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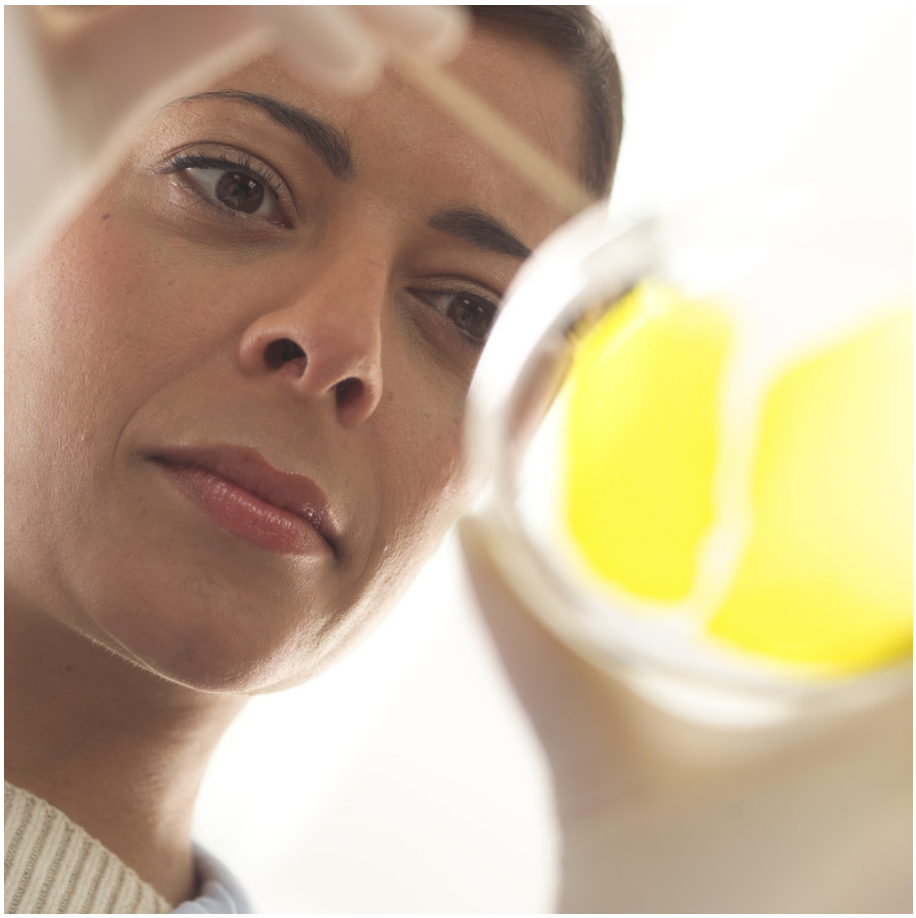
#10470
EXPLORING BACTERIA

HUMAN RELATIONS MEDIA, INC., 2002
Grade Level: 10-12
26 Minutes
10 Instructional Graphics Included



CAPTIONED MEDIA PROGRAM RELATED RESOURCES

#3343 BIOLOGY: ECOLOGY OF THE HUMAN BODY
#3354 DEFEND AND REPAIR
#9470 VIRUSES AND MONERAN

Funding for the Captioned Media Program is provided by the U.S. Department of Education

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INTRODUCTION

Discovery is a powerful inducement for learning—for instance, a student's first look through a microscope at the hidden world of microorganisms provides just that kind of discovery. For many students, ***Exploring Bacteria*** will provide one of their first glimpses into the world of bacteria. Students viewing the program will realize that they are surrounded by organisms they cannot see. Though tiny, these microscopic bacteria are busily carrying out complex life functions in a stunning variety of habitats. Even inside the students' own intestines, a huge community of bacteria is engaged in getting food, reproducing and fighting off predators.

Bacteria provide a rich and engaging topic for the study of the big ideas of biology. The video program ***Exploring Bacteria*** tackles important basic concepts through a series of questions posed in familiar language. The video program delivers live-action video showing stunning microscopic sequences, people at work in laboratory settings, beautiful outdoor images and helpful graphics to answer these questions.

All too often, the study of biology focuses on larger, more familiar plants and animals and overlooks the amazingly versatile and widespread bacteria. Yet these microorganisms reproduce at fantastic rates, make use of a huge variety of living conditions, survive in extreme hardship, colonize our own bodies, and provide powerful tools for genetic engineering. Their relatively simple structure makes bacteria an excellent example for study.

Exploring Bacteria shows how versatile bacteria are, living and competing even in the harshest environments. The program introduces the idea of cell structure and shows how it relates to biological function. Students learn some simple clues to the identity of different bacteria, including differences in shape, in how they can be stained using laboratory techniques, and in their ability to move. One of the most exciting sequences in the video shows bacteria reproducing and quickly building a huge population from just a few cells.

This video program and Teacher's Resource Book, with its accompanying review questions, discussion guide and classroom activities, will awaken students to many fundamental concepts in biology and broaden their knowledge and understanding of one of the most numerous and diverse groups of organisms, the bacteria.

LEARNING OBJECTIVES

After viewing the video ***Exploring Bacteria***, participating in class discussions, and completing the activities and review questions in this Teacher's Resource Book, your students should:

- realize that bacteria are found almost everywhere on Earth.
- understand that some bacteria cause disease, but other bacteria are beneficial.
- recognize that each bacterium consists of a single prokaryotic cell that carries out all major life processes.
- understand that bacteria reproduce by rapid cell division and form large populations.
- understand the role of DNA and mutations in heredity and adaptation.
- recognize the interdependence of bacteria and other organisms.

For many students, viewing the video ***Exploring Bacteria*** will be their first serious investigation into the microscopic realm. The study of bacteria taps into the natural curiosity of young students. It's exciting to see what only a microscope can reveal—and even more intriguing to learn that these organisms consist of just a single cell and yet they are able to perform all the major activities of any living thing. Bacteria demonstrate the major principles of life, including reproduction, cell structure and function, genetic mutation, use of resources for a population, and interactions with other organisms.

Exploring Bacteria organizes these ideas through a series of questions posed in familiar language:

- Where do bacteria live?
- How long have bacteria been around?
- What is the difference between bacteria and other organisms?
- How can you tell bacteria apart?
- How do bacteria reproduce?
- What do bacteria do to people?
- What do people do to bacteria?
- What do bacteria do to the environment?

For each question, the video combines rich images of these fascinating microorganisms and their habitats with instructive graphics and laboratory scenes to explain the answers. The questions themselves offer a simple and engaging way to get students to think about the major biological concepts.

Where do bacteria live? The program opens with a trip to some of the strange places that bacteria are found: the blazing desert, frozen Antarctica, boiling hot springs, and even in the intestines of buffalo, cows and humans. Students learn that bacteria found in the dark depths of the ocean floor, near hot thermal vents make their own food without using energy from the sun. Instead, they depend on chemical energy from sulfur compounds. This situation is in dramatic contrast to life in the upper, sunlit ocean waters, where huge quantities of photosynthetic bacteria called cyanobacteria are found.

How long have bacteria been around? Bacteria have lived on Earth for over three-and-a-half billion years—that is over three-quarters of the age of the planet itself. It took another billion years for bacteria similar to the photosynthetic bacteria of the modern oceans to appear—and once they did, they began to supply oxygen and, indirectly, protective ozone to our atmosphere.

What is the difference between bacteria and other organisms? The video takes the student into the microscopic world, first seeing the variety of tiny organisms in a droplet of pond water. Bacteria are not the only single-celled organisms. The program uses vivid images through a microscope and clear diagrams to contrast prokaryotic bacterial cells with eukaryotic cells such as the amoeba, paramecium and mammalian cells. This sequence provides an active and entertaining introduction to cell structure and function. Students learn that eukaryotic cells, including human cells, have a nucleus and other organelles such as mitochondria. The nucleus houses and protects the genetic material. The prokaryotic bacterial cell, in contrast, is generally smaller and simpler in structure, lacking a nucleus and organelles but surrounded by a protective cell wall. Even the ribosomes are different in bacteria, so they are an important target for the action of antibiotics. The video discusses how differences in eukaryotes and prokaryotes form a basis for biological classification.

How can you tell bacteria apart? Each bacterium is a single cell, yet there are many different species. Excellent micrographs show the three main shapes of bacteria: spherical cocci, rod-shaped bacilli, and spiral spirilli. A special staining process known as the Gram stain causes some species to appear violet-blue (Gram positive) while others appear reddish (Gram negative).

The connection between structure and function is also apparent in bacteria that swim. They have one or more rotating structures called flagella that enable them to move toward useful substances or away from harmful ones.

How do bacteria reproduce? Bacteria reproduce by a simple process of cell division. Reproduction first requires a round of DNA replication so offspring will have the correct genetic instructions. A time-lapse sequence of bacterial cells dividing dramatically shows how bacteria achieve huge populations in a matter of hours. Without limitation, a bacterial population can double in as little as 20-30 minutes. Students learn that fortunately there are limitations to population size: lack of food, accumulation of toxins or predators can slow or stop growth. The video demonstrates the action of one natural enemy of bacteria, the bacteriophage virus. The DNA of the virus takes over the bacterial cell and turns it into a factory for more viruses.

What do bacteria do to people? Students may be surprised to learn that any bacteria normally live on and in the human body without causing harm. Some are even helpful. *E. coli* found in the intestines and bacteria growing on the skin are good examples. They compete with harmful or pathogenic bacteria. Sometimes bacteria enter the body through cuts in skin, through food, through the respiratory tract or through sexual contact. These bacteria may be pathogenic. Some cause common conditions such as acne, body odor or dental cavities. Others may cause serious or fatal illnesses including tetanus, food poisoning, sore throat, pneumonia or sexually transmitted diseases including syphilis.

The video demonstrates that pathogenic bacteria cause damage to the human body in two ways: by direct invasion of tissues, or by production of toxins that act at a distance. The body has a variety of natural defenses. The unbroken skin itself is a barrier. Lungs have ways to expel foreign material, and the body makes specific defense proteins known as antibodies. Immune cells also attack and ingest invading bacteria.

People do not always rely solely on the body's own defenses against bacterial infection. Antibiotics are chemicals used to target specific features of the prokaryotic bacterial cell that differ from the eukaryotic cells of the human host. Antibiotics have greatly reduced the threat of bacterial infections, but they are becoming less effective as bacteria mutate and become resistant. The program describes the molecular basis of mutation, showing that errors can be introduced into the DNA code and passed on to offspring.

What do people do to bacteria? People unintentionally change bacteria in harmful ways by overusing antibiotics. However, people use bacteria for many useful purposes, too. Bacteria turn milk into yogurt, they can be used to clean up toxic wastes and oil spills, and they are important tools for genetic engineering. For instance, genetically engineered bacteria are used to produce human insulin for the treatment of diabetes.

What do bacteria do to the environment? Ancient photosynthetic bacteria actually helped build our oxygen rich atmosphere. Bacteria known as decomposers feed on dead organisms and recycle this material. Bacteria also are involved in the nitrogen cycle. *Rhizobium* bacteria live in knobs on roots of plants known as legumes. This is a mutually helpful relationship between bacteria and plants. Plants protect the bacteria and provide some nutrients. The bacteria capture nitrogen from the atmosphere and make it available for the plant and other bacteria. The nitrogen cycle is completed by denitrifying bacteria that break down nitrogen-containing compounds.

The video closes with a brief review of these questions.

TEACHING STRATEGIES

Students at this level have some familiarity with living systems, but they are only just beginning to really *think* about the big concepts in biology. The dynamic format of the video and the active nature of this Teacher's Resource Book help students to expand their knowledge and to gain experience applying that knowledge as they dig deeper into the subject.

A good way to start is to do a quick preview to find out what students already think about the topics in the video. A preview also helps focus students' attention on the ideas in the video. This process is a way of "testing the water" rather than giving a test *per se*. The following questions are offered as samples. The important thing is to quickly and informally explore what students think rather than to push for correct answers or to penalize students for mistakes.

Sample preview questions:

1. What do you think of when you hear the word "bacteria"?
2. Are all bacteria dangerous?
3. How big are bacteria?
4. What do bacteria look like? Are they all alike?
5. How do bacteria interact with the world around them?

After students have a few minutes to express their existing ideas about bacteria, view the video. Then reinforce the concepts by using the *Discussion Guide* on pages 9-10, and by letting students try the *Student Activity Sheets* which begin on page 11 of this Teacher's Resource Book. In addition, you may want to use the *Video Review Questions* on pages 11-13 to reinforce their recall of basic information.

Keep in mind that the *Video Review Questions* focus on basic information. For deeper understanding, use the *Discussion Guide* questions on pages 9-10. The *Student Activity Sheets* provide a way for students to apply and reinforce their new knowledge. The organizing questions in the video also can be used to guide a discussion or a review. They are related to major concepts in the National Science Education Standards.

Making the most of the student activities:

The student activities in this Teacher's Resource Book require the use of worksheets, interpretation of diagrams and data, or access to outside resources. They may work best as a homework assignments. When appropriate, an answer sheet is offered.

ADDITIONAL POINTS OF INTEREST

- **COLOR ENHANCEMENT:**
  Please note that micrographs have been color enhanced for clarity. You may want to explain to students that bacteria are not in reality the bright colors depicted in some of the images.

- **CELL SIZE:**
  Help your students get a sense of the huge difference in size between a bacterium and a human being. If you have access to microscopes, let students investigate bacteria first-hand. You can observe prepared slides, or make slides from natural sources such as standing water or soil. Not all bacterial cells are smaller than eukaryotic cells, though the larger ones are rare. An extreme example is a huge bacterium discovered in 1993 by Ester Angert and Norman Pace. The huge bacterium was found in the digestive system of surgeonfish. It is about the size of a typewritten period. Clearly, bacteria show enormous diversity.

- **PLASMIDS:**
  The program refers to genetic engineering but does not attempt to describe the technology in the short time available. You may want to explain to students that bacteria are useful for a variety of reasons. For one thing, they are the source of cloning vehicles known as plasmids. A plasmid is a small loop of DNA found outside the DNA chromosome (the major genetic material). Bacteria may contain more than one plasmid. In genetic engineering, a plasmid is cut open at a specific site, the DNA fragment of interest is inserted, and new copies are made as the plasmids are replicated.

NATIONAL SCIENCE EDUCATION STANDARDS: KEY CONCEPTS

Biology is a much richer study when it is presented as a group of powerful ideas rather than a litany of facts. The ***Exploring Bacteria*** video program and this Teacher's Resource Book can be used to teach many key concepts based on the National Science Education Standards (NSES) content standards for life science and scientific inquiry, grades 5 through 8. In particular, they are:

Structure and function
The relationship between structure and function is developed in the video in a comparison between bacterial (prokaryotic) cells and eukaryotic cells. For example, the cell wall protects the bacterial cell from stress. Flagella provide motility. Cell membranes help regulate flow of molecules in and out of cells. The nucleus of eukaryotic cells houses and protects the genetic material.

Reproduction and heredity
The program describes the role of DNA as the storage molecule for genetic information. It explains that a new copy of DNA must be made before cells divide so that the offspring have the correct genetic information. The video shows how molecular alterations in DNA result in heritable changes (mutations).

Behavior
It might be surprising that bacteria provide a useful way to teach about behavior and how it helps organisms survive, but bacteria do exhibit simple behaviors. For instance, motile bacteria move toward useful substances such as food and away from dangerous ones.

Populations
Bacteria reproduce quickly and can form large populations. Time-lapse video sequences dramatically show this process. This image also encourages students to wonder what might limit growth of a population. The video discusses issues of limited resources and environmental factors that limit growth.

Diversity and adaptation
Bacteria were among the first life on Earth, and through billions of years, many diverse species have evolved. The video shows the wide variety of habitats and lifestyles of various bacteria. For example, students learn that bacteria are found almost everywhere on the planet. Photosynthetic bacteria are shown to be one of the major sources of energy that flow from nonliving systems into living systems. Bacteria even inhabit our own bodies. The video also makes clear that not all bacteria are alike. Even so, similarities between cells and other features also show that all these species are related. The topic of antibiotic resistance is introduced, and it provides an excellent, current and tangible example of adaptation and selective pressure.

The video's organizing questions (listed in the *Program Summary* on pages 3-5) can be used after viewing the video to help students recall what they have seen. The *Discussion Guide* questions below go into more depth than the review questions. These questions are useful to foster discussion and encourage students to apply and expand what they have learned. It is not necessary to use all the questions listed below—we provide a variety of discussion areas. Select the points you want to emphasize.

1. **Why does a bacterial cell need to replicate its DNA before the cells divides during reproduction?**

   The DNA is the genetic material. It contains instructions for life processes for an organism. When a cell divides, each resulting cell will need a set of these instructions. For this reason, the DNA must be copied before the cell divides.

2. **Antibiotics are chemicals used to kill bacteria without killing the human host.**

   a) **What might be the target of antibiotics effective to treat a bacterial infection?**
   Prokaryotic cells have different ribosomes than eukaryotic cells. They also have a cell wall with a specific chemical composition. Antibiotics could target these prokaryotic features and thus not hurt the human host, which has eukaryotic cells.

   b) **Viruses can cause human disease. Explain why bacterial antibiotics are not useful against viral infections.**
   The virus is a parasite that enters the human host cell and relies on its protein machinery and DNA replication enzymes to reproduce. Antibiotics that target bacterial cells will not kill the human cell and hence won't harm the virus inside. There are some relatively modern drugs that can target viral replication and thus are effective. They are separate from the bacterial antibiotics.

3. **Producers are organisms that make their own food. Name two sources of energy for different producers.**

   Sunlight and chemical energy provide energy for producers. Photosynthetic producers use light energy from sunlight. Chemosynthetic producers use energy from chemical compounds such as oxidization of sulfur compounds.

   a) **How do producers help other organisms?**
   They bring energy into living systems and build organic molecules from chemicals found in the nonliving world. Other organisms depend on producers for food.

b) **Based on what you saw in the video, name two examples of bacterial producers and describe where they live.**
There are photosynthetic bacteria (cyanobacteria) in the upper waters of the ocean where sunlight filters through the water. In the dark, deep bottom of the ocean, bacterial producers live near hot vents on the ocean floor. These producers use chemical energy from sulfur compounds.

4. **How do bacteria move? Can all bacteria do it? How might motility (the ability to move) be an advantage for bacteria?**

Not all bacteria are motile. Most species that are motile move by means of one or more long, rotating structures known as flagella. Motility enables bacteria to move toward food or away from danger.

5. **Some bacteria are pathogens that can cause human disease. What are the entry points for bacterial infection?**

Entry points include a break in the skin, through the mouth or nose while breathing, through food, and through sexual contact.

a) **What natural defenses does the body have?**
Natural defenses include immune cells (white blood cells) that attack invaders; proteins known as antibodies made specifically to attach to chemical components of a particular invader; the unbroken skin as a barrier to invasion; cilia in airways to push out foreign material; and our conscious choice for low-risk behaviors.

b) **Why might these defenses sometimes be unable to protect a person?**
Illness can lower immune defenses; the invading organisms could be present in such high numbers that they overwhelm defenses; and invading organisms could actually attack the immune system.

c) **What behaviors can you personally choose to reduce your risk of infection?**
You could have good personal hygiene, such as washing hands often; you could choose not to engage in unprotected sexual activity; you could avoid people with contagious infections; you could keep your body strong by good nutrition, sleep and exercise; don't leave food unrefrigerated; cook meat well; and wash fruit and vegetables before eating them.

STUDENT ACTIVITIES

Name: _____

ACTIVITY 1-A

VIDEO REVIEW QUESTIONS

After you have viewed the video ***Exploring Bacteria***, answer the following questions on the back of this page, or on a separate sheet of paper.

1. Are all bacteria dangerous to people? Explain.
2. What is antibiotic resistance, and what can make it increase?
3. Describe two ways in which pathogenic bacteria harm people.
4. Describe two large groups of organisms that are classified based on differences in cell structure.
5. How do bacteria reproduce?
6. What happens to DNA when a mutation occurs?
7. How can a mutation affect a bacterial population?
8. How can overuse of antibiotics increase resistance in bacterial populations?
9. What roles do bacteria play in the nitrogen cycle?
10. Why are photosynthetic cyanobacteria found in the upper few meters of the ocean instead of deeper?
11. Bacterial populations are found everywhere on Earth, and they show great ability to adapt to new conditions. How long have bacteria lived on Earth?
12. What effect did early photosynthetic bacteria have on the atmosphere?
13. A simple way to tell bacteria apart is by their shape. What are the three main shapes of bacteria?
14. What group is an exception to these three shapes and why?
15. What is a Gram stain?

Name: _____

ACTIVITY 1-B

ANSWER KEY

1. Are all bacteria dangerous to people? Explain.
   No, some are pathogenic but many are beneficial. They are normal inhabitants of the human body that compete with pathogens or maintain body conditions. Bacteria also are used in food processing, waste management and genetic engineering.

2. What is antibiotic resistance, and what can make it increase?
   Antibiotic resistance is the ability of bacteria to survive treatment with an antibiotic. It results from an altered gene (mutation) that can be passed from one bacterium to another or inherited by offspring in a population. Continued exposure to the antibiotic provides a selective pressure that favors survival of the resistant bacteria.

3. Describe two ways in which pathogenic bacteria harm people.
   Bacteria cause harm by directly invading and damaging tissue or by producing toxins that attack the body often away from the site of infection.

4. Describe two large groups of organisms that are classified based on differences in cell structure.
   The two groups are prokaryotes and eukaryotes. Bacteria are prokaryotes. Other organisms, including single-celled amoebas and paramecia, are eukaryotes. They differ in their cell structure.

5. How do bacteria reproduce?
   They reproduce by cell division (binary fission).

6. What happens to DNA when a mutation occurs?
   A physical alteration in DNA changes the encoded genetic information. The change could result in a change in the protein or RNA encoded by the mutant gene. Students should realize that the mutation results in a new trait.

7. How can a mutation affect a bacterial population?
   A mutation in reproducing cells can be inherited by offspring. If the mutant has a better chance to survive, its offspring will be more numerous and have more offspring. Eventually, cells like the mutant bacterium will be the most common in the population.

8. How can overuse of antibiotics increase resistance in bacterial populations?
   It provides a selective pressure that favors bacteria carrying the resistance genes.

9. What roles do bacteria play in the nitrogen cycle?
   Nitrogen fixing bacteria bring nitrogen from the atmosphere into living systems. Other bacteria produce various nitrogen compounds. Denitrifying bacteria break down nitrogen compounds and return nitrogen to the atmosphere.

10. Why are photosynthetic cyanobacteria found in the upper few meters of the ocean instead of deeper?
    Sunlight only filters through the upper waters, and it is the source of energy for photosynthesis.

Name: _____

ACTIVITY 1-C

ANSWER KEY

11. Bacterial populations are found everywhere on Earth, and they show great ability to adapt to new conditions. How long have bacteria lived on Earth?
Bacteria have lived on Earth for about three-and-a-half billion years, about three-quarters of the age of the planet.

12. What effect did early photosynthetic bacteria have on the atmosphere?
They contributed oxygen and, indirectly, ozone to the atmosphere.

13. A simple way to tell bacteria apart is by their shape. What are the three main shapes of bacteria?
The three shapes are: spheres (cocci), rods (bacilli), and spirals (spirilli).

14. What group is an exception to these three shapes and why?
Mycoplasmas lack a cell wall to give rigidity to the cell, so they form twisted and irregular shapes.

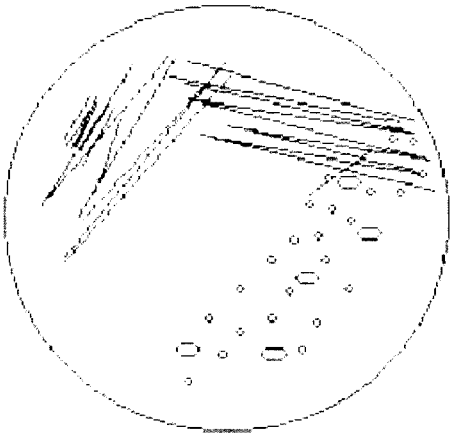
15. What is a Gram stain?
It is a differential staining technique used to tell different bacteria apart. The first dye or stain turns cells a deep blue-violet color. After decolorizing and exposure to a second dye, some cells retain the original color (Gram positive), while others lose the first stain and pick up the second, turning a reddish color (Gram negative). This process lets the laboratory worker quickly distinguish bacteria in these groups. The difference in staining is based on differences in the cell wall composition.

Name: _____

ACTIVITY 2-A

CULTURE PLATE

Look at the following diagram of a bacterial culture plate. The bacteria are grown on a support substance known as agar that contains nutrients needed for growth.



1. A bacterial sample was streaked across the culture plate. What is each dot on the plate?

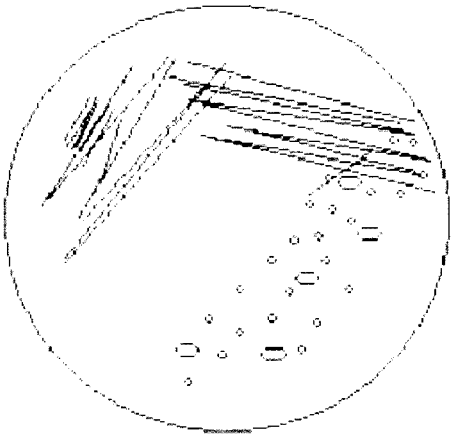
2. Why is it important to keep a lid on the culture plate?

Name: _____

ACTIVITY 2-B

ANSWER KEY

Look at the following diagram of a bacterial culture plate. The bacteria are grown on a support substance known as agar that contains nutrients needed for growth.



1. A bacterial sample was streaked across the culture plate. What is each dot on the plate?
   Each dot on the plate is a colony which contains millions of bacteria. The bacteria in each colony are a population grown from a single cell, so most of the bacteria in a colony are identical.

2. Why is it important to keep a lid on the culture plate?
   The lid prevents additional microorganisms or spores from falling onto the surface of the plate and contaminating the culture. Also you would not want to expose yourself or others to the bacteria growing on the plate if they are pathogenic.

Name: _____

ACTIVITY 3-A

BACTERIAL REPRODUCTION

Assume you are growing bacteria under excellent conditions in a liquid culture. Cell division for these bacteria takes place in 30 minutes.

1. If you have 20 bacterial cells at 8 o'clock in the morning, how many cells will be in the culture at 9 o'clock in the morning? How many will be there at noon of the same day? Explain your answer.

2. Will they grow without stopping? Explain.

Name: _____

ACTIVITY 3-B

ANSWER KEY

Assume you are growing bacteria under excellent conditions in a liquid culture. Cell division for these bacteria takes place in 30 minutes.

1. If you have 20 bacterial cells at 8 o'clock in the morning, how many cells will be in the culture at 9 o'clock in the morning? How many will be there at noon of the same day? Explain your answer.
   At 9 a.m. there have been two rounds of division, so there will be about 80 cells. By noon, another six rounds of division will give you 5120 cells.

2. Will they grow without stopping? Explain.
   During this short growth period and good conditions, the bacteria population will continue to grow. Eventually, however, limitations of food, space, and accumulation of toxins or waste material will slow and stop reproduction.

Name: _____

ACTIVITY 4-A

CELL STRUCTURE

1. In the space below, or on a separate sheet, draw a diagram of a bacterial (prokaryotic) cell and a diagram of a eukaryotic cell. Be sure to label the major parts of each cell.

bacterial (prokaryotic) cell	*eukaryotic cell*

2. List at least two differences in eukaryotic and prokaryotic cells.

3. List at least two similarities in eukaryotic and prokaryotic cells.

4. Write a paragraph to describe the connection between structure and function in a cell.

Name: _____

ACTIVITY 4-B

ANSWER KEY

1. In the space below, or on a separate sheet, draw a diagram of a bacterial (prokaryotic) cell and a diagram of a eukaryotic cell. Be sure to label the major parts of each cell.
Answers will vary but may include the cell membrane; cell wall in bacterial cell; nucleus, genetic material and mitochondria in eukaryotic cell. Students may supply a diagram to show ribosomes, or they may label the DNA molecule in the bacterial cell. Their bacterial cell may have flagella.

2. List at least two differences in eukaryotic and prokaryotic cells.
Ribosomes have different structure; most prokaryotes have a cell wall, the DNA is not in a nucleus, the cell may have flagella; eukaryotes have a nucleus and organelles such as mitochondria.

3. List at least two similarities in eukaryotic and prokaryotic cells.
Responses may include that the cell is a protective compartment; each cell contains genetic material; both types of cells have ribosomes that do protein synthesis; both are surrounded by a cell membrane.

4. Write a paragraph to describe the connection between structure and function in a cell.
There are many examples that students can describe: Flagella provide a way to move; the nucleus protects genetic material;, the cell wall protects a cell from stresses such as water pressure; the cell membrane regulates the flow of molecules through pores; the membrane encloses the contents of a cell. The small size and simple structure of the bacterial cell make it easier for it to divide (reproduce) quickly. The structure of DNA molecule is the key to the genetic information it contains.

Name: _____

ACTIVITY 5-A

HELP OR HARM?

Read the following description of two strains of bacteria and then write your answers to the questions below. Also recall what you learned in the video to make your responses.

> Not all *E. coli* are alike. These Gram negative bacilli are normal inhabitants of the human intestines. However, health professionals have been very worried about another strain of *E. coli*, called *E. coli* O157:H7. If a serving of undercooked ground beef is infected with as few as ten of these bacteria, the person who eats the meat can become dangerously ill. Every year about 70,000 people get sick from *E. coli* O157:H7.
>
> The pathogenic *E. coli* O157:H7 produce a toxin that attacks the intestines and other organs. Genetic data show that there are many genes in *E. coli* O157:H7 that are not present in the common, nonpathogenic strains of *E. coli*.
>
> (Reference: "Busting the Gut Busters" by Charlotte Schubert in the August 4, 2001 issue of Science News, pp. 74-75.)

1. Based on information in the video, what effect do the populations of *E. coli* that normally live in the gut have on humans?

_____
_____
_____

2. What shape are *E. coli*? Explain your evidence.

_____
_____
_____

3. How do the pathogenic (disease-causing) *E. coli* O157:H7 make people sick?

_____
_____
_____

4. What evidence is there for the difference in normal *E. coli* and the strain called *E. coli* O157:H7?

_____
_____
_____

5. Why is it useful for the description to list a reference?

_____
_____
_____

Name: _____

ACTIVITY 5-B

ANSWER KEY

Read the following description of two strains of bacteria and then write your answers to the questions below. Also recall what you learned in the video to make your responses.

> Not all *E. coli* are alike. These Gram negative bacilli are normal inhabitants of the human intestines. However, health professionals have been very worried about another strain of *E. coli*, called *E. coli* O157:H7. If a serving of undercooked ground beef is infected with as few as ten of these bacteria, the person who eats the meat can become dangerously ill. Every year about 70,000 people get sick from *E. coli* O157:H7.
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>
> (Reference: "Busting the Gut Busters" by Charlotte Schubert in the August 4, 2001 issue of Science News, pp. 74-75.)

1. Based on information in the video, what effect do the populations of *E. coli* that normally live in the gut have on humans?
   They do not harm people unless the gut is ruptured, and the E. coli *get into other tissues or organs. In fact, they are somewhat helpful by competing with pathogenic organisms.*

2. What shape are *E. coli*? Explain your evidence.
   They are rod-shaped. The evidence is that the article describes them as bacilli.

3. How do the pathogenic (disease-causing) *E. coli* O157:H7 make people sick?
   They infect the body through food, especially undercooked meat. They reproduce in the intestines and produce a dangerous toxin that attacks the intestines and other organs, causing illness.

4. What evidence is there for the difference in normal *E. coli* and the strain called *E. coli* O157:H7?
   Genetic analysis of the two strains shows that there are many different genes in E. coli O157:H7 *that are not present in the common strain. Presumably some of these different genes in E. coli* O157:H7 *encode the toxins or other traits related to pathogenicity.*

5. Why is it useful for the description to list a reference?
   If you want to know more about the topic, you can find this article. Also, the reference shows that the report is based on a reliable scientific report.

Name: _____

ACTIVITY 6-A

BACTERIA ON MARS?

Could bacteria live on Mars? First, consider some of the extreme places that scientists are search for bacteria on Earth.

1. What observations from the video or from the news suggest that bacteria might be able to live on Mars?

2. What is necessary to be able to answer the question about life on Mars in a scientific way?

Name: _____

ACTIVITY 6-B

ANSWER KEY

Could bacteria live on Mars? First, consider some of the extreme places that scientists are search for bacteria on Earth.

1. What observations from the video or from the news suggest that bacteria might be able to live on Mars?
   Responses will vary but may include the observation that bacteria show a wide variety of metabolic styles and that extremophiles (thermophiles) live in unusual and harsh environments, showing the versatility of bacterial species. Students may point out that bacteria can withstand high and low temperatures. The possible lack of liquid water on Mars might argue against life, including bacteria. Evidence of bacterial fossils or organic molecules would suggest life at an earlier date on Mars, when there could have been more water. The point of this activity is not to guess wildly or produce a specific "right" answer, but to stimulate students to think and to look for current evidence pro or con. The nature of this topic suggests that students likely will find evidence published after this guide is brought to press.

2. What is necessary to be able to answer the question about life on Mars in a scientific way?
   Scientists will need a lot of evidence. Evidence could include investigations of the Martian surface to see if water is (or has been) present, to determine the temperature range, to measure levels of radiation and to look for direct clues about life. These clues might include fossils, organic compounds or actual living cells.

Name: _____

ACTIVITY 7

BACTERIA IN THE NEWS

To complete this activity, you and your classmates should look in magazines, newspapers or on the Internet for recent news announcements about bacteria. Daily newspapers often have a science section—or you may want to look in the business section under reports on biotech companies. The publication Science News also is an excellent resource.

Working with a team of four students, make a report to your class on the news story. As part of your report, use the questions from the video and apply some of them to this story. For example:

- Where do the bacteria in your news story live?
- How are they different from other organisms?
- How can you tell them from other bacteria?
- What do the bacteria do to people?
- What do the bacteria do to the environment?
- What are people doing to the bacteria?

FACT SHEETS

Name: _____

FACT SHEET 1-A

GLOSSARY

Amoeba (plural is **Amoebas** or **Amoebae**): A single-celled, microscopic eukaryote with an unusual and irregular cell shape. Amoebas move by extending lobe-shaped extensions into which cell contents flow. Amoebas are protists.

Antibodies: Part of the human body's natural defense system. Antibodies are Y-shaped proteins produced to recognize chemical components of specific foreign invaders and bind to and immobilize them.

Antibiotics: Chemicals used to kill specific classes of pathogenic micro-organisms without harming the human host.

Bacillus (plural is **Bacilli**)**:** Refers to the rod-shaped bacteria.

Bacteria (singular is **Bacterium**)**:** Microscopic, single-celled organisms that are prokaryotes.

Bacteriophage: A virus that attacks bacteria.

Cell: A compartment that is surrounded by a membrane and serves as a basic unit of a living system.

Cell Membrane: A highly organized, flexible layer that surrounds a cell. It consists mainly of lipids and proteins, and surrounds a cell. Bacterial cells have one or two cell membranes. Membranes contain pores that regulate the flow of molecules into and out of the cell.

Cell Wall: A rigid protective layer that surrounds and protects a cell. Bacterial cell walls have a different composition than plant cell walls. Animal and fungal cells and a few bacteria (the mycoplasmas) lack cell walls.

Chemosynthesis: Chemical process that uses energy from inorganic compounds, such as oxidation of sulfur compounds, to fuel the process of making organic molecules (food). Bacteria that do chemosynthesis are producers, also called chemotrophs (chemosynthetic autotrophs).

Coccus (plural is **Cocci**)**:** Refers to the sphere-shaped bacteria.

Consumers: Organisms that eat material from other organisms. Also known as heterotrophs.

Cyanobacteria: A group of photosynthetic bacteria that are sometimes known as blue-green bacteria. Some live singly and others in colonies or chains. Cyanobacteria are major photosynthetic producers in ocean ecosystems.

Name: _____

FACT SHEET 1-B

GLOSSARY

Decomposers: A special group of consumers that break down the material of dead organisms. Decomposers recycle the material, returning elements back to non-living systems.

Denitrification: Process through which nitrogen is released from nitrogen-containing compounds or ions and returned as nitrogen gas to the environment. Bacteria carry out this step in the nitrogen cycle. See also "Nitrogen Fixation."

DNA: Deoxyribonucleic acid. This molecule serves as the main genetic storage material of cells including bacteria.

Eukaryote: Refers to organisms that have cells in which the genetic material is protected in a membrane-enclosed nucleus. Subcellular organelles include mitochondria, which are involved in oxidative energy metabolism, and chloroplasts, which are found in photosynthetic (green) plant cells.

Fission: Refers to the process of cell division through which bacteria reproduce. First, the DNA is replicated. Next the cell elongates and finally divides into two offspring cells.

Genetic Material: Molecules that store or serve as copies of genetic information, the information that directs protein and RNA synthesis. Genetic material is the basis for heredity. The major long term storage material for cellular genetic information is DNA.

Gram Stain: A differential staining process to help identify different bacteria. The process involves exposing cells to a stain called crystal violet and fixing that stain with iodine. Then a decolorizing agent, acetone-alcohol, is used and followed by a second stain, safranin. Cells that retain the first stain look violet-blue and are said to be Gram positive. Cells that lose the first stain are able to pick up the second stain and have a reddish appearance. They are said to be Gram negative.

Legume: Plant involved in nitrogen fixation. The legume plant produces knobs or nodules on the roots that are infected with nitrogen-fixing bacteria. Beans and peas are legumes.

Mitochondria: Membrane-bound organelles found in eukaryotic cells that carry out important oxidative reactions involved in supplying energy for the cell.

Mutation: Error introduced into the DNA of a cell and passed on to offspring. A mutation can result in a difference in protein function that is helpful or harmful. If a mutation makes a bacterium more likely to survive in specific conditions, its offspring may come to dominate a population and become the "norm."

Name: _____

FACT SHEET 1-C

GLOSSARY

Mycoplasmas: Bacteria that lack a cell wall and consequently have irregular shape.

Nitrogen Fixation: A step in the nitrogen cycle in which bacteria use atmospheric nitrogen gas to produce nitrogen-containing compounds such as ammonia, that can be used by plants and other organisms. Nitrogen fixing bacteria live in nodules on the roots of plants called legumes. Nitrifying bacteria convert ammonia into nitrates.

Nucleus: Membrane-bound compartment found in eukaryotic cells that houses the genetic material (chromosomes).

Organelle: Subcellular structure with a specific function, such as mitochondria and chloroplasts that are found in eukaryotic cells.

Organism: A single living thing. An organism may be composed of a single cell, such as a bacterium, or the organism may contain millions or trillions of cells, such as a human being.

Paramecium (plural **Paramecia**): The genus or an individual from the genus called *Paramecium* that are single-celled microscopic eukaryotes in the kingdom Protists.

Pathogen: Organism that infects a host and causes disease.

Photosynthesis: Chemical process that uses energy from sunlight and carbon dioxide as an carbon source to produce organic molecules (food). Photosynthesis is the basis of most food webs on Earth. Photosynthetic producers also are known as phototrophs (photosynthetic autotrophs).

Plants: One of four kingdoms of eukaryotes in the domain Eukarya. Green plants are photosynthetic.

Plasmid: Small loop of DNA found in bacteria in addition to the chromosomal DNA. There can be more than one plasmid per cell, and they can be transferred from cell to cell. Antibiotic resistance genes often are carried on plasmids. Plasmids provide a powerful tool in cloning procedures used in genetic engineering.

Producers: Organisms that bring energy into living systems by making their own food from inorganic sources. Another name for producers is autotrophs. Producers include photosynthetic bacteria that use sunlight for energy and chemosynthetic bacteria that get energy from oxidation of inorganic compounds.

Prokaryote: Refers to a taxonomic classification in which the cells are simple in structure and do not contain a nucleus. Bacteria are prokaryotes. Compare to eukaryote.

Name: _____

FACT SHEET 1-D

GLOSSARY

Protein Synthesis: The process of making protein molecules according to the instructions copied from DNA in a messenger RNA molecule. Proteins are composed of specific sequences of twenty amino acid subunits. Protein synthesis takes place on ribosomes.

Replication: Refers to the process through which genetic material, DNA, is duplicated. A new copy of DNA is needed prior to cell division so that each resulting cell has a copy.

Reproduction: The process of producing offspring for perpetuation of a species. In bacteria, reproduction occurs by a process called binary fission. First, the DNA is replicated. Next the cell elongates and finally divides into two cells. Bacterial reproduction is quite rapid under favorable conditions, with a new generation appearing in as little as 20-30 minutes in some species.

Resistance (antibiotic): Refers to the ability of some mutant bacteria to survive exposure to antibiotics. Bacterial antibiotic resistance is rapidly increasing due in part to overuse of antibiotics. Resistance is an example of natural selective pressure in the evolution of bacterial populations.

Ribosome: Subcellular structure on which protein synthesis is carried out. Ribosomes are composed mainly of ribosomal RNA with specific protein factors. Ribosomes of bacteria (prokaryotes) have a different structure than those of eukaryotes.

Ruminants: A group of mammals that include cattle, sheep and deer that can digest cellulose. This process requires the help of bacterial populations living in a part of the animals' gut known as a rumen.

Spirillus (plural is **Spirilli):** Refers to the spiral-shaped bacteria.

Thermophile: Means "heat loving" and refers to any organism that lives above 50°C; extreme thermophiles live above 80°C. Extreme thermophiles are found in the domain Archaea. Examples include bacteria found at hot ocean vents and in hot springs such as those in Yellowstone National Park.

Name: _____

FACT SHEET 2

INTERNET RESOURCES

Web addresses do not stay constant. For that reason we do not list a large selection of addresses, as they may change after publication. Instead, we recommend that students expand their understanding by choosing appropriate keywords for a search. For example, information about the use of bacteria in waste clean-up can be found using the words "bacteria" and "bioremediation." A list of suggested keywords follows below.

We will suggest two genomes sites as they are particularly useful. Genome information is available at websites for the U.S. Department of Energy Microbial Genome Program and the TIGR Institute for Genome Research. Their current addresses are:

http://www.ornl.gov/microbialgenomes/organisms.html
http://www.tigr.org/tdb/

For more information on research concerning life on Mars, you might try:

http://spaceflight.nasa.gov/mars/science/ancient/

For an exploration of the biological classification, a useful site is the Tree of Life site maintained by the University of Arizona. The address is:

http://phylogeny.arizona.edu/tree/phylogeny.html

Similar information may be found at a University of California, Berkeley site at:

http://www.ucmp.berkeley.edu/alllife/threedomains.html

Useful keywords for searches include:

Bacteria
Archaea
Bioremediation
Cyanobacteria
Antibiotic resistance
Food production bacteria
Nitrogen fixation legumes

Name: _____

FACT SHEET 3

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