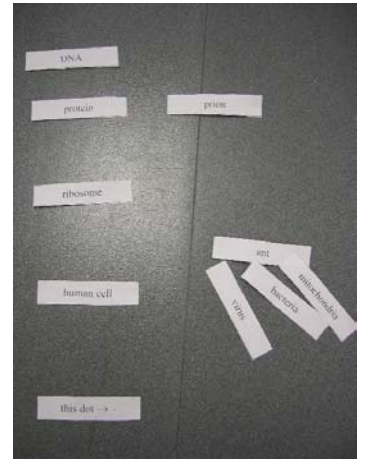


## Life Size

Explore the size and scale of microscopic biology.

### Part I: Line 'em up!

Biological interactions occur on length scales that span several orders of magnitude. Not only is it difficult for us to conceptualize things that are too small to see, it is often surprising to discover the range of sizes in the microscopic world. In this activity, students will compare the relative sizes of biological objects that can't be seen by the naked eye.



### Materials

Individual labels with the following words:

DNA, protein, prion, ribosome, virus, mitochondria, bacteria, human cell, a dot, ant

One sheet of paper

### To do and notice

Order the objects in terms of size, from smallest to largest.

Guess the actual size of each object.

If a sheet of paper represents the size of the largest object, space the other labels on the page to represent their size compared to the largest object. What's the best way to space them so that everything can fit on the page? If we wanted to see what was going on inside a virus, how much would we have to magnify it?

### What's going on?

It is often difficult to grasp the relative sizes of things at length scales beyond what we can see. By trying to space items on a page according to size, students will discover that we can only see lengths over 5 orders of magnitude and hence need a system such as a logarithmic scale to represent a range of sizes larger than this.

Since just about everything comes in a range of sizes, here are approximate for the items listed above.

DNA: 2 nm (diameter of a single strand)

protein: 5-50 nm

prion: 10 nm

ribosome: 25 nm

virus: 20-100 nm

mitochondria: 1  $\mu$ m diameter x 2  $\mu$ m length

bacteria: 1-5  $\mu$ m

human cell: 10-100  $\mu$ m

period in 24 pt font: 1 mm

ant: 5 mm

DNA	DNA	DNA
protein	protein	protein
prion	prion	prion
ribosome	ribosome	ribosome
virus	virus	virus
mitochondria	mitochondria	mitochondria
bacteria	bacteria	bacteria
human cell	human cell	human cell
this dot → .	this dot → .	this dot → .
ant	ant	ant

**Part II: What's in a microbe? A microbe by any other name would be as infectious...**  
(Adapted from "Bacteria and Viruses" activity by Linda Shore, 2001)

This activity helps students visualize the relative size and structural differences between microbes that have the potential to cause disease.

**Materials:**

- rulers and meter sticks
- scissors
- construction paper
- balloons
- glue and tape
- tooth picks
- clay
- chenille craft sticks
- other misc. disposable objects that students can use to construct a model

**To do and notice:**

1. Groups of students will be constructing scale models of different types of viruses. On the attached pages there are images of some bacteria and viruses that cause illness in humans. Each image is labeled with the diameter of the actual microbe and other information.
2. Based on the results of the activity in Part I, we see that we need a new scale to represent things that are so small. Let's make everything 1 million times bigger than it really is.

Let 1 micrometer ( $\mu\text{m}$ ) = 1 meters (m) That means 1 nanometer (nm) = 1 millimeter (mm)
--

3. Using this scale, groups of 2-3 students will work together to build a scale model of one of the viruses on the attached page with the materials on the table. Virus models should include (a) An exterior that has spikes, bumps, indentations, or other structures listed in the virus descriptions, (b) an outer shell made of "proteins", (c) an interior that enclosed the genetic material of the virus (RNA or DNA strands). If students are working in a group of 3, they should construct part of the cell membrane to which the virus might attach.
4. After the students finish their models, have each group present their virus to the rest of the class. Note the varying shapes, structures, and sizes of viruses.
5. Have each group figure out how big each of the bacteria species would be at the scale they were using.
6. A typical red blood cell is 8 micrometers in diameter. A lymphocyte is about 10 micrometers in diameter. How large would a scale model of a red blood cell be if 1 nanometer = 1 centimeter? What about a lymphocyte?

## What's Going On?

For students to understand disease processes in the body, it's helpful for them to be able to conceptualize the relative sizes of viruses (much are much smaller than the cells they invade) and bacteria (which are about the size of most cells).

### Some Background

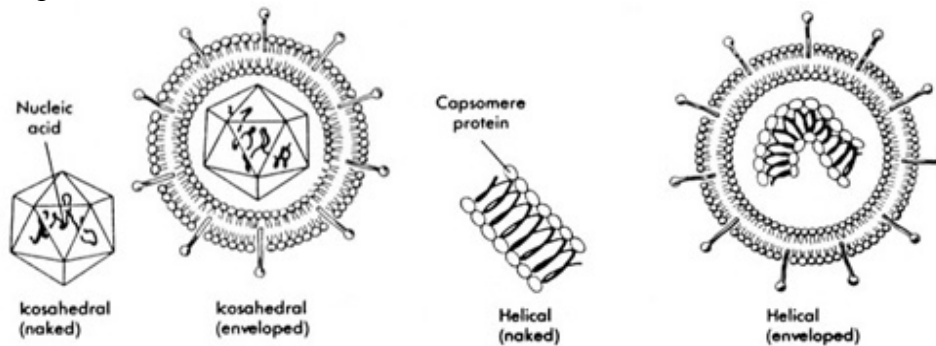
There are major differences between bacteria and viruses. Even though both can cause us to become ill, the microbes themselves are as different as night and day. In fact, viruses and bacteria differ greatly with respect to (1) size, (2) structure, and (3) method of reproduction.

#### (1) Size:

Viruses are much smaller than bacteria. If the average virus were enlarged so it was the size of an orange, an average bacterium would be about the size of a sofa.

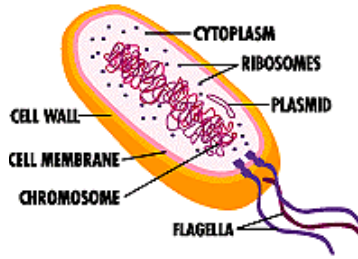
#### (2) Structure:

A virus is a very simple thing – it consists of nucleic acid (DNA or RNA) surrounded by a protein shell called a **capsid**. Some viruses are **enveloped**, which means they are surrounded by a lipid envelope, just like our cells. But even through viruses are constructed with some of the same building blocks that make up other organisms, a virus is not actually alive, it is an **obligate parasite**. On its own, an individual virus cannot reproduce nor can it combine somehow with another virus. In order to replicate, they must invade another organism and use the host's cell machinery to reproduce. Viruses come in a variety of different shapes – some are long and skinny, some are round and spiky, some are multisided, and others are brick-like in shape. Here are examples of the structure of different viruses...



Viruses are picky about their hosts – each virus has a unique organism and cell type it prefers to pirate. The surfaces of enveloped and non-enveloped viruses are usually covered with protein spikes or knobs that attach to certain receptors on different cell types. For example, some viruses infect liver cells (and cause hepatitis), some infect cells in the lung (and cause viral pneumonia) and still others infect mucous membrane cells lining your nose (and cause “colds”).

Bacteria are single-celled organisms and are living things. They are part of the kingdom called **prokaryotes**. Bacteria, like all prokaryotes, have an important characteristic – they **have no nuclei**, so, unlike eukaryotes, their DNA is not enclosed within a nucleus. Also, individual species of bacteria typically have three basic shapes: rods, spheres, and spirals. Individuals can exist alone or they can form chains, clumps, and other groups. This is an example of the structure of a bacterium ...



### (3) *Reproduction*

A virus' only mission is to make more copies of itself. But since it has no reproductive machinery of its own, it invades other organisms and, like a very bad house guest, it sponges off the reproductive resources of its host. Viral genomes are made of DNA or RNA and encode for the proteins needed to make more virions. There are an incredible variety of strategies that different viruses use to have their genetic material transcribed and translated within a host cell. These tactics include hijacking the host's DNA polymerase, bringing their own polymerase with them, or having host cell ribosomes directly translate their genome as if it were host mRNA. Retroviruses, a unique family of viruses that includes HIV, carry a protein called reverse transcriptase that copies their viral RNA genome into DNA. It then inserts the DNA version of its genome directly into the host cell's chromosome. Its genes, which say how to make more retroviruses, are transcribed and translated just as if they were one of the host cell's genes. Whatever their strategy, viruses replicate when their genes are copied over and over again and expressed to make new protein coats. New virions – all identical copies of the invader – are either released from the host cell or eventually build up to a large enough number that they burst apart the cell.

Bacteria are living things that create copies of themselves. Each bacterium has its own DNA and all the machinery needed to reproduce. **Antibiotics** are drugs that kill bacterial cells, but don't hurt human cells. That is why antibiotics are only effective for bacterial infections and not viral. Since viruses enter the host cells, any drug that destroys those cells could destroy healthy cells too. Does that mean that a virus could potentially use the reproductive engine of a bacteria to reproduce itself? Can a bacterium be infected by a virus? The answer is yes! A virus that targets bacteria is called a **bacteriophage**, and there are many known kinds. The discovery of bacteriophages may lead to new treatments for bacterial infections that don't rely on antibiotics. Imagine – one day your doctor might prescribe a virus to help you fight off a bacterial infection!

### **Resources**

(includes sources for images in this handout)

**All the Virology on the WWW:** <http://www.tulane.edu/%7Edmsander/garryfavweb.html>

The name says it all.

**The Big Picture Book Of Viruses:**

[http://www.tulane.edu/~dmsander/Big\\_Virology/BVHomePage.html](http://www.tulane.edu/~dmsander/Big_Virology/BVHomePage.html)

No kidding – this is a virtual library of literally thousand of known viruses. Some are computer models, but others are actual electron microscope images!

**Microbial World:** <http://www.bact.wisc.edu/themicrobialworld/AnimalViruses.html> and  
**Textbook Of Bacteriology:** <http://www.textbookofbacteriology.net/>  
References on viral and bacterial basics from Ken Todar, University of Wisconsin, Madison.

**Cells Alive:** <http://www.cellsalive.com/howbig.htm>  
A great interactive tool for studying the size and structure of various microbes.

**Stalking The Mysterious Microbe:** <http://www.microbe.org/index.html>  
A great overview of the difference between microbes. Has great student activities, too.

**The Microbe Zoo:** <http://commtechlab.msu.edu/sites/dlc-me/zoo/>  
A fabulous virtual “zoo” where you can take trips to microbes (especially bacteria) living in a variety of different environments. Perfect for your students!

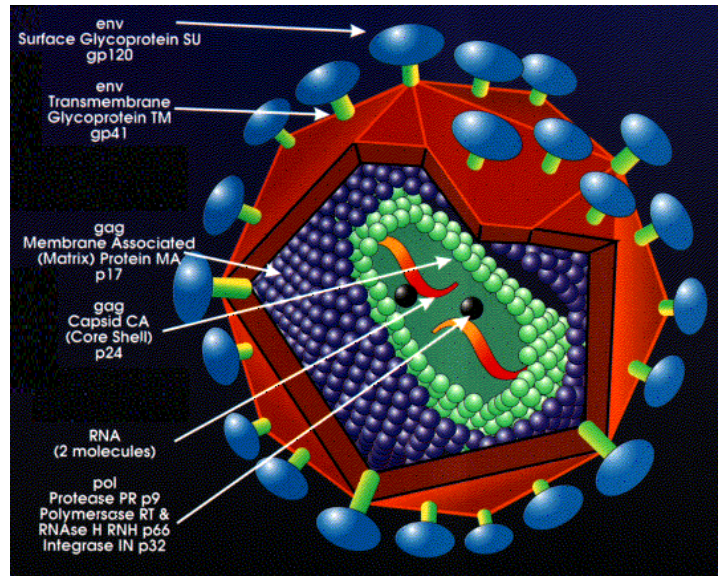
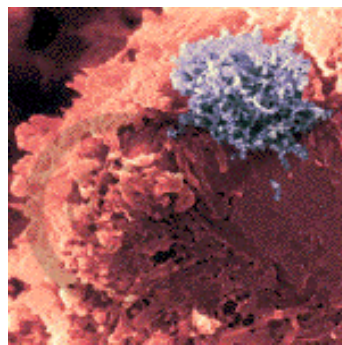
**How Your Immune System Works:** <http://www.howstuffworks.com/immune-system.htm>  
A very comprehensive tutorial on how your immune system functions.

Thanks to Linda Shore and Karen Kalumuck for their help creating these activities!

# Some Viruses

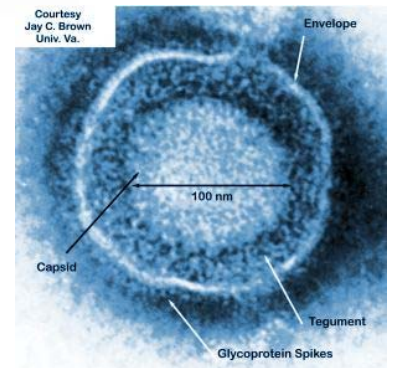
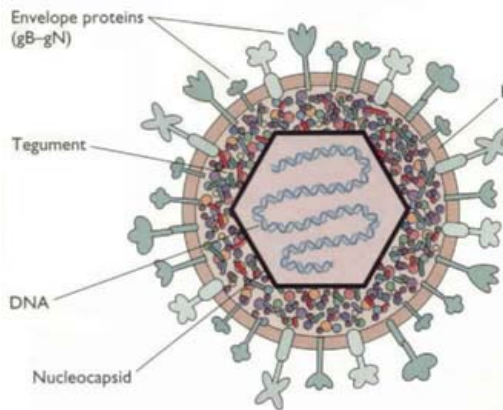
## Human Immunodeficiency Virus (HIV)

Shape: Spherical  
 Diameter: 100 nm  
 Spikes: 8 nm  
 Inside: two single-stranded RNA genomes  
 Other: HIV and other retroviruses reverse transcribe their RNA genome into a DNA genome that gets inserted into the host's own DNA



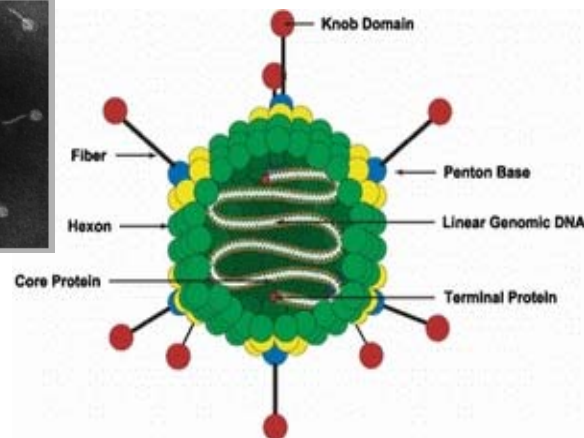
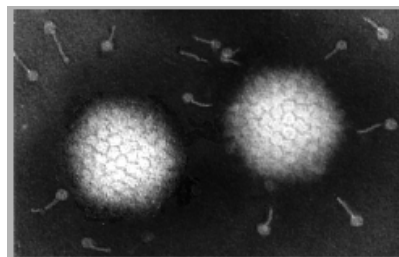
## Herpes Simplex Virus-1 (causes cold sores)

Shape: Spherical  
 Diameter: 200 nm  
 Capsid diameter: 100 nm  
 Inside: double-stranded DNA  
 Other: Other herpesviruses can cause genital sores, chicken pox, shingles, and mononucleosis.



## Adenovirus

Shape: Spherical  
 Diameter: 80 nm  
 Spikes: 9 nm  
 Inside: double-stranded DNA  
 Other: Used in clinical trials for gene therapy against cancer.



### Influenza virus

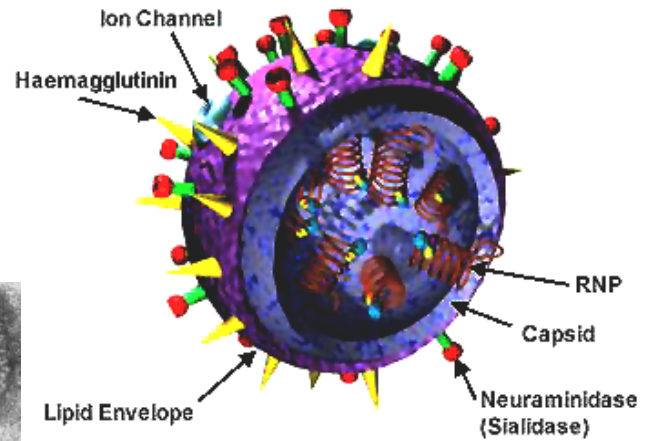
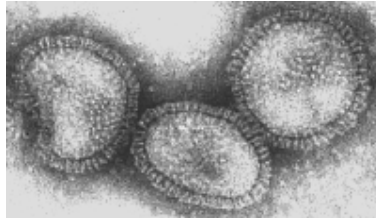
Shape: Spherical

Diameter: 100 nm

Spikes: 10-14 nm

Inside: single-stranded RNA in 8 segments

Other: Has likely killed more humans than any other virus.



### Ebola virus

Shape: thread-like filament

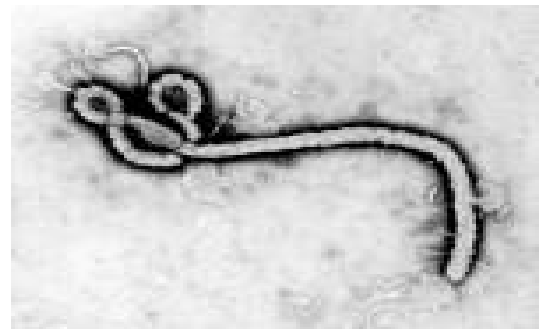
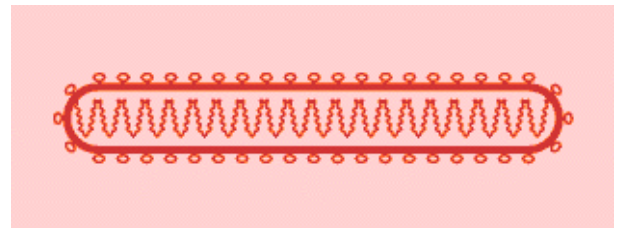
Diameter: 80 nm

Length: 1000 nm

Spikes: 10 nms long, 10 nms apart

Inside: single-stranded RNA

Other: A viral polymerase directly transcribes the RNA genome into mRNA read by the host cell. Ebola is classified as a Biosafety Level 4 agent since it acts very quickly and mortality rates are 50-90%.



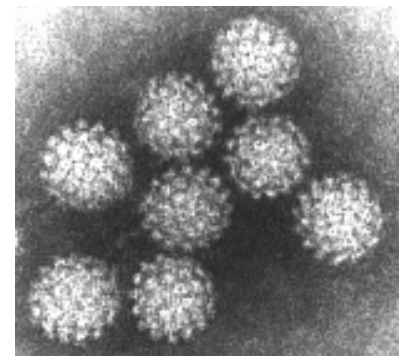
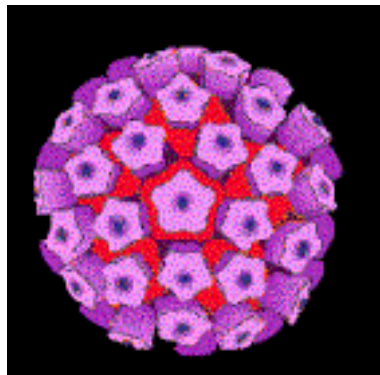
### Papillomavirus (can cause some cancers)

Shape: Spherical

Diameter: 45 nm

Spikes: 2 nm

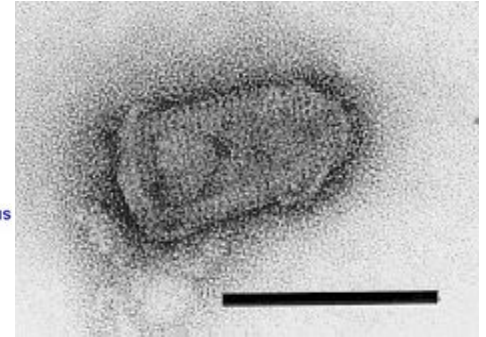
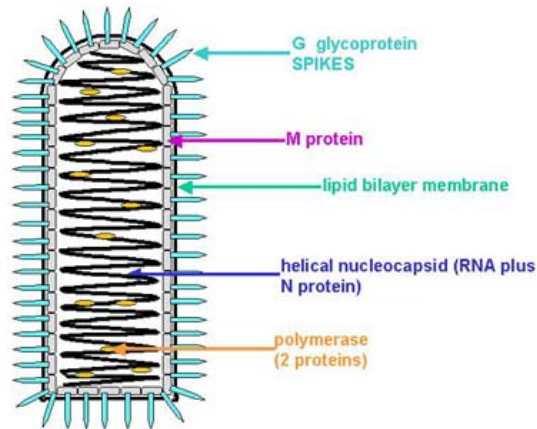
Inside: double-stranded DNA





### Rabies (rhabdovirus)

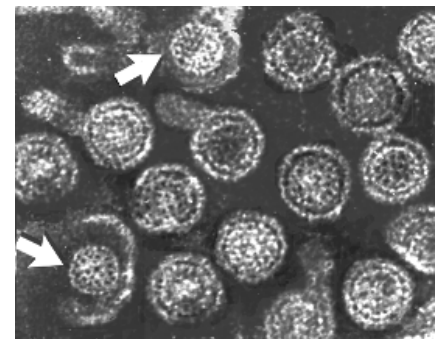
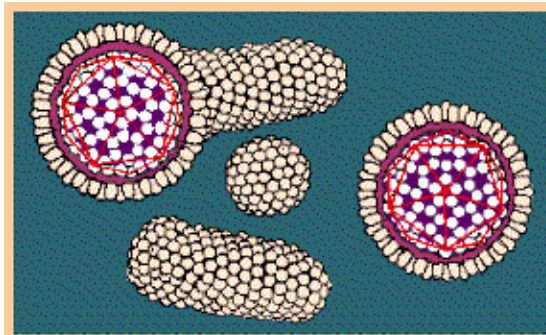
Shape: Bullet-like  
Length: 180 nm  
Width: 75 nm  
Spikes: 9 nm  
Inside: single-stranded RNA



100 nm

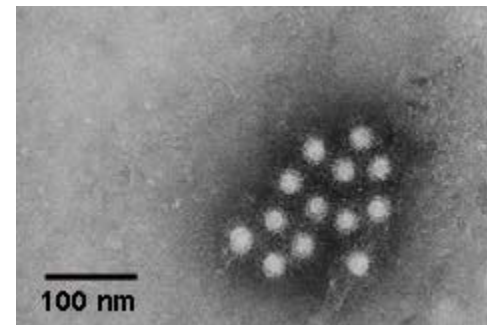
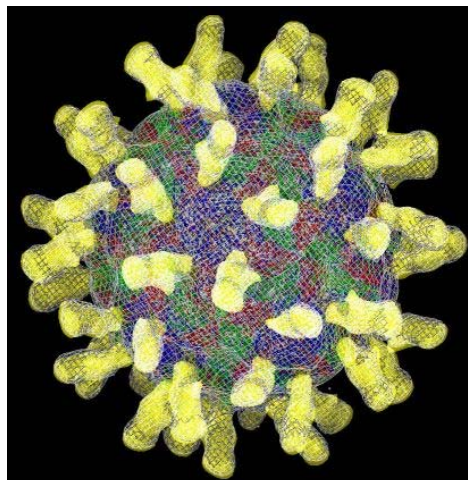
### Hepatitis B (Hepadnaviridae)

Shape: Cocktail weiner  
Capsid diameter: 27 nm  
Length: 42 nm  
Tail diameter: 22 nm  
Spikes: (none)  
Inside: partially double and single-stranded DNA  
Other: Concentric rings of proteins, 7 nm thick envelope



### Rhinovirus (200 types cause colds)

Shape: Spherical  
Diameter: 20 nm  
Spikes: 8-10 nm  
Inside: single-stranded RNA  
Other: A 20-sided structure with depressions on its protein surface.



100 nm

## Some Bacteria

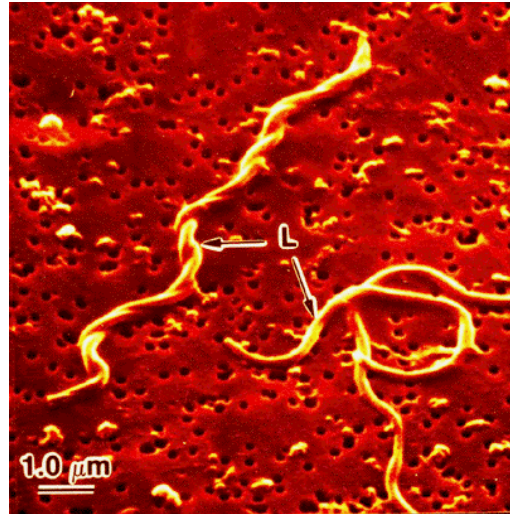
### ***Borrelia burgdorferi* (Lyme Disease)**

Shape: string-like, sprial

Type: spirochete

Length: 15  $\mu\text{m}$  (15,000 nm)

Width: 0.3  $\mu\text{m}$  (300 nms)



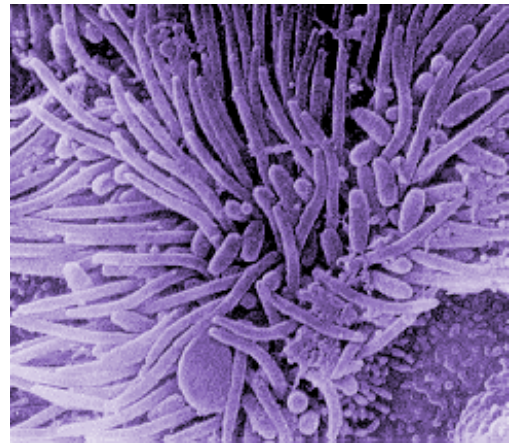
### ***Bordetella pertussis* (Whooping Cough)**

Shape: long oval rod

Type: rods

Length: 1  $\mu\text{m}$  (1000 nm)

Width: 0.3  $\mu\text{m}$  (300 nm)



### ***E. Coli* (intestinal infection)**

Shape: long oval rod

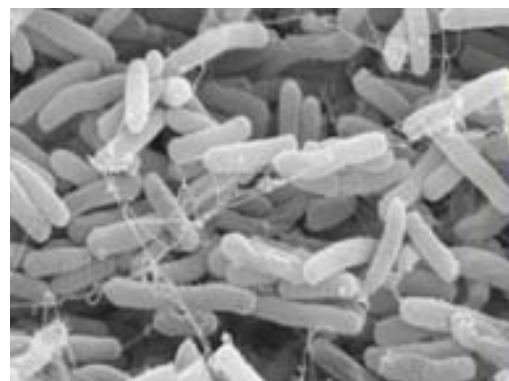
Type: rods

Length: 1  $\mu\text{m}$  (1000 nm)

Width: 0.2  $\mu\text{m}$  (200 nm)

Other: Not all strains of *E. coli* are bad for humans.

Beneficial *E. coli* make vitamin K for us.



**Helicobacter Pylori (stomach ulcers)**

Shape: long rod

Type: rod

Length: 3  $\mu\text{m}$  (3000 nm)

Width: 1/2  $\mu\text{m}$  (500 nm)



**Streptococcus (“Strep” Throat)**

Shape: round

Type: sphere

Diameter: 1  $\mu\text{m}$  (1000 nm)

Other: This is an image of two bacteria just after cell division. You might notice tiny protein fibers (about 50 nanometers long) coming off the bacterial surface.

