Introduction

Welcome to the wonders of Microbes: Invisible Invaders...Amazing Allies, a traveling exhibit developed by BBH Exhibits Inc., San Antonio, Texas, with sponsorship from Pfizer Inc in collaboration with the National Institutes of Health.

Microbes: Invisible Invaders...Amazing Allies is a study of microbes-viruses, fungi, bacteria, protozoa-life forms so small you need a microscope to see them. Microbes are all around you. They're on your skin, in your bed, in your food and water. They're even living inside you. Without them, you would have no oxygen to breathe and no food to eat.

From the exhibit you and your students can explore the ecology and biology of microbes. You'll learn how microbes work by your side (and in your insides) to make some of the foods you eat and help you digest your meals. You'll learn about diseases caused by microbes. And you'll discover how modern science is using microbes to fight and prevent diseases, and how modern medicines are invented and developed.

The purpose of this Teacher's Guide is to enhance your class' visit to Microbes: Invisible Invaders...Amazing Allies. The activities are multi-disciplinary and can easily be integrated into your curriculum to enhance and enliven your current lesson plans.

To help guide you we have divided this guide into three sections. In the first you'll find pre-visit activities that will help introduce your students to the microscopic world of microbes. The second section includes activities that you can use as part of pre-visit or post-visit lessons. Activities that require a bit more knowledge or that can be used to assess students' learning have been placed in the third section. You can follow this sequence or just use the activities that fit your needs. The glossary and list of references at the back of this guide may be helpful when planning your Microbes adventure.

Enjoy!

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Suggested Pre-Visit Activities

MICROBES
INVISIBLE INVADERS AMAZING ALLIES

collaboration with the National Institutes of Health.

A Teacher's Guide

Pre-Visit Activities

Seeing is Believing

Subjects: life sciences

Grades: 3 - 9

Concepts: observation skills and the microscopic world

Duration: one to two 45-minute class sessions

Objective

Students will learn that...

- there are living organisms smaller than the eye can see.
- they can see microscopic plants and animals with the help of a magnifying lens or microscope.

Background Information

A first look into a microscope at a familiar object reveals an unfamiliar landscape. Objects that look smooth to the naked eye may appear rough or fuzzy under the microscope. This new view of the world may seem scary at first, but easing your students into the microscopic realm can help make it less intimidating to explore.

Observing, describing and recording the details of the microscopic world helps students explore microbes in a fun and meaningful manner.

Activity Materials

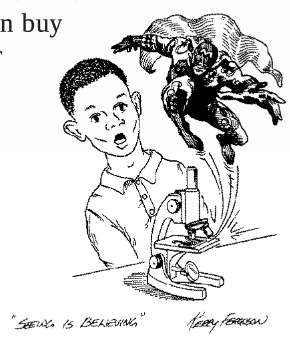
- magnifying lenses
- microscopes
- glass slides and cover slips
- variety of objects for observing
- poster board and marker pens for making optional class chart

Questions to Begin

- Do you think things look the same up close as they do far away?
- Do you think there are living organisms you can't see?

Procedure

1. One or two days ahead of time, ask students to bring five small objects from home-things they would like to see through a magnifying lens.
2. Have students describe their objects (as seen with the naked eye) in as much detail as they can. Encourage them to look closely and record their observations on paper.
3. Hand out the magnifying lenses and let students explore the same familiar objects. Have the students describe what they see through the magnifying lens and compare their observations. Students can do this exercise in teams, recording their observations in notebooks; or, the class can do it as a whole, recording their observations on a large chart.
4. After the students are used to looking at objects up close, have them look at natural objects through a magnifying lens-a flower or a dead house fly. This time, ask them to observe the object for 20 seconds, then have them write down descriptions. When they're finished, let them compare their observations with the actual object. What did they miss?
5. By now your students should be ready to see things really close up-through a microscope. Start with one of the fly's wings or one of the flower's petals.
6. Place the object on a clean glass slide and cover it gently with a cover slip. Begin viewing at a low magnification, moving to a higher magnification once the object is centered and in focus.
7. As the students' observation skills improve, give them smaller and smaller things to look at, eventually moving to slides of microbes (you can buy prepared slides of microbes from a biological supply company or make them yourself using some of the activities in this booklet).



Questions to Close

- Do things look different magnified than they do when you look at them with the naked eye?
- How do they look different?
- Did you see any living organisms through the microscope?
- What did they look like?

Adapted from
Zook, Dr. Douglas, ed. The Microcosmos Curriculum Guide to Exploring Microbial Space. Dubuque, IA: Kendall/Hunt Publishing Company, 1992.

Pondering Protozoa

Subjects: life sciences, microbiology, art

Grades: K - 8

Concepts: life sciences, microbiology, art

Duration: one 30 to 60-minute class sessions not including the pond-gathering trip

Objective

Students will learn that...

- the world is teeming with a variety of different life forms that are too tiny to see. Some of them affect you.

Background Information

Ponds are teeming with microscopic plants and animals. As microscopic plants, called algae, make food from water and sunlight, they give off oxygen. The oxygen collects in bubbles, which you can see. The bubbles are a source of oxygen for the microscopic animals called protozoa living in the pond. Protozoa are made of only one cell.

There are over 60,000 species of protozoa living in all types of environments. Some protozoa eat other one-celled organisms called bacteria. Others eat other protozoa. Some are parasites on other animals including humans, and cause disease, such as malaria and dysentery.

Look through a magnifying lens or microscope and you can enter this microscopic world.

Activity Materials

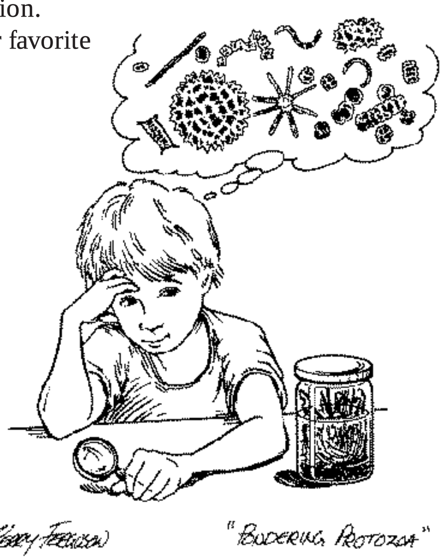
- pond water (or salt marsh water)
- shallow dishes for observing pond life
- glass slides and cover slips
- pencils and paper
- glass jars for collecting pond water
- one magnifying lens for each student
- eyedropper

Questions to Begin

- Do you think there's anything living in this water? If so, what might it be?

Procedure

1. If possible, take the class to a nearby pond or salt marsh to collect water samples. If you can't take the class, collect the water ahead of time.
2. Hand out magnifying lenses and one or two shallow dishes to each team.
3. Using the eyedropper, place a sample of water into each team's shallow dish.
4. Have the students look in the water with their hand lenses. Can they see bubbles? What else can they see? Have the teams record their observations.
5. After the students have examined their samples, distribute the microscopes and show them how to prepare a sample for viewing: To make a slide, place a drop of pond water onto a clean glass slide. Gently place a cover slip over the sample, starting with one edge and lowering it slowly so that no air gets trapped beneath. (You may have to help younger students with this step.) To view, place the slide under the microscope lens. Start with low magnification, then move to higher magnification.
6. While students are viewing the protozoa, they can draw their favorite ones or record the activities they see.



Questions to Close

- How many protozoa did you see?
- What color were they?
- Did they all look alike or different?
- Did you have a favorite one? Why?
- If you were a protozoa, what would you want in your pond to ensure you would survive

Adapted from
Science: Model Curriculum Guide, Kindergarten Through Grade Eight. Sacramento: California State Department of Education, 1987.

The Fungus Among Us

Objective

Students will learn that...

- mold is a type of microbe related to mushrooms and mildew. Like all living organisms, mold needs certain conditions to grow.

Background Information

You're probably familiar with mold. It's the fuzzy stuff that grows on bread, oranges, banana peels or any other organic material left in a damp area too long. Mold belongs to the group of microbes called fungi, and is related to mushrooms and mildew. Like other fungi, mold spreads through the air-its small, hard, seedlike spores riding air currents. If the spores happen to land on fruit, bread, leaves or other organic matter, any amount of dampness will make them burst open and grow. Within days brown, green or white fuzz covers the area.

Mold has many uses. If it weren't for mold, there would be no cheese. Cheese is milk that's fermented then inoculated with a unique type of mold to give each variety its distinctive flavor and aroma. Some medicines come from mold. The first mass-produced antibiotic, penicillin, came from bread mold.

Activity Materials

- organic material (apples, oranges, banana peels, bread, leaves, etc.)
- zip-close baggies
- permanent marker pens to label baggies
- one lab notebook for each student or team of students
- water
- poster board
- color markers

Questions to Begin

- How many of you have taken something from the back of the refrigerator only to find it covered with fuzzy stuff?
- How many of you know what that fuzzy stuff is?
- Have you seen mold growing in other places? Where?
- What conditions do you think mold needs to grow?

Subjects:

life sciences, microbiology

Grades: 4 - 9

Concepts:

scientific method,

microscope use,

record keeping,

verbal communication

Duration:

one classroom session for

original discussion and set-up

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4 to 5 class sessions

(for observation and

wrap-up periodically during

the next 4 weeks)

Procedure

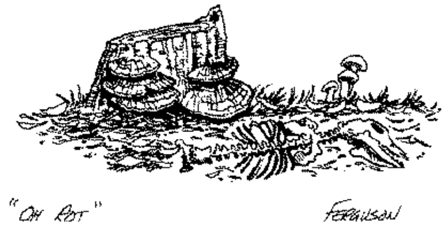
1. with a class discussion of what mold is, what mold needs to grow, and what conditions might retard mold growth. Then, ask each student or team of students to think of four mold-growing conditions they would like to test. If they need help, tell them to think about places they've seen mold growing. Have them write each one down on a separate page in their notebooks. Be sure they include a hypothesis or guess about what will happen in each treatment. Conditions can include dry, wet, in the light, in the dark, baggie open, baggie closed, contained with another moldy item or without, etc. Encourage the students to use their imaginations.
2. The next step is to set up the experiments. Each student chooses a mold-growing medium: apple slices, oranges, banana peels, potato pieces, leaves from the yard, etc. They place a piece of mold-growing medium in each of four zip-close baggies, then subject each to one of the conditions (independent variables) they chose to test. (For example: dry, wet, in the light, in the dark, etc.) The students should record the date, time and condition of each medium at the start of the experiment on the appropriate page in their notebooks. The test condition should be marked on the outside of each baggie with permanent marker. Let the experiment sit for four weeks.
3. Have the students periodically examine their mold samples using microscopes, hand lenses, etc. You can decide how often to do this. During observation periods, students should make notes in their notebooks about what is happening in each baggie, and draw what they see.
4. At the end of the four weeks have the students make a final observation and record it in their notebooks. They should compare their initial predictions with the results. Then have them prepare a presentation of their study by making a chart on poster board. On the chart they will list the treatments and the outcome for each. Included should also be important information such as the date the experiment started and the date it ended.
5. The activity culminates with each student or team giving a brief oral presentation of his or her hypothesis, the methods, and the results.

Questions to Close

- Did your mold grow equally well in the four treatments?
- If not, in which treatment did it grow the best? the worst?
- How do you think the mold got there?
- How does mold spread over an area?
- From your observations, what do you think mold needs to grow?
- How would you prevent mold from growing?

Adapted from
Zook, Dr. Douglas, ed. The Microcosmos Curriculum Guide to Exploring Microbial Space. Dubuque, IA: Kendall/Hunt Publishing Company, 1992.

Oh Rot!



Objective
Students will learn that...
- bacteria need food, moisture and warmth.
- bacteria are important decomposers, providing nutrients that plants need to grow.

Background Information
Over time, dead plant and animal matter rots (decays) as bacteria digest this organic material. Floating around in the air, on plants and on everything else are millions of these bacteria. But they're not active. They have a covering that protects them until conditions are just right. When they land on a warm, moist place, like on a piece of fallen fruit in an orchard, the bacteria burst from their coverings and begin feeding on the organic material, causing decomposition.

Decomposition is a good thing. It's a natural process that helps return nutrients and minerals to the soil where plants can use them to build more roots, stems and leaves. Then, animals, including humans eat the plants, or eat animals that eat the plants. If it weren't for bacteria, you'd have no food to eat!

Activity Materials
- one or two raw potato pieces (peeled), a few dried lima beans or a few dried peas for each
- student or team
- test tube holders/racks
- permanent markers
- cotton
- microscopes
- two test tubes for each student or team
- tap water
- masking tape
- eyedroppers
- glass slides and cover slips

Questions to Begin
- Have you ever been walking in the forest or along the beach and come across a dead animal? Was it rotting? How do you know it was rotting?
- What do you suppose causes dead things to rot?

Procedure
1. For this activity you can have students work independently or in teams.
2. Distribute test tubes. Ask each student or team to write their names on a piece of tape and stick the tape to the test tube. For fun, teams can adopt names of bacteria like Staphylococcus, Streptococcus or Salmonella.
3. Have each student or team fill a test tube about half full of water, then add one or two raw potato pieces. Place the test tubes in a rack and leave in a warm place (out of direct sunlight) uncovered for three days.
4. Do the same with the beans.
5. After 3 to 5 days, stuff a plug of absorbent cotton loosely in each test tube, at the top. Let sit another 3 to 5 days.
6. With the eyedropper, have each team or student place a drop of water from their "potato" (or "bean" or "pea") test tube onto a clean glass slide and cover with a cover slip. Observe under the microscope, starting with low magnification, then moving to higher magnification (you may have to help younger students with this part).
7. Older students can take notes or make detailed drawings of what they see and label their drawings.

Questions to Close
- What did you see in the water? What did it look like?
- What was it? (bacteria)
- Where do you think the bacteria came from?
- Did the bacteria all look alike or were they different shapes?
- Were they different colors?
- Did they move in similar ways or different ways?

Adapted from
Hanauer, Ethel. Biology Experiments for Children. New York: Dover Publications, Inc., 1962.

Subjects:

life sciences

Grades: 3 - 9

Concepts:

learning to view the

microscopic world

Duration:

one to two

45-minute class sessions

Subjects:

life sciences, microbiology

Grades: 3 - 8

Concepts:

reproduction, growth of yeast,

microbe ecology

Duration:

one 45- to 60-minute

class session

to make sugar solution

and observe yeast

•

one to two class sessions

for observation of bacteria

(6 to 10 days later)

Yeast Buddies

Objective

Students will learn that...

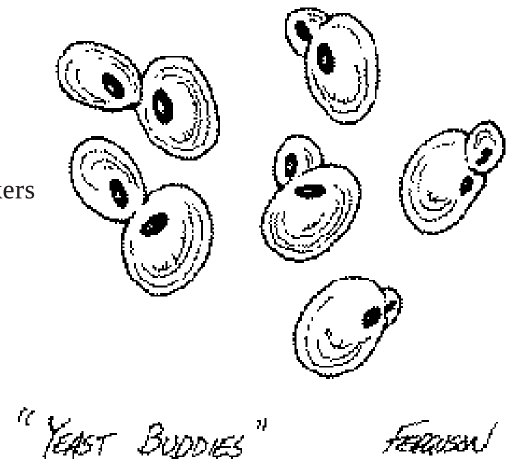
- yeast is an organism whose body consists of only one cell.
- yeast grows by splitting in two (budding), forming colonies.

Background Information

Yeast is a type of fungus with a body made of one cell. To grow, yeast need sugar, water and warm temperatures. Yeast cells grow by dividing in two, a process called "budding." Budding starts when a small lump appears on the parent cell. In time, this lump, called the bud, will grow into a full-sized yeast cell. Sometimes the bud splits from the parent cell, and sometimes it stays attached. In time, the new bud will start producing buds of its own.

Activity Materials

- 1 package of dried yeast powder for each team
- 1-1/2 tablespoons (13 g) of sugar for each team
- 1 half-pint (250 ml) jelly jar with a cover for each team
- compound microscopes (450X minimum)
- tap water (warm)
- clean slides and cover slips
- masking tape
- eyedroppers
- permanent markers



Questions to Begin

- Have you ever heard of yeast?
- Can someone tell the class what yeast is?
- Is yeast alive?
- Do you know what yeast is used for?

Procedure

1. Before class, buy a packet of fresh yeast at the grocery store. Be sure to check the freshness date on the package. Yeast that's too old may not be alive.
2. Split the class into teams so that each team has its own microscope. If you only have one microscope, you can do this activity as a demonstration for the whole class.
3. Have each team make a sugar solution for the yeast. Fill a jelly jar with 1 cup (250 ml) of warm tap water, then dissolve 1-1/2 tablespoons (13 g) of sugar. Dissolve one teaspoon (3 g) of yeast in the sugar solution. Stir gently.
4. Using an eyedropper, place a drop of the solution onto a slide. Cover with a cover slip and have the students look at it under a microscope. Have each student describe or draw what he or she sees. Begin viewing under low magnification, then move to higher magnification.
5. Cover the jars. Separate the teams into two categories: cold or warm. Have each team label their jar as "warm" or "cold" with marker pens and masking tape. Put the "cold" solutions in the refrigerator, and the "warm" solutions in a warm place. (If you're doing this as a demonstration, split your solution into half; place one half in the refrigerator and the other in a warm place.) Let sit for 24 to 48 hours.
6. Have each team make a hypothesis: which treatment will have more yeast buds? Why? Have students record their hypotheses and reasons.
7. After a day or two, have each team take a sample from the "warm" treatment and one from the "cold" treatment. Have the students examine a drop of each under the microscope, then draw what they see.

Questions to Close

- Which yeast solution-warm or cold-has the most buds?
- Can you think of any reasons why you saw what you did?
- What do you think would happen if you didn't put sugar in the water?

Adapted from
Abruscato, Joe and Jack Hassard. The Whole Cosmos. Santa Monica, CA: Goodyear Publishing Co., 1977.
Hanauer, Ethel. Biology Experiments for Children. New York: Dover Publications, Inc., 1962.

Hay! Isn't that a Protozoan?

Objective

Students will learn that...

- protozoa are one-celled microscopic animals.
- protozoa use cilia, flagella or pseudopodia to move; some don't move at all.
- protozoa need food and water to live and grow. If there's no food or water, they can form a cyst around themselves and wait until conditions improve.
- some protozoa cause disease.

Background Information

There are over 60,000 known species of protozoa-simple one-celled animals too small to be seen with the naked eye. You'll find protozoa wherever you find water.

Like other animals, protozoa need food and water to grow. If conditions dry out, or if food supplies diminish, some protozoa can enclose themselves in cysts. A cyst is a protective casing that keeps the animal from drying out and keeps the temperature relatively constant. When favorable conditions return, a protozoan emerges from the cyst and begins feeding and reproducing again.

Protozoa move by beating tiny hairlike structures called cilia, or by whipping long tail-like structures, called flagella. Some protozoa move by making their inner fluids (cytoplasm) flow in a certain direction. This makes one part of them (called a pseudopodium) extend in one direction; the rest of the cell follows. Other protozoa don't move at all.

Some protozoa cause disease. One protozoa causes malaria and is transmitted to humans through the bite of an infected mosquito; another causes sleeping sickness in people bitten by the tsetse fly. Fortunately, most protozoa are harmless to humans.

After making this hay infusion and culturing some protozoa, you and your students will have your own personal supply of protozoa to observe and study.

Activity Materials

- one 1-quart jar (1-liter jar) with lid
- dried timothy grass (hay)
- a few dried leaves
- clean culture dishes
- microscopes
- mall pieces of cotton
- a jar of pond water containing scum (you can also use salt water from a nearby salt marsh)
- a small amount of silt or mud-like soil from the bottom of the pond (or salt marsh)
- uncooked rice
- hand lenses
- glass slides and cover slips
- eyedroppers

Questions to Begin

- Does anyone know what protozoa are? Has anyone ever seen a protozoan? Where do they live?
- Are protozoa plants, animals or something else?

Subjects:

life sciences, microbiology

Grades: 4 - 8

Concepts:

protozoan biology,

ecology of microbes

Duration:

one 45-minute class session

to collect leaves and pond water

and to make the infusion

•

5 minutes to add uncooked rice

(2 to 5 days later)

•

two 45-minute class sessions

to observe and draw protozoa

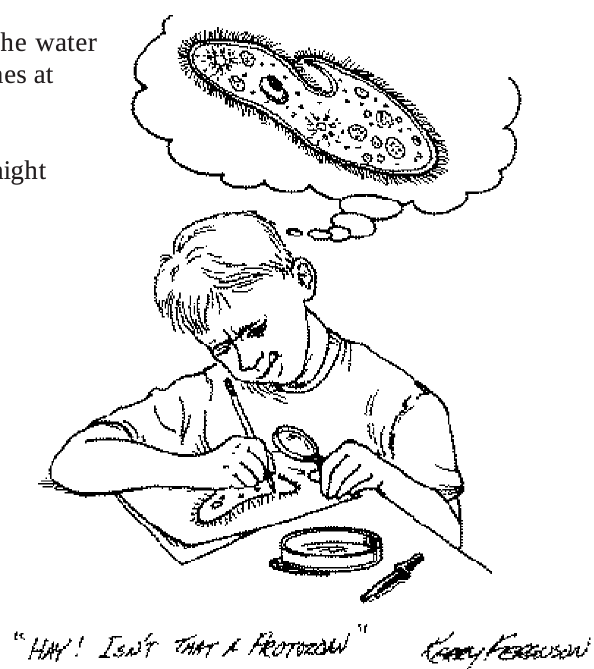
(2 to 5 days after adding the rice)

Procedure

1. Take the class outside on a leaf-gathering mission. Ask each student to find a few dried leaves on the ground and bring them back to the class. If you have a pond nearby, they can also collect samples of pond water and mud to bring back to class. If you don't have a pond nearby, you'll have to make a special trip with the class or by yourself ahead of time.
2. Fill a quart (liter) jar one-fourth full of pond water, pond scum and mud. Add a few spears of hay and the leaves. Cover the jar and put in a warm place, out of direct sunlight. You can ask for volunteers to help you with this step. Let the jars sit for 2 to 5 days.
3. At the end of that time, add a few grains of uncooked rice to the mixture. Don't be alarmed if the water turns a dark color and begins to stink. Inside the jar, the hay and leaves are decomposing, making a prime environment for protozoa to grow.
4. After the protozoa have had a few days to grow, give each student (or team) a clean culture dish. Open the jar, and with an eyedropper collect a sample of the water from the top. Be careful not to disturb the mud. Place the water in a culture dish.
5. Have the students observe their water samples with a hand lens. They'll probably see the larger protozoa, such as Paramecium, swimming around.
6. Next, have each student observe the protozoa in their culture dishes through the microscopes. Place a drop of water on a clean, dry glass slide. Cover the drop with a cover glass by placing one edge down first to avoid trapping air bubbles beneath the glass. If the protozoa are moving around too much, try placing a few fibers of cotton on the slide before adding the drop of water. This should trap the protozoa. Try observing first under low power, then gradually move to stronger power.
7. Have each student draw the animals they see and if possible, identify how each is moving. Does it have cilia, or one or more flagella? Does it move at all?
8. Repeat the process, this time with a sample of water from the bottom of the jar. Be careful not to stir up or collect the mud. Again, have the students draw the protozoa they see and identify how each is moving.
9. Close with a discussion of the class' findings.

Questions to Close

- Where did the protozoa come from?
- How did the protozoa in your sample move? Using cilia? Flagella? Some other way? Not at all?
- Were the protozoa at the top of the water the same or different than the ones at the bottom?
- What do you think protozoa eat?
- Can you think of anything that might eat a protozoan?



Adapted from
Hanauer, Ethel. Biology Experiments for Children. New York: Dover Publications, Inc., 1962.
Lowery, Lawrence F. The Everyday Science Sourcebook. abridged ed., Boston: Allyn and Bacon, Inc., 1978.

Additional Sources
Arms, Karen and Pamela S. Camp. Biology. Philadelphia: Saunders College Publishing, 1987.

VAN LEEUWENHOEK'S SURPRISE

Objective

Students will learn...

- how microbes were first discovered.

Background Information

The first person to ever see microbes through a microscope was Anton van Leeuwenhoek, a Dutch merchant who lived from 1632 to 1723. Although he sold dry goods for a living, van Leeuwenhoek liked to grind lenses in his spare time. His lenses were so good that they made some of the best microscopes of his day.

Van Leeuwenhoek looked at almost everything through his microscopes-rain water, hair, blood and fleas, among others. One day when he looked at scrapings from his teeth, he saw something new: "little animalcules" were tumbling, leaping and wriggling about. He knew they were living creatures. What he didn't know was they were bacteria...and they were rotting his teeth!

By accident, van Leeuwenhoek had discovered microbes. His natural curiosity drove him to look at all sorts of everyday objects and substances, including parts of his body, through the microscope. While observing cells of the human body, your students will make some exciting discoveries of their own.

Activity Materials

- flat-ended toothpicks
- dilute iodine solution
- glass slides and cover slips
- eyedroppers
- microscopes

Questions to Begin

- Do you think scientists plan their discoveries?
- Do you think scientists are sometimes surprised by what they discover?

Procedure

1. Begin the lesson by telling the students the story of van Leeuwenhoek's surprise discovery of microbes.
2. Depending on the number of microscopes you have available, divide the class into teams so that each team has its own microscope.
3. Give each student one or two glass slides and a supply of cover slips.
4. Hand out a tongue depressor to each student.
5. Using the eyedropper, place a drop of the iodine solution on each student's glass slide.
6. When everyone has a prepared slide, instruct each student to gently scrape the inside lining of his or her cheek with the flat end of a clean tongue depressor, then put the scrapings into the iodine drop on the slide.
7. Cover with a cover slip. Observe under low power of the microscope, then when the cells are centered and in focus, change to a higher magnification and re-focus. Have your students draw a cheek cell and label the nucleus and the membrane. Remind them that some of the cells will be flat, others will be rolled, but they all have the same basic shape.
8. If there's time, the students can look at other students' cheek cells and compare.
9. When they're finished looking at cheek cells, have them pluck a hair from their own head (not someone else's). Place the hair on a clean glass slide and cover with a cover slip.
10. View the hair under the microscope, first under low magnification, then switch to higher magnification. Again, ask them to draw what they see. When they're finished, they can look at other students' hairs and compare them to their own.
11. If you have time, have each student take a tooth scraping with a fresh tongue depressor and place it on another glass slide. Cover with a cover slip and observe through the microscope. Have them draw what they see.

Subjects:

life sciences, history

Grades: 4 - 8

Concepts:

scientific discoveries,

the human body

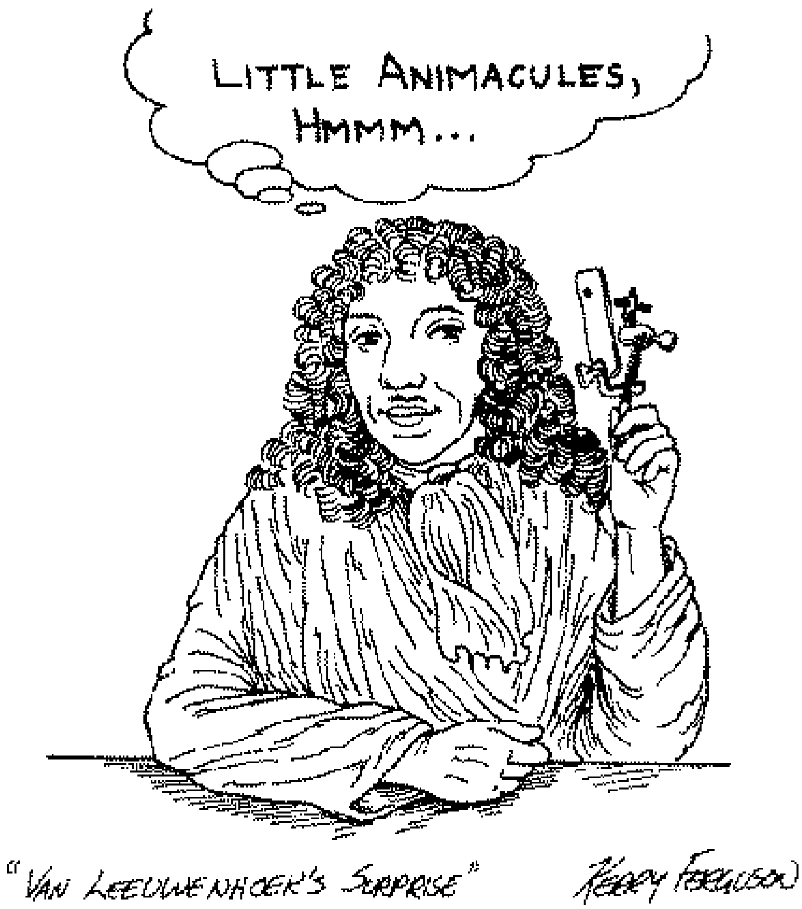
Duration:

one or two 45- to 60-minute

class sessions

Questions to Close

- Did your cheek cells look the same or different under different magnifications? If different, how did the two views differ?
- Did your hair look the same or different under different magnifications? If different, how did the two views differ?
- Did everyone's cheek cells look the same?
- What about hair? Did everyone's hairs look alike?
- What differences did you see between the cheek and tooth scraping samples?
- Did you see what you expected, or were you surprised by what you saw?
- Louis Pasteur wrote "In the field of observation, chance favors only the prepared mind". How does that apply to scientific discovery?



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Hanauer, Ethel. Biology Experiments for Children. New York: Dover Publications, Inc., 1962.
Abruscato, Joe and Jack Hassard. The Whole Cosmos. Santa Monica, CA: Goodyear Publishing Co., 1977.

Pass It On

Objective
Students will learn that...
- bacteria are one source of infections.
- when bacteria transfer to a new place, they cause a new infection.

Background Information
You've probably heard of germs. But do you know exactly what they are? "Germ" is the everyday word that refers to the bacteria, viruses and protozoans that make you sick.

Bacteria are tiny organisms made of a single cell. Not all bacteria make you sick, but the ones that do cause diseases such as cholera or pneumonia. Viruses are even smaller organisms. If you've ever had chicken pox, the measles or the common cold, you've had a virus. Protozoans are the giants of the bunch. Protozoa are single-celled organisms, but most are bigger than bacteria. Protozoans cause diseases such as malaria.

Let's say your sister has strep throat, a disease caused by the Streptococcus bacterium. She coughs on you. What are the chances you'll catch strep?

Chances are you've caught strep bacteria from her. Depending on your current state of health you may or may not come down with strep throat. But that's another matter. What's important here is that bacteria have moved from one person to another. And that's good for bacteria. Eventually your sister will get over her strep-her body's immune system will have fought off the invading bacteria. But every time she coughed, she spread her "germs" around, giving the bacteria another chance to continue living. Diseases that spread when bacteria (or other microbes like viruses and protozoa) move from one person to another are called infectious diseases.

Activity Materials
- three apples-two good ones and one with a rotten spot
- two sewing needles
- rubbing alcohol
- string

Questions to Begin
- Does anyone know what causes an infection?
- What do you think will happen when I stick a germ-free needle into the rotten apple, then into one of the good apples?
- What do you think will happen when I stick a germ-free needle into the other good apple?
- Can you think of some diseases that people get when bacteria or viruses spread?

Procedure
1. Begin by dipping one of the sewing needles in rubbing alcohol to sterilize it. Stick the sterile needle into the rotten spot of the rotten apple, then stick it immediately into one of the good apples. Tie a string around the stem of the good apple so you can identify it later. Throw away the rotten apple.
2. Sterilize the second needle in the same way as the first. Stick it into the second good apple. This apple will serve as a control in this experiment to insure that sticking an apple with a sterile needle will have no effect on the results.
3. Place the two good apples in a warm place and check them daily. The apple with the string should develop a rotten spot; nothing should happen to the control apple.

Questions to Close
- What happened to the apple with the string? Why?
- Why did we sterilize the needles?
- If you have a cut, what are some ways to keep it from getting infected?

Adapted from
Brown, Robert J. 333 More Science Tricks and Experiments. Blue Ridge Summit, PA: Tab Books, 1984.

Subjects:

life sciences,

microbiology, health

Grades: 1 - 4

Concepts:

how "germs" spread

Duration:

15 minutes for initial experiment

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15 to 20 minutes for class

observation of results

2 to 5 days later

MICROBES

INVISIBLE INVADERS AMAZING ALLIES

A Teacher's Guide

Pre- or Post-Visit Activities

Yeast Gas

Objective

Students will learn that...

- yeast are one-celled organisms that need sugar and water to grow.
- as yeast digest sugar, they give off carbon dioxide gas.

Background Information

Yeast are one-celled organisms. They are a type of fungi, related to mushrooms, mold and mildew. In order to grow, yeast need glucose ($C_6H_{12}O_6$) or sucrose (table sugar, $C_{12}H_{22}O_{11}$), water (H_2O) and warm temperatures. As yeast digest the sugar, they turn it into alcohol. In the process they give off carbon dioxide (CO_2) gas. The alcohol dissolves in the water and the gas escapes into the air. Yeast is used to make bread. The carbon dioxide is what makes the bread light and fluffy. The heat of the oven kills the yeast and burns off the alcohol. You can test for carbon dioxide with limewater. When you feed yeast in the presence of limewater, the calcium in the limewater reacts with carbon dioxide gas from the yeast to form calcium carbonate. Calcium carbonate stays in suspension and creates a milky color. The chemical reaction is $Ca(OH)_2 + CO_2$ ($CaCO_3 + H_2O$.

If too much carbon dioxide reacts with the limewater, then the calcium carbonate becomes calcium bicarbonate and dissolves. The solution becomes clear again. The chemical reaction is $CaCO_3 + H_2O + CO_2$ ($Ca(HCO_3)_2$.

Activity Materials

Experiment 1: Fill a balloon with carbon dioxide

Each team will need:

- a one-gallon (4-liter) jug
- 1 cup (250 ml) sugar
- 1 package yeast
- a large balloon
- water
- 2 T (30 ml) molasses
- clean mixing spoon

Experiment 2: The limewater test

Each team will need:

- 2 one-gallon (4-liter) jars with wide mouths
- 2 small glasses
- 1 package yeast
- 1 T (15 ml) molasses
- clean mixing spoon
- limewater (purchase from a chemical supply company, or make it yourself: mix lime, also known as calcium oxide, and water in a jar or beaker. Let the mixture settle, then pour the clear limewater off the top.)

Questions to Begin

- What by-products do yeast give off when they digest sugar? (Here's a hint: think about rising bread dough)
- Can you think of an experiment that would test your idea?

Subjects:

life sciences, microbiology, chemistry, mathematics

Grades: 7 - 12

Concepts:

fermentation, yeast

microscopic world

Duration:

30 to 45 minutes for initial set up (Experiment 1)

•

10 to 15 minutes to discuss results (Experiment 1) (1 to 2 days later)

•

20 to 30 minutes for initial set up (Experiment 2)

•

10 to 15 minutes to discuss results (Experiment 2) (2 days later)

Adapted from
Science: Model Curriculum Guide, Kindergarten Through Grade Eight. Sacramento: California State Department of Education, 1987.

Procedure

Experiment 1

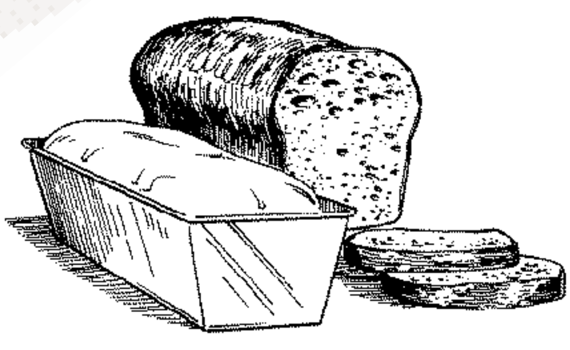
1. Split the class into teams. Each team will perform their own experiment.
2. Distribute a one-gallon (4-liter) jug and a large balloon to each team. Have one student in each team inflate then deflate the balloon to loosen up the rubber.
3. Have each team fill the jug 3/4 full of water, then mix 1 cup (250 ml) of sugar, two tablespoons (30 ml) of molasses, and a packet of yeast in the jug of water. Set in a warm place and attach the balloon to the mouth of the jug. Have students record their hypotheses regarding what will happen. (The balloon should fill with carbon dioxide overnight or within 3 to 4 days.)
4. Each day have students observe the balloons and record their observations.
5. On day 3 or 4, have students hold the opening of the inflated balloon to their mouths or noses and "taste" some of the gas. (It may smell like molasses, and will definitely have a tingle as from a soft drink.) Have students record their observations.

Experiment 2

1. You can set up this experiment as a demonstration or split the class into teams and have each team set up their own experiment.
2. Fill a glass with limewater and carefully set it inside one of the gallon jars.
3. Empty a packet of yeast into the jar, and add the molasses. Add water to the jar until it's about an inch from the top of the glass. Be careful not to get yeast, molasses or water into the glass of limewater.
4. Have students record their hypotheses about what will happen to the limewater.
5. In a second gallon jug, place another glass of limewater. Fill the jug with water until it's about an inch from the top of the glass. This will be the control.
6. Leave both containers in a warm dark place for two days. Be careful when moving the jars so that you don't spill the glass of limewater into the yeast solution. You may want to hold the glass in place.
7. On day 3, have students observe the jars and record their observations. (The limewater in the jug with yeast should turn milky white from carbon dioxide gas given off by the yeast, while the limewater in the control jar should stay clear.)

Questions to Close

- What caused the balloon to inflate? Where do you suppose the gas came from?
- Would the balloon fill if you didn't add molasses to the solution?
- Why did the limewater turn color but the control did not?
- Where did the carbon dioxide that turned the limewater color come from?



"YEAST GAS"

Adapted from
Brown, Robert J. 333 Science Tricks and Experiments. Blue Ridge Summit, PA: Tab Books, Inc., 1984.
Brown, Robert J. 333 More Science Tricks and Experiments. Blue Ridge Summit, PA: Tab Books, 1984.

Additional Sources
Bearman, Gerry. Ocean Chemistry and Deep-Sea Sediments. Oxford: Pergamon Press in association with The Open University, Milton Keynes, England, 1989.
Brady, James E. and Gerard E. Humiston. General Chemistry, Principles and Structure. 3d edition. New York: John Wiley & Sons, 1982.

Preserving Foods & Making Medicines

Subjects: life sciences, microbiology, culinary arts, chemistry, history, geography, anthropology, medicine

Grades: 7 - 12

Concepts: fermentation, microbes and food, microbes and medicine

Duration: one class session, plus library work

Objective

Students will learn that...

- many human cultures have developed ways of using microbes to make foods taste better and, in some cases, last longer. Different fermentation processes produce yogurt, bread, cheese, beer, wine, soy sauce and other foods.
- penicillin and other antibiotics are made using fermentation.

Background Information

Fermentation is the process in which microbes break down complex substances into simpler ones. Many everyday foods are fermented including cheese, yogurt and soy sauce. Some antibiotic medicines are made using fermentation.

The fermented foods we eat today developed in different parts of the world, some as early as thousands of years ago. The first raised (yeasted) bread probably appeared in Egypt around 4,000 B.C. By about 300 B.C. yeast making had become a specialized profession. The earliest evidence of cheese-a residue on an Egyptian pot-dates back to 2,300 B.C.

Medicines using fermentation, such as penicillin, have only been around since the 1940s. Even so, they've saved millions of lives.

Activity Materials

- library books and other references
- pen and paper

Questions to Begin

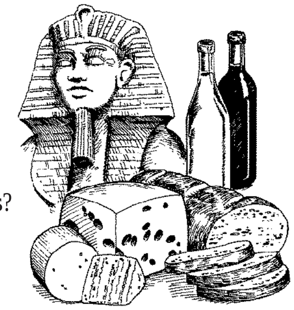
- What is fermentation? How does it change the taste or texture of food?
- What are some fermented foods that you often eat?
- Can you name fermented foods from other cultures? How do you think the people in these cultures learned to make these foods?
- Write the names of several countries or regions, then list some of the fermented foods that come from those parts of the world. (Examples: Middle Eastern yogurt, Asian soy sauces, French cheese and wine)

Procedure

1. Have students read and discuss how various cultures have developed ways of using microbes to make longer lasting, more nutritious, better tasting food. Have students write reports emphasizing the use of microbes in various fermentation processes.
2. Have students read and discuss ways that fermentation is used to make medicines. Have students write reports emphasizing the use of microbes in medicines.

Questions to Close

- What types of microbes do people use for fermentation of foods?
- What do the different fermentation processes share in common (e.g., warm temperature, moisture)?
- Did different cultures develop fermentation in similar ways? What made each process unique?
- Have you ever taken a medicine that was made with fermentation?



"Preserving Foods" Kerry Ferguson

Adapted from
Science: Model Curriculum Guide, Kindergarten Through Grade Eight. Sacramento: California State Department of Education, 1987.

Additional Sources
McGee, H. On Food and Cooking: The science and lore of the kitchen. New York, Charles Scribner's Sons, 1984.
Yellow Magic: The Story of Penicillin. Teacher's Curriculum Guide. New York: The Brooklyn Historical Society, 1992.

The Artful Microbe

Subjects:

microbiology, art

Grades: 5 - 9

Concepts:

variety of microbes,

science process

Duration:

one 45- to 60-minute

class session

Objective

Students will learn that...

- art and science go hand-in-hand.
- making sketches and taking notes is an important part of doing science.

Background Information

Learning to observe is a key component of studying microbes, and of doing science. In science, more often than not it's the little details that make a big difference. Close observation leads to deep understanding.

One way to encourage close observation is to ask students to draw what they see. This forces them to look at shapes, configurations and relationships-things they might otherwise miss. As they observe microbes, questions may come to their minds. When students couple their observations with outside research, questions get answered and voila! -students learn.

Activity Materials

- selection of microbes: pictures, live specimens or other visual aids
- white paper
- pencils for drawing
- microscopes or magnifying lenses for viewing live specimens
- black ink pens
- reference material on microbes: books, magazines, etc.

Questions to Begin

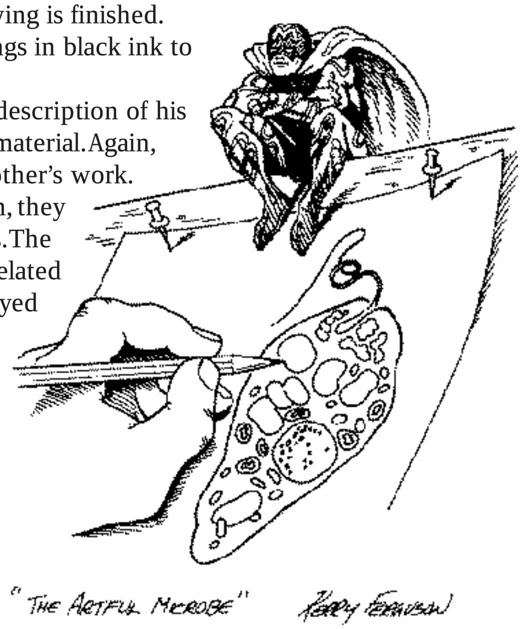
- What does art have to do with science?
- Can you do science without doing art?
- Can art improve science?

Procedure

1. Students begin by choosing a microbe to draw. If you want, have them draw numbers from a hat to decide who chooses first, second, etc.
2. Each student collects the microbe, a piece of white paper and a drawing pencil.
3. Ask them to draw their microbes in as much detail as possible. Remind them to try to do their best work, but they don't have to be super artists to succeed.
4. Encourage them to share their sketches with you or other students for suggestions on how to improve the drawing.
5. Have the students swap pictures, then see if they can identify key features from the other person's drawing. This is a good way to test if a drawing is finished.
6. When the picture is finished, have them trace their drawings in black ink to make a permanent record.
7. On a separate piece of paper, each student writes a short description of his or her microbe using texts, magazines or other reference material. Again, have the students swap descriptions and proofread each other's work.
8. When the drawings and descriptions reach their final form, they can be incorporated into a class encyclopedia of microbes. The encyclopedia can be saved for use during other microbe-related activities. It can also be shared with other classes or displayed during visitors' night or parents' night.

Questions to Close

- Did drawing a microbe help you observe it closely?
- While you were drawing, did any questions about the microbe come to mind?
- Were you able to answer your questions by using the reference materials?



Adapted from
Zook, Dr. Douglas, ed. The Microcosmos Curriculum Guide to Exploring Microbial Space. Dubuque, IA: Kendall/Hunt Publishing Company, 1992.

MICROBES

INVISIBLE INVADERS
AMAZING ALLIES

Suggested Post-Visit Activities

Microbe Zoo

Subjects:

life sciences, microbiology

Grades: 3 - 7

Concepts:

variety of microbes,

microbes are everywhere

Duration:

one 45- to 60-minute

class session to set up

the microbe zoo

•

up to three 45- to 60-minute

class sessions for

oral presentations

Objective

Students will learn that...

- two types of microbes are fungi and protozoa.
- fungi and protozoa are everywhere.

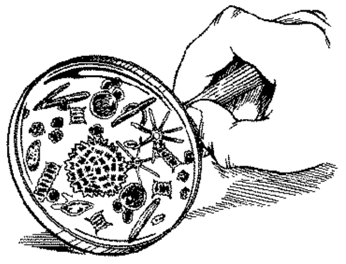
Background Information

Microbes are everywhere-in your house, in the garden, in soil, water and air. But they don't live in a world by themselves. Microbes are interrelated to the plants and animals you're familiar with, including humans.

Some microbes are predators. They eat other microbes. Other microbes are decomposers, living off dead plants and animals. As they digest their meals, they return nutrients into the soil or water making them available for plants to grow. Some microbes are parasites and cause disease. Athlete's foot is a fungus that grows between people's toes. A protozoan called a plasmodium causes malaria in people bitten by certain tropical mosquitoes. In the microbe world there are producers (green plants), predators, grazers, decomposers and parasites just like there are in the macro world.

Activity Materials

- zip-close bags
- marker pens
- small jars with lids
- 3x5 index cards



Questions to Begin

- If you wanted to find microbes, where would you look?
- Can you think of any places around your house to look?

Procedure

1. Ask the students to collect microbes from home and bring them to class for display in the class Microbe Zoo. Space constraints may require you to limit them to 3 or 5 items each. They can bring in a dirty kitchen sponge, a moldy towel, a stinky shoe or sock, an old toothbrush, moldy fruit, mildew scrapings from a shower, pond water, soil from the backyard, etc. They can also bring in food items that were made by microbes: cheese, bread, sauerkraut, etc. Encourage them to be creative about where they find their examples. Have students collect these items in a zip-close bag or a jar with a lid. Tell them to be careful not to breathe mold spores.
2. In the classroom have each student set up his or her items and identify the microbe type (mold, mildew, other fungus, bacteria, protozoan, yeast) and its habitat (bathroom shower, garden, Miller's pond) for each item on 3x5 index cards.
3. Each student then researches his or her microbes. They can use printed materials, TV documentaries, films, videos or the Internet for their research. Tell them to include information such as what each microbe eats, what eats it (if anything), and how humans depend on it.
4. Students can then give an oral report to the class, or act as tour guides with the rest of the class acting as zoo visitors.
5. You can give out prizes for the most original microbe source, the best exhibit, the collection with the most variety or the best explanation. You may have other ideas for prize categories as well.

Questions to Close

- Were you surprised how many places you can find microbes?
- Can you name three ways that microbes are helpful to humans?
- What do you think the world would be like without microbes?

Adapted from
Science: Model Curriculum Guide, Kindergarten Through Grade Eight. Sacramento: California State Department of Education, 1987.

Virus or Bacteria?

Objective

Students will learn that...

- bacteria and viruses are two types of microbes.
- strep throat is caused by bacteria, while viruses cause the common cold.

Background Information

Strep throat is an example of an infection caused by bacteria-Streptococcus bacteria. Bacteria are one-celled microbes. Basically, a bacterium is a sack of fluids containing structures that perform life-sustaining functions, all surrounded by a fat (lipid) membrane. Fortunately, there are medicines that help fight bacterial infections. These medicines, called antibiotics, work by interfering in a bacterium's life processes. They may inactivate the enzyme that a bacterium needs to build a cell wall during reproduction, prevent the formation of nucleic acids (DNA) or block the formation of proteins. Others bind to the cell membrane causing the cell to leak ions, which are charged atoms or groups of atoms used in the formation of molecules. Research to find new antibiotics is going on all over the world.

The common cold is caused by a virus, which is very different than a bacterium. A virus is a ball of genes (DNA) surrounded by a protective protein coat. Whereas bacteria reproduce by splitting in two, viruses reproduce by injecting their DNA into another cell. The virus' DNA takes over the cell's DNA, and instructs it to make more viruses. In time, thousands of viruses burst from the cell, ready to find another cell to invade.

Because viruses are so simple, they have few life processes that are vulnerable to medicines. Until recently, viral infections could be prevented with vaccines, but not fought directly. Vaccines work by training your body to be ready in case a live virus attacks. Everyone is born with a supply of antibodies, sitting in "storage," waiting to be called into action. When you get a vaccine (a dose of killed or weakened viruses) your immune system sends out antibodies that are specialized to fight that particular type of virus. Because a vaccine is made of debilitated viruses, you usually don't get sick. What you do get is an army of activated antibodies, so that next time you're exposed to the same virus, your immune system is ready to go.

Recently, with the discovery of protease inhibitors, science may have found a weapon to fight viruses directly. Protease is an enzyme that viruses use in the production of more viruses. Protease inhibitors block the production of viruses. Protease inhibitors are new-serious testing of protease inhibitors did not begin until 1995-and may prove effective in fighting HIV, the virus that causes AIDS.

Activity Materials

- poster board
- marker pens

Questions to Begin

- Do you know the difference between a strep throat infection and a common cold?
- What causes each?

Procedure

Invite the school nurse, a local pharmacist, a doctor, public health official or scientist familiar with antibiotic research to give a talk about "Diseases Caused by Bacteria and Viruses-Causes and Treatments." Leave time at the end for a question and answer period. Afterwards, lead the class in a discussion comparing bacterial and viral infections. Make a chart comparing the two.

Subjects: life sciences, microbiology, health

Grades: 4 - 6

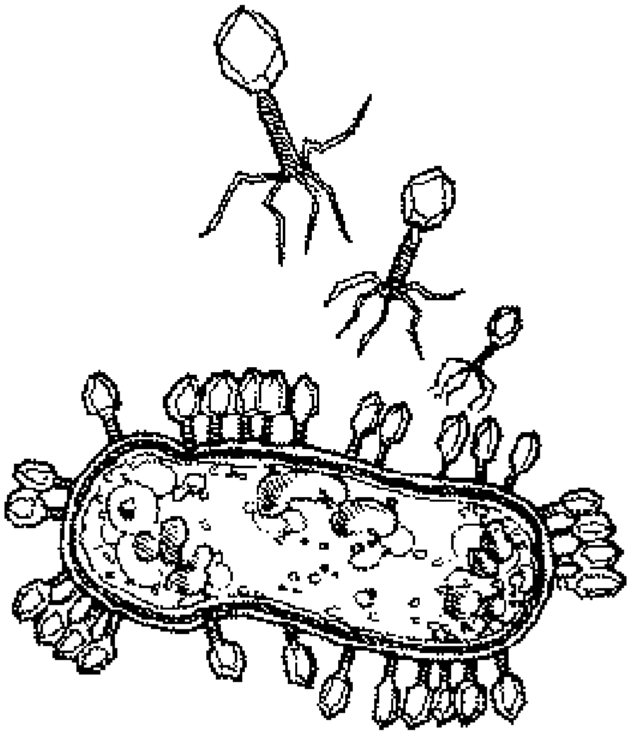
Concepts: causes of common diseases, treatment of viral vs. bacterial illnesses, viruses and bacteria compared

Duration: one to two 45-minute class sessions

Microbe Zoo

Questions to Close

- Why can you take medicine to fight strep throat but not a common cold?
- How do bacterial infections spread?
- How do viral infections spread?
- How can you avoid catching each type of infection?
- Where do new antibiotics come from?



"VIRUS OR BACTERIA" FERGUSON
(PHAGES)

Adapted from
Science: Model Curriculum Guide, Kindergarten Through Grade Eight. Sacramento: California State Department of Education, 1987.

Additional sources
Zimmerman, Barry E., and David J. Zimmerman. Killer Germs: Microbes and the diseases that threaten humanity. Chicago: Contemporary Books, Inc., 1996.

Microbe Treasure Chest

Subjects: microbiology, art

Grades: 4 - 10

Concepts: microbes and humans

Duration: 5- to 15-minute sessions every day, every other day, or once a week; occasional 30-minute sessions for in-depth discussions and reports

Objective
Students will learn that...

- microbes are everywhere, playing important roles in our lives.

Background Information
Even though they're too small to see, microbes play a tremendous role on the planet and in our lives. Go anywhere on Earth, and you'll find microbes. Name any natural process that humans depend on for survival, and microbes most likely have a hand in it.

Activity Materials
everyday items that come from or use microbes, such as

- toothpaste tube
- antibiotic container
- linen
- paper and wood
- green beans
- bread
- scissors
- a large box
- can of oil
- copper tube or wire
- various cheeses and a milk carton
- rice
- apple or other fruits
- a clean, empty jar with a lid
- glue
- items to decorate the box (fabrics, ribbons, paints, etc.)

Questions to Begin
- Are microbes good or bad?
- Where can we find microbes?
- Are microbes important to us? Why?
- Where do you come across microbes on a typical day?

Procedure
1. Collect various everyday items that come from or use microbes. (This is very easy because just about every visible object in the world has some connection to microbes.)
2. Have a team of students decorate the box that will hold the items. They can label the box "Microbe Treasure Chest," or make up another name.
3. Divide the class into teams.
4. Every day (or every other day or once a week), have a student reach into the box and pull out the "treasure of the day." Challenge the student's team to figure out what that object has to do with microbes. Have them research the issue, then report their findings to the class.
5. Provide reference books, illustrations and photographs of the microbes under discussion. Have your students keep a record of the items picked and the role of microbes.
6. When the items in the box run out, have a different student bring in an item each day. Challenge your students to draw on their knowledge of earlier items to figure out the new item's relationship to the world of microbes.

Questions to Close
- Can you name an item that has nothing to do with microbes?
- Think of one of the items from the box and the related microbe. What would happen if that type of microbe suddenly disappeared?
- Are there microbes in your body? In the sea? In outer space?

Adapted from
Zook, Dr. Douglas, ed. The Microcosmos Curriculum Guide to Exploring Microbial Space. Dubuque, IA: Kendall/Hunt Publishing Company, 1992.

Microbe Towers

Subjects:

life sciences, microbiology

Grades: 7 - 12

Concepts:

diversity of microbes

Duration:

one 45- to 60-minute class session to set up the microbe towers

•

several 20- to 30-minute sessions for students to make observations (1, 3 and 5 weeks later)

Objective

Students will learn that...

- a variety of microbes live in different environments.
- some microbes can grow in environments that have no oxygen.

Background Information

In mud or soil, different microbes live at different levels because environmental conditions at each level are different. At the surface, oxygen dissolves from the air into water overlaying the soil, or into water in the soil. Deeper down, oxygen levels decrease until they disappear completely. The microbes in the upper oxygen-rich layers are like animals: they need oxygen to live. Deeper down, where oxygen levels are low or nonexistent, the microbes are more like the microbes that first lived on Earth. They can survive without oxygen, and for many, oxygen is a poison. The zone where oxygen is present is called the aerobic zone, and microbes found there are called aerobes. The zone where no oxygen is present is the anaerobic zone. Microbes there are called anaerobes.

Sulfur levels vary opposite to oxygen levels. Where oxygen concentrations are low, sulfur concentrations are high. Sulfur, in the form of hydrogen sulfide, is released as bacteria and fungi decompose dead plant and animals. In the Microbe Towers, which your class will be building as part of this activity, sulfur levels are highest at the bottom. You can't mistake hydrogen sulfide-it smells like rotten eggs. A sulfur smell indicates anaerobic conditions. Some bacteria live where sulfur concentrations are high. Others can't tolerate any sulfur in the environment.

As your microbe towers mature, colorful areas will develop. The colors come from photosynthetic bacteria-bacteria that make their own food from carbon dioxide, water and sunlight, just like green plants. The bacteria are different colors because they're using different wavelengths of light to produce food. Some of the anaerobic bacteria make their own food, like the photosynthetic bacteria in the upper layers. Except they use sulfur from hydrogen sulfide instead of carbon from carbon dioxide to do so.

Activity Materials

- transparent containers over 6-inches (15-cm) tall. Clear plastic soft-drink containers will do.
- sharp scissors
- large bucket of soil, mud or sand from a nearby pond or salt marsh; you can also use
- soil from a garden, forest or field. You'll need enough to fill all the plastic bottles.
- water (use pond water if you're using pond mud or soil; tap water is OK if you let it sit
- two days to let the chlorine escape. If you're using salt marsh mud, use salt water.)
- boiled egg yolks or entire raw eggs
- shredded newspaper as a source of carbon
- calcium carbonate (lime) (optional)
- masking tape
- eyedropper
- clear plastic wrap
- rubber bands
- several 40- or 60-watt incandescent light bulbs (optional)

Questions to Begin

- Do all organisms need oxygen to survive?
- Why do stagnant pools sometimes smell like rotten eggs?

Procedure

1. Begin by making the microbe towers containers. Each student can make his or her own, or you can make them ahead of time. In either case, you'll make the first cut. With sharp scissors, make a small cut near the top of each plastic bottle, at the level where the bottle becomes its widest. Then you or the students can finish cutting the tops off the bottles.
2. If you can, take the class on a mud- and water-gathering field trip. Collect mud and water in buckets with lids. If a field trip is not feasible, collect the water and mud ahead of time yourself.
3. When you return to the classroom, choose a well-ventilated area. Open all windows or find a place outside to set up the microbe towers. (Warning: the experiment will get smelly.)
4. In an extra bucket, mix soil or mud with water so that it's as thick as heavy cream. Remove any rocks, sticks or leaves. Pour a portion into another container and mix in the eggs, newspaper and calcium carbonate. This will become the bottom layer. Pour the smelly mixture into each container until it makes a layer 2 or 3 inches (5 to 7 cm) deep. You can use the cut-off top of a bottle as a funnel. Tap each bottle gently to remove any air bubbles (trapped air will prevent the layer from becoming anaerobic) and to flatten the layers.
5. To each container add 2 or 3 inches (5 to 7 cm) of mud with no egg or newspaper and tap them again. Continue filling the containers layer by layer until they are filled to about 2 inches (5 cm) from the top.
6. Each student should write his or her name and the date on a small piece of masking tape and label his or her microbe tower with it.
7. Place the microbe towers in a well-lit place out of direct sunlight and let settle overnight. A counter near a north-facing window works well. By morning there should be a half-inch (1 cm) of water on the surface. You can remove any extra water or add a little if you need to with an eyedropper.
8. Cover each container with clear plastic wrap and secure with a rubber band. If you can, set up 40- or 60-watt incandescent light bulbs so they shine on the tops and sides of the towers, but don't heat them. Turn on the bulbs every day or let them shine continuously.
9. In the coming weeks the bacteria in your microbe towers will bloom with color as colonies sprout and grow.
10. If you like, you can collect mud from different environments (pond, salt marsh, river, etc.) and build a few towers with each. Then the students can take notes and compare what grows in each container. The class may have some ideas of experiments they can do. Be sure they form a hypothesis as part of designing the experiment.
11. Each student can make daily observations of his or her tower and keep track of them in a notebook or use the Microbial Towers Worksheet (attached). They can diagram the microbe tower, the different layers and the bacteria growth in each layer helps.
12. The students can place towers in different environments (warm, cool, sunny or dark) and compare bacterial growth in each.

Questions to Close

- In which layers are aerobic bacteria growing?
- In which layers are the anaerobic bacteria growing?
- Which layer has the highest sulfur concentrations? How do you know

Adapted from
Zook, Dr. Douglas, ed. The Microcosmos Curriculum Guide to Exploring Microbial Space. Dubuque, IA: Kendall/Hunt Publishing Company, 1992.

Microbe Towers Worksheet

Name ______________________________

Soil source ______________________________

Date microbe tower was built ______________________________

Date first colors were seen ______________________________

Week One

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Notes:

____

____

____

Week Three

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Notes:

____

____

____

Week Five

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Number of inches (or cm) from top ______ Color observed ______

Notes:

____

____

____

Flagellates on the Go

Objective

Students will learn that...

some microbes propel themselves with a whip-like structure called a flagellum. These microbes are called flagellates.

flagella help some microbes survive by allowing them to escape predators or to move to a more favorable environment.

Background Information

Scientists classify the one-celled microbes called protozoa by how they move. Protozoa that propel themselves with one or more whip-like tails are called flagellates. The whip is called a flagellum. Other protozoa, called ciliates, move by beating tiny "hairs" called cilia. Protozoa called amoebae move by reshaping themselves so that a part of the cell extends, forming a pseudopodium.

Some flagellates have chloroplasts like plants and can manufacture their own food. They're called phytoflagellates. Others, called zooflagellates, have no chloroplasts and are more animal-like.

A flagellum is very long compared to a protozoan's body size. Usually they're attached to the leading edge of the protozoan's body, but not always. If you took a flagellum apart you'd see it's built like a cable. Nine pairs of microtubules (hollow strands of protein) surround a core of two single microtubules. The entire bundle is surrounded by a sheath that blends into the cell membrane. Some protozoa have dozens of flagella extending from all sides. You'll find flagella on some protozoa, but plant and animal cells that are specialized for movement (like sperm cells) have flagella too.

Activity Materials

- collecting bucket
- 2 half-gallon (2-liter) glass jars per student or team
- eyedroppers
- 1 gallon (4 liters) of pond water for each team of students
- dried organic matter (leaves, hay or tall grass)
- dark, rich topsoil
- a microscope for each student or team
- glass slides and cover slips
- 10% aqueous Nigrosin dye solution (obtain from a biological supply company)
- carbon-black India ink
- protozoan-slowing solution (obtain DetainTM from Ward's Natural Science Establishment, Inc. or ProtosloTM from Carolina Biological Supply Co.)
- protozoan cultures (optional; obtain from a biological supply company)
  - Euglena
  - Peranema
  - Phacus
  - Distigma
  - Chlamydomonas
  - Carteria

Questions to Begin

- If you were a protozoan and you lived in a pond, how would you get around?
- Would you have any special body structures for propulsion?

Subjects:

life sciences, microbiology

Grades: 7 - 12

Concepts:

microbe locomotion

Duration:

15 to 30 minutes to set up the jars with pond water

•

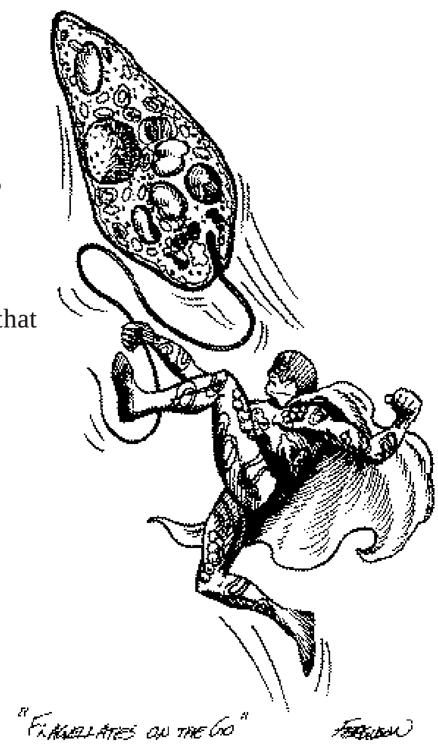
one 45- to 60-minute session to observe and chart movement of flagellates

Procedure

1. Take the class on a field trip to collect pond water, or collect some yourself ahead of time.
2. Back in the class, ask for two volunteers to make miniature ponds. One will fill one glass jar 3/4 full of pond water, then add a handful of dried leaves. The other will fill the other glass jar 3/4 full of pond water and add 1/4 cup (20 g) of soil.
3. Let the miniature ponds stand in a cool area with indirect sunlight for about a week.
4. Split the class into teams so each has its own microscope. Have students in each team take turns taking a sample of water from each jar with an eyedropper. Drop the water onto a clean glass slide and cover with a cover slip, and view through the microscope. Each team should sample from the top, middle and bottom of each jar and take notes on what they see. If you’re using cultured protozoa, have them view these as well.
5. To use the microscope, begin viewing at the lowest magnification. Look for spherical or rod-shaped protozoa whirling or spiraling through the water. Watch for the long, whip-like flagella. There may be one or many on each protozoan, depending on the species. If you want the protozoa to stand out more clearly, add a small drop of India ink or Nigrosin stain to the slide before you apply the cover slip. If they’re moving to fast, add a small drop of protozoan-slowing solution when you prepare the slides.
6. Increase the magnification and re-focus. Watch the way flagellates move. Do different species move the same or differently?
7. Make another slide using a small drop of water and a small drop of Nigrosin stain. Let dry before viewing. Add a cover slip then observe under the microscope for a vivid view of the flagellum.
8. Have each team make a chart of what they see at each level in each jar. Label the columns “Dried grass” and “Soil.” Label the rows “Top,” “Middle,” and “Bottom.” If you don’t know the species names of the flagellates, the students can draw what they saw in each category.

Questions to Close

- Did all the protozoa have flagella?
- Did the pond water have the same flagellates as the water with soil added?
- What types of behaviors did you see in flagellates?
- How do flagella help protozoa?
- What types of environments would best suit a flagellate? What types would a flagellate be ill-suited for?
- Do all species of flagellates live at all water levels or do different species live at different levels?
- Can you think of other types of cells besides flagellates that have a flagellum?



Adapted from
Anderson, O. Roger and Marvin Druger, ed. Explore the World Using Protozoa. Arlington, VA: National Science Teachers Association and Society of Protozoologists, 1997.

Additional Sources
Barnes, Robert D. Invertebrate Zoology. fourth ed., Philadelphia: Saunder’s College/Holt, Rinehart & Winston, 1980.

Ciliates on the Go

Objective

Students will learn that...

- some microbes propel themselves with tiny hair-like structures called cilia. These microbes are called ciliates.
- cilia help microbes survive by providing a means of escape from predators and by creating water currents that deliver food and fresh water to the microbe.

Background Information

There are over 60,000 one-celled organisms called protozoa, of all shapes, colors and forms. Those that move by beating tiny "hairs" are called ciliates. The "hairs" are called cilia. Other protozoa that propel themselves with one or more whip-like tails are called flagellates. The whip is called a flagellum. Protozoa called amoebae move by reshaping themselves so that a part of the cell extends, forming a pseudopodium.

Some flagellates have chloroplasts like plants and can manufacture their own food. They're called phytoflagellates. Others, called zooflagellates have no chloroplasts and are more animal-like.

Cilia have two functions. Most ciliates use their cilia for swimming. Each individual cilia beats like an oar of a boat. The "backstroke" propels the ciliate through the water. During the return stroke the cilia bends to reduce drag. In addition to swimming, cilia beat to create a water current. The current delivers food and fresh water to the microbe. Most animal species have cilia. You have cilia in your throat and lungs to help clear passages of dirt and pathogens (disease-causing microbes) that get trapped in mucus.

Activity Materials

- microscopes
- glass slides and cover slips
- eyedroppers
- India ink
- protozoan-slowing solution (obtain DetainTM from Ward's Natural Science Establishment, Inc. or ProtosloTM from Carolina Biological Supply Co.)
- ciliate cultures (obtain from a biological supply company):
- Blepharisma
- Spirostomum
- Stentor
- Vorticella
- pencil and paper

Questions to Begin

- If you were covered with thousands of tiny beating hairs, what do you think they would be used for?
- What do you think microbes use their cilia for?

Subjects:

life sciences, microbiology

Grades: 7 - 12

Concepts:

microbe locomotion

Duration:

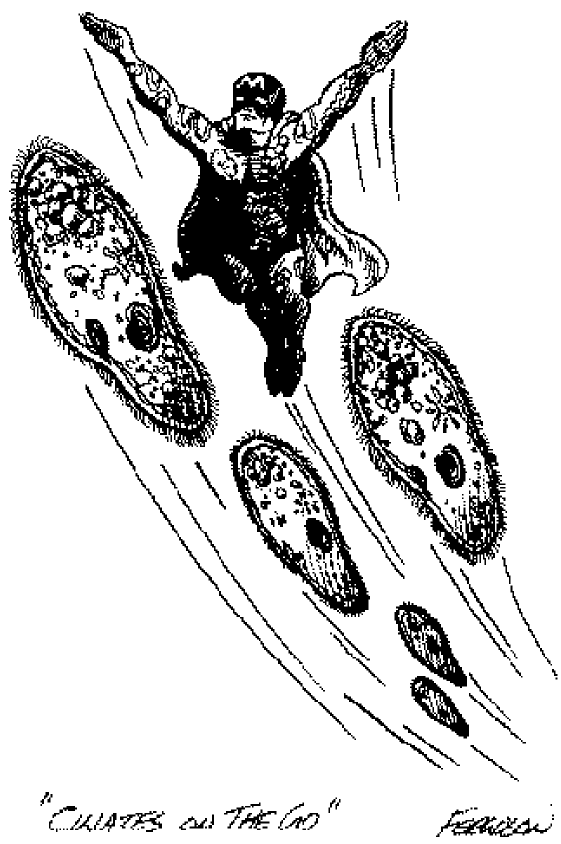
one 45- to 60-minute session

Procedure

1. If you don't have enough microscopes for each student, divide the class into teams so that each has a microscope.
2. Hand out glass slides and cover slips.
3. Have each student place a drop of ciliate culture on a glass slide. Add a drop of protozoan-slowing solution, then cover with a cover slip. (If students are working in teams, they can take turns preparing slides).
4. View the specimens through the microscope beginning at low magnification and moving to higher magnification. At higher magnification you should be able to observe the action of the cilia.
5. To increase detail, students can add a small drop of India ink. Watch what happens to the small particles in the ink as the cilia beat.
6. Have the students observe all the different ciliates that are available, and take careful notes of what they see. Ask them to draw each ciliate and indicate the direction of water flow with arrows. Be sure to label each drawing with the power of magnification the view represents.

Questions to Close

- Do all ciliates use their cilia in the same way or for the same purpose?
- Name two different uses for cilia.
- Do cilia beat together or do they each have their own rhythm?
- Do cilia always beat in one direction, or can they change direction?
- How do ciliates change their swimming direction?
- Are all the cilia on one animal the same length or different lengths?
- When you added the India ink, did you notice any patterns in the water flow?



Adapted from
Anderson, O. Roger and Marvin Druger, ed. Explore the World Using Protozoa. Arlington, VA: National Science Teachers Association and Society of Protozoologists, 1997.

History of Microbes Book Report

Objective

Students will learn that...
microbes have been affecting humans since the beginning of humankind.

Background Information

In ancient times when a person got an infectious disease, the best medicine was rest and hope. People had remedies and tonics, but they didn't always work. That's because people didn't know microbes were the true cause of infectious disease. They didn't even know microbes existed.

Microbes weren't discovered until the late 1600s, when Anton van Leeuwenhoek discovered "little animalcules" (bacteria) wriggling around on scrapings he took from his teeth. He was the first person to see microbes through a microscope, but didn't understand that they were the cause of his rotting teeth. The connection between microbes and disease didn't come for some time.

In 1796, an English doctor named Edward Jenner made a breakthrough. It was common knowledge of that day that people who once had cowpox were immune to smallpox. To prove it scientifically, Jenner scraped cowpox material into a boy's arm, waited several weeks, then scratched in smallpox material. The boy didn't get sick. Over and over he tried to introduce smallpox into the boy; time and again the boy remained healthy. No one understood how this first vaccine worked, but that didn't matter. What mattered was that it worked.

As scientific knowledge about microbes grew, scientists discovered more and more ways to fight microbes. In the late 1920s penicillin was discovered and by World War II it was being mass produced. In the 1950s a vaccine that prevented polio was developed. By the 1960s, things were looking so good that the Surgeon General announced that the end of infectious disease was imminent.

Then, disaster struck. Microbes that once were easily killed with antibiotics began evolving into resistant forms. New antibiotics had to be found to help infected people. New viruses-Ebola, and HIV appeared. Today cutting-edge techniques such as genetic engineering offer a new hope for fighting disease.

This activity will allow your students to choose a microbe or infectious disease and to research its effects and impacts on society.

Activity Materials

none required

Questions to Begin

- How many of you have ever had an infectious disease?
- What diseases have you had?
- Did you take medicines, or just let your body heal naturally?
- Do you know where your medicine originally came from?
- Do you know what causes infectious disease?
- Do you think there will ever be a day when microbes can no longer make humans sick?

Subjects:

life sciences, microbiology, health, medicine, language arts, history

Grades: 7 - 12

Concepts:

microbes and disease, microbes and humans

Duration:

20 to 30 minutes for initial discussion and assignment. Several class sessions for students to give oral presentations.

Procedure

1. Begin with a discussion of the impact microbes have on humans, and the impact humans have on microbes. Use examples from history or current events: the black plague, the history of polio or smallpox in North America, the influence of the Spanish flu outbreak during World War I, famous scientists of the past or stories of people currently trying to combat infectious diseases such as AIDS or Ebola.
2. Ask each student to find a book to read where microbes play a major role. It can be a biography, a historical account, the story of someone who survived an infectious disease, or an exposÈ on an emerging disease, among other topics.
3. The following week students will begin writing a book report. For auxiliary information, encourage them to look up the disease or microbe in an encyclopedia, Physicians Desk Reference or other reference materials. They can also use the Internet or interview health care providers.
4. When the book report is finished, have each student give a 5 to 10 minute oral report about what they learned.

Questions to Close

- Has the microbe you chose been around for a long time or is it a newly emerging species?
- How does your microbe affect humans?
- What have humans done to fight or learn to live with the microbe?
- Do you think we'll ever figure out a way to wipe out all disease? Why or why not?

Adapted from
Martha Boedecker. "Infectious Disease and Chronic Disorders Unit," National Science Teacher's Association Global Summit on Science and Science Education, Dec. 28, 1996.

Additional Sources
Radetsky, Peter. "Microbes: Invisible Invaders...Amazing Allies. An Exhibition Treatment." 1997.

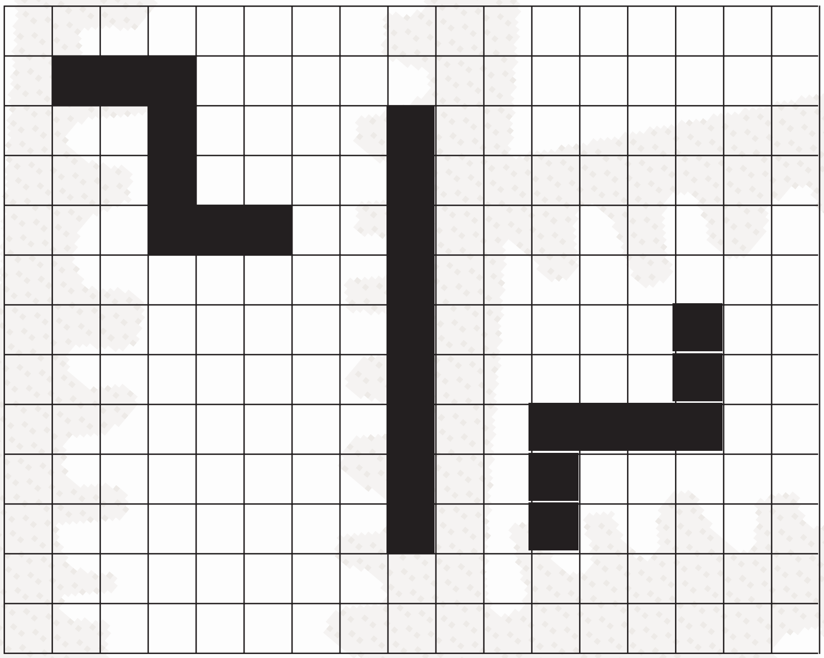
Microbes Word World

Objective
Students will learn to...
- identify words and concepts associated with microbes.

Background Information
This activity gives your students practice learning vocabulary associated with microbes.

Activity Materials
copies of the following crossword puzzles and word searches

What lives in the world of microbes?



Down
1) The smallest living unit of life.
3) This disease gives you a spotted rash all over your body.

Across
2) This is what most people call microbes.
4) Leave bread or fruit out and this microbe will grow all over it.
5) Get one of these and you won't get measles.

Subjects:

life sciences,

language arts

Grades: 3 - 12

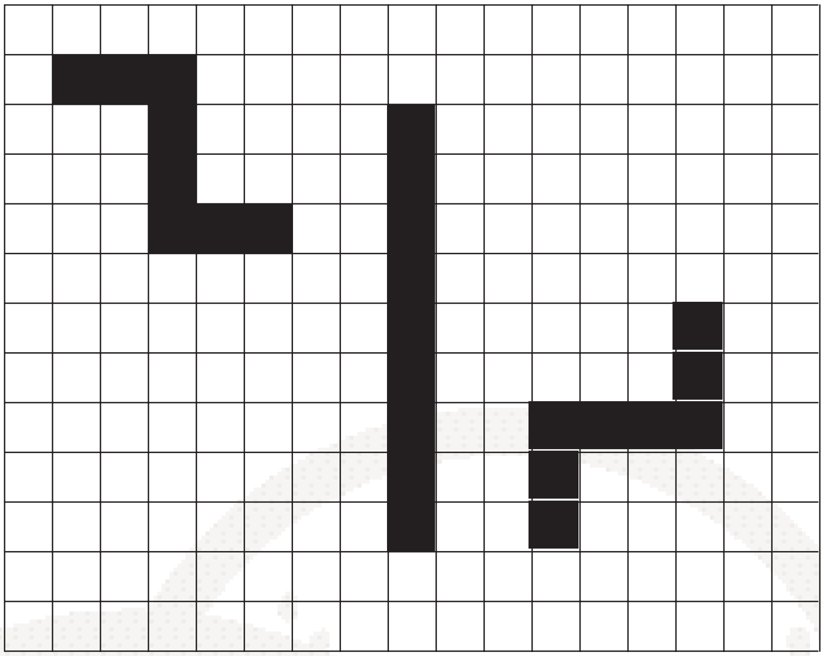
Concepts:

microbes and humans

Duration:

one class sessions

What lives in the world of microbes?



Down

1) The smallest living unit of life.
3) This disease gives you a spotted rash all over your body.

Across

2) This is what most people call microbes.
4) Leave bread or fruit out and this microbe will grow all over it.
5) Get one of these and you won’t get measles.

What do you have in common with microbes?

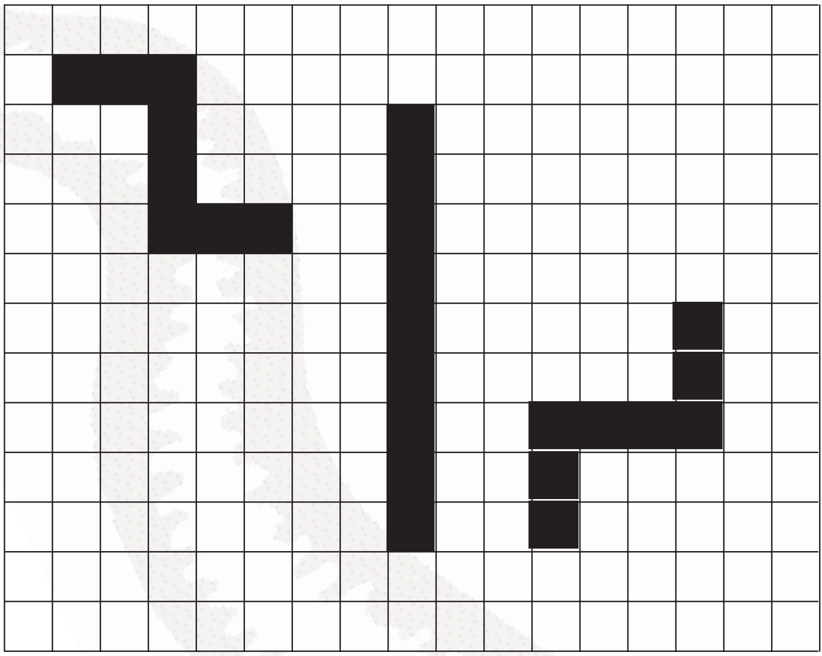
Down

1) A shot that’s made of dead or weakened germs (microbes).
2) The smallest living unit of life.
3) A type of microbe you can eat in salad or soup, or find growing in your yard.

Across

1) The type of microbe that causes the flu.
3) An instrument that scientists use to look at microbes.
4) A gas that’s in air and water. Most organisms need it to survive.

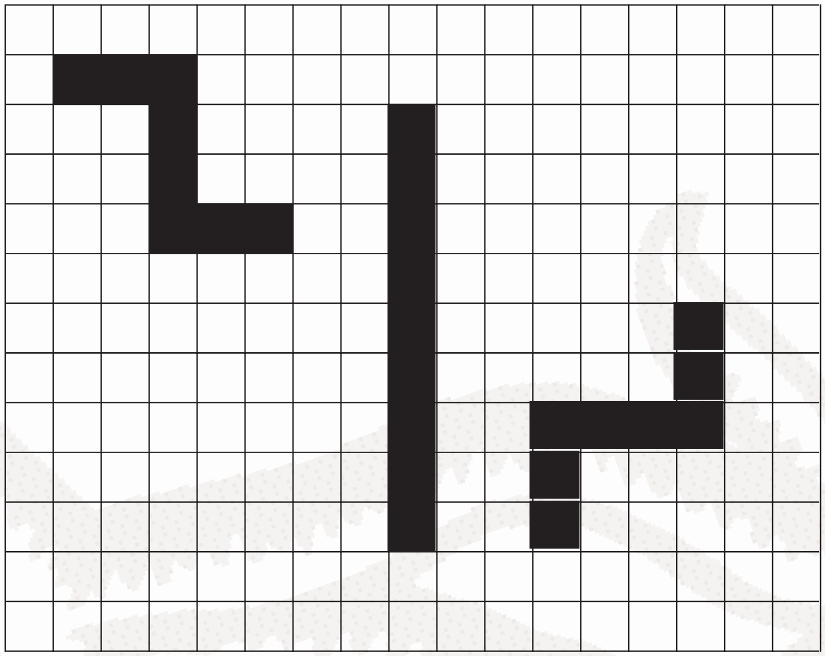
What do you have in common with microbes?



Down
1) A shot that’s made of dead or weakened germs (microbes).
2) The smallest living unit of life.
3) A type of microbe you can eat in salad or soup, or find growing in your yard.

Across
1) The type of microbe that causes the flu.
3) An instrument that scientists use to look at microbes.
4) A gas that’s in air and water. Most organisms need it to survive.

What might you find in the microbial universe?



Down

1) The outer layer of the smallest living unit in your body.
2) "One that eats"; a cell that eats other cells or matter.
4) These immune system proteins look for microbes in your bloodstream.
7) A poison; microbes sometimes excrete these.

Across

1) Another name for tuberculosis.
3) In this process a species changes over time.
5) The study of microscopic organisms.
6) Yeast changes sugars into carbon dioxide during this process.
8) A group of organisms of one species that's slightly different from other members of the species.
9) The control center of a cell.

Mixed-Up Microbes

Unscramble the letters to find a word that's related to microbes.

TONIATIBCI	A substance that kills microbes or keeps them from growing. People use it to treat infections.
EHTARBIGPECOA	A virus that attacks bacteria.
ROETELNC OMEPSIROCC	An instrument that records images of viruses by shooting tiny atom particles at an object.
MEEZNY	A protein in an animal's body that causes chemical reactions to happen.
ATNTUIMO	A genetic change that happens during reproduction.
MLEFUGLAL	A tail or whip that some microbes use to move around.
ZOORTAPO	Amoebas are members of this group of microbes.
STAAPERI	An organism that grows and feeds off another organism (host) but doesn't help it survive.
GOTAEHNP	A microbe that causes disease.

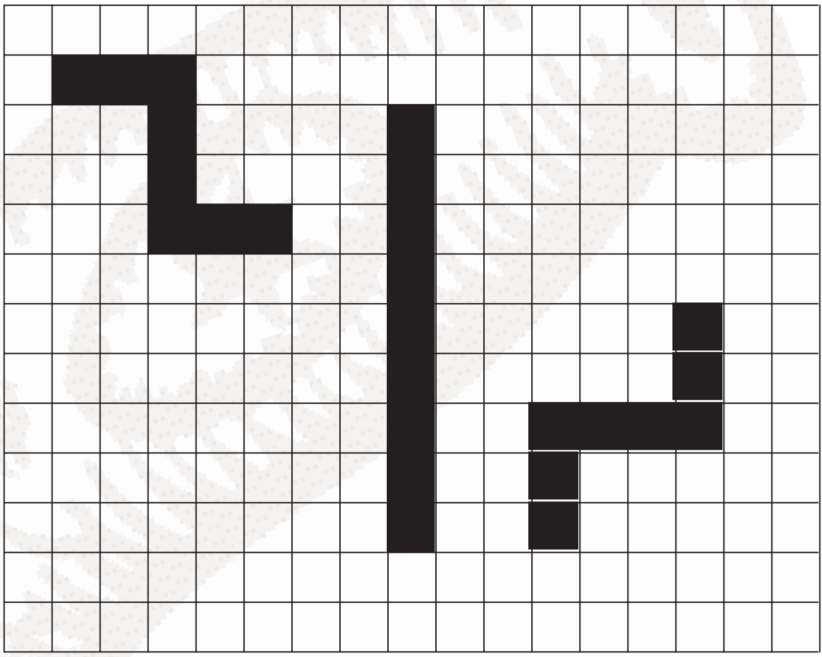
What's hiding here?

Instructions
Circle all the words you can find. You'll find some forward, backward, diagonally and upside-down.

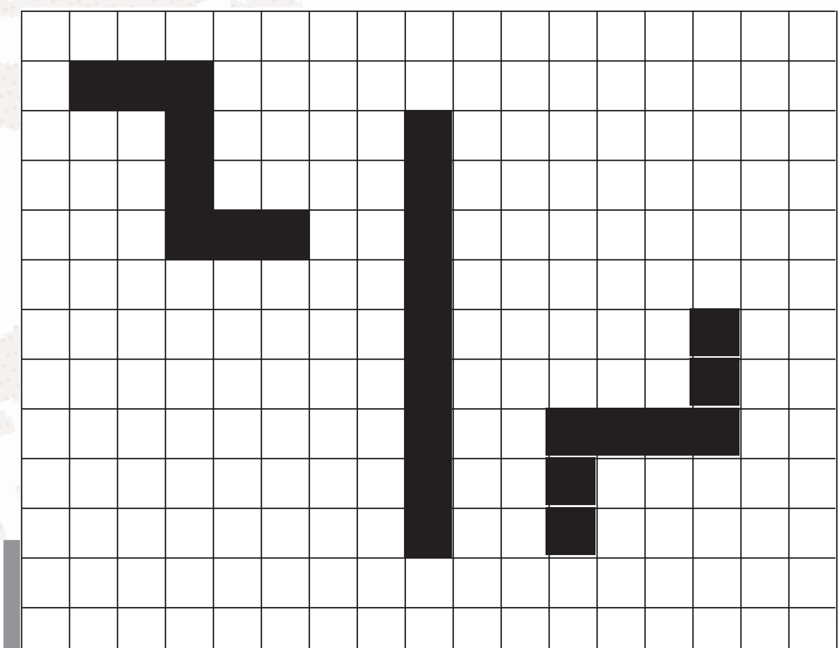
J	H	C	I	T	O	I	B	I	T	N	A
M	D	N	A	B	A	C	T	E	R	I	A
I	M	M	U	N	E	S	Y	S	T	E	M
C	P	O	V	A	C	C	I	N	E	M	V
R	P	R	L	M	A	I	K	O	U	L	X
O	B	H	O	D	U	F	U	N	G	U	S
B	P	D	A	T	C	S	T	R	A	I	N
E	L	S	E	G	O	G	H	Y	C	E	E
R	A	D	F	W	E	Z	N	R	R	T	G
E	G	R	E	M	E	Z	O	M	O	X	E
Q	U	I	P	A	Y	B	E	A	N	O	R
T	E	V	S	T	S	A	E	Y	N	U	M

Answer Keys

Answers to Puzzle on Page 39

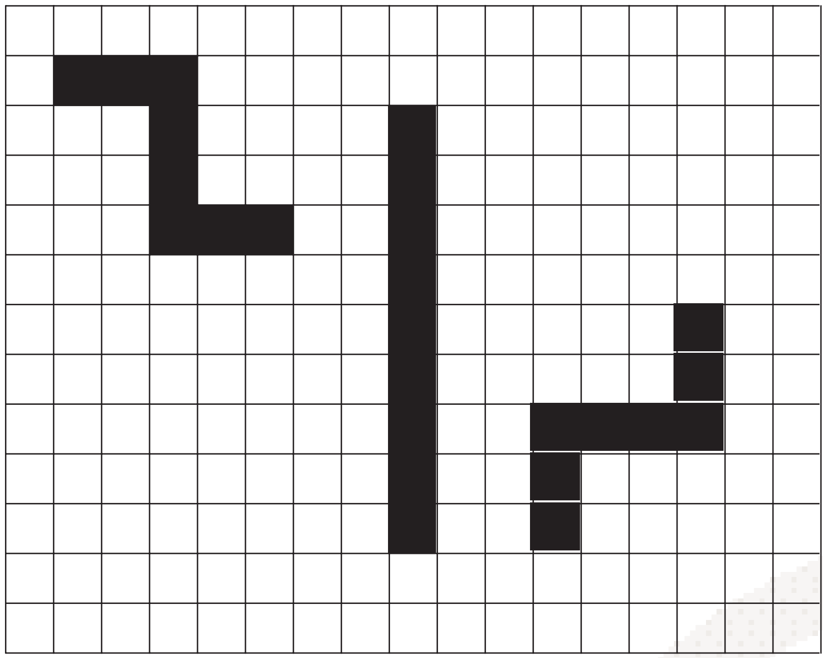


Answers to Puzzle on Page 40

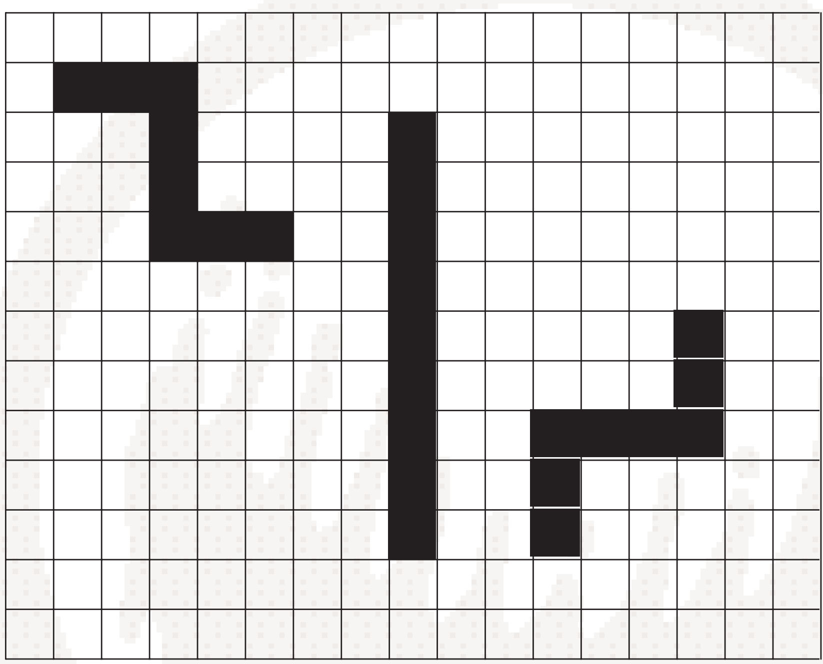


Answer Keys

Answers to Puzzle on Page 41



Answers to Puzzle on Page 42



Answers to Puzzle on Page 43

ANTIBIOTIC	A substance that kills microbes or keeps them from growing. People use it to treat infections.
BACTERIOPHAGE	A virus that attacks bacteria.
ELECTRON MICROSCOPE	An instrument that records images of viruses by shooting tiny atom particles at an object.
ENZYME	A protein in an animal's body that causes chemical reactions to happen.
MUTATION	A genetic change that happens during reproduction.
FLAGELLUM	A tail or whip that some microbes use to move around.
PROTOZOA	Amoebas are members of this group of microbes.
PARASITE	An organism that grows and feeds off another organism (host) but doesn't help it survive.
PATHOGEN	A microbe that causes disease.

J	H	C	I	T	O	I	B	I	T	N	A
M	D	N	A	B	A	C	T	E	R	I	A
I	M	M	U	N	E	S	Y	S	T	E	M
C	P	O	V	A	C	C	I	N	E	M	V
R	P	R	L	M	A	I	K	O	U	L	X
O	B	H	O	D	U	F	U	N	G	U	S
B	P	D	A	T	C	S	T	R	A	I	N
E	L	S	E	G	O	G	H	Y	C	E	E
R	A	D	F	W	E	Z	N	R	R	T	G
E	G	R	E	M	E	Z	O	M	O	X	E
Q	U	I	P	A	Y	B	E	A	N	O	R
T	E	V	S	T	S	A	E	Y	N	U	M

Microbes words	antibiotic	mushroom
bacteria	phage	DNA
plague	emerge	protozoan
fungus	strain	germ
vaccine	immune system	virus
microbe	yeast	mold

Other words		
band	ear	quip
bean	gal	roan
bet	man	sow
bit	mat	turf
blue	may	web
can	men	yam
dew	nab	

MICROBES

INVISIBLE INVADERS
AMAZING ALLIES

Glossary

aerobe	An organism that needs oxygen to live.
agar	A gelatin-like material that comes from seaweed. Scientists use it as a base for growing (culturing) microbes.
alga	Any of a large group of simple plants that photosynthesize, but don't have leaves, stems and roots. (plural: algae)
amoeba	A tiny, simple organism that multiplies by dividing in two (fission), and moves by changing its body shape to form temporary "feet" (pseudopodia).
anaerobe	An organism that doesn't use oxygen to live.
animal	An organism that moves on its own (in most cases), reacts quickly to stimuli, and doesn't photosynthesize. The body's cells lack the stiff cell walls found in plants.
animalcule	A microbe. Anton van Leeuwenhoek used this word to describe the organisms he saw under his microscope.
antibiotic	A medicine that kills microbes or stops their growth. Some are made by humans, other are made by microbes.
antibodies	Special microbe-fighting proteins in your blood. By attaching to invading microbes, they help white blood cells spot invaders and "eat" them up.
bacterium	A microscopic, one-celled organism that feeds on live hosts or dead matter, or makes its own food through chemical processes. (plural: bacteria)
bacteriophage	A virus that infects bacteria.
biotechnology	The use of microbes to carry out manufacturing or industrial tasks, such as making new medicines or cleaning up oil spills.
capsid	The outer shell of a virus.
carbon dioxide	A colorless, odorless gas that plays a part in fermentation, photosynthesis, and other processes.
cell membrane	A soft, flexible, thin layer of fats and proteins that surrounds every living cell.
cell wall	A stiff covering that surrounds bacteria and plant cells.
cilium	A hairlike structure on some cells. It beats rapidly to move the cell or produce feeding currents. (plural: cilia)
classification	1) The act of grouping or arranging in classes according to a system or principle; 2) A system of groups or classes.
cocci	Globe-shaped bacteria.
colony	A group of organisms of the same kind that live close together and depend on one another.
community	A group of different species of organisms that live in the same area or region, and are interdependent.
consumption	An infectious disease that eats away the tissue of the lungs. Also known as tuberculosis.
culture	1) To grow microbes on a specially prepared material (medium); 2) A mass of microbes grown on a medium.
decomposer	A microbe that breaks down the waste or dead tissue of other organisms into simpler materials, such as nutrients.
disease	A condition that has a specific cause and specific symptoms, and that weakens the normal functioning of an organism.
DNA	A molecule that's shaped like a twisted ladder and carries genetic information in the nucleus of a cell.
electron microscope	A microscope that bounces atom particles (electrons) off objects to create an image on film.
electron microscopy	The use of an electron microscope.
emerging disease	A disease that's new to humans, either because it developed in a remote part of the world or because it's caused by a new strain or species of microbe.
enzyme	A natural chemical that causes or speeds up chemical reactions in the body.

envelope	A layer of fats and proteins that surrounds some viruses.
epidemic	The rapid spreading of an infectious disease to many individuals in an area.
eukaryote	An organism whose cells each have a nucleus that's enclosed by a membrane.
evolution	The change in the genetic makeup of a species population over time.
fermentation	The breaking down of complex substances into simpler ones, such as when yeast breaks down sugar into carbon dioxide and alcohol.
flagellum	A whiplike structure on some cells that helps them swim. (plural: flagella)
fluid	Any substance that can flow, move and change shape without separating under pressure; liquid.
food web	A complex network of interrelated organisms that feed upon one another within a community or among several communities.
fungus	One of a large group of mostly non-moving (sedentary) organisms that have cell walls and absorb nutrients from either living organisms or the remains of dead organisms. (plural: fungi)
gene	A piece of DNA that codes for a protein (or other product) that determines a specific trait in an organism.
genetic engineering	The artificial altering of a living organism's genetic material to produce new traits, species or products.
germ	A microbe, usually one that causes disease.
host	An organism that a parasite lives in or on.
immune	Having the ability to resist a specific disease.
immunology	The study of the immune system.
infection	Invasion of the body by microbes.
infectious disease	Disease that can be transmitted by touching, coughing or other types of contact; contagious disease.
inoculation	The introduction of disease-causing microbes into the body to produce or boost immunity to a specific disease.
light microscope	A microscope that uses light to make a specimen visible.
membrane	see cell membrane
microbe	An organism that's so small you can see it only with a microscope.
microbiology	The study of microbes.
microcosm	A small community and its environment; literally, a "little world."
microorganism	A microbe.
microscope	An instrument that magnifies small objects.
microscopic	Too tiny to be seen without a microscope.
mildew	1) Any fungus that attacks plants, paper, cloth and other objects, and forms a downy or powdery whitish growth; 2) The whitish growth formed by some fungi.
mold	1) Any fungus that feeds on dead or decaying matter, and forms a slimy, cottony growth; 2) The slimy, cottony growth formed by some fungi.
molecule	A combination of atoms of two or more elements that forms the smallest unit of a specific substance.
mushroom	Any fleshy fungus that has a stalk capped by an umbrella-shaped top.
mutation	A change in the genetic makeup of an organism.
nitrogen	An element that's a building block for all proteins and some acids.
nitrogen fixation	The changing of gaseous nitrogen into other substances (compounds) by the bacteria that live on some plant roots, or in soil.
nucleus	The control center of a cell, where genes are found.
organelle	A structure within a cell that performs a specific function.
organism	A living being.
oxygen	An element that plant and animal cells use to break down food molecules to produce energy.
pandemic	An epidemic that has spread over a large geographic area.

parasite	An organism that grows and feeds on another organism (host), but offers no benefits to the host.
pathogen	An organism that causes disease.
petri dish	A round, shallow, transparent dish and lid in which scientists culture microbes.
phage	A bacteriophage.
pharmaceutical	Having to do with medicines.
photosynthesis	The chemical process by which green plants use sunlight to make food (carbohydrates) from carbon dioxide and water.
plague	An infectious and usually deadly epidemic disease.
predator	An organism that hunts or catches other organisms for food.
prey	An organism that is hunted or caught by another organism for food.
prokaryote	A one-celled organism that lacks a true nucleus. Its DNA doesn't have a membrane around it.
protein	A nitrogen-based molecule that's present in all living cells. All animals need it to grow and repair tissue.
protozoan	Any of a group of one-celled organisms, such as amoebas and paramecia, that don't photosynthesize. Most are larger than bacteria, and can move themselves. (plural: protozoa)
rod	A capsule-shaped bacterium.
spikes	Protein structures in the envelope of a virus that help the virus find and bind to a host cell.
spirochete	A long, spiral-shaped bacterium.
strain	A group of organisms of the same species that are more like one another than others in the species.
symbiosis	A close living relationship in which two organisms of different species help one another survive.
taxonomy	The classification of animals and plants according to natural relationships.
toxin	A poisonous substance that some microbes produce. It often causes the symptoms of a disease.
vaccine	A preparation of killed or weakened bacteria or viruses that, when taken into the body, causes the immune system to produce antibodies, which leads to immunity.
vaccination	The introduction of a vaccine into the body to produce immunity to a disease.
virus	A disease-causing microbe that's made of DNA surrounded by a protein coat. It's the smallest of all microbes.
white blood cell	One of your immune system's main microbe killers.
X-ray crystallography	A method of seeing viruses by turning them into crystals, shooting them with X-rays, then recording the image on film.
yeast	Any of a number of one-celled fungi that break down sugar into alcohol and carbon dioxide.

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American Society for Microbiology
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