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the science of MICROBES

Comparing Sizes of Microorganisms

Activity 6 from *The Science of Microbes: Teacher's Guide*

by

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RESOURCES

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

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

INTRODUCTION

Microbial Challenges

Infectious diseases have plagued humans throughout history. Sometimes, they even have shaped history. Ancient plagues, the Black Death of the Middle Ages, and the "Spanish flu" pandemic of 1918 are but a few examples.

Epidemics and pandemics always have had major social and economic impacts on affected populations, but in our current interconnected world, the outcomes can be truly global. Consider the SARS outbreak of early 2003. This epidemic demonstrated that new infectious diseases are just a plane trip away, as the disease was spread rapidly to Canada, the U.S. and Europe by air travelers. Even though the SARS outbreak was relatively short-lived and geographically contained, fear inspired by the epidemic led to travel restrictions and the closing of schools, stores, factories and airports. The economic loss to Asian countries was estimated at $18 billion.

The HIV/AIDS viral epidemic, particularly in Africa, illustrates the economic and social effects of a prolonged and widespread infection. The disproportionate loss of the most economically productive individuals within the population has reduced workforces and economic growth in many countries, especially those with high infection rates. This affects the health care, education, and political stability of these nations. In the southern regions of Africa, where the infection rate is highest, life expectancy has plummeted in a single decade, from 62 years in 1990–95 to 48 years in 2000–05. By 2003, 12 million children under the age of 18 were orphaned by HIV/AIDS in this region.

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

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

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

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

Using Cooperative Groups In The Classroom

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

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

The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

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

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

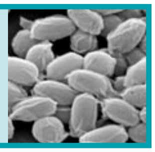
Maintenance Director
- Follows the safety rules
- Directs the cleanup
- Asks others to help

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

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

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

6



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

TIME

Setup: 20 minutes

Activity: 45–60 minutes

SCIENCE EDUCATION CONTENT STANDARDS

Grades 5–8

Inquiry

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

Life Science

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

Overview

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

COMPARING SIZES OF Microorganisms

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

Students will use metric measurements for their calculations.

MATERIALS

Teacher (see Setup)

- Paper square (2.5 m x 2.5 m)

Per Group of Students

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

SETUP

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

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

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

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

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

PROCEDURE

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

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

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

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

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

Continued

METRICS

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

SI subdivisions of a meter (m)

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

SI measures larger than 1 m

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

Other equivalents

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

*1 mm is about 1/25 in.

ONE METER EQUALS

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

Micrometers also are referred to as "microns."

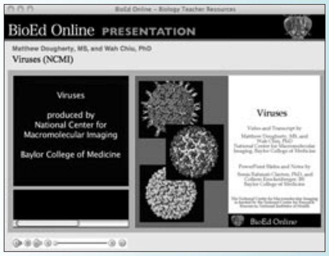
MODEL SCALE

50 cm = 100 micrometers (µm)

EXTENSION

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

TEACHING RESOURCES



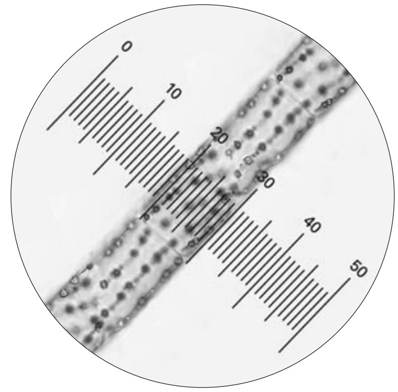
For a discussion about how viruses work and view examples of virus images, see the presentation and slide set, produced by the National Center for Macromolecular Imaging, entitled "Viruses," at www.BioEdOnline.org/.

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

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

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

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



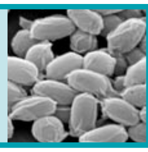
Spirogyra. Courtesy of David R. Caprette, Ph.D., Rice University.

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

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

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

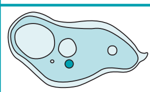
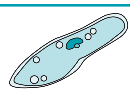
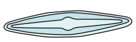
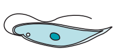
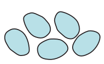
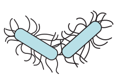
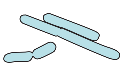
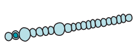
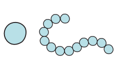
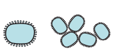
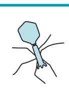
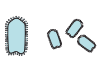
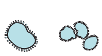
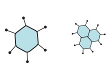
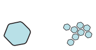
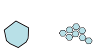
    The microbe sizes described on the *Microbe Scaling Chart* represent typical measurements within the normal size range for each kind of organism. Students may find references to different sizes if they are conducting additional research about the organisms. In addition, some organisms named on the chart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



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

6 Microbe Scaling Chart

Model Scale Size 0.5 cm = 1 µm

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

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