BioEd℠

the science of MICROBES

Activity: The Variety and Roles of Microbes

from *The Science of Microbes Teacher's Guide*

by Nancy P. Moreno, Ph.D., Barbara Z. Tharp, M.S., Deanne B. Erdmann, M.S., Sonia Rahmati Clayton, Ph.D., 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.

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

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

BAYLOR-UT CENTER FOR AIDS RESEARCH
www.bcm.edu/cfar

MOLECULAR VIROLOGY AND MICROBIOLOGY
www.bcm.edu/molvir

BAYLOR-UT CENTER FOR AIDS RESEARCH
www.bcm.edu/cfar

BROOKHAVEN NATIONAL LABORATORY
BIOLOGY - STEM FACILITY
www.biology.bnl.gov

CENTERS FOR DISEASE CONTROL AND PREVENTION
PUBLIC HEALTH IMAGE LIBRARY
www.cdc.gov | http://phil.cdc.gov

DARTMOUTH COLLEGE
ELECTRON MICROSCOPE FACILITY
www.dartmouth.edu/~emlab

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

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

MICROIMAGING SERVICES (Canada)
www.microimaging.ca

MICROGRAPHIA (Australia)
www.micrographia.com

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

NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES, NIH
www.niaid.nih.gov

NATIONAL INSTITUTE OF ARTHRITIS AND MUSCULOSKELETAL AND SKIN DISEASES, NIH
www.niams.nih.gov

NATIONAL INSTITUTES OF HEALTH (NIH)
www.nih.gov

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

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

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

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

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.

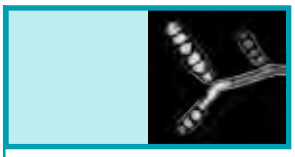
Principal Investigator
- Reads the directions
- Asks the questions
- Checks the work

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.



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. 2 .

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 6).

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 and 20 *Microbe Examples* cards
- 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. 6).

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. 1.

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.

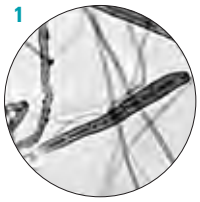
Yeast produce CO_2 as a waste product when oxygen is present. Some yeast cells are able to break down food through the process of fermentation, which does not require oxygen and produces ethyl alcohol and CO_2 as waste. Beer and wine are products of yeast fermentation.

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.

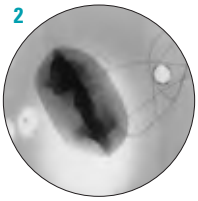
and the microbes that cause disease? What general statement could we make about microbes? (Microbes have many roles. Some are helpful; some are harmful.) *Is it possible for the same microbe to be both helpful and harmful to humans or to another organism?* (yes)

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



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.



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).

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).

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.

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.

Exserohilum rostratum fungus. CDC\3784 L. Ajello.

Microbe Examples

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.

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.