per slide will slow paramecia if they are overly active)
- Permanent marker to label droppers

Per Group of Students

- Microscope (one or more per group)
- Samples of microorganisms in three small containers
  - 50 mL of pond water
  - 20 mL of yeast mixture
  - 20 mL of enriched yogurt
- 20 mL of tap water in a cup
- 3 plastic cover slips
- 3 plastic slides
- 3 droppers (one each for yeast mixture, pond water or paramecia, and tap water)
- Toothpick (for yogurt)
- Plastic tray (to hold materials)
- Set of colored pencils or markers
- Set of *Slide Preparation* cards (p. 17)
- Science notebooks
- Group concept map (ongoing)

SETUP

Order pond water, make your own (see Making Pond Water, right sidebar), or collect 500 mL of fresh pond water from a ditch or pond. (Look for standing water that has a greenish color; collect some of the algae and sediment.)

On the day before class, mix one teaspoon of yeast and one teaspoon of sugar into a cup containing 250 mL of warm water.

To enrich the microbe count in yogurt, use an individual-sized container of plain, unflavored yogurt that is past the expiration date, or let it sit unrefrigerated overnight.

Make six copies of the *Slide Preparation Cards* student sheet on cardstock. Cut out cards.

Place materials for each group on trays, which will be picked up by each group's materials manager. Leave the containers with pond water and yeast mixture on the distribution table until needed. For each group, label one dropper or pipette for the yeast mixture, one for pond water or paramecia, and one for tap water. At least one microscope should be placed on each group's table before class begins.

Optional: As an alternative to science notebooks, make and distribute clean copies of the *Magnification Observations* student sheet (see p. 8).

SAFETY ISSUES

See sidebar, right.

PROCEDURE

1. Ask students, *Have you ever seen a microbe? What do you think different kinds of microbes might look like?* Tell students that they will have opportunities to observe and compare different kinds of microbes: bacteria in yogurt, yeast cultures, and paramecia (or other pond organisms).

Continued

SAFETY ISSUES

Have students wash their hands before (to avoid contaminating the cultures) and after any lab activity. Hand washing is critical when handling microorganisms. Long hair should be pulled back. If students are immunocompromised, they should wear gloves when handling pond water. No food or drink should be allowed in the lab.

MAKING POND WATER

To create your own pond water culture, boil water, then let it cool. Add the cooled water to straw or dried grass. Cover it with a cloth or paper towel, and place the mixture in a warm, sunny spot for several days. When it turns cloudy or green, it's ready!

TEACHING RESOURCES

For more examples of pond life, visit the Microscopy-UK website at www.microscopy-uk.org.uk/.

- The Pond Life ID Kit offers a table with pages linked to some common groups of small and microscopic pond life.
- The Virtual Pond Dip presents information using a graphic interface that is fun for beginners of any age.

EXTENSION

It's easy to make yogurt using the following ingredients.

- 2 quarts of whole milk
- 1 cup of plain yogurt
- 1 cup of half-and-half

Bring milk to a boil in a very clean pot. (Greasy or dirty pots and utensils won't produce the desired results.) Remove from heat and let stand until cool. Pour the cooled milk into a glass or pottery jar, bowl or other glass container.

Measure one cup of the milk and pour it into a medium-sized bowl. Mix in the yogurt and half-and-half. Slowly add the remaining milk, stirring gently. Place a lid on the container or cover it with plastic wrap.

Wrap the container in a blanket or heavy towel. Place it in a corner of the room where it will stay warm and undisturbed for about six hours. Then refrigerate for 10 hours.

If you prefer a more tart flavor, leave the container wrapped for eight or nine hours. For a sweeter, softer yogurt, leave the container out for about four hours.

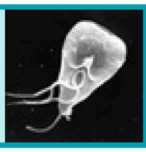
Always keep one cup of yogurt from the previous batch to use as a starter for the next batch.

2. First, students will prepare and examine a slide to observe bacteria in yogurt. If necessary, demonstrate how to make a slide before having groups of students make their own. Students should follow the instructions on the Bacteria card to prepare and observe their slides. Have students draw what they observe. (Students will not be able to see any parts inside the bacterial cells, which will appear as tiny rods.) Be sure students record on their drawings the magnification at which they made their observations.
3. Ask, *Were you able to see cells or groups of cells?* Explain that students observed tiny rod-shaped bacteria, called *Lactobacillus,* that live on milk sugar (lactose).
4. Have students follow the procedures on the Yeast card to observe and draw yeast cells. Students will be able to observe many round yeast cells, some of which may be reproducing by budding. Ask, *Were the yeast cells larger or smaller than the bacteria?* (larger) *What other differences did you notice?*
5. Finally, have students observe the paramecium culture (or pond water, which may or may not contain paramecia).

   If you are using pond water that includes a variety of organisms, you may want students to examine the water with a hand lens before using a microscope. Students should follow the directions on the Paramecia card to prepare their slides.

   Have students draw one paramecium (or other pond organism). These organisms may be large enough for students to observe and label the cell nucleus and cell membrane. Students also may be able to see the cilia around the edge of each paramecium.

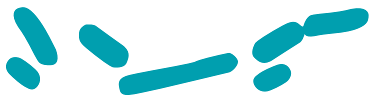
   Note: A tiny drop of glycerin on slides with pond water will slow the movement of microorganisms so that they are easier to observe.
6. Conduct a class discussion or have each student group create a table that summarizes the similarities and differences observed among the three kinds of microorganisms. Allow time for groups to add new information to their concept maps.
7. Have students research or discuss other types of bacteria, fungi, and protists. For descriptions of major groups of living things that have microscopic members, see Activity 5 (p. 18).



Giardia lamblia protist. CDC\8698 J. Carr.

Slide Preparation Cards

Bacteria



These shapes are typical of bacteria in yogurt. Keep in mind that the actual microbes will appear smaller or larger, depending on the magnification.

A. Follow steps 1–3 below to prepare the slide for viewing.

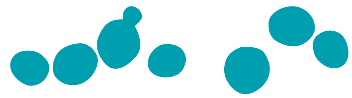
1. Using a toothpick, place a small amount of yogurt in the center of a slide.
2. Use a pipette or dropper to add one drop of water to the yogurt. Stir to mix.
3. Carefully place a cover slip over the mixture.

B. To examine the yogurt with a compound microscope, follow the steps below.

1. First, focus the low-power objective and find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
2. Once you have found a section with yogurt, center the sample in your field of view and rotate the objectives to medium-power or high-power, as directed by your teacher.
3. Refocus the microscope using only the fine focus knob.

C. Draw what you observe, and label any parts you recognize.

Yeast



These shapes are typical of yeast. Keep in mind that the actual microbes will appear smaller or larger, depending on the magnification.

A. Follow steps 1–2 below to prepare the slide for viewing.

1. Using a pipette or dropper, place a small amount of yeast mixture in the center of a slide.
2. Carefully place the cover slip over the liquid.

B. To examine the yeast with a compound microscope, follow the steps below.

1. First, focus the low-power objective and find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
2. Once you have found a section with yeast, center the sample in your field of view and rotate the objectives to medium-power or high-power, as directed by your teacher.
3. Refocus the microscope using only the fine focus knob.

C. Draw what you observe, and label any parts you recognize. You may notice that some cells have buds.

Paramecia

These shapes are typical of paramecia. Keep in mind that the actual microbes will appear smaller or larger, depending on the magnification.

A. Follow steps 1–2 below to prepare the slide for viewing.

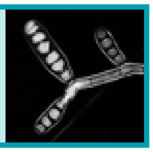
1. Using a pipette or dropper, place a small amount of pond water in the center of a slide.
2. Carefully place the cover slip over the liquid.

B. To examine the microbes in pond water with a compound microscope, follow the steps below.

1. First, focus the low-power objective and find an area of the slide that has some of your sample. Avoid bubbles (clear circles with heavy black borders).
2. Once you have found a section with organisms, center the sample in your field of view and rotate the objectives to medium-power or high-power, as directed by your teacher. Paramecia are slipper-shaped microbes.
3. Refocus the microscope using only the fine focus knob.

C. Draw what you observe, and label any parts you recognize. If your sample does not have any paramecia, select another microorganism to observe and draw what you see.

5



Exserohilum rostratum fungus. CDC\3784 L. Ajello.

TIME

Setup: 20 minutes

Activity: 45–60 minutes

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.
- Use mathematics in all aspects of scientific inquiry.
- Develop descriptions, explanations, predictions, and models using evidence.
- Use appropriate tools and techniques to gather, analyze, and interpret data.

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the systems. Others are the result of damage by infection by other organisms.
- Millions of species of animals, plants, and microorganisms are alive today. Though different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.

Continued on p. 19 .

Overview

Students will learn that microbes can be members of several different major groups: bacteria, fungi, protists or viruses. Most microorganisms are helpful, but some cause disease. Students will use sets of cards to assign microorganisms to different groups. In addition, students will learn about the roles of microorganisms in the natural world and how they are used by humans for food production and other processes (see Answer Key, page 23).

THE VARIETY AND Roles of Microbes

Microbes live almost everywhere on Earth—including within and on other living organisms. They can be found in almost all climates, from extreme heat to freezing cold. Some microbes can make us sick, but only a very small percentage actually cause disease. In fact, many microbes—including most bacteria—are helpful. Much of the oxygen released into the atmosphere through photosynthesis comes from algae and blue-green bacteria. Many fungi and bacteria are essential for cycling nutrients in ecosystems and for acting as decomposers, breaking down dead organisms and the waste of living things.

We depend on microbes for food. What would a hamburger be without a bun, cheese and pickles (all of which are produced with direct assistance from microbes)? The cattle used for beef also rely on microbes to digest the tough grasses they eat. In our own intestines, microbes aid in digestion, make several essential vitamins and help prevent disease.

This activity focuses on the diverse array of microbes and the functions they perform. Three kingdoms within the five kingdoms system of classification are included here: Monera (bacteria), Protista and Fungi. The two kingdoms not considered to have single-celled, free-living individuals are plants (Plantae) and animals (Animalia). Many scientists now favor a three-domain classification system: Bacteria, Archaea and Eukarya.

Viruses represent a special case within the groups of microbes. They do not have all of the structures necessary for independent life. They must invade and use living cells to reproduce. For this reason, many biologists do not consider viruses to be “living” organisms, and do not assign them to a kingdom or domain.

MATERIALS

Teacher (see Setup)

- 12 sheets of cardstock (to prepare cards)
- 6 resealable plastic bags

Per Group of Students

- Set of 4 *Microbe Groups* cards (p. 21) and 20 *Microbe Examples* cards (p. 22)
- Group concept map (ongoing)

SETUP

Copy the *Microbe Groups* and *Microbe Examples* pages on cardstock. Cut out and make six sets of cards (4 large, 20 small cards per set). Place each card set in a resealable plastic bag (see Answer Key, p. 23).

Have students work in groups of four.

Optional: Change the enlargement setting on a photocopier to 129% and copy pages onto 11-in. x 17-in. paper.

SOMETIMES THE BODY'S IMMUNE SYSTEM needs help to fight a disease caused by a microbe. Many different drugs and chemicals are used either to kill or slow the growth of different microbes. Common antimicrobial agents include antibacterial drugs (which kill bacteria), antiviral agents (which kill viruses), antifungal agents (which kill fungi), and antiparasitic drugs (which kill parasites, including some protists and larger non-microbial parasites, such as tapeworms). The term "antibiotic" usually refers to antibacterial drugs, such as penicillin. Sometimes, "antibiotic" is used in a more general sense to describe agents that are effective against an infection caused by any kind of living organism (not viruses). It is important to remember that each antimicrobial agent is effective only against a limited group of organisms.

PROCEDURE

1. Ask students, *What are some different kinds of microorganisms? Do microorganisms have different kinds of roles? What are some examples?* Discuss students' ideas. Tell students they they will be looking at specific examples of materials and resources that involve microbes.
2. Give each student group one bag of cards. Have students remove the set of 20 smaller cards, which describe roles performed by certain microbes. Instruct student groups to read, discuss and decide the best way to sort the cards into categories. Have groups make notes about how they made their decisions. Then, have a spokesperson from each group explain its rationale for sorting and discuss as a class.
3. If students did not organize the cards by "role in food production," "role in causing disease," and "role in ecosystem/environment," have them sort the cards into these new categories.
4. Tell students that the cards also may be sorted by "kind of microbe" involved in each process. Instruct groups to take the four large cards ("Viruses," "Fungi," "Protists," "Bacteria") from the bag and read each card. Discuss the information and ask questions, such as, *Which microbe group does not have members with cells?* (viruses) *Which groups have multi-celled members?* (protists, fungi) Mention that all roles described on the small Microbe Examples cards are carried out by one or more members of the four groups described on the large cards.
5. Have students place their large Microbe Group cards on the table. Starting with the cards related to food production, have students use the clues on each small card to assign it to one or more Microbe Group cards. Students may notice that some roles are fulfilled by microbes belonging to two groups (e.g., cacao seeds are fermented by bacteria and fungi).
6. Discuss as a class. Point out that microbes related to food production are found in either the bacteria or fungi group. Ask, *Are you surprised by this? What can we now say about microbes?* Explain that most microbes are not harmful, and many are helpful. But some microbes, called pathogens, cause diseases in humans, animals, plants and other organisms. Ask, *What do you know about disease?* Instruct groups to select the small cards related to disease and place each one by the appropriate Microbe Group card.
7. Ask students, *What are the differences and similarities between the microbes involved in food production*

Continued

Continued from p. 18.

Science in Personal and Social Perspectives

- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions), with chemical hazards (pollutants in air, water, soil, and food), with biological hazards (pollen, viruses, bacteria, and parasites), with social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting, and drinking).

EXTENSIONS

- Bring to class examples of the foods used in this activity. Or have students bring different foods produced by using microbes and/or recipes that use microbe-produced foods.
- Have students investigate other common foods produced with the aid of microbes, such as root beer (yeast), vinegar (bacteria), pickles (bacteria) or cheese (bacteria, and sometimes fungi).

DID YOU KNOW?

- The word "bacteria" is derived from the Greek word *bakteria,* or staff cane, because the first bacteria discovered were rod-shaped.
- A virus that infects bacteria is known as a "bacteriophage," or a "phage."
- The word "virus" comes from the Latin word for poison or slime.

FERMENTATION

Many foods are produced through fermentation, a process used by some microorganisms to obtain energy from food in the absence of oxygen.

Yeast produce CO_2 as a waste product when oxygen is present. Some yeast cells are able to break down food through the process of fermentation, which does not require oxygen and produces ethyl alcohol and CO_2 as waste. Beer and wine are products of yeast fermentation.

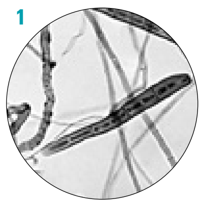
Some bacteria also obtain energy through fermentation. By-products of bacterial fermentation include CO_2 and acetic acid or lactic acid. The acids give food a characteristic sour flavor. The by-products or waste products of different species of bacteria produce different flavors and tastes. For example, the bacteria used in yogurt produce lactic acid, which lowers the pH, changes the milk proteins and thickens the mixture. Many foods processed through bacterial fermentation, such as sausage or sauerkraut, also have added salt. The salt favors the growth of desirable strains of bacteria that are tolerant of salty conditions. It also prevents the growth of harmful bacteria.

and the microbes that cause disease? What general statement could we make about microbes? (Microbes have many roles. Some are helpful; some are harmful.) *Is it possible for the same microbe to be both helpful and harmful to humans or to another organism?* (yes)

8. Repeat the sorting activity with the last group of small Microbe Examples cards: ecosystems. Discuss students' groupings. Mention that while microbes often are invisible members of ecosystems, they play important roles in decomposition and in soils, and are important members of food webs.
9. Ask, *Why should we care about microbes?* Discuss as a group. Have students add any new ideas to their concept maps.
10. Have students sort and place the cards back in the plastic bags.

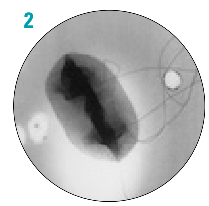
Major Groups That Contain Microbes

1



FUNGI (Rusts, Molds, Mushrooms, Yeasts) - Members of this group have variable sizes. Some are microscopic, some are single-celled, and some are multi-cellular. Each cell has a cell membrane, a well-defined nucleus, and organelles (such as mitochondria) surrounded by membranes. Typically, fungal cells have cell walls. Fungi are not motile (capable of movement). They are heterotrophic and must obtain nutrients from their environments, often from dead or decaying materials. Yeasts are single-celled fungi. The bodies of larger fungi consist of threads (hyphae) that can be tangled loosely, as in bread mold, or packed tightly, as in the body of a mushroom.

2



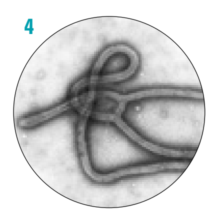
BACTERIA - All members of this group are microscopic and single-celled, with a cell membrane and typically with a cell wall. Bacterial cells do not have a well-defined nucleus or organelles surrounded by membranes. Some bacteria are autotrophic and are capable of making their own food by using light energy (photosynthesis), or through other chemical reactions. Other bacteria are heterotrophic and must derive energy by breaking down organic material (food) that they obtain from their environments. Some bacteria are motile. Bacteria usually are rod-, sphere- or spiral-shaped. However, blue-green bacteria can clump together as green threads that look like algae. Recent classification systems place the archaebacteria in a separate kingdom or domain (Archaea).

3

PROTISTS - Members of this extremely diverse, informal group vary in size and structure. Some are microscopic, some are single-celled, and some are multicellular. Each cell has a cell membrane, a well-defined nucleus, and organelles. Some have cell walls. Recent classifications assign different protist groups to several separate kingdoms within the domain Eukarya. The following three groups of protists often are recognized informally.

- **Algae** - Plant-like; single-celled or multicellular; contain chloroplasts; autotrophic (able to carry out photosynthesis).
- **Protozoa** - Animal-like; always single-celled; no cell walls; often motile; absorb nourishment from the environment by feeding on prey or surviving as parasites (heterotrophic).
- **Water and Slime Molds** - Fungus-like; single-celled or multicellular; absorb nourishment from the environment (heterotrophic).

4



VIRUSES - All members of this group (which is not part of a kingdom or domain) are microscopic. Individual particles consist of genetic material (DNA or RNA) encased in a protein coat (which is not equivalent to a cell membrane or cell wall). Viruses must invade living cells to make copies of themselves.

---

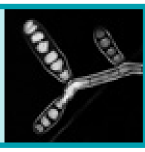
[1] *Corynespora cassiicola* fungus. *C. cassiicola* causes "leaf spotting disease" in soybeans, cucumbers, tomatoes and tobacco. Other plants also are sometimes affected. CDC\4203 L. Ajello.

[2] *Escherichia coli* bacteria. CDC\9995 E. White, P. Hayes.

[3] Flagellate protist. Ron Neumeyer © MicroImaging Svcs.

[4] Ebola virus. CDC\1832 C. Goldsmith.

5



Exserohilum rostratum fungus. CDC\3784 L. Ajello.

Microbe Groups

MICROBE GROUP

VIRUSES are the tiniest microbes. They must be magnified about 150,000 times to be seen. They are not considered cells, because they do not have a cell wall, cell membrane, or nucleus. They also cannot grow or reproduce on their own. Instead, they invade cells in living organisms and force these cells to produce more viruses. This invasion of healthy cells is how viruses cause disease. Antibiotics cannot destroy viruses.

MICROBE GROUP

FUNGI can be made of one or many cells. The main bodies of many-celled fungi are composed of tiny threads and may appear fuzzy (like bread mold) or almost solid (like mushrooms). Fungi do not have chlorophyll (green pigment). They are some of nature's recyclers. Fungi live by absorbing nutrients from other living things or from dead and decaying organisms. Each fungus cell has a defined nucleus, a cell membrane, and a cell wall made of different material than the cell walls of bacteria or plants. Yeasts, which are single-celled fungi, are able to break down food sources through a process called fermentation. Yeast cells must be magnified at least 100 times to be seen.

MICROBE GROUP

PROTISTS may consist of one or many cells. Some protists (such as paramecia) are microscopic, while others are macroscopic. Cells of all members of the protist group have a defined nucleus and a cell membrane. Some have cell walls. Protists vary greatly in how they obtain food. There are three main groups of protists.

ALGAE - Plant-like; able to carry out photosynthesis.

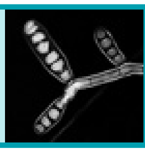
PROTOZOA - Animal-like; feed on prey or survive as parasites; always single-celled; sometimes motile (capable of movement).

WATER AND SLIME MOLDS - Fungus-like; absorb food from the environment.

MICROBE GROUP

BACTERIA are made of only one cell and are much larger than viruses. Bacterial cells usually are shaped like rods, spheres or spirals. They have a cell membrane and usually a cell wall, but they do not have a defined cell nucleus. Some bacteria are motile (capable of movement). They are valuable as recyclers in ecosystems. Some bacteria can break down food sources through a process called fermentation. Others have chlorophyll and carry out photosynthesis. Bacterial infections can be treated with antibiotics, but some bacteria have become resistant to common types of antibiotics. Most bacteria must be magnified 1,000 times to be visible.

5 Microbe Examples



Exserohilum rostratum fungus. CDC\3784 L. Ajello.

TUBERCULOSIS
is a deadly, contagious disease transmitted through the air. It's also referred to as "TB." Not all antibiotics are effective against the microbe that causes TB.

RINGWORM
is a circular, scaly or red rash caused by single-celled or thread-like microbes in the surface layers of skin (not a worm). The rash, which is similar to athlete's foot, can be spread by animals, people, or contaminated clothing.

YOGURT
is milk or cream fermented by certain kinds of heat-loving microbes that are much smaller than yeast.

RED TIDE
is an overgrowth of a microbe that produces a poison. The poison affects the nervous system of fish. The animal-like microbe lives in the ocean.

THRUSH
is a disease that causes painful, whitish patches in the mouth and on the tongue. The microbe responsible for this infection is single-celled, has a defined nucleus and must be magnified about 100 times to be visible.

STOMACH ULCER
is a sore in the lining of the stomach or small intestine that leads to burning pain. Ulcers usually are not caused by spicy food. Instead, most stomach ulcers are caused by an infection that can be treated with antibiotics.

CHOCOLATE
comes from cacao seeds that are broken down and fermented by two kinds of microbes.

NITROGEN
is introduced into the food chain by very tiny single-celled microbes that live in water and soil.

HIV
is transmitted through the exchange of infected blood or other body fluids. It invades and kills one type of white blood cell needed to fight disease. Once people with HIV become unable to fight infections, they are said to have AIDS.

PEPPERONI SAUSAGE
is made of chopped meat that is aged and fermented to improve the flavor. The microbes used to produce this sausage must be magnified around 1,000 times to be clearly visible.

COMPOST
results from the breakdown of plant materials by microbes and other organisms, such as earthworms and insects.

MOSAIC DISEASE
affects tomatoes, peppers and other food sources. It is caused by a tiny microbe that invades and destroys cells.

MALARIA
is caused by a single-celled parasite with a complex life cycle. The animal-like parasite is carried from an infected person to a healthy person by certain kinds of mosquitoes.

SANDWICH BREAD
is a baked mixture of ingredients, including flour, water and a single-celled microbe. When the microbe multiplies and releases bubbles of gas, it causes the bread to "rise."

GREEN POND WATER
gets its color from tiny photosynthetic microorganisms that are not members of the Plant Kingdom.

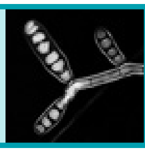
PENICILLIN
is an antibiotic that kills certain kinds of bacteria. It is a form of natural protection produced by a microbe that forms fuzzy clumps.

ANTHRAX
is an infectious disease that spreads from animals to other animals and humans. Anthrax is caused by a single-celled microbe without a defined cell nucleus.

BEER
is a mixture of barley, wheat, hops, and sugar that is fermented by a microbe. The microbe is quite large. It must be magnified about 100 times to be visible.

IRISH POTATO BLIGHT
is a serious plant disease that killed most Irish potato crops between 1845 and 1851. It is caused by a fungus-like microbe that infected the leaves and stems of potato plants.

MEASLES
is a disease spread by coughing, sneezing, or contact with people infected by a microbe that does not have a cell membrane or cell wall.

5 

Exserohilum rostratum fungus. CDC\3784 L. Ajello.

ACTIVITY 5

Answer Key

ROLES: (D) = Disease; **(E)** = Ecosystem; **(F)** = Food Production

Viruses

HIV/AIDS (D) is a disease caused by human immunodeficiency virus (HIV). This virus attacks a specific type of white blood cell (CD4+ T cells), thereby weakening the immune system and placing a person at greater risk for other infectious diseases and cancer. A person is considered to have Acquired Immunodeficiency Syndrome (AIDS) when the number of CD4+ T cells drops below a defined level, or when he or she develops an HIV-related illness. There is no cure for HIV/AIDS infection, which is fatal.

MEASLES (D) is a highly contagious disease caused by a virus. Typical symptoms include fever, cough, rash, and inflamed eyes. Persons who have had a case of active measles or who have received a measles vaccination have immunity (biological defenses) against the virus.

MOSAIC DISEASE (D) is a crop disease caused by tobacco mosaic virus that affects tomatoes, peppers and other food sources.

Fungi

BEER (F) is a mixture of barley, wheat, hops and sugar that is fermented by baker's yeast, a single-celled fungus known formally as *Saccharomyces cerevisiae.*

PENICILLIN (D) is a chemical substance produced by the fungus, *Penicillium,* that is toxic to many kinds of bacteria. It is the basis for many modern antibiotics.

RINGWORM (D) is a contagious disease of the skin and scalp caused by several different kinds of fungi. Growth of the fungus on the skin often causes a circular, reddish, itchy rash. Ringworm and related infections, such as athlete's foot, are treatable with antifungal lotions and creams.

SANDWICH BREAD (F) is a baked mixture of flour, water and baker's yeast that rises when the yeast cells begin to multiply rapidly and give off bubbles of CO_2 gas. Small amounts of alcohol are produced, but they evaporate during baking.

THRUSH (D) is a disease of the tongue and mouth caused by a single-celled yeast, called *Candida albicans* (not the same as baker's yeast). Thrush is most common in infants or in adults with weakened immune systems. It may be treated with certain antifungal products.

Protists

IRISH POTATO BLIGHT (D) is a disease caused by a fungus-like protist that killed most Irish potato crops between 1845 and 1851. Since potatoes were the main food source for most of the population, crop losses due to this disease led to widespread famine. There were many social consequences of the Irish potato famine—including the immigration of more than one million Irish citizens to the United States.

MALARIA (D) is a sometimes fatal, mosquito-borne disease caused by parasitic protozoans of the genus *Plasmodium.* The parasite invades and destroys red blood cells. Malaria is spread by certain mosquitoes that bite an infected person and then become infected themselves; these mosquitoes transmit the disease by biting other persons. Worldwide, more than 350 million cases of malaria are reported each year.

RED TIDE (D) is a rapid overgrowth of dinoflagellates, a type of protist found in marine plankton, which gives a reddish hue to water. Dinoflagellates produce a neurotoxin (poison that affects the nervous system) that is concentrated enough to kill fish.

Bacteria

ANTHRAX (D) is a disease of the blood that affects humans as well as animals such as cattle, deer and camels. *Bacillus anthracis,* the bacterium that causes anthrax, typically is found in soil. People can catch anthrax by handling products from infected animals or by coming in contact with the dormant (inactive) forms of the bacteria, called spores. Anthrax is treated with antibiotics.

PEPPERONI SAUSAGE (F) is a dried meat mixture that is fermented by lactic acid-producing bacteria. The process produces acids that contribute to the flavor.

NITROGEN (E) - Certain bacteria assimilate ("fix") nitrogen from the atmosphere into nitrogen-containing compounds that can be taken up by plants.

STOMACH ULCER (D) is a disease of the stomach and the first part of the small intestine that damages the protective lining of these organs. The most common cause is infection by a bacterium, *Helicobacter pylori.* Infections are treatable with antibiotics.

TUBERCULOSIS (D) is a disease of the lungs caused by the bacterium, *Mycobacterium tuberculosis.* Some strains of the bacterium have developed resistance to the antibiotics once commonly used to treat tuberculosis.

YOGURT (F) is milk or cream fermented by one or more kinds of heat-loving bacteria.

Protists & Bacteria

GREEN POND WATER (E) - When fresh water appears greenish, many forms of algae, other protists, and blue-green bacteria (cyanobacteria) may be present.

Fungi & Bacteria

CHOCOLATE (F) - Cacao seeds must be fermented by yeast (fungi) and bacteria in order for the complex flavors of chocolate to develop.

COMPOST (E) - Bacteria and fungi help to decompose leaves and other decaying organic materials found in compost piles. Some protists, such as slime molds, also may participate. Compost is used to enrich soil.

6

Bacillus anthracis spores. CDC\10123 J. Carr, L. Rose.

TIME

Setup: 20 minutes
Activity: 45–60 minutes

Overview

Students will create scale models of microorganisms and compare the relative sizes of common bacteria, viruses, fungi and protozoa (microscopic members of the protist group) using metric measures: meters, centimeters and micrometers. Students will learn that microbes come in many different sizes and shapes, and frequently are measured in micrometers (µm).

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

- Think critically and logically to make the relationships between evidence and explanations.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.
- Develop descriptions, explanations, predictions, and models using evidence.
- Use appropriate tools and techniques to gather, analyze, and interpret data.

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.
- All organisms are composed of cells—the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.

COMPARING SIZES OF Microorganisms

Microbes are organisms too small to be seen with the naked eye. Even so, there are enormous variations in size and type among microbes. This activity allows students to compare the sizes of various microorganisms, relative to an object with a standard size (0.5 mm) that is visible without magnification. Students will compare microbes listed on the *Microbe Scaling Chart*, which range from an amoeba—measuring 300 micrometers (equivalent to 0.3 millimeters) in diameter or larger—to the polio virus, which is only 0.03 micrometers in length.

Students will use metric measurements for their calculations.

MATERIALS

Teacher (see Setup)

- Paper square (2.5 m x 2.5 m)

Per Group of Students

- Set of 4 prepared text strips
- 4 hand lenses
- 4 metric rulers marked in millimeters
- 4 pairs of scissors
- Assorted markers or colored pencils
- Meter stick
- Paper or science notebook
- Several sheets of colored or plain paper, or roll of chart or kraft paper
- Tape or glue
- Copy of the *Microbe Scaling Chart* student sheet (p. 27)
- Group concept map (ongoing)

SETUP

Use a word processing program to type the following text passage on *one* line, using 12-point Helvetica font.

"The period at the end of this sentence is larger than a/an ______."

Create a total of 24 rows of text with this same phrase. Print the page and cut into strips, so that each strip contains one sentence (one strip per student). Do not photocopy the page, as this will reduce the sharpness of the printed text, particularly the period at the end of the sentence.

Create a model of the period character by making one 2.5-m x 2.5-m (250-cm x 250-cm) paper square. The square represents the period character enlarged 5,000 times. Obtain several sheets of plain or colored paper, or a roll of chart or kraft paper, for students to use to make large microbe models.

Make copies of the student sheet. Place materials for each group on trays in a central location.

PROCEDURE

1. Call students' attention to the prepared strips of paper.
2. Ask students to examine the periods at the end of the phrase, first with their eyes only, and then with a hand lens. Tell students to draw what the period looked like in each case. Discuss their observations. Ask, *Did the period appear the same when it was magnified as*

CUTTING EDGE TOOLS AND TECHNIQUES enable scientists to isolate and examine things as small as individual virus particles and their components. Joanita Jakana and Matthew Dougherty, of the National Center for Macromolecular Imaging at Baylor College of Medicine, look at two virus images obtained using a high resolution electron microscope. The virus image on the left monitor was taken directly from the microscope. The image on the right monitor is a 3-D structural composite of the virus, created with specialized software developed by Mr. Dougherty.

The National Center for Research Resources, National Institutes of Health, supports several centers dedicated to visualizing 3-D structures within cells and viruses (www.ncrr.nih.gov). M. Young © Baylor College of Medicine.

when you observed it with a naked eye? (When magnified, the periods are square.)

3. Have students record their observations in science notebooks or on sheets of paper.
4. Ask, *What can you say about the size of the period?* Tell students the period is about 0.5 millimeters (mm), or 500 micrometers (µm), in length and width. Have students identify the centimeter and millimeter markings on a centimeter ruler. Ask, *How many periods could be lined up, end-to-end, within a meter?* (2,000)
5. Before continuing, you may wish to review the metric system. Explain that the meter is the fundamental unit of length in the metric system. At 39.37 inches, a meter is slightly longer than a yard (36 inches). A centimeter is approximately the width of an average fingernail (0.3937 inches). Ask students, *How many centimeters make a meter?* Hopefully, they will say "100" (the prefix, "centi," is Latin for one hundred). Ask, *How many millimeters make a meter?* (1,000; the prefix, "milli," signifies one thousand.) Thus, one centimeter (cm) is equivalent to 10 millimeters (mm).
6. Introduce students to an even smaller measure, the micrometer (µm), or micron, which is one millionth (or 10^{-6}) of a meter. Mention that a micrometer is a measure too small for the naked eye to see, and that one centimeter contains 10,000 micrometers. Ask, *What is the size, in micrometers, of the period you observed?* (500 µm) Follow by asking, *Why is the ruler not divided into micrometers?* (markings would be too small)
7. Ask students, *What do you know about scale models?* For example, you might mention a road map or a model of the solar system. Ask, *Why do we make scale models?* (to understand the relative position, size or distance of objects)
8. Next, tell students that they are going to make a scale model of microbes, called a "Microbial Mural," using the size of the period as the scale standard. Ask, *If I increased the length and width of the*

Continued

METRICS

The word "meter" comes from the Greek word for "measure." The meter (m) is the standard unit of length in the International System of Units (SI). Below are definitions of SI units for length.

SI subdivisions of a meter (m)

0.1 m = 1 decimeter (dm)
0.01 m = 1 centimeter (cm)
0.001 m = 1 millimeter (mm)
0.000001 m = 1 micrometer (µm)
0.000000001 m = 1 nanometer (nm)

SI measures larger than 1 m

10 m = 1 decameter (dam)
1,000 m = 1 kilometer (km)

Other equivalents

1 m = 39.37 inches (in.)
1 cm = 0.3937 in.
1 mm = 0.03937 in.*
1 nm = 10 Ångstrõm

*1 mm is about 1/2

ONE METER EQUALS

100 centimeters (cm)
1,000 millimeters (mm)
1,000,000 micrometers (µm)

Micrometers also are referred to as "microns."

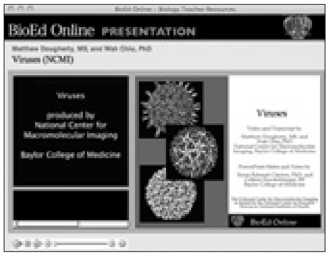
MODEL SCALE

50 cm = 100 micrometers (µm)

EXTENSION

Have students research other microbes and create additional scale models to add to the Microbial Mural.

TEACHING RESOURCES



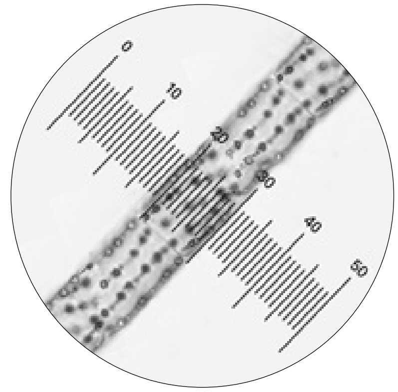
For a discussion about how viruses work and view examples of virus images, see the presentation and slide set, produced by the National Center for Macromolecular Imaging, entitled "Viruses," at www.BioEdOnline.org.

To see the video presentation and slide set "Measuring and Counting with a Light Microscope," visit the BioEd Online website.

It can be difficult to imagine the relative sizes of microbes. *CELLS alive!* has a useful animation to help students visualize and compare the sizes of different microbes on the head of a pin.

The animation may be viewed or downloaded for single use or for use in a classroom at www.cellsalive.com/howbig.htm.

LIGHT MICROSCOPES make excellent measurement instruments when they are calibrated properly. By using a special insert in the eyepiece (called a reticule), one can measure the length or width of any visible object. In the example (right), the investigator estimated the filament to be 13 divisions wide. With a calibration of 20 micrometers per division, the estimated diameter is 260 µm, or 0.26 mm. Note that the edges of the filament are blurry. A different investigator might estimate its diameter as 12, or even 14 divisions. It is useful to set criteria for standard measurements. For example, always measure to the outside edge on both sides of the specimen, or measure one outside edge and one inside edge.



Spirogyra. Courtesy of David R. Caprette, Ph.D., Rice University.

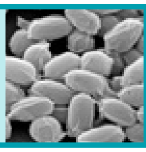
period by 5,000 times, what shape would it have? (square) *How large do you think it would be?* (If the size of the period is 0.5 mm, multiply 0.5 mm x 5,000. Answer: 2,500 mm x 2,500 mm, which is equivalent to 2.5 m x 2.5 m.)

9. Bring out the prepared square of paper (period model) and display it on the wall. Explain that the sheet represents the size of the period enlarged 5,000 times. Ask, *If we enlarged most microbes 5,000 times, do you think they would be larger or smaller than the period?* (Even when enlarged 5,000 times, each of the microbe models will fit on the period.)
10. Distribute the student sheets and assign each group several microbes. Instruct students to make scale drawings or artwork of each of their assigned microbes, based on the line drawings and sizes provided on the chart. Depending on students' ages and experience, you may want to give them only the information from one or both of the "approximate actual size" columns, and have each group calculate the scale sizes of their organism models.

    Note: Make certain every group is assigned at least one microbe large enough to draw (organisms 1–7). The remaining microbes are so small that some will be represented only by a tiny dot on the mural.

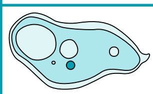
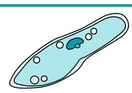
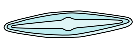
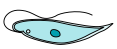
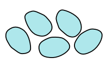
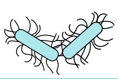
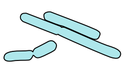
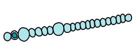
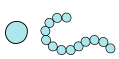
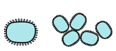
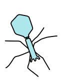
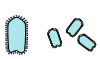
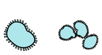
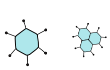
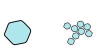
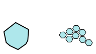
    The microbe sizes described on the *Microbe Scaling Chart* represent typical measurements within the normal size range for each kind of organism. Students may find references to different sizes if they are conducting additional research about the organisms. In addition, some organisms named on the chart actually represent relatively large groups of related species or forms. For example, there are approximately 150 different known species of *Euglena*.
11. Have students place their models on the large paper square. This is an effective way for students to self-check.
12. Discuss the mural with students. Ask students if they could use the names of the any of the microbes on the mural to complete the sentence on their sentence strips. Revisit the concept maps and have students add information from this activity.

6 Microbe Scaling Chart



Bacillus anthracis spores. CDC\10123 J. Carr, L. Rose.

Model Scale Size
0.5 cm = 1 µm

		Group	Organism	Approximate Actual Size of a Single Unit: Micrometers (µm)	Approximate Actual Size of a Single Unit: Millimeters (mm)	Model Scale Size: Centimeters (cm)
–	.		**"Period" character** - Helvetica type,12-point size.	500	0.5	**250**
1		Protists	**Amoeba** - Group of single-celled organisms known for their constantly changing shape.	300	0.3	**150**
2		Protists	**Paramecia** - Group of single-celled freshwater organisms that are slipper-shaped and move with cilia.	250	0.25	**125**
3		Protists	**Diatoms** - Large group of single-celled fresh or saltwater algae.	200	0.2	**100**
4		Protists	**Euglena** - Group of single-celled freshwater organisms that use a single hair (flagellum) to propel themselves.	130	0.13	**65**
5		Fungi	**Baker's yeast** - Single-celled organism used to make bread rise.	10	0.01	**5**
6		Bacteria	***Escherichia coli*** - Bacterium that helps digest food in the intestines; one form of *E. coli* causes serious food poisoning.	2	0.002	**1**
7		Bacteria	***Lactobacillus*** - Group of bacteria used to make yogurt; also found in the digestive tract.	2	0.002	**1**
8		Bacteria	**Cyanobacteria** - Large group of bacteria capable of photosynthesis.	1	0.001	**0.5**
9		Bacteria	***Staphylococcus*** - Group of bacteria on skin that can cause infections; some kinds cannot be killed with most antibiotics.	1	0.001	**0.5**
10		Viruses	**Smallpox virus** - Virus that causes smallpox (brick-shaped); also called "Variola virus."	0.3	0.0003	**0.15**
11		Viruses	**T4 bacteriophage** - Virus that attacks *E. coli* bacteria.	0.2	0.0002	**0.1**
12		Viruses	**Rabies virus** - Bullet-shaped virus that causes the disease called "rabies."	0.15	0.00015	**0.075**
13		Viruses	**Influenza virus** - Group of viruses that cause influenza; also known as the "flu."	0.1	0.0001	**0.05**
14		Viruses	**Adenovirus** - Group of viruses that cause respiratory diseases.	0.08	0.00008	**0.04**
15		Viruses	**Polio virus** - Virus that causes the disease known as polio-myelitis; also called "polio."	0.03	0.00003	**0.015**
16		Viruses	**Rhinovirus** - Group of viruses that cause the common cold.	0.03	0.00003	**0.015**

Actual size: 1 millimeter (mm) = 1,000 micrometers (µm). Drawings not to scale.
Micrometers also are referred to as "microns."

Pediculus humanus, or female body louse. CDC\9244 J. Carr, J. Strycharz, K. Yoon, F. Collins.

STUDENT READING

A Powerful Tool

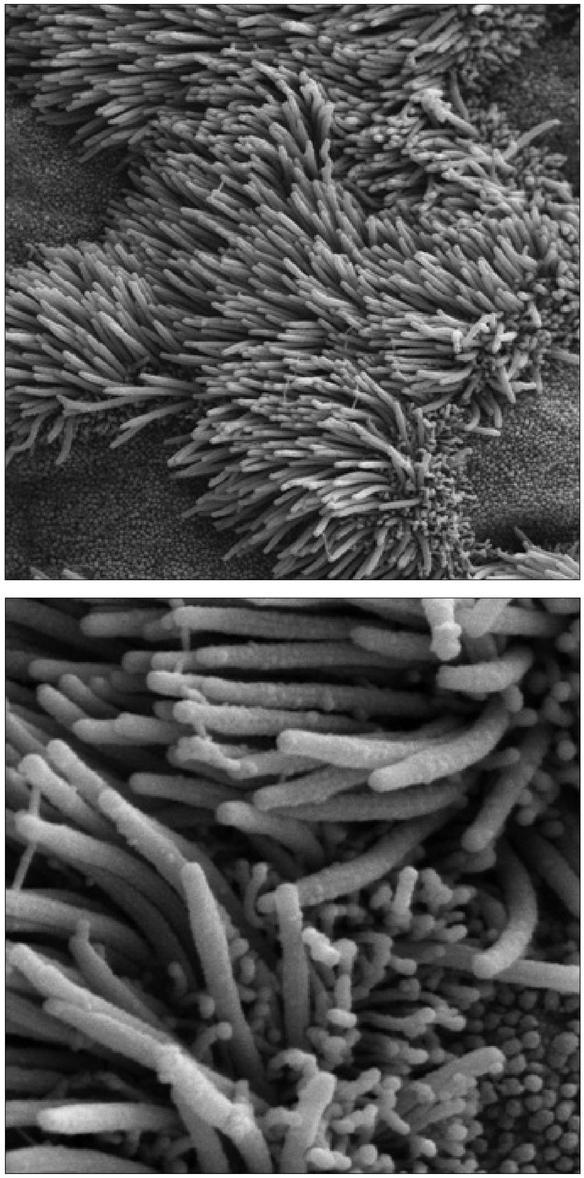
Medical researchers and other scientists today have powerful tools for observing and studying microbes. One such tool is the scanning electron microscope, or SEM.

This type of microscope uses electrons to view and image structures too tiny to be seen with an ordinary light microscope. It allows scientists to see three-dimensional aspects of infectious agents, living organisms and nonliving surfaces, without distortion and without destroying specimens in the process.

To create the images, a filament inside an electron "gun" shoots a beam of electrons down through a stack of electromagnetic lenses onto a specimen, held in a vacuum chamber below. The beam continually scans across the sample, which responds by emitting electrons from its own surface. These are collected by a detector inside the sample chamber.

This process results in a simultaneous recreation of the sample's surface on a viewing screen. With the twist of a dial, or the wiggle of a mouse (in newer models), the specimen's contours can be explored in any magnification, from about eight times the actual size up to hundreds of thousands of times—as much as a million times!

Watching the image on the screen is like looking out the window of a plane. The landscape "below" continually changes as your "plane" flies above or around it, zooming in and out or hovering for a photo.



The images above resemble some kind of sea creature. They are, in fact, scanning electron microscope images of human lung trachea cells. Note the difference in resolution between the two images. The upper image was magnified at 5,000x, while the lower one was magnified at 20,000x. Dartmouth College\L. Howard, C. Daghlian.

Other research instruments can be attached to the SEM to extend the range of information a specimen can yield. One tool produces a spectrum of elements present in a given sample. Software programs are utilized to further analyze a sample's size, shape and other physical characteristics.

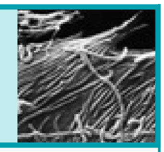
Most modern SEMs are controlled by computer software, and require samples to be dry and coated with a thin film of gold. Some SEMs also can vary the pressure in the sample chamber, or even introduce water vapor. This makes it possible to observe fresh samples (like medical tissues) in their natural state and introduces the dimension of time. For example, crystals now can be seen dissolving and resolidifying in real time.

Microscopes like the SEM have allowed researchers to see the external and internal appearance of microbes. Still, scientists and engineers continue to develop more powerful SEMs and other tools, including new microscopes that allow us to see cells at the subatomic level. These advancements in microscope technology will help solve a host of medical problems.

Overview

Students will read about six important events in the history of microbiology and decide on these events' most probable chronology, based on evidence provided. Students will learn that most scientific discoveries are related to other work, and that scientific advances often depend on the development of appropriate tools and techniques (see Answer Key, sidebar, p. 30).

7



Ebola virus. CDC\1836 C. Goldsmith.

TIME

Setup: 10 minutes

Activity: 45 minutes for one or two class periods

MILESTONES IN

Microbiology

Very little attention was paid to the world of microbes until the 1600s, when Robert Hooke developed a primitive compound microscope (one which uses two lenses in sequence) and described tiny organisms that he observed with it. Even more detailed observations of microscopic organisms were made by Anton van Leeuwenhoek, who developed precise techniques for grinding magnifying lenses. Van Leeuwenhoek observed numerous small, swimming organisms in pond water and named them "animalcules."

It was not until the mid-1800s that scientists had enough tools to begin serious studies of microbes. In the 1850s, Louis Pasteur studied the fermentation of wine, which he found to be caused by yeast cells. He proposed that microorganisms also could cause disease, and later developed the process of pasteurization to remove harmful bacteria from food.

Pasteur's work stimulated that of Robert Koch, a physician who studied anthrax (a disease of cattle and sheep). Koch is credited with developing many culture techniques, including the use of nutrient agar for growing bacteria. He also established a set of rules to guide decisions about whether a given microbe actually caused a disease. These rules are known as "Koch's Postulates" (see sidebar, right).

Much later, in the 1930s, Walter Fleming accidentally discovered that substances produced by a common fungus, *Penicillium,* could kill *Staphylococcus* bacteria in cultures. His work led to the development of penicillin, the first antibiotic.

Since viruses are so much smaller than bacteria, most research on viruses and viral diseases began later than work on other microbes. In the 1890s, two investigators working separately, Martinus Beijerinck and Dmitrii Ivanowski, studied juices extracted from the leaves of plants infected with what is now known to be tobacco mosaic virus. They filtered the juices to remove bacteria and found that even when highly diluted, the liquid still could cause infection in plants. Ivanowski concluded that an infectious agent other than a bacterium—a filterable "virus"—led to the disease. Beijerinck called the substance "contagious living fluid."

Neither investigator was able to observe or grow the hypothesized disease-causing agents. Later, in the 1930s, Wendell Stanley isolated crystals of tobacco mosaic virus. The invention of the transmission electron microscope by Ernst Ruska in 1933 made it possible to observe viruses for the first time at magnifications of 10,000 times or more. For this, Ruska received the Nobel prize in physics.

The process by which microbiology knowledge has accumulated is typical of how science proceeds. Often a critical tool, such as the microscope, is needed before questions even can be

Continued

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

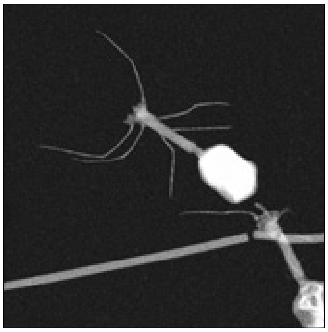
History and Nature of Science

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields, such as the health professions.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry.
- Many individuals have contributed to the traditions of science.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

KOCH'S POSTULATES

One can conclude a microbe causes a disease if:

- the same microbe is present in every case;
- it is possible to take a sample from a sick animal and grow the microbe in the laboratory;
- a healthy animal exposed to a sample from the microbes grown in the lab develops the same disease; and
- it is possible to isolate and grow the same microbes from the newly infected animal.



Rod-shaped tobacco mosaic virus and alien-like T4 bacteriophages (viruses that infects bacteria). NIAMS, NIH\A.Steven, M. Cerritelli, and Brookhaven National Laboratory\ M. Simon, J. Wall, J. Hainfeld.*

ANSWER KEY

1600s - A New World: Early microscopes make tiny life forms visible.

1881 - A Culture Medium: Culture techniques make it possible to "grow" bacteria.

1884 - Mechanisms of Disease: Scientists learn how to connect a specific bacterium to a disease.

1890s - Contagious Living Fluid: Scientists learn that something smaller than a bacterium can cause disease.

1929 - The Discovery of Penicillin: Scientists find that penicillin acts to kill bacteria in culture.

1930s - Seeing Viruses: Science advances sufficiently to allow viruses to be observed.

* Fibers enhanced by M. Young, Baylor College of Medicine. Image courtesy of the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), NIH. Image taken with the Brookhaven National Laboratory Scanning Transmission Electron Microscope.

asked. Progress occurs unevenly, with one critical discovery suddenly opening entire new areas of investigation.

MATERIALS

Teacher (see Setup)

- 24 sheets of cardstock

Per Group of Students

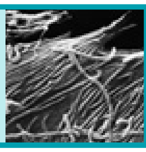
- Set of prepared *Discovery Readings* cards (p. 31–33)
- 4 highlighters (4 different colors)
- Pair of scissors
- Paper clips
- Transparent tape
- Copy of the *Timeline* student sheet (p. 34, see Answer Key, left sidebar)
- Group concept map (ongoing)

SETUP

Make six copies of the student sheets on cardstock. Cut out the *Discovery Readings* to make sets of cards (one set of all readings per group). Place materials in a central location. Have students work in groups of four.

PROCEDURE

1. Ask students a question about how one discovery or invention can lead to another, such as, *Which came first, the wheel or the cart?* Or *Would a light bulb be of any value if ways to utilize electricity had not been invented?* Discuss students' responses.
2. Distribute the *Discovery Readings* sets to each group. Tell students that they will use clues from each reading to figure out the historical order in which events described in the articles occurred. Have each student select a highlighter and one article from the group's set. Instruct students to highlight words that provide clues related to the order of events.
3. When a student finishes an article, he or she should pass it to another group member until all members have read and marked all of the articles. If a word or phrase already has been highlighted and the next reader agrees with the marking, that reader should draw a line with his or her highlighter above the mark.
4. Next, have each group discuss and determine the most likely order of events and discoveries.
5. At the bottom of each reading, have each group list major clues that might help others recreate the order of events.
6. Distribute the *Timeline* sheets. Have groups cut out the sections and tape the timeline together.
7. Tell students to paper clip (not tape) the articles in order along the top of the timeline. Have each group share its results with the class. Discuss any differences among the groups' timelines. If there is a disagreement, let students present their cases. Lead the class toward consensus. Ask, *Why do all of the groups have the same article first on the timeline?* (microscope) *What is the most logical second event?* (agar plates) Ask, *Why is the development of this technique important?* (It provided a reliable way to grow bacteria for study.)
8. Based on the readings, it will be difficult for students to decide whether "The Discovery of Penicillin" or "Contagious Living Fluid" came first. Ask, *What additional information might help us to make a decision?* You may want to ask students to research these topics on their own.
9. Finally, have groups calculate the number of years between events and discuss the possible reasons for the varying time intervals between discoveries. You may wish to discuss why related discoveries sometimes occur close together in history.
10. Allow students time to add this information to their concept maps.



Ebola virus. CDC\1836 C. Goldsmith.

7 Discovery Readings

Seeing Viruses

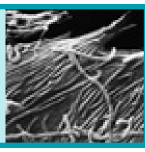
Wendell Stanley and his collaborators found particles of what they believed was tobacco mosaic virus. They learned that the particles could cause the disease in other plants and concluded they had tracked down a virus first described by Ivanowski and Beijerinck. Each particle was made of several thousand viruses. At the same time, other scientists found that they could grow viruses in the living cells of fertilized eggs. This allowed them to produce larger quantities of viruses for study. Finally, thanks to a new microscope designed by German physicist **Ernst Ruska**, it became possible to see viruses for the first time. Ruska created the first electron microscope, which allowed magnifications up to 10,000 times.

Clues about when this happened:

The Discovery of Penicillin

An Englishman named **Alexander Fleming** was studying *Staphylococcus,* a bacterium that causes skin and other diseases. Scientists already had studied many different bacteria, and Fleming was about to make an important new contribution. Before going on vacation, he started some cultures of *Staphylococcus* on agar plates. He had opened the plates several times to study them, which exposed the plates to the air. When Fleming returned, he discovered that one plate was full of *Penicillium,* a common green mold, and that no bacteria were growing near the mold. He grew more *Penicillium* in a liquid culture and added a few drops to a different plate of *Staphylococci*. He was amazed to see that the *Staphylococci* were destroyed. His work laid the foundation for the development of modern antibiotics, such as penicillin.

Clues about when this happened:



Ebola virus. CDC\1836 C. Goldsmith.

7 Discovery Readings

Mechanisms of Disease

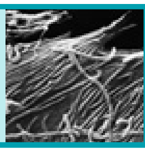
Scientists were beginning to realize that infections by bacteria might lead to diseases, such as tuberculosis or anthrax. However, they couldn't figure out how to decide whether a particular microbe actually caused an illness. **Robert Koch** developed a series of rules, now known as "Koch's Postulates," to help make the decision. He proposed that in order to conclude that a microbe causes a disease: 1) the same microbe must be present in every case; 2) it must be possible to take a sample from a sick animal and grow the microbe in the laboratory; 3) a healthy animal must develop the same disease when exposed to a sample from the microbes grown in the lab; and 4) it must be possible to isolate and grow the same microbes from the newly infected animal.

Clues about when this happened:

Contagious Living Fluid

Martinus **Beijerinck**, a Dutch biologist, worked mostly with bacteria, but he became curious about another scientist's work on diseases of tomato and tobacco plants. The other scientist, named **Dmitrii Ivanowski**, had squeezed juice from the leaves of a diseased plant and filtered the juice to remove any bacteria. He discovered that the juice still caused other plants to get the disease. Beijerinck repeated the work and observed that even when diluted, the filtered liquid could cause the disease. He concluded that the disease was caused by something smaller than a bacterium. The two scientists are credited with finding the first known virus, tobacco mosaic virus, which Beijerinck called "contagious living fluid." However, they did not yet understand what it was or how it caused disease.

Clues about when this happened:



Ebola virus. CDC\1836 C. Goldsmith.

7 Discovery Readings

A New World

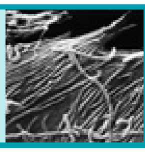
Anton van Leeuwenhoek and **Robert Hooke** created the first microscopes. They were simple by today's standards, but these early microscopes allowed scientists to see tiny insects, plant cells, bacteria and protozoans for the first time. Hooke is credited with inventing the compound microscope, which has two lenses. He also was the first person to use the word "cell" in biology. Van Leeuwenhook perfected the process for making glass lenses. He made detailed observations of tiny organisms never seen before, and was the first person actually to see bacterial cells. Over the course of his lifetime, he made more than 400 microscopes by hand.

Clues about when this happened:

A Culture Medium

Robert Koch used a microscope to study anthrax and other bacteria. One of the technical challenges he faced was finding a substance on which bacteria would grow. He tried liquids, such as broth (clear soup), potato slices, and even gelatin. None of these methods worked well. Then, **Angelina Hesse**, (the wife of **Walter Hesse**, one of Koch's collaborators) suggested trying agar-agar, a seaweed agent that was used to thicken jellies and puddings. Together, this team developed a gelatinous product that could be poured into the bottoms of thin flat plates. Once cooled, the gelatin remained solid at room temperature. Scientists now had a way to grow and observe bacteria. Today, the gelatin used for the culture of bacteria often is called "nutrient agar."

Clues about when this happened:



Ebola virus. CDC\1836 C. Goldsmith.

Timeline

Cut out the sections and tape together to form a long strip, starting with the 1600s on the left and ending with the 1930s on the right.

1600s

1881

1884

1890s

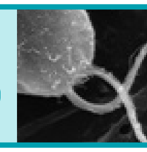
1929

1930s

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.

8



***Chlamydomonas* algae.** Dartmouth College\L. Howard, C. Daghlian.

TIME

Setup: 30 minutes

Activity: 45 minutes for first class session

Following 3 days: 15 minutes daily to observe cultures

MICROBES ARE 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 hardiest of microbes, referred to by scientists as "extremophiles." Most extremophiles are single-celled organisms similar to bacteria, called Archaea. Many classifications place Archaea (or archaebacteria) 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 of bacteria) grow large enough to be seen clearly.

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.

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

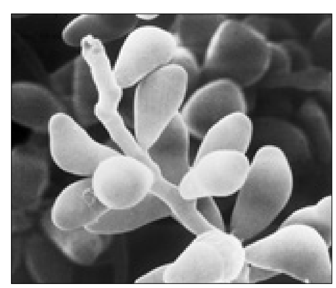
Grades 5–8

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

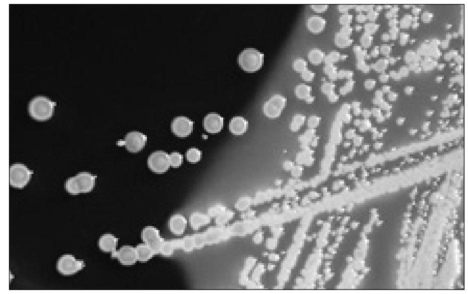
Teacher (see Setup)

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.

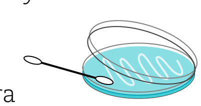
SAFETY ISSUES

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 severa 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.

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.

8. Collect used swabs from students and discard as instructed in Safety Issues. Clean all work areas with paper towels and disinfectant.
9. Collect and store sealed Petri dishes.

Sessions 2–4: Follow-up

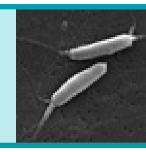
1. Distribute clean Petri lids or dishes. Have each student use a dish as a template to draw three separate circles, labeled "Day 1," "Day 2" and "Day 3." Have each group member observe and draw one of the group's cultures each day. Ask one group member to prepare an additional sheet for observing the 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 Activity 1, 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.

Overview

Students will be introduced to the immune system through an overview of how the body protects and fights against microbes. They will use this information to solve a crossword puzzle featuring vocabulary related to the immune system and microbes (see Answer Key, p. 60).

9



Flexispira rappini bacteria. CDC\5709 J. Carr, P. Fields, C. Fitzgerald.

TIME

Setup: 10 minutes
Activity: 45 minutes

DEFENDING AGAINST

Microbes

We are surrounded by potential disease-causing microbes, yet most of us remain remarkably healthy. How do our bodies protect themselves against infections by microorganisms and viruses? The answer lies with the remarkable immune system, which consists of many types of proteins, cells, organs and tissues—all working together to identify and destroy foreign invaders (primarily microbes) and abnormal cells (such as tumor cells) within the body.

A healthy immune system can distinguish between the body's own cells (including helpful microbes inside the body) and foreign cells. When immune system cells detect foreign cells or organisms, they quickly attack. Anything that triggers this immune response is called an "antigen." An antigen can be a microbe, a part of a microbe, or even cells from another organism (such as from another person). Parts of the immune system also can remember a disease-causing agent (or pathogen) and mount an attack if the pathogen reappears. These immunological memories are the basis of vaccination. Vaccines "teach" the immune system to recognize a specific pathogen by mimicking a natural infection by that pathogen.

MATERIALS

Per Group of Students

- Set of colored highlighters (at least one marker per student)
- 4 copies of each student sheet
- Group concept maps (ongoing)

SETUP

Make copies of the student sheets (p. 40–41).

Have students work individually or in groups of four.

PROCEDURE

1. Ask students, *If microbes are everywhere, why aren't we sick all the time?* Conduct a class discussion or make a list of students' ideas on the board. If not mentioned by students, introduce the idea that the body's defense system—called the immune system—helps to find and destroy microbes.
2. Distribute a copy of the *Germ Defense* article to each student. Have students read the article individually and then discuss it within their groups. Students should use their markers to highlight new words or concepts they find in the article.
3. Within their groups, have students discuss the words or concepts they highlighted. Encourage groups to search the Internet for additional, related information. Reliable websites include the National Institutes of Health (www.nih.gov) and the Centers for Disease Control and Prevention (www.cdc.gov).
4. Have students use what they have learned to complete the crossword puzzle, individually or in groups.
5. Allow time for students to add to their concept maps.

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

- Communicate scientific procedures and explanations.

Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- The human organism has systems for protection from disease.
- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the systems. Others are the result of damage by infection by other organisms.

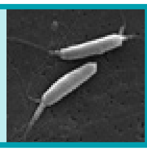
VIRAL GENETICS

Many disease-causing microbes, including the viruses that cause colds, mutate frequently during reproduction. This genetic process yields constantly changing virus strains that are not recognized by the immune system.

ANSWER KEY

Answers to the crossword puzzle are on page 60.

9 Germ Defense



Flexispira rappini bacteria. CDC\5709 J. Carr, P. Fields, C. Fitzgerald.

Some microbes, known as "pathogens," can make you sick. Luckily, your body has several ways to fight these microbes before they can cause disease or infection. Your skin and the moist linings of your nose, eyes and mouth are the first lines of defense. They keep potential invaders outside the body. Mucus in the respiratory and digestive passages traps some microbes. Coughing and sneezing help to eliminate microbes. Crying and urination both flush microbes out of the body. In addition, tears and saliva have germ-killing proteins. In the stomach, strong acids destroy many pathogens.

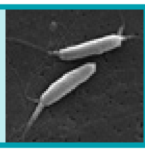
And if bacteria or viruses get past these defenses, your body has a built-in system—the immune system—to find and kill the invaders. A healthy immune system is able to tell the difference between the body's own cells and foreign substances. Anything that the body identifies as "foreign" will cause the immune system to spring into action. Materials that trigger an immune system response are called "antigens." An antigen can be a microbe, like a bacterium, part of a microbe, or other molecule.

The billion-cell army of the immune system is always on guard. The soldiers of the immune system are several dozen different kinds of white blood cells, each with a special job. Some cells attack any foreign particle from outside the body. For example, some "eating" cells gobble up invaders or infected cells in the bloodstream. Other white blood cells target and destroy specific invaders. Some white blood cells make products, called antibodies, that tag invaders so that they can be destroyed. The immune system "remembers" invaders, so it is better prepared to defend against them in the future.

Vaccines use the body's immune system to protect against diseases, such as polio, measles and tetanus. Vaccines contain dead or weakened microbes, which are recognized as invaders and attacked by the immune system. Because the immune system remembers information about the weakened microbe in the vaccine, it is able to fight off future infections—even if a new invader is a stronger version of the one contained in the vaccine. Vaccines are effective only against microbes that don't change (mutate) very much. Microbes that change constantly, such as viruses that cause colds, don't match the immune system's memories of previous infections, so they are able to cause illness.

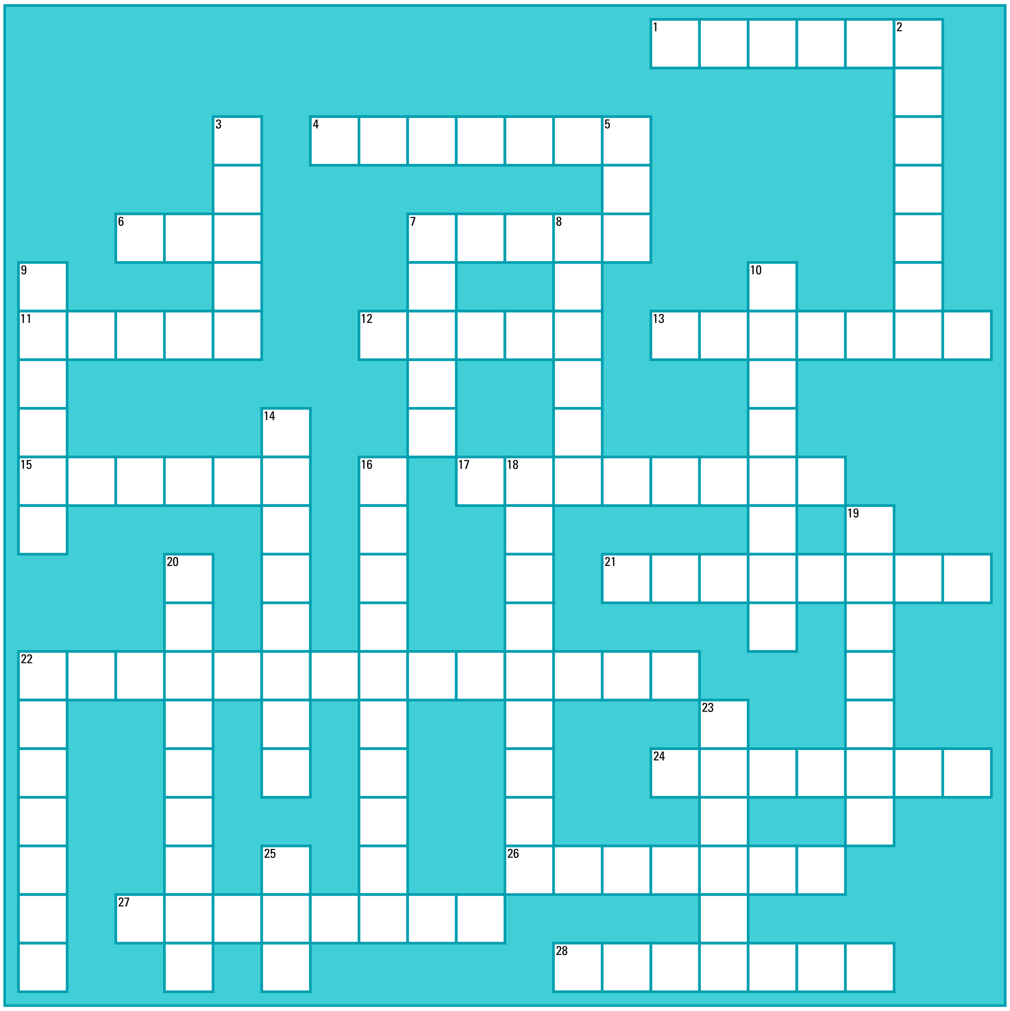
Sometimes, the immune system itself becomes damaged or weakened. This is what happens when HIV, the virus that causes AIDS, infects the body. HIV attacks a certain kind of white blood cell, called a "T cell," and weakens the body's ability to defend itself.

In other cases, the immune system makes a mistake and attacks the body's own cells or tissues. This kind of response causes diseases like arthritis and Type 1 diabetes. These illnesses are called "autoimmune disorders." Sometimes, the immune system reacts to a seemingly harmless foreign substance, like tree pollen. The result is called an allergy. Hay fever, which is a reaction to several different kinds of pollen, actually is an allergy, rather than an infection, like a cold.



Flexispira rappini bacteria. CDC\5709 J. Carr, P. Fields, C. Fitzgerald.

9 Attackers & Defenders



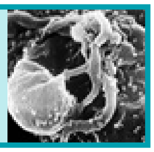
ACROSS

1. The immune ________ can be triggered by fragments of organisms or by entire organisms.
4. There are about this many cells in the immune system.
6. The body has many ways to tell invaders, "Keep ________!"
7. The linings of your nose and mouth are not dry or completely wet; they are ________.
11. You have a lot of these in your nose to trap germs.
12. This immune system cell is destroyed by HIV.
13. This childhood illness, which causes a red, blotchy rash, can be prevented with a vaccine in most cases.
15. Some immune system cells ________ up invaders as if the invaders were chocolate candy.
17. The Type 1 form of this disease is caused when the body's own immune system makes a mistake.
21. An ________ helps to tag and destroy invaders before they are able to spread throughout the body.
22. There are many kinds of this defender cell (three words).
24. An ________ is something that triggers an immune response.
26. This structure is in the center of many cells.
27. The immune system attacks ________ that enter the body from outside.
28. This happens when the immune system reacts to a seemingly harmless substance.

DOWN

2. Also called microorganism.
3. Some microbes enter the body when an insect ________ a person.
5. Once you are vaccinated against a disease, you probably will ________ get it.
7. Microbe-trapping slime in the nose is called ________.
8. This liquid, found in the mouth, has germ-killing properties.
9. It is difficult to create vaccines for microbes that mutate or ________ easily.
10. This kind of microbe does not have a defined nucleus.
14. After it has fought a certain invader once, the immune system can ________ that invader the next time it enters the body.
16. A ________ is a useful tool for observing microbes.
18. When a harmful microbe invades and starts reproducing in the body, it causes an ________.
19. From somewhere else; not belonging to the body.
20. Disease-causing agents are called ________.
22. An HIV infection reduces or ________ the body's ability to defend against disease.
23. Ah-choo! When you ________, it helps to get germs out of your body.
25. This is a kind of fever that you can't catch.

10



HIV virus budding from blood cells. CDC\1197 C. Goldsmith, P. Feorino, E. Palmer, W. McManus.

Overview

Students will use evidence to determine whether a patient has a cold, flu or strep infection. In the process, they also will learn about the differences between bacterial and viral infections.

TIME

Setup: 30 minutes
Activity: 45–60 minutes

SCIENCE EDUCATION CONTENT STANDARDS

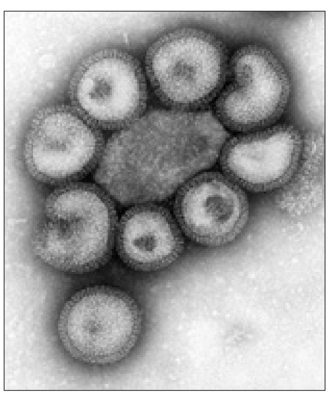
Grades 5–8

Inquiry

- Develop descriptions, explanations, predictions and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.

Life Science

- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of infection by other organisms.



This transmission electron microscope image shows several influenza virus particles. CDC\8432 C. Goldsmith, F. Murphy.

INFECTIOUS DISEASE

Case Study

Many different microorganisms can infect the human respiratory system, causing symptoms such as fever, runny nose or sore throat. Even the common cold, which may range from mild to serious, can be caused by any of more than 200 viruses! Colds are among the leading causes of visits to physicians in the United States, and the Centers for Disease Control and Prevention (CDC) report that 22 million school days are lost in the U.S. each year due to the common cold. Usually, cold symptoms appear within two to three days of infection and include: mucus buildup in the nose, swelling of sinuses, cough, headache, sore throat, sneezing and mild fever (particularly in infants and young children). The body's immune system, which protects against disease-causing microbes, almost always is able to eliminate the viruses responsible for a cold.

Flu (or influenza) often is more serious than the common cold. Caused by one of three types of closely related viruses, flu can come on quickly, with chills, fatigue, headache and body aches. A high fever and severe cough may develop. Flu may be prevented in some cases through a vaccine. However, since the viruses that cause flu change slightly from year to year, a new vaccine is required each flu season. Influenza was responsible for three pandemics (worldwide spread of disease) in the 20th Century alone.

> A disease can be any change in the body or mind that causes discomfort, loss of function, distress or death. Some diseases are caused by microorganisms that invade or infect the body. Examples of infectious diseases are colds (virus), strep throat (bacteria), and malaria (protozoa).
>
> Other diseases, such as most kinds of heart disease, are not considered to be caused by infection (although microbes may be involved indirectly) and cannot spread from one person to another.

Antibiotics do not kill viruses, and therefore, are not helpful in fighting the common cold or flu. But these diseases can make a person more susceptible to bacterial infections, such as strep throat, a common infection by a *Streptococcus* bacterium. Symptoms of "strep" infections include sore throat, high fever, coughing, and swollen lymph nodes and tonsils. Diagnosis should be based on the results of a throat swab, which is cultured, and/or a rapid antigen test, which detects foreign substances, known as antigens, in the throat. Strep infections usually can be treated effectively with antibiotics. Without treatment, strep throat can lead to other serious illnesses, such as scarlet fever and rheumatic fever.

Symptoms similar to those of a cold

Cold or Airborne Allergy?

SYMPTOM	COLD	ALLERGY
Cough	Common	Sometimes
Itchy eyes	Rare	Common
Sneezing	Usual	Usual
Sore Throat	Common	Sometimes
Runny Nose	Common	Common
Stuffy Nose	Common	Common
Fever	Rare	Never
Length	3–14 days	Weeks

can be caused by allergens in the air. Health experts estimate that 35 million Americans suffer from respiratory allergies, such as hay fever (pollen allergy). An allergy is a reaction of an individual's disease defense system (immune system) to a substance that does not bother most people. Allergies are not contagious.

MATERIALS

Teacher (see Setup)

- 90 letter-size plain envelopes
- 6 sheets of white, self-stick folder labels, 3-7/16 in. x 2/3 in., 30 labels per sheet (Avery™ #5366, 5378 or 8366)
- Overhead projector
- Overhead transparency of *Disorders & Symptoms* student sheet (p. 46)

Per Group of Students

- Set of prepared envelopes (15 envelopes per set)
- Copy of *What is Wrong with Allison?* and *Disorders & Symptoms* student sheets (p. 45–46)
- Group concept map (ongoing)

SETUP

Photocopy *What is Wrong with Allison?* and *Disorders & Symptoms* sheets (one copy of each per student), to be distributed in order (see Procedure).

Photocopy the label template sheet (p. 47) onto six sheets of white, self-stick labels, such as Avery™ #5366, 5378 or 8366, which contain 30 labels per sheet.

Use one page of photocopied labels to create each set of envelopes. Place a Question label on the outside of one envelope and stick the corresponding Clue label on the inside flap of the same envelope. Close the flap, but do not seal the envelope. Make six sets of 15 envelopes (one set per group).

Make an overhead transparency of the *Disorders & Symptoms* sheet.

Have students work in groups of four.

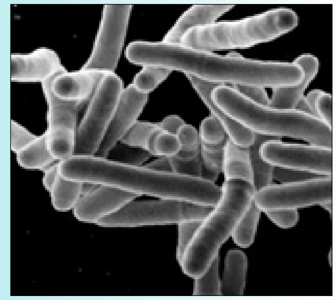
Optional: Instead of using self-stick labels, copy the label template page onto plain paper and cut out each question and clue. Tape one question to the outside of an envelope and the corresponding clue to the inside flap of the envelope.

PROCEDURE

1. Begin a class discussion of disease by asking questions such as, *How do you know when you are sick? What are some common diseases? Are all diseases alike? Are all diseases caused by a kind of microbe? Do some diseases have similar symptoms?*
2. Tell your students that in this class session, they will be acting as medical personnel trying to diagnose a patient. Give each group a copy of the *What is Wrong with Allison?* sheet. Have one student read the case to the group, and then have groups discuss it. The reporter should record each group's ideas about what might be wrong with Allison.
3. Have each student group list four possible questions that a doctor might ask a patient like Allison. Write these questions on the board and discuss with the class.
4. Have groups identify three possible diseases that Allison may have, based on the story, class discussion and their own experiences.

Continued

ANTIBIOTIC RESISTANT BACTERIA



The emergence of multidrug-resistant tuberculosis represents a large and growing threat to TB control programs. NIAID, NIH\C. Barry, E. Fischer.*

Overuse and inappropriate use of antibiotics (to treat the common cold, for example) have contributed significantly to the evolution of antibiotic-resistant bacteria.

When bacteria are exposed to an antibiotic, a few may survive. The hereditary information of these survivors is just a little different from the rest, and it provides an advantage that allows them to live. The surviving bacteria reproduce and pass the resistant characteristic on to future generations. The original antibiotic will not kill bacteria that have acquired the resistant trait.

* Image courtesy of the National Institute of Allergy and Infectious Diseases (NIAID), NIH. Image taken at the Rocky Mountain Laboratories, NIAID, NIH.

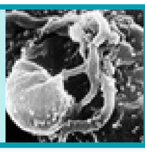
WHAT IS A VECTOR?

"Vector" is more than a term used in physics and mathematics. In medicine, a vector is an organism (often an insect or rodent) that carries and transmits disease-causing agents like bacteria, viruses or parasites to a host. Microbiologists use this term to describe viruses or bacteria that transport genes into a host cell. U.S. Environmental Protection Agency.

5. Give each student a copy of the *Disorders & Symptoms* sheet and briefly introduce the four illnesses to the entire class. Compare these illnesses to the ones that students suggested. Ask, *Are there any similarities?* Have students follow the instructions on the sheet to complete the exercise.
6. Give each group of students a set of envelopes. Warn students not to open the envelopes until they are instructed to do so. Tell students that each envelope contains information that a medical doctor might need about a patient. All information is important to the diagnosis, but only certain information will help to distinguish among the four possible respiratory disorders. Tell students their task is to decide which envelopes contain information that will help them determine Allison's illness.

   Once a group has agreed on question choices, it may open as many envelopes—one at a time—as needed. The challenge is to use as few envelopes as possible to diagnose Allison's illness. Each group should keep a tally of the number of envelopes opened. Remind students that in real life, a physician would conduct a complete examination and gather all possible information before making a diagnosis.
7. Allow time for groups to work. Provide assistance to students who may not understand the information contained in the envelopes. If the medicine and body temperature envelopes have been opened, make sure students understand that some medications, like Tylenol™, will mask the presence of mild fevers.
8. Have each group present its diagnosis and the reasoning used to arrive at its decision. (Allison's disease is a common cold. If students have arrived at other conclusions, discuss the evidence they used. Mention the challenges of diagnosing respiratory diseases.)
9. Expand the discussion to address the importance of not taking antibiotics for viral diseases. Ask, *Since Allison has a cold, should her doctor prescribe antibiotics? Would it be okay to take leftover antibiotics?* Help students understand that antibiotics are effective for bacterial infections, but do not help against viral infections like colds.

   Also, mention that if antibiotics are prescribed for a bacterial infection, it is important to follow the doctor's instructions and to take all the medication, even if symptoms start to improve before the medicine is gone. Otherwise, the disease may reoccur. Taking antibiotics incorrectly, or using them inappropriately (such as taking leftover medicine without a doctor's guidance) can contribute to the development of antibiotic resistant forms of bacteria, which cannot be killed by existing antibiotics (see Antibiotic Resistant Bacteria, sidebar, p. 43).
10. Have student groups add information to their concept maps.

10 

HIV virus budding from blood cells. CDC\1197 C. Goldsmith, P. Feorino, E. Palmer, W. McManus.

What is Wrong with Allison?

Allison is an active, healthy girl. She loves to play outside with her dog. She missed only one day of school last year. But when she woke up this morning, Allison had a headache and a sore throat. She wasn't hungry, so she just had juice for breakfast.

Allison's mom felt her forehead, and said Allison seemed a little too warm. Her mom decided to take Allison to their family doctor, because Allison's cousin had a strep throat infection.

What do you think could be causing Allison's symptoms?

Acting as Allison's doctor, your team will use clues to figure out what is making Allison ill. List four questions that you think Allison's doctor might ask.

1.

2.

3.

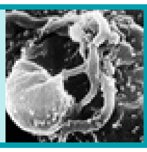
4.

Based on class discussion, what are three likely diseases Allison may have?

1.

2.

3.

10 

HIV virus budding from blood cells. CDC\1197 C. Goldsmith, P. Feorino, E. Palmer, W. McManus.

Disorders & Symptoms

Illness	Symptoms	Causes	Treatment
Common Cold	• Headache • Cough • Sore throat • Sneezing • Clear mucus in the nose	Viruses	Resting, drinking plenty of fluids
Flu	• Headache • Sore throat • Muscle aches • Tiredness (fatigue) • Dry cough • Diarrhea and/or vomiting • High and sudden fever	Viruses	Resting, drinking plenty of fluids (if caught early, flu can be treated with special antiviral medication)
Strep Throat	• Red, painful throat • White patches on tonsils • Fever • Headache • Stomach pain • Vomiting	Bacteria	Resting, drinking plenty of fluids, taking antibiotics prescribed by a doctor
Nasal Allergy	• Itchy eyes and throat • Clear mucus in nose • Frequent sneezing or coughing • Irritated or sore throat • Headache	Reaction by the body to substances in air, such as pollen or dust	Taking medications recommended by a doctor

1. Study the table above to familiarize yourself with the four illnesses listed. Allison has one of these four illnesses.

2. Read the question on the outside of each envelope, but do not open the envelopes yet. On the inside flap of each envelope is a clue, or answer, to the question on the outside. However, only some of the questions and clues will help you.

   As a group, try to select the fewest number of questions (and clues) possible to help you distinguish among the illnesses above and diagnose Allison's illness. Open only one envelope at a time.

   a. According to your group's analysis, Allison has ______________________.

   b. How many questions/clues did your group use? ______________________

   c. Which question numbers (1 through 15) did your group select? ______________________

   ____

3. On the back of this sheet, answer the following questions.

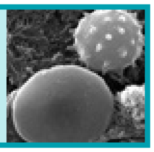
   a. Which information helped you to diagnose Allison's illness? Explain why or how this information helped.

   b. Why would it be important to know if Allison had been given aspirin or Tylenol™?

   c. Would antibiotics be helpful to Allison? Why or why not?

QUESTIONS — OUTSIDE OF ENVELOPE	CLUES — INSIDE OF ENVELOPE
1. Does Allison have a headache?	1. Yes, she has a headache.
2. What is Allison's body temperature?	2. Her body temperature is 98.6°F (normal).
3. What is Allison's weight?	3. She weighs 104 lbs.
4. What is Allison's height?	4. She is 59 inches tall.
5. What is Allison's blood pressure?	5. Her blood pressure is 120 over 80 (normal).
6. What is the condition of Allison's nose?	6. She has lots of clear mucus (runny nose) and difficulty breathing through her nose.
7. What is the appearance of Allison's throat?	7. She has no redness or white patches.
8. Are bacteria that cause strep throat present? (A doctor or nurse would swab her throat and run a rapid antigen test for bacteria.)	8. There are no disease-causing bacteria present in her throat.
9. Does Allison have a cough?	9. Yes. She has a congested cough (a cough with mucus).
10. Does Allison's body ache?	10. No. Her body does not ache.
11. Has Allison vomited in the past 24 hours?	11. No. She has not vomited.
12. Has Allison taken any medicine?	12. No. She has not taken any medicines. (This is important because medications, like Tylenol™, can mask symptoms.)
13. What did Allison eat yesterday and this morning?	13. Yesterday, she ate waffles, syrup, milk, pizza, apple juice, tacos, tortilla chips, beans, candy and ice cream. Today, she had orange juice.
14. What is the weather like outside?	14. The weather is cold and rainy.
15. Have any of Allison's friends or family members been sick?	15. Her cousin had strep throat two weeks ago. Two classmates have colds. Her Dad has a headache and her brother vomited last night.

11


Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

TIME

Setup: 15 minutes

Activity: 45 minutes for each of two class periods

Overview

Language arts activity in which students will read about several serious, infamous diseases and collect/discuss information about the pathogens, their modes of transmission and their impacts on society. Students also will create art projects that represent these diseases. Students will learn that many diseases are caused by microbes. Some diseases that have caused serious debilitation and/or loss of human life are cholera, HIV/AIDS, malaria, tuberculosis, smallpox and plague.

MICROBES AND Disease

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

History and Nature of Science

- Science as a human endeavor: Women and men of various social and ethnic backgrounds—with diverse interests, talents, qualities and motivations—engage in the activities of science, engineering and related fields, such as the health professions.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry.
- Many individuals have contributed to the traditions of science.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time and reach the conclusions that we currently take for granted.

EXTENSION

Have students create world maps illustrating where each of the six diseases highlighted in this activity still may be found. Geographic maps can be downloaded free from the United Nations Cartographic website at www.un.org/Depts/Cartographic/english/htmain.htm/.

Organisms that cause diseases are called "pathogens," from the Greek word *pathos,* or suffering. Most pathogens are microbes, such as bacteria, protozoa, fungi or viruses.

> Some viruses cause abnormal changes in cells that can lead to cancer. For example, certain types of human papillomavirus (HPV) increase women's risk for cervical cancer. A new vaccine now protects against two types of HPV infection that can cause cervical cancer.

Sometimes, we call these tiny pathogens "germs." Pathogens cause communicable, or infectious, diseases (diseases that can spread from one organism to another). Some diseases are harder to catch than others, because different pathogens are transferred from one organism to another in different ways (through droplets in air or in fluids, through contact with a surface containing the pathogen, from insect bites, etc.). Some pathogens can make you a lot sicker than others, and some can kill.

A widespread outbreak of a disease is called an "epidemic." An epidemic that spreads broadly throughout the world is referred to as a "pandemic." This activity highlights six microbe-based diseases with major global historical impacts: cholera, plague, malaria, smallpox, HIV/AIDS and tuberculosis.

Of course, microbes do not cause all diseases. Invertebrates, such as hookworms, tapeworms, etc., also can make people and animals sick. Other illnesses, such as arthritis, diabetes, heart disease related to atherosclerosis, and some kinds of cancer, are not caused by infections. But in some cases, diseases thought to be unrelated to microorganisms have been found to be infectious after all. Stomach ulcers are a good example. Scientists now know that the most common cause of peptic ulcers is infection by a bacterium called *Helicobacter pylori.*

MATERIALS

Per Group of Students (See Setup)

- Paper and supplies for art projects
- Sheet of paper on which to create an activity concept map
- 6 copies of the 3-2-1 student sheet (p. 50)
- 4 copies of one *Disease Information* sheet (p. 51–56; all members of a group receive the same disease sheet)
- Group concept map (ongoing)

SETUP

Divide the class into six groups of four students. Each group will work with one disease (i.e., one group

DR. TERRENCE TUMPEY, CDC, examines the reconstructed 1918 pandemic influenza virus in a Biosafety Level 3 enhanced lab. The 1918–1919 pandemic killed as many as 50 million people worldwide. By forming a better understanding of the molecular characteristics of the 1918 virus, specifically the ones that made it so virulent and easily transmissible, CDC researchers can work to protect against the spread of other influenza viruses with pandemic potential. CDC\7987 J. Gathany.

investigates and presents information about TB, another group works with plague, etc.).

Make four copies of each *Disease Information* sheet.

Make 36 copies of the 3-2-1 sheet (six copies per group). As each group presents information on a specific disease, all other groups will complete a 3-2-1 sheet for that disease.

Gather a variety of materials for students to use in their art projects. Place materials in a central location.

PROCEDURE

1. Ask students, *Do you think diseases have changed history? Do any diseases affect society today?* Tell students that they will be learning about diseases that have had impacts worldwide.
2. Provide each group with a set of *Disease Information* sheets for a single disease. Each student should receive his or her own copy of the sheet.
3. Instruct each student to read the information on his or her sheet. Depending on students' reading levels, you may need to provide assistance with the readings.
4. Have students within each group jointly create a concept map to summarize the important ideas from the group's *Disease Information* sheet. (At this point, students should be familiar with concept maps.) Then, have each group use its newly-created concept map to prepare a presentation about its assigned disease.
5. Distribute six copies of the 3-2-1 sheet to each group.
6. Have each group present its overview to the class. After each presentation, allow all groups, including the one that just presented, five to six minutes to complete a 3-2-1 sheet on the presentation. Repeat the process until all student groups have made their presentations.
7. As an assessment, have each group work collectively to create a piece of art that illustrates one of the diseases covered, and then write a paragraph explaining how the artwork represents the chosen disease(s).
8. Ask a student representative from each group to present the group's artwork in class, along with related information from the readings or other sources.
9. Allow groups to add information to their concept maps.

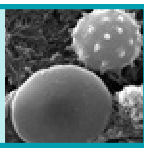
DID YOU KNOW?

Leeches *(Hirudo medicinalis)* have been used to treat diseases for centuries and still are used in some cases today. In fact, leech saliva does contain several important compounds with medicinal applications. Leeches produce a substance, called hirudin, that prevents blood from clotting. They also produce a compound, called a vasodilator, that enlarges (dilates) blood vessels and stimulates blood flow. In addition, leeches produce an anesthetic so that it doesn't hurt when they attach!

NEW THREATS

New diseases continue to emerge that could affect human populations worldwide. One recent example, bird flu (avian influenza), primarily affects birds, but it can be transmitted to humans. So far, human-to-human transmission has been very rare. However, investigators are concerned that the current strain of bird flu may mutate and become capable of spreading directly from one person to another.

11



Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

3–2–1

Group

Disease

3

What are three new things you learned?

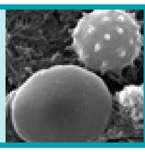
2

What are two things that surprised you?

1

What is one question you have?

11



Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

DISEASE INFORMATION

Tuberculosis

Tuberculosis, a disease also known as "TB," has affected humans for thousands of years. For most of that time, there was no known cure and very little understanding of the disease. In the past, TB sometimes was called "consumption," because it seemed to devour people from the inside.

TB is one of the deadliest diseases known to man. At one point, it was the leading cause of death in the U.S. Its dark history is reflected in novels, artwork and dramas. Back in the 1800s, some people even thought TB was caused by vampires. *It's true!* The symptoms of TB look like characteristics often associated with vampires (red, swollen eyes that are sensitive to bright light, pale skin, and worst of all, coughing up blood). In fact, some people thought TB sufferers caught the disease from dead family members who visited at night.

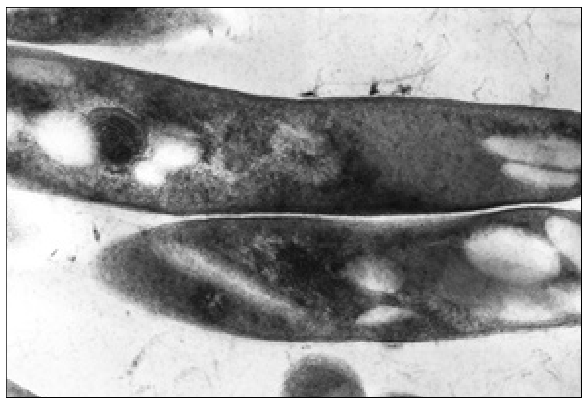
An Invisible Enemy

We have come a long way since then, and scientists have developed effective treatments against TB. Caused by the *Mycobacterium tuberculosis* bacteria, TB can be deadly for people who do not get proper treatment. The disease most often infects the lungs, because it is transmitted through the air we breathe. However, it can attack any body organ or system.

How TB Spreads

TB spreads from person to person through the air. When someone who is infected with tuberculosis sneezes, coughs, talks or spits, TB bacteria are released into the air. Anyone nearby who breathes in these bacteria can become infected. If a person with TB does not receive treatment, he or she could infect an average of 10 to 15 people each year.

People infected with TB bacteria may not show symptoms or develop the disease. In fact, only about 10% of otherwise healthy people infected with TB bacteria ever become sick. The other 90% are said to have a latent TB infection. These people do not get sick and do not transmit the disease.



Mycobacterium tuberculosis, bacterium that causes TB.
CDC\8433 E. White.

However, some people with latent TB infection do become ill when they get older. Therefore, they may choose to take antibiotics right away to prevent the disease from occurring later in life.

Babies and young children have an increased risk for catching TB because their immune systems are not yet mature. Other people at higher risk for contracting (catching) TB are those with weakened immune systems, such as people with HIV (the virus that causes AIDS), diabetes, cancer, kidney disease or other serious medical conditions. People who abuse drugs or alcohol also are more likely to develop this illness.

Where Things Stand Today

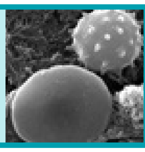
Until the 1940s, there was no cure for TB. But with education, improvements in public health care and the creation of new antibiotics, the numbers of deaths from TB dropped dramatically in the U.S. and Europe. To cure the disease, patients were required to take antibiotics for six months.

However, over time, drug-resistant forms of TB began to emerge. Doctors discovered that some patients stopped taking their medicine as soon as they felt better, instead of completing the course of antibiotics designed to kill all of the bacteria. In these cases, the surviving TB bacteria changed, or mutated, so that the original antibiotic became less effective. Eventually, the antibiotic-resistant TB bacteria were passed on to other people, who then developed forms of TB that were even more difficult to treat.

There are many reasons why TB still exists, including lack of medical facilities, cost of antibiotics and poor hygiene. The disease remains a very serious health problem today. Each year, almost nine million new cases of TB are reported worldwide, and nearly two million people die from the disease.

Without better treatment, it is estimated that over the next 15 years, almost one billion people will become infected with TB bacteria, more than 150 million will become sick, and more than 36 million people will die.

11



Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

D I S E A S E   I N F O R M A T I O N

Malaria

What do you know about malaria? In the United States, we don't hear much about this disease, because it was eradicated (removed completely) from our country in the 1950s.

But malaria still is a serious threat in warmer and poorer regions of the world, including India, Africa, Central and South America, and tropical parts of Asia. The World Health Organization reports that each year, 300–500 million new cases of malaria are diagnosed, and more than one million people—mostly young children—die from it.

Notice the bulging "stomach" of this *Anopheles* mosquito. It has just had a blood meal. CDC\7950 J. Gathany.

A Microscopic Parasite

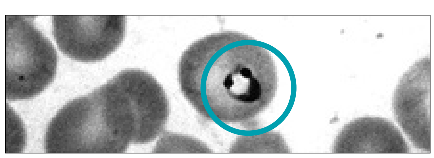
Malaria is a life-threatening disease caused by *Plasmodium*, a parasite in the protozoan group. A parasite is an organism that lives in, with, or on another organism (or host), from which it obtains nutrients and to which it causes harm. The malaria parasite is carried by female *Anopheles* (ah-NOF-il-eez) mosquitoes. The symptoms of malaria—severe headache, high fever, shaking, vomiting and chills—appear about 9 to 14 days after an infected mosquito bites a human. There are four strains (forms) of malaria. All are very serious, and one strain often is fatal.

Once a person is infected, the parasite attacks and destroys red blood cells. It also blocks blood vessels leading to the brain or other organs. If medicine isn't obtained, or if that particular strain of malaria is resistant to (not killed by) the medicine, a malaria infection can quickly become deadly.

The Cycle of Malaria Infection

We know that when a female *Anopheles* mosquito bites a person who already has malaria, the mosquito takes in malaria parasites and becomes a carrier. When the mosquito bites someone else, it transmits parasites to (infects) that person. But it's not clear if the parasite kills the mosquito. It is possible that the mosquitoes are not affected by the malaria parasite.

Once the *Plasmodium* parasite enters a person's bloodstream, it travels to the liver, where it begins to grow and multiply. During this incubation period, before the parasite has fully developed, the person will not feel ill, and may not even know he or she is infected. When the parasite moves from the liver to the blood stream, the person will begin to feel symptoms. At this point, the disease has developed enough to infect any *Anopheles* mosquito that may bite this newly infected person, and the cycle of infection continues.



This photograph shows a Malaria parasite (*Plasmodium sp.*) inside a red blood cell. CDC\1456 M. Melvin.

People also can get malaria from having a blood transfusion or organ transplant, or by sharing used needles. A pregnant mother infected with malaria can give the disease to her child. But malaria cannot spread from casual contact between people. You can't get it if someone sneezes on you.

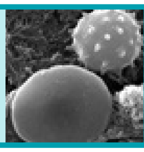
Still a Deadly Disease

During the 20th Century, malaria was eliminated from most parts of the world that are not hot year-round. But it was not wiped out everywhere, and it may be making a comeback. Evidence suggests that *Anopheles* mosquitoes have become resistant to pesticides that previously killed them. Meanwhile, vaccines that once prevented infection, along with the drugs used to treat malaria, are becoming less effective. Some experts think malaria may be moving into new parts of the world, including places where it once had been eliminated.

Although scientists believe most deaths from malaria are preventable, this disease remains a major global health concern. It also is preventing development in some of the poorest countries in the world. For example, in Africa, on average, a child dies from malaria *every 30 seconds*. And even if a child survives malaria, he or she often is left with learning problems or brain damage.

The U.S. is not entirely free from malaria. Approximately 1,200 infections and 13 deaths from malaria are reported here each year, mostly among travelers and immigrants from parts of the world where malaria remains a problem. Further, *Anopheles* mosquitoes still exist in the U.S., so it is possible for the mosquitoes to reintroduce malaria into the U.S.

11

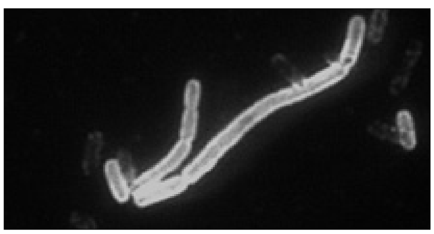


Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

DISEASE INFORMATION

Plague

When you hear about "the plague," you probably think of the Middle Ages, when the Bubonic form of plague killed millions of people throughout Europe, Asia and Africa. In Europe, as many as 2.5 million people—one third of the population—died between 1347 and 1350. It has been said that there weren't enough people left alive to bury the victims. At the time, people didn't know what caused plague and no cure was available. So there was panic whenever an outbreak occurred. Many works of literature and art depict the terror surrounding the plague and the horrible effects it had on the population.



***Yersinia pestis*, the bacterium responsible for the plague.** Oregon Health Authority, Public Health-CDC\1918 L. Stauffer.

Maybe you think plague is gone and part of history, like the Middle Ages. If so, you'll be surprised to learn that it is alive and well. Today, we have protective vaccines and medications that cure people with plague, so it takes far fewer lives than other deadly diseases. But the name alone continues to cause fear. And although we know much more about plague than medieval people did, it continues to kill people even today.

Rodents!

Plague is a disease that affects animals and humans. It is caused by the bacterium, *Yersinia pestis.* This bacterium was named after Alexandre Yersin, the scientist credited with discovering how the disease spread during an epidemic in 1894. (How would you like to have a deadly bacterium named after you?)

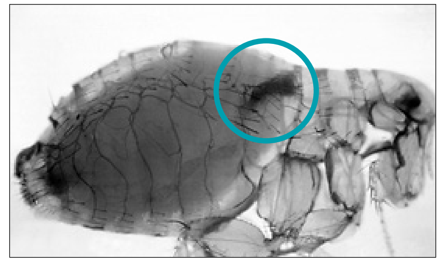
Yersinia pestis bacteria are carried by fleas and the wild rodents on which they live (often rats and squirrels). Plague outbreaks are rare these days, but still can happen in places where infected rodents and their fleas live in people's homes. In the Middle Ages, it was much more common for homes to be infested with rats and fleas—which is one reason why so many people were infected with plague then.

There are three different kinds of plague. Bubonic plague is an infection of the lymph nodes, which are glands located throughout the body that help to fight off illness by acting as filters for bacteria and viruses. Septicemic plague is an infection of the blood. Pneumonic plague is an infection of the lungs. The type of plague a person gets depends on how he or she was infected in the first place. Septicemic plague can cause a victim's skin to turn very dark purple. That's why plague sometimes was called the "Black Death."

The most recent outbreak of plague in the U.S. was in 1924. But it still exists here, mostly in the Southwest and Midwest. And while only about 2,000 cases of plague are reported worldwide each year, it remains a very serious disease. If you get plague and don't get treatment, it can kill you.

One Small Pest = A Huge Health Risk

Most often, plague is spread when an infected flea bites a person, or when someone handles an animal infected with plague. It also is possible to catch plague through the air, if someone with pneumonic plague sneezes near you.



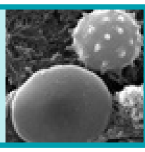
Oriental rat flea, shown with a clump of plague bacteria blocking its stomach. The blockage forces bacteria to be passed to a new host once the flea bites it. CDC\2025.

A few days after infection, sudden fever, chills, headache, nausea, weakness, and painful, swollen lymph nodes may develop. These are symptoms of plague. The disease advances quickly, so it is important to see a doctor as soon as possible after infection. Most plague patients who are treated quickly and properly with antibiotics will recover fully. But if left untreated, plague can invade the lungs and bloodstream. Once in the lungs, plague can be spread by sneezing or coughing, and it is far more difficult to cure. About half of all people with this kind of plague die.

A Disease that Won't Die

Plague is not likely to be eradicated (eliminated). Even with new technology, improved conditions, and good healthcare in most modern cities, plague and *Yersinia pestis* bacteria remain strong opponents. In fact, overcrowding, combined with a lack of proper sanitation and pest control in some poorer countries, has increased the chances for another plague outbreak. Like the fleas that carry it, this disease is tough to kill.

11



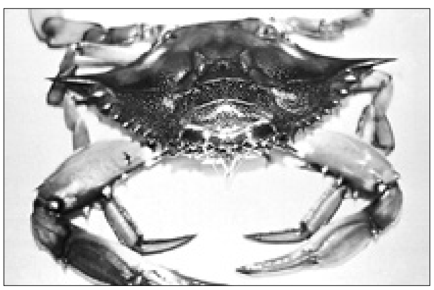
Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

DISEASE INFORMATION

Cholera

Are you familiar with the phrase, "Don't drink the water"? It's usually heard when someone is traveling, especially outside of the U.S. Our water treatment system is very good, so the water in our homes usually is healthy to drink. Also, laws in this country help to ensure that our food sources generally are safe.

But this is not the case everywhere. When you visit some countries, you may be warned not to drink water from the faucet, not to drink beverages containing ice, and not to eat any food unless you have cooked or peeled it. There's a good reason for these warnings. Sometimes, uncooked food and untreated water can make you sick!



Crabs have been a repeated source of cholera in the U.S. and elsewhere, even though they are rarely eaten raw. CDC\5318.

Something in the Water and Food

Every year, many people around the world get dangerous diseases from food and water that are not safely prepared or treated. One of these diseases is cholera, an infection of the intestines caused by the bacterium, *Vibrio cholerae*. We don't have many cases of cholera in the U.S. In fact, it has been rare in much of the world for 100 years or more. Unfortunately, it still affects millions of people in Asia, Africa, and other places that suffer from poor hygiene, unsanitary conditions, and lack of money for proper medical care and medicine.

Many people who get cholera do not feel ill. Some experience nothing more serious than a bad case of diarrhea. But about 10% of cholera victims suffer life-threatening symptoms, including continuous diarrhea, vomiting and leg cramps. These people lose body fluids so quickly that they become severely dehydrated, and even may go into shock. Without medication, they can die within hours.

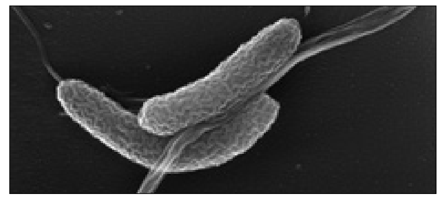
Wash Your Hands, Please

Cholera is spread by contaminated (dirty or spoiled) water and food. Most often, contamination happens when human and/or animal waste (feces) gets into our water or food. It's disgusting, but that's the way it usually happens.

Vibrio cholerae bacteria infect the intestine and remain in the body for one to two weeks. If an infected person who is preparing food doesn't wash his or her hands after using the bathroom, he or she might spread the bacteria to the food. Anyone who eats this food might get sick. Other kinds of intestinal diseases are spread in the same way. That's why you often see signs in restaurant bathrooms, reminding employees to wash their hands before returning to work.

In places with poor sewage systems or improper water treatment, human waste can get into the water supply. In these places, many people can become sick with cholera. That's how some outbreaks happen.

But cholera isn't always caused by human waste. *Vibrio cholerae* bacteria can exist naturally in salty rivers and coastal waters, where shellfish (crabs, clams, oysters, etc.) live. If shellfish are boiled for less than 10 minutes, steamed for less than 30 minutes, left unrefrigerated for several hours, or eaten raw, they can cause cholera and other diseases.



Vibrio cholerae **bacteria, which cause cholera.** Dartmouth College\L. Howard, C. Daghlian.

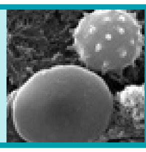
The Danger Today

Cholera outbreaks have occurred throughout the world for thousands of years. Stories from ancient Greece, and even earlier, report epidemics of cholera-like illnesses. The disease was common in the U.S. in the 1800s, but it no longer is a major concern, because we have modern water treatment, food preparation and sewage systems.

Cholera is easy to prevent with good sanitation and water treatment. It can be cured by giving fluids along with antibiotics, if necessary. But some countries do not have the resources needed to fight a cholera outbreak, so this disease continues to present a very real threat to human life.

The most recent cholera pandemic (worldwide outbreak) began in Asia in 1961. It spread to Europe and Africa and, by 1991, to Latin America, where there had been no cholera for more than 100 years. This outbreak has killed thousands of people and continues to spread. Cholera can be a risk for anyone traveling to places where outbreaks are occurring.

11

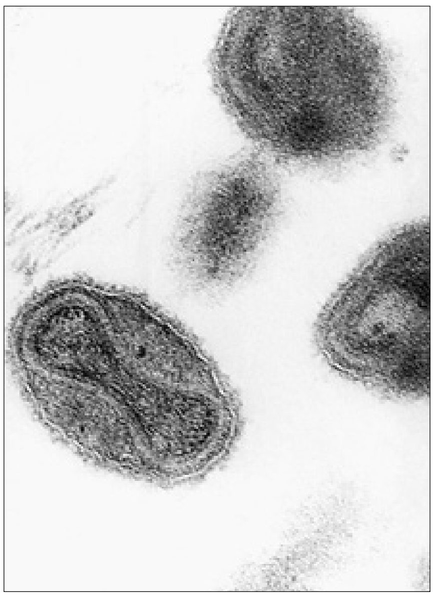


Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

DISEASE INFORMATION

Smallpox

Smallpox has been in the news quite a lot recently. Maybe you heard about it first after the terrorist attacks in 2001. Since then, there has been a lot of talk about the possible use of "biological weapons," including smallpox, to infect and even kill a large number of people.



This photograph reveals the internal structure of a smallpox virus. CDC\1849 F. Murphy, S. Whitfield.

An Ancient Nemesis

Smallpox is a very contagious disease caused by the Variola (smallpox) virus. Scientists believe it originated in humans in India or Egypt more than 3,000 years ago. Since then, smallpox has been one of our deadliest diseases. Smallpox epidemics once spread throughout entire continents. (An epidemic is a widespread outbreak of a disease.) Many of those who got smallpox died, and some those who survived were blinded and physically marked by the disease with scars.

The name, "smallpox," refers to the bumps that infected people get on their faces and bodies, and in their throats, mouths and noses. There are two common forms of smallpox: Variola major and Variola minor. (The word, "variola," comes from the Latin word for "spotted.") Both forms lead to sores on the skin, fever, headache and other flu-like symptoms. However, Variola major is a far more deadly disease. It is estimated that 30% of the people who have caught this illness have died.

Smallpox affects only humans. It does not make animals sick, and it is not transmitted by insects. There is no cure for smallpox, but there now is a vaccine that can prevent infection, even up to four days after a person has been exposed to the Variola virus. However, some people should not get the vaccine, including pregnant women and people with skin problems, a weakened immune system or some other medical problems.

Chicken pox is not a mild form of smallpox. Although it causes similar (but less disfiguring) sores, it is caused by a different virus.

It's in the Air

Most often, smallpox is transmitted when a person infected with the disease sneezes or coughs near someone else. If the infected person has a fever and rash, he or she is able to spread smallpox to others until the very last blister heals. The disease is easiest to spread during the 7–10 days after the rash first appears. Although smallpox is deadly, it takes direct and fairly prolonged face-to-face contact to spread smallpox to another person.

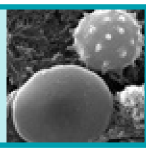
It also is possible to catch smallpox from contaminated objects, such as blankets or clothing. In very rare cases, smallpox has been spread through the ventilation systems of buildings, trains and other closed places.

Shown above, the *Vaccinia* vaccine can prevent infection from smallpox. It does not contain the smallpox virus. CDC\2676 J. Gathany.

Usually, it takes 12–14 days for a person who has been exposed to smallpox to be able to spread the disease. During this time, the virus is multiplying inside the person and usually causes no symptoms.

Some Risk Remains

Following a worldwide vaccination program, smallpox was eliminated globally by 1980. The last U.S. case was in 1949. But smallpox still exists in laboratories, so it is possible that another outbreak could occur. Since the disease has been eradicated (eliminated) for more than 25 years, almost no one has been vaccinated against it recently. Therefore, very few people have immunity. If there is an outbreak, it might not be possible to vaccinate every person exposed to smallpox in time to prevent them from being infected. This combination of factors makes any future smallpox epidemic extremely dangerous.



Red (round) and white (knobby) blood cells. CDC\7320 J. Carr.

DISEASE INFORMATION

HIV/AIDS

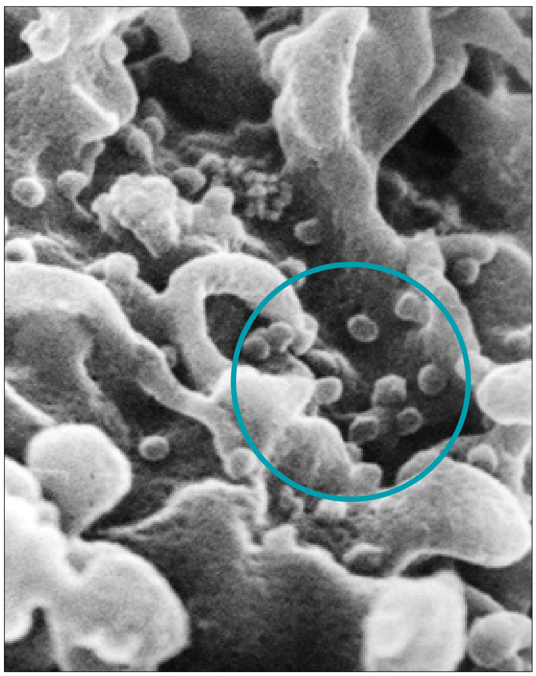
Everyone has heard of HIV and AIDS. You might even know someone infected with HIV. But what, exactly, is HIV? What's the difference between AIDS and HIV? And why is it important for you to know about it?

The Difference Between HIV & AIDS

HIV (human immunodeficiency virus) is the very serious—and always deadly—virus that causes the disease called AIDS (acquired immunodeficiency syndrome). Scientists and doctors aren't sure exactly when or where the HIV virus developed, but they know it has been present in the U.S. since the late 1970s. They also know that the HIV virus kills specialized blood cells needed by the body's immune system to fight disease.

Over time, as the virus kills more and more of these blood cells, people who carry the virus (referred to as HIV-positive) lose the ability to battle infections and diseases. People infected with HIV often develop specific illnesses or types of infections associated with this virus. At that point, they are considered to have AIDS. Microbes that might not make another person sick can be life threatening for people with AIDS, because their immune systems are weakened.

A simple blood test can show if a person has the HIV virus. On the other hand, doctors have to look for specific symptoms, such as a decrease in the number of certain blood cells, to determine if a patient's illness has progressed to AIDS. It may take years for these symptoms to appear or for a person to begin feeling ill, so HIV is considered to have a long incubation period (length of time between when the disease-causing microbe enters the body and when symptoms develop). Thus, it is possible for someone to have the virus in his or her body and not know it. All the while, this person could be spreading HIV to others.



The multiple round bumps are pockets with HIV virus that have formed on the surface of a cell. CDC\C. Goldsmith, P. Feorino, E. Palmer, W. McManus.

Facts, Myths & Hope

You can become infected with HIV if you come in close contact with body fluids, such as blood, of someone who has the virus. Most often, HIV is spread through unprotected sex or by sharing needles for drug use. HIV-positive mothers can infect their babies during pregnancy or birth, or by breast-feeding. It also is possible to become infected if dirty needles are used when getting tattoos or piercings.

You cannot get HIV or AIDS through saliva, sweat or tears; from mosquitoes; or from an animal bite, such as from a dog or cat. Some animals can carry viruses that are similar to HIV, but these viruses do not affect humans.

Twenty years ago, about half of all people with HIV developed AIDS within ten years. But in the last decade, powerful new drugs have been created to slow the progress of HIV. Other medicines also are being developed to prevent or treat life-threatening AIDS-related illnesses. The side effects of treatment are very serious, but many people infected with HIV now are able live longer than they would have in the past.

A Universal Problem

Unfortunately, not everyone is able to get the new medicines, and millions of people continue to die from AIDS every year. By the end of 2003, more than 500,000 people in the U.S had died from AIDS—about as many people as live in Las Vegas or Oklahoma City. In 2006, about 2.9 million people around the world died from AIDS; 39.5 million people were living with HIV; and 4.3 million people became newly infected with HIV. Today, about one of every 300 Americans over the age of 13 is HIV-positive.

HIV doesn't care who you know, how old you are, how wealthy or poor you may be, the color of your skin, your gender, or your sexual orientation. If you do risky things, you may become infected. And once you're infected, you have HIV forever. While new drug treatments are helping some people with HIV live longer, more normal lives, there is no cure for this disease.

Overview: Post-assessment

Students will share what they have learned over the course of the unit by revisiting their concept maps, presenting them to the class, and completing the same assessment they received at the beginning of the unit (see Answer Key, sidebar, p. 1).

12

Pseudallescheria boydii fungus. CDC\L. Ajello.

TIME

Activity Session 1: 45–60 minutes to review concept maps

Activity Session 2: 45 minutes to conduct and examine post-assessments

AND NOW, WHAT DO YOU KNOW

About Microbes?

This activity is matched to the unit pre-assessment. It provides an opportunity for you, the teacher, to gauge students' learning over the course of the unit. It also allows students to evaluate their own learning by examining their concept maps and responses to the pre-assessment.

MATERIALS

Per Group of Students

- Group concept map
- Markers and writing materials

Per Student

- Completed pre-assessment (hold for distribution, see Session 2, item 2)
- Copy of *What About Microbes?* student sheet (p. 58)

SETUP

Make 24 copies of *What About Microbes?* Hold for distribution during Session 2.

For Session 1, have students work in groups of four. For Session 2, have students work individually to complete the post-assessment.

PROCEDURE

Session 1:

1. If you recorded questions from Activity 1 at the beginning of this unit, review each question with the class. Ask, *Can you answer any of the questions now?* Discuss students' responses.
2. Next, have students work in their original groups to review the concept maps started in Activity 1 and used throughout the unit. Each group should discuss the additions made to its concept map and decide which findings were most important.
3. Ask each group to appoint a spokesperson. Call on each group and ask the spokesperson to explain one concept on the group's map. Do this two or more times, in round-robin fashion among the groups, until most major concepts have been covered.
4. Create a class concept map using the information presented.

Session 2:

1. On the following day, give each student a copy of the post-assessment. Students should complete it individually.
2. After students have completed the post-assessment, distribute the pre-assessments. Have students compare their answers on both assessments so they can see how much they have learned during the unit. Discuss any remaining student questions and collect the assessments, which can become part of students' portfolios or can be placed in their science notebooks.

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.

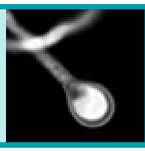
Life Science

- Living systems at all levels of organization demonstrate the complementary nature of structure and function.
- Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic systems failures. Others are the result of damage from infection by other organisms.
- Millions of species of animals, plants and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of chemical processes, and the evidence of common ancestry.

Science in Personal and Social Perspectives

- Students should understand the risks associated with natural hazards (fires, floods, tornadoes, hurricanes, earthquakes and volcanic eruptions), with chemical hazards (pollutants in air, water, soil and food), with biological hazards (pollen, viruses, bacteria and parasites), with social hazards (occupational safety and transportation), and with personal hazards (smoking, dieting and drinking).

12



Pseudallescheria boydii fungus. CDC\L. Ajello.

POST-ASSESSMENT

What About Microbes?

Name ______________________________

Circle the best response to each question.

1. Microbes usually are
   a. germs.
   b. bad.
   c. good.
   d. microscopic.

2. A microbe does NOT cause
   a. polio.
   b. HIV/AIDS.
   c. asthma.
   d. malaria.

3. One way to prevent the spread of disease is to
   a. wash your hands with soap and water.
   b. not ever get sick.
   c. wear a jacket.
   d. take aspirin.

4. Diseases caused by viruses can be cured with
   a. antibiotics.
   b. anesthetics.
   c. vitamin C.
   d. none of the above.

5. Flu is caused by a
   a. virus.
   b. bacterium.
   c. fungus.
   d. protist.

6. Most bacteria are
   a. harmful.
   b. helpful.
   c. viral.
   d. disease-causing.

7. A paramecium is an example of a
   a. virus.
   b. bacterium.
   c. fungus.
   d. protist.

8. Microbes are an important part of the environment because they
   a. break down waste.
   b. cause the water cycle.
   c. protect the ozone layer.
   d. block global warming.

9. The incubation period of a disease is the length of time
   a. it takes to get over a disease.
   b. between being exposed and showing the symptoms of a disease.
   c. it takes for the eggs to hatch.
   d. between showing the symptoms of a disease and getting well.

10. In order for bacteria to grow, they need
   a. a source of energy.
   b. a source of young viruses.
   c. specialized equipment.
   d. someone to cough or sneeze.

11 Infectious diseases can spread
   a. from one person to another.
   b. by eating only fresh fruit.
   c. from washing your hands.
   d. by inheritance.

12. Most diseases caused by bacteria can be cured with
   a. antibiotics.
   b. anesthetics.
   c. vitamin C.
   d. none of the above.

13. One of the most common microbes used in food production is a
   a. fungus.
   b. protist.
   c. virus.
   d. micron.

14. Scientific advances depend on all of the following, EXCEPT
   a. being curious about what is observed.
   b. always being successful.
   c. appropriate tools and methods.
   d. work by other scientists.

15. The large structure you can often see inside of a cell is called
   a. protein.
   b. flagella.
   c. the cell wall.
   d. the nucleus.

16. Antibiotic resistance is
   a. beneficial for most humans.
   b. caused, in part, by lack of antibiotics.
   c. caused, in part, by overuse of antibiotics.
   d. caused, in part, by overuse of vaccines.

17. A worldwide spread of infectious disease is called a/an
   a. anemic.
   b. epidemic.
   c. systemic.
   d. pandemic.

18. It is possible to catch HIV/AIDS from
   a. body piercing.
   b. saliva.
   c. sweat.
   d. mosquito bites.

19. A way to protect yourself from some diseases is called
   a. polarization.
   b. fertilization.
   c. constipation.
   d. vaccination.

20. Microorganisms often are measured in
   a. decimeters.
   b. centimeters.
   c. millimeters.
   d. micrometers.

Glossary

Aerobic - an organism or process that requires oxygen.

AIDS - acquired immunodeficiency syndrome; late stages of HIV infection in which numbers of T cells are reduced and other secondary infections may be present.

Algae (singular, alga) - a plant-like (photosynthetic) member of the protist group; can be single-celled or consist of clustered or multiple cells.

Allergy - abnormal reaction of the body's defense system (immune system) to a substance that is otherwise harmless.

Anesthetic - substance (drug or agent) that causes a temporary loss of sensation or consciousness.

Antibiotic - chemical or natural substance (drug) that kills or slows the growth of bacteria.

Antibiotic resistance - condition in which a bacterium no longer is affected or killed by an antibiotic.

Antibody - protein made by certain white blood cells that tags invaders for destruction by the immune system.

Antigen - any substance that triggers an immune system response; an antigen can be a microbe, part of a microbe or any other material foreign to the body.

Antimicrobial - refers to any substance that destroys or weakens one or more kinds of microbes.

Autotroph (adjective, autotrophic) - organism that is capable of making its own food, usually through photosynthesis.

Bacteria (singular, bacterium) - single-celled organism without an organized nucleus; often separated from other forms of simple organisms known as archaea.

Carrier - someone who is infected with a pathogen but does not show symptoms of a disease.

Cell - basic unit of living organisms.

Cell membrane (also called plasma membrane) - outer boundary that controls the movement of substances into and out of a cell, which it encloses.

Cell wall - strong wall outside the cell membrane of some cells, such as those of plants.

Chlorophyll - any of a group of green pigments found in photosynthetic organisms, such as plants.

Cilia (singular, cilium) - hairlike projections from the surface of a cell, usually involved in movement.

Compound microscope - magnification tool that uses two magnifying lenses in series.

Contagious disease - illness that can be spread from one organism to another through direct or indirect contact.

Culture - in biology, a process by which cells or organisms are grown under laboratory conditions.

Cytoplasm - contents of the cell between the nucleus and the cell membrane.

Decomposers - organisms that break down waste materials and dead organisms.

Digestion - process by which food is broken down into molecules small enough to be absorbed and used by the body.

Disease - any change in the body that causes discomfort, loss of function, distress or death.

DNA - deoxyribonucleic acid; long spiral molecule built of smaller molecules (nucleotides); the order of nucleotides in DNA provides instructions for the development and function of living organisms and many viruses.

Drug - any substance that modifies the functions of the body; used in the treatment, cure or prevention of illness, or to enhance physical or mental wellbeing.

Ecosystem - community of living organisms and the environment in which they live.

Epidemic - widespread outbreak of a disease.

Extremophile - single-celled organism that lives in an extreme environment, such as very hot or salty conditions; usually considered part of the Domain Archaea or the Kingdom Monera (in the five kingdom system of classification).

Fermentation - process by which cells break down food in the absence of oxygen.

Flagella (singular, flagellum) - long, whip-like structures that enable some single-celled organisms to move.

Fungi (singular, fungus) - kingdom of organisms that absorb nutrients from other living things, dead or decaying organisms, or waste materials; can be single-celled or consist of multiple cells.

Gene - unit of inherited information; composed of DNA (or RNA in some viruses).

Germ - non-technical term for a disease-causing microbe.

Heterotroph (adjective, heterotrophic) - organism that obtains food by consuming other organisms or waste from other organisms.

HIV - human immunodeficiency virus; infects certain kinds of T cells in humans and causes the disease known as AIDS.

Host - organism that harbors a disease-causing organism or parasite, or that provides nutrition or shelter to another organism (for example, humans are hosts to the helpful bacteria in the intestines).

Hyphae (singular, hypha) - thread-like filaments that make up the body of a fungus.

Immune system - body's defense system; protects against infections and foreign substances.

Immunity - having biological protection or defenses against infection, disease or unwanted invasion of the body.

Incubation period - the time between being infected by a pathogen and showing symptoms of the disease.

Lymph nodes - organs that act as filters to collect and destroy bacteria and viruses.

Macroscopic - visible by the unaided human eye.

Microbiology - field that involves the study of microbes.

Glossary

Micron - micrometer, one millionth of a meter; this term is no longer in frequent use.

Microorganism, microbe - any organism (usually single-celled) that must be magnified to be visible to the naked eye; sometimes also refers to viruses, which are not considered living by most definitions.

Microscopic - too small to be seen with the unaided human eye; requiring magnification to be visible.

Mold - member of the Fungus Kingdom that grows rapidly on a surface.

Monera - kingdom of unicellular organisms without an organized nucleus; when considered part of the five-kingdom system of classification, Monera contains both bacteria and archaebacteria (which also are single-celled and lack an organized nucleus); other systems of classification separate bacteria and archaebacteria (archaea) into distinct kingdoms or domains.

Multicellular - composed of more than one cell.

Mutation - change in the sequence of nucleotides in DNA.

Nitrogen fixation - process by which some kinds of bacteria convert nitrogen from air into forms usable by plants.

Nucleus - center of a cell containing hereditary material and bounded by a membrane; found in the cells of protists, plants, animals and fungi.

Nutrient agar - gelatinous substance derived from certain seaweeds that is used as a thickener in foods and as a medium on which to grow microorganisms.

Organelle - part of a cell with a specific function, bounded by a membrane and located in the cytoplasm.

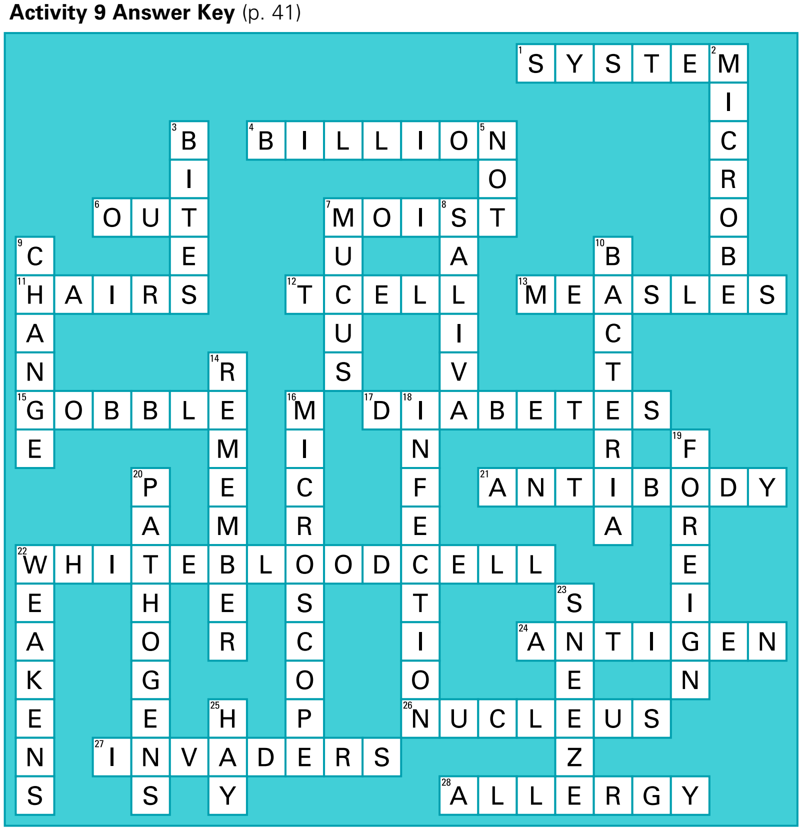
Pandemic - epidemic that has spread broadly throughout much or all of the world.

Parasite - organism that obtains nourishment or shelter by living on or within another organism, and causes harm to the host.

Pathogen - organism or virus that causes disease.

Photosynthesis - process by which energy from the sun is used to convert water and carbon dioxide into sugar molecules (food); carried out by plants, algae and some microbes.

Activity 9 Answer Key (p. 41)



Population - group of individuals of the same species living within the same geographic area at the same time.

Protein - large molecule made of amino acids; the sequence of amino acids in a protein is determined by the sequence of nucleotides in DNA; proteins are involved in a variety of functions in cells, including chemical reactions, signaling between cells, protection against disease, and as structural components.

Protist - member of the Kingdom Protista (in the five kingdom system); often used informally to classify any organism that has cells with organized nuclei, but is not a plant, animal or fungus.

Protozoan - single-celled protist often described as animal-like because it shows characteristics (such as locomotion and ingestion of food) typical of animals.

Red blood cell - blood cell that transports oxygen and contains hemoglobin; also called an erythrocyte.

RNA - ribonucleic acid; several kinds of long molecules that act as messengers between DNA and the cellular mechanisms for manufacturing proteins; some viruses have RNA, rather than DNA, as their genetic material.

T Cell - class of white blood cells that recognize and attack cells of the body that contain multiplying bacteria or viruses; some T cells also release chemicals that communicate the presence of a pathogen.

Vaccine - harmless version of a pathogen that stimulates the development of a long-term immune response to the pathogen; used to prevent diseases such as measles and tetanus.

Virus - infectious particle that consists of genetic material (DNA or RNA) encased in a protein coat; viruses must invade a cell in order to make copies of themselves.

White blood cell - class of blood cells that defend the body against disease and infection; leukocytes and lymphocytes are types of white blood cells.

Yeast - single-celled fungus.

THE SCIENCE OF MICROBES

BioEd℠

Teacher Resources *from* the
Center *for* Educational Outreach
Baylor College *of* Medicine

BCM
Baylor
College of
Medicine

ISBN-13: 978-1-888997-54-5