The Scale of the Microbial World

Marion Field Fass

Video II: The Unity of Living Systems

In a world where you were as tall as the Sears Tower, how big would a single spore of *Bacillus anthracis* be?

We can calculate this if we know the height of the Sears Tower (442 meters), your height (1.676 meters if you're 5 feet 6 inches tall), and the diameter of the *B. anthracis* spore (average size is 4 micrometers or 4 x 10^{-6} meters). The Sears Tower is 264 times bigger than you are. A spore of *Bacillus anthracis* would therefore be 264 times bigger as well, which is 264 x (4 x $10^{-6)}$ meters or 1.056 x 10^{-3} meters–about 1 millimeter in size. Just visible, but pretty small!

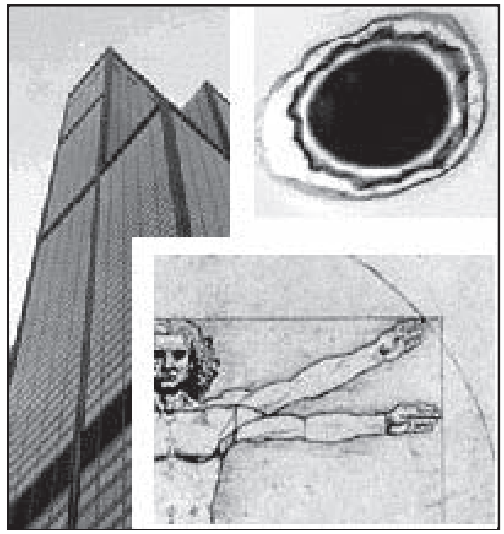

Figure 1. Collage of images including the Sears Tower, spore *of B. anthacis*, and DaVinci's man.

To understand microbiology, you must be able to imagine the unseeable and be able to relate the microworld to your own. Great microbiologists learn to "see" their microorganisms and appreciate their complexity and skills at surviving in difficult environments. Beginning microbiologists struggle to visualize bacteria and to come to grips with issues of scale as they learn about the relations between eukaryotic cells, bacteria and viruses and their interactions in the environment and as agents of disease.

The appreciation of scale is important to an understanding of the processes of pathogenesis. How do antibodies recognize viral particles? How many HIV particles can burst forth from an infected lymphocyte? Is it easy to see a bacterium infecting a cell? If you were asked to make a sketch of streptococcus bacteria attacking a human epithelial cell, how large would the bacteria appear in comparison to the epithelial cell? Just what would an "attack" look like?

Scale is a necessary consideration as microbiologists strive to understand the microenvironments bacteria inhabit. The complex community in a pinch of soil is only comprehensible to scientists who appreciate the scale of the organisms they are working with.

It is challenging to establish an understanding of scale for bacteria and viruses in a meaningful way. Yes, we can discuss how many bacteria will fit on the head of a pin, but we don't really have much of a sense of how a pin compares to the size of our own body cells. You might wish to explore the web resource called *Cells Alive* (www.cellsalive.com) for a great animation that demonstrates the size of microbes. We can look at microbes under the microscope in the lab, but when even the best light microscopes show bacteria only as small dots and lines, it is hard to gauge size. How big is that microscopic dot in the field?

Activity 1. Calculating relative sizes using a human scale

How can we develop a better sense of the relative size of the living entities in the microworld? First, you will need to become familiar with the metric units for length that are commonly used for measurement in the microworld. Note that the units differ by multiples of ten.

Table 1. Metric measurements

1 meter	1 x 10^{0} meter
1 millimeter	1 x 10^{-3} meter
1 micrometer	1 x 10^{-6} meter
1 nanometer	1 x 10^{-9} meter

Now, to put your measurements in familiar terms, calculate the size of the microbes on a human scale. For example, if an *E. coli* bacterium, actual size about 0.002 millimeters, is magnified to a size equal to your own height, how many times larger than its actual size would it be? That is, what is the factor needed to convert from the actual size to a size relative to a human of your height? Divide your height by the length of the bacterium. This is your conversion factor. So, if you are 5 feet 6 inches (1.676 meters) tall, an *E. coli* as tall as you would be 838,000 times larger than its actual size.

On this human scale, in which an *E. coli* is as big as you are, how big would a red blood cell be? A red blood cell (rbc) is about 10 micrometers in diameter. To calculate the size of the rbc relative to a human, multiply its actual size by the conversion factor you calculated above.

Another way to make this conversion is to use the proportional relationship below. (The calculations assume a height of 1.676 meters; you'll want to use your actual height.)

$$\frac{\textit{Your Height}}{\textit{Actual Bacterium Length}} = \frac{\textit{Relative RBC Size}}{\textit{Actual RBC Size}}$$

$$\frac{\textit{1.676 meters}}{\textit{2 micrometers}} = \frac{x}{\textit{10 micrometers}}$$

Calculate the relative size of each of the items in the following table:

	Actual Size	Size to Scale
An Influenza virus	100 nanometers	
The Smallpox virus	200-350 nanometers	
Bacillus anthracis	1-1.5 by 4-10 micrometers	
A spore of *Bacillus anthracis*	2-6 micrometers	
The largest life form of *Pfeisteria pisicida*	450 micrometers	
The smallest form of *Pfeisteria pisicida*	5 micrometers	
A human red blood cell	10 micrometers	
The width of a strand of human hair	0.1 millimeters	
T 7 bacteriophage	40 nanometers	
Saccharomyces cerevisiae	4 micrometers	
HIV	80-100 nanometers	
Average human epithelial cell	10 micrometers	
Lactobacilli	3-5 micrometers	
Paramecium	200 micrometers	

Activity 2. Comparing sizes under the microscope

A strand of hair provides an easy comparison for the scale of microbes, because a hair is both visible to the eye and able to be studied under the light microscope. It is too big, however, to be seen in its entirety under the 100x lens of the microscope.

If you have access to a light microscope and prepared slides of bacteria and protozoa, look at five different microbes under the microscope. Use the information in the table below, or information provided by your instructor for field sizes (microscopes vary), to determine the actual size of the microbes you see magnified.

Eyepiece Magnification	Objective Magnification	Total Magnification	Viewfield Diameter
10x	4x	40	4.5 mm
10x	10x	100	1.8 mm
10x	40x	400	0.45 mm
10x	100x	1000	0.18 mm

- How do your estimates compare to the sizes identified in your textbook or lab manual?
- How can you explain the discrepancies?

Activity 3. Determining size from scale

Although you may have access to images of microbes in your text, this activity requires you to search the Internet for images of microbes. One useful search strategy is to go to Google.com and select the image option for your search. The *ASM Microbe Library* visual resources include photomicrographs that are excellent for exploring the relative size of microbes. Many of these images indicate the scale or the size of the organism, but some do not.

- Find examples of two bacteria, two viruses and two eukaryotes. Identify the method used to visualize each organism, its actual size, and what it does in the world.
- For some of these organisms, it may be necessary to calculate the size from the magnification given in the description of the image.

Additional Resources

Available on the *Microbes Count!* CD

Text

A PDF copy of this activity, formatted for printing

Related *Microbes Count!* Activities

Chapter 1: Population Explosion: Modeling Phage Growth

Chapter 3: The Living World of Yogurt

***Unseen Life on Earth* Telecourse**

Coordinates with Video II: The Unity of Living Systems

Relevant Textbook Keywords

Measurement, Microscope, Microscopy, Size

Related Web Sites (accessed on 2/20/03)

American Society for Microbiology
http://asmusa.org

Image of a Macrophage Cell Attacking Bacteria
http://www.people.virginia.edu/~rjh9u/macro.html

Length Conversion Calculator
http://www.worldwidemetric.com/metcal.htm

Microbes Count! Website
http://bioquest.org/microbescount

Unseen Life on Earth: A Telecourse
http://www.microbeworld.org/htm/mam/is_telecourse.htm

References (web sites accessed on 3/8/03)

Microbe Library Visual Resources
http://www.microbelibrary.org/Visual/page1.htm

Cells Alive
http://www.cellsalive.com

Figure and Table References

Figure 1. Collage courtesy of Ethel D. Stanley