Meet the Pathogens

Teaching the LifeStraw®: Student Activities

Grade level: 3-5

National Science Content Standards:

A: Science as Inquiry
B: Physical Science
C: Life Science
E: Science and Technology

OBJECTIVE:

To explain and explore pathogens and the metrics used to distinguish their size and scale.

DESCRIPTION:

Students will be introduced to the metrics used to measure microscopic organisms. They will use a designated scale to distinguish between the different sizes of pathogens and will gain an understanding of why size matters in relation to filter design. Students will see that contaminated water doesn't always look polluted, and that even the tiniest unseen pathogen can make someone very sick.

It's clear, so it's clean. Right?

Maybe not! Sometimes water looks clean but is actually not safe to drink because it contains germs, or microbes. Germs that make us sick are called pathogens. The smallest of these microbes, viruses, bacteria, and protozoa, are sometimes found in water and can make us very ill. Fortunately, in the United States, the Safe Drinking Water Act (1974) ensures that our drinking water supply is safe. The law requires treatment for our public drinking water which limits the level of contaminants and kills germs that can cause diarrheal diseases. The Environmental Protection Agency has information on your drinking water, where it comes from, and what's being done to keep it safe. (See: http://water.epa.gov/drink/guide/upload/book_waterontap_full.pdf)

BACKGROUND: The good, the bad and the really weird looking!

Millions of minute microbes are everywhere - they live all around us and even in us!

Viruses: *Viruses are the smallest of all microbes and hardly can be seen with even the strongest and most expensive microscopes. Because they are so small, they cannot be measured using our usual scales for measurement. Scientists use a different scale to describe the size of microbes.*

Viruses are measured in nanometers, which are one million times smaller than a millimeter (0.000001 millimeter). Viruses cause the most familiar diseases such as chicken pox, warts, and AIDS. But they also have other roles. Tulips would be dull without them. The white stripes on the petals of many tulip varieties are caused by infection with viruses. Much of our biotechnology, including the development of vaccines and drugs, could not take place without the ability of viruses to transfer genetic information from one organism to another.

Bacteria: *Bacteria are bigger than viruses, although they are still very small. They are found almost everywhere. We find them in the freezing cold of Antarctica and in boiling hot springs. Bacteria also live around and even in us. They are so small that one spoonful of soil contains more than one hundred million bacteria! Most bacteria are measured in micrometers, which are one thousand times smaller than a millimeter (0.001 millimeter). Bacteria cause many diseases such as strep throat, tuberculosis, sexually transmitted diseases, and food poisoning. However, we could not live without them. They convert energy from the sun into forms we can use. All the bacteria in your body would fill a soup can. Almost all of them are found in your digestive system and on your skin. Among their most important tasks is making several vitamins that you need to survive, as well as helping you digest food.*

Protozoa: *Protozoa can be seen without a microscope. Most protozoa move around very easily. Some have hundreds of tiny leg-like parts. Some protozoa eat bacteria, and some make their own food using the sun's energy. They live all around us, and we depend on them for many things. Some keep cows alive by changing dry hay into food they can use. Other protozoa cause some of the more common diseases found in the tropics such as amoebic dysentery, malaria, and Giardia.* (Excerpted from "Let's Get Small", microbeworld.org)

MEASUREMENT:

Pathogens come in all shapes and sizes. Scientists around the world use the base unit of a meter to measure length. A meter is equal to 3.28084 feet; how many inches are in a meter? (Hint: there are 12 inches in a foot.)

Bacteria and protozoa are so small they are measured in micrometers, also called microns. If you divide a meter into a million equal pieces, that small unit of measurement would be one micrometer. Most viruses are even smaller than a micron, and are measured in nanometers, one billionth of a meter! We cannot see viruses with the naked eye; we need to magnify them through the lens of a microscope. [Units in the metric system are based on factors of 10. Prefixes added to the base unit word meter identify how many times larger or smaller the unit is. For example, "centi" means 1/100, so a centimeter is 100 times smaller than a meter.]

How big is a meter?

One meter equals:

- The height of a school chair – or -
- An average 3-year-old

How big is a centimeter?

One centimeter equals:

- The width of an average paperclip
- The length of a housefly

You will find prefixes from throughout scientific literature. Here are some of the more common prefixes used to measure very small items:

PREFIX	UNIT	SYMBOL	DECIMAL EQUIVALENT	SCIENTIFIC NOTATION (FACTOR)
deci-	decimeter	dm	0.1	10^{-1}
centi-	centimeter	cm	0.01	10^{-2}
milli-	millimeter	mm	0.001	10^{-3}
micro-	micrometer	μm	0.000001	10^{-6}
nano-	nanometer	nm	0.000000001	10^{-9}

Each of these items is comparatively ten times smaller than the item that comes before it on the measuring tape. So, if a flea is the biggest on this scale… imagine how small a virus is!

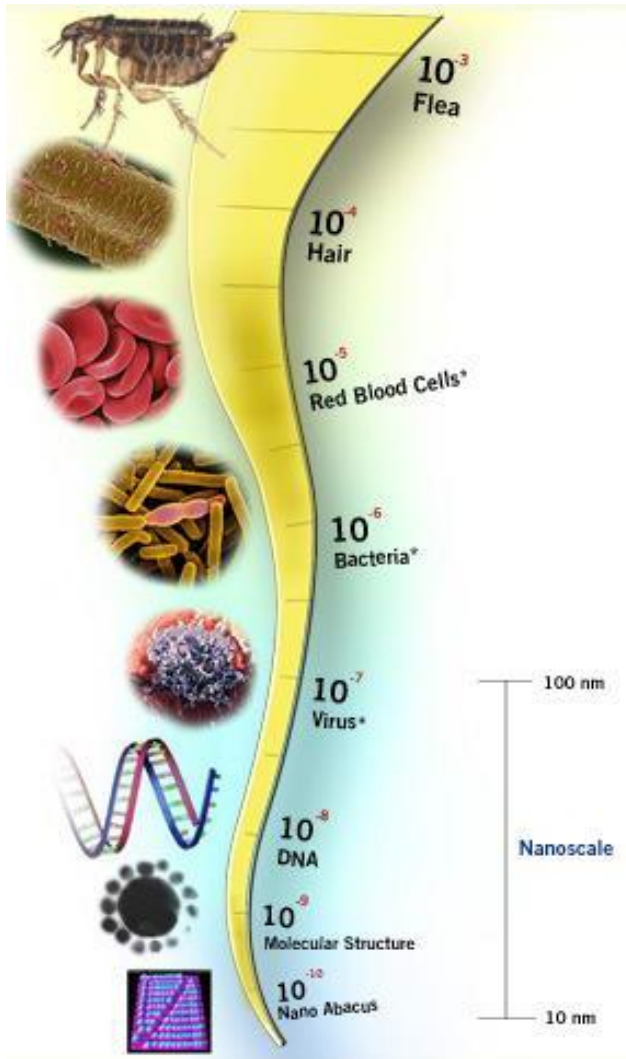


Image credit: www.nanodic.com

Did you know?

A **Nano Abacus** really exists!
James Gimzewski, a physicist at IBM's research lab in Zurich, created a real working nano-abacus, with beads of individual molecules less than a millionth of a millimeter wide. Gimzewski, made the device--which admittedly has no immediate practical application--to demonstrate the sophistication of the techniques he and his colleagues have developed for manipulating individual molecules. **Discover**, March 1, 1997.
http://discovermagazine.com/1997/mar/thenanoabacus1088

Let's Get Small

Grades 3 and 4

(Activity reproduced with permission from microbe.world.org and the American Society of Microbiology.)

MATERIALS

Have the one of following for each team of 2 or 3 students:

- meter stick or ruler
- measuring wheel (optional)
- box sidewalk chalk
- Microbe Reference Chart (see below)
- magnifying glass

GETTING READY

- Arrange to use a large area like a parking lot, gymnasium, or sidewalk. Bigger is better for this activity.
- Several of the participants' measurements may not fit in the space available. They will still be able to compare the size differences.
- Measure off a section that is 100 meters (m) long to represent the width of a piece of human hair.
- Have each group draw a different microbe from the Figure 1. Microbe Reference Chart (below).

HOW TO START THE ACTIVITY

- Discuss the use of models with the students. Models are often used in science to compare and study subjects that are difficult to see.
- Explain that sometimes models are larger than the real item and sometimes they are smaller. Remind them of models they are familiar with such as model cars, planes, and game pieces. Explain that these models help us when the real item is very large. Other models, especially those used by scientists, are used when the real item is very small.
- Discuss different units of measurement.
- Have students pull a single piece of hair and hold it between their thumb and index finger. Explain that the space between their thumb and finger is the width of a piece of hair. Be sure they understand the difference between the width and length of the piece of hair.

WHAT TO DO

1. Take the piece of hair you looked at earlier and examine it with the magnifying glass. Does it look larger when you look at it under the glass? Examine a piece of hair from another participant with the magnifying glass. Compare its thickness, or width, to your own hair. If you were going to make a model of a piece of human hair, would you make it larger or smaller than a real piece of hair? Do you think microbes are smaller than the width of a piece of hair? If you needed to make a model of a microbe, would you make it larger or smaller than the original?
2. Lay your meter stick or ruler out in front of you. What kinds of things do you measure in meters? Viruses, bacteria, and protozoa are so small that we use much smaller measurements for them. They are even so small that we cannot use any sort of "stick" to measure them at all.
3. Move to the area set aside for your group to create models to compare the sizes of viruses, bacteria, and protozoa with the width of a human hair and a human red blood cell. The marked off area is 100 meters. It represents the width of a piece of hair. That would be the tiny space between your fingers where you held a piece of hair earlier. Select one of the microbes from the first column of the Microbe Reference Chart (See Figure 1.) and draw what you think it might look like in the marked off area. Decide how its size might compare to the width of a human hair.
4. Now go back to the Microbe Reference Chart and see what size the microbe you selected really is. Return to your drawing and make another drawing the proper size. How does it compare to your

original?

5. Circulate among the drawings made by the other groups. Compare the microbe sizes and shapes. Are you surprised by the different sizes of microbes? How could you see these microbes? Did you create a good model of microbial size? Why do viruses, bacteria, and protozoa have such different shapes? How many bacteria do you think could fit into a teaspoon?
6. Why do scientists need to use models? Why can't they just look under a microscope to see what they need to see?

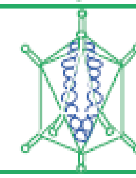
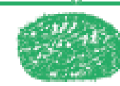
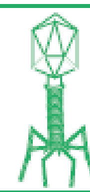
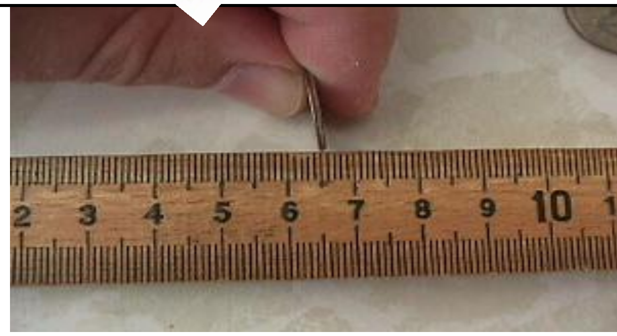
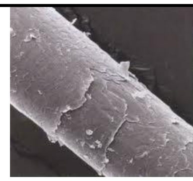
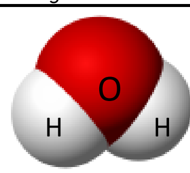
Organism	Effect on Body	Actual Size	Model Size	Shape not to scale
Poliovirus	Diseases of digestive tract, brain, and spinal cord	20 nm (0.02 µm) (0.00002 mm)	2 cm	
Adenovirus	Diseases of respiratory tract and digestive tract	90 nm (0.09 µm) (0.00009 mm)	9 cm	
Vaccina virus	Cowpox	200 nm (0.20 µm) (0.0002 mm)	20 cm	
Bacteriophage	Useful, transfers genes from one organism to another helping survival and biotechnology	60nm (0.06µm) (0.00006mm)	6 cm	
Paramecium	Common protozoa important in the food chain	200 µm (0.20 mm) (you can almost see it)	200 m (more than two football fields)	
Cilia of Paramecium	Leg-like hairs	200 nm wide (0.2 µm) (0.0002 mm)	20 cm	
Staphylococcus	Causes food poisoning	0.5 µm (0.0005 mm)	0.5 m	
Escherichia coli (E. coli)	Causes diseases and helps digestion	2.0 µm (0.002 mm)	2.0 m	
Human hair		0.1mm wide	100 m	
Human red blood cell	Carries oxygen in our bodies	10.0 µm (0.01 mm)	10 m	

Figure 1. Microbe Reference Chart.

Dangerous Friends and Friendly Enemies 47

Chart reproduced with permission from microbe.world.org, and the American Society of Microbiology.

Scale Models: (Grades 5 and older)

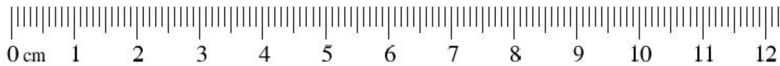
	SCALE	
cm (10mm)	1 jellybean	
mm (1/10th of a centimeter)	the thickness of one dime or 1/26th of an inch (the head of a pin is approximately two mm across)	 http://www.lcurve.org/millbill.htm
µm	Diameter of a single strand of human hair = 50-100 µm	 image of a strand of hair viewed under a microscope
nm	1 water molecule	 enlarged water molecule (illus.)

Size matters! Water suppliers use a variety of treatment processes to remove contaminants from drinking water. Usually those processes include filtration. Engineers have created filters that can block even the tiniest germ from entering our drinking water. "Pore size" in filters refers to the tiny holes through which the liquid flows. The smaller the pore size, the smaller the "particle" that is blocked from entering the liquid. Pore size determines whether or not bacteria and viruses can pass through the filter material; therefore it is important for the purposes of water purification to know the relative size of the **pathogens** –those tiny little nasty things that will make you sick - that need to be filtered out of the water.

Small, smaller, smallest. A scale model below compares the size of a pathogen relative to a size that is visible without magnification. Of the three, protozoa are the biggest, bacteria are smaller, and a virus is the smallest. A virus is smaller even than a grain of salt, much, much, much smaller! In fact, a billion times smaller than a meter. In water filters built to block those tiny pathogens, the pore size has to be even smaller than they are. Now that's super small! In fact, the pore size in LifeStraw® filters is so small it filters particles of approximately .2 µm (microns) and effectively removes at least 99.9999% of waterborne bacteria and 99.9 % of waterborne protozoan parasites. LifeStraw Family filters block 99.99% viruses also, through an even smaller 20 nm (nanometer) membrane.

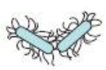
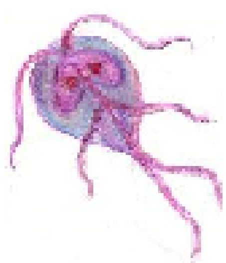
For our scale model we will use a centimeter (a size we can see) to express the size in micrometers (a size we can't see) of the various pathogens found in dirty water sources. Using our ruler, one centimeter will equal two micrometers, or µm. So, we will take an object so small that we can't see it, and enlarge it to the size of something we can see.

Our **scale-sized ruler** below measures objects in centimeters:



EXTENSION ACTIVITY: (Grade 5 and older)

Use the above scale-sized ruler and complete the model scale size in the table below and compare the different sizes of pathogens! Invent your own pathogen and include the approximate size and corresponding model size. **Model scale: 0.5 cm = 1 µm (micrometer) and 1.0 cm = 2 µm (micrometers)**

Pathogen	Group	Pathogen Name	Approximate Size of Single Unit	Model Scale Size
	Bacteria	*Escherichia* or *E.coli*	3 µm	1.5 cm
	Protozoa	*Giardia lamblia*	9 µm	
	Bacteria	*Vibrio cholerae*	2 µm	

EXTENSION ACTIVITY 2:

Have students visit the University of Utah website and use the fun interactive sliding scale to visualize and compare everyday items to different cell sizes.
http://learn.genetics.utah.edu/content/begin/cells/scale/.
OR, using the site below, have students research the different pathogens in the model scale table above. http://www.cellsalive.com/howbig.htm

SOURCES:

BioEd: *the Science of Microbes* http://www.bioedonline.org/resources/microbesIndex.cfm
Nanoscale: Nanodic.com http://www.nanodic.com/general/Nanoscale.htm
Understanding Emerging and Re-emerging Infectious Diseases:
http://science.education.nih.gov/supplements/nih1/diseases/guide/understanding1.htm