# Germs: Viruses, Bacteria, and Fungi

*Drs. Foster & Smith Educational Staff*

What is a germ?

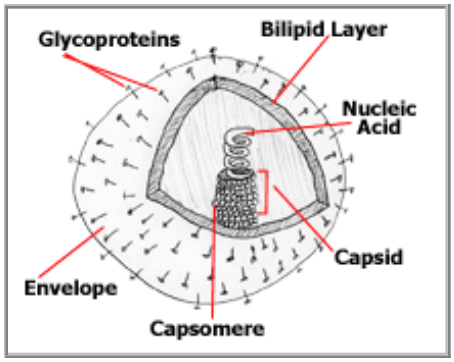
The term 'germ' actually refers to any microorganism, especially those microorganisms that cause disease. Included in this category are certain viruses, bacteria, and fungi. What is the difference between these three types of microbes? Which ones cause which diseases, and should they be treated differently? Because viruses, bacteria, and fungi cause many well-known diseases, it is common to confuse them, but they are as different as a mouse and an elephant. A look at the size, structure, reproduction, hosts, and diseases caused by each will shed some light on the important differences between these germs.

What is a virus?

Viruses are very tiny, simple organisms. In fact, they are so tiny that they can only be seen with a special, very powerful microscope called an "electron microscope," and they are so simple that they are technically not even considered "alive." There are six characteristics of all living things:

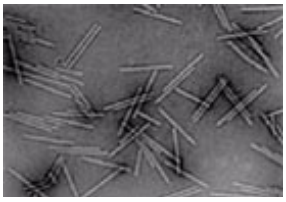
- Adaptation to the environment
- Cellular makeup
- Metabolic processes that obtain and use energy
- Movement response to the environment
- Growth and development
- Reproduction

A virus is not able to metabolize, grow, or reproduce on its own, but must take over a host cell that provides these functions; therefore a virus is not considered "living." The structure of a virus is extremely simple and is not sufficient for an independent life.




Structure: Each virus is made up of two elementary components. The first is a strand of genetic material, either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). Unlike living cells, viruses will have either DNA or RNA, but not both. The genetic material is a blueprint for determining the structure and behavior of a cell. In a virus, a protein coat called a "capsid" surrounds the nucleic acid. This coat serves to protect the nucleic acid and aid in its transmission between host cells. The capsid is made of many small protein particles called "capsomeres," and can be formed in three general shapes – helical, icosahedral (a 20-sided figure with equilateral triangles on each side), and complex. Some of the more advanced viruses have a third structure that surrounds the capsid. This is called the "envelope" and is composed of a bilipid layer, like the membrane on a cell, and glycoproteins, which are protein and carbohydrate compounds. The envelope serves to disguise the virus to look like a 'real' cell, protecting it from appearing as a foreign substance to the immune system of the host. The structure of a virus is closely related to its mode of reproduction.

Reproduction: A virus's sole purpose is to reproduce, but it needs a host cell to do so. Once a suitable host cell has been located, the virus attaches to the surface of the cell or is ingested into the cell by a process called "phagocytosis." It then releases its genetic material into the cell, and essentially shuts down normal cell processes. The cell stops producing the proteins that it usually makes and uses the new blueprint provided by the virus to begin making viral proteins. The virus uses the cell's energy and materials to produce the nucleic acid and capsomeres to make numerous copies of the original virus. Once these 'clones' are assembled, the virus causes the host cell to rupture, releasing the viruses to infect neighboring cells.

| Viral Shapes | | |
|---|---|---|
| **Name** | **Basic Shape** | **Example (electron micrograph)** |
| Helical | |  |



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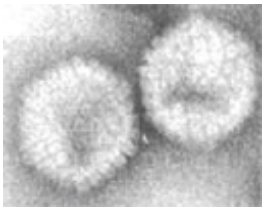
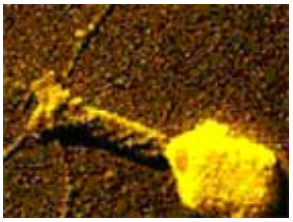
| | | |
|---|---|---|
| | |  Tobacco mosaic virus |
| Icosahedral | |  Herpes simplex |
| Complex | |  T-4 Bacteriophage |

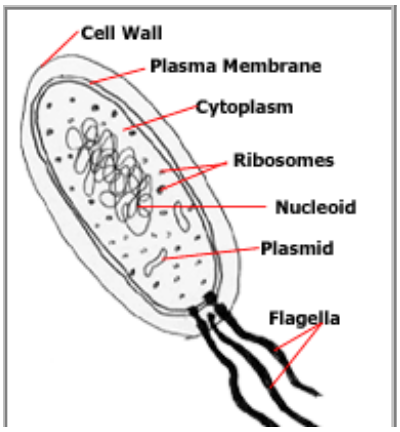
Hosts and resistance: Viruses are known to infect almost any kind of host that has living cells. Animals, plants, fungi, and bacteria are all subject to viral infection. But viruses tend to be somewhat particular about what type of cells they infect. Plant viruses are not equipped to infect animal cells, for example, though a certain plant virus could infect a number of related plants. Sometimes, a virus may infect one creature and do no harm, but cause havoc when it gets into a different but closely related creature. For example, deer mice carry the Hantavirus without much noticeable effect on the rodents, but if Hantavirus infects a person, it causes a dramatic, and frequently deadly, disease marked by excessive bleeding. Most animal viruses, however, are species specific. This means, they will infect one species of animal. For instance, feline immunodeficiency virus (FIV) will only infect cats; human immunodeficiency virus (HIV) will only infect humans.

What does the host do in order to fight off the invasion of a virus? Any foreign substance introduced into the body produces what is called an "immune response." Through this process, the host's body produces antibodies. Antibodies are substances that will destroy an invader and prevent the host from contracting the same disease again in the future. Antibodies are specific to each invader, and each time that a new disease is contracted, a new set of antibodies will have to be manufactured. This process of making antibodies specific to the infecting virus takes about seven days. In the meantime, the cell infected with a virus produces small proteins called "interferons." These interferons are released within three to five days and function to prevent infection in neighboring cells until the antibodies can be made. Needless to say, research on the benefit of interferons in viral treatment is underway, but the actual mechanism of an interferon is not entirely known. There are some antiviral medications that can be administered in the case of viral infection, but the body's immune system is largely relied upon to fight off these kinds of infections.

What are bacteria?

Bacteria are very different from viruses. First of all, bacteria are much larger in size. The largest virus is only as big as the very smallest bacterium (singular for bacteria). But bacteria are still microscopic and cannot be seen with the naked eye. They are so small that the sizes of bacteria are measured in micrometers (10,000 micrometers = 1 centimeter). By comparison, the head of a pin is about 1000 micrometers wide. Though more complex than a virus, the structure of a bacterium is still relatively simple.

Structure: Most bacteria have an outer, rigid cell wall. This provides shape and support. Lining the inside of the cell wall is a plasma membrane. This is like the membrane found around all living cells that provides both a boundary for the contents of the cell and a barrier to substances entering and leaving. The content inside the cell is called "cytoplasm." Suspended in the cytoplasm are ribosomes (for protein synthesis), the nucleoid (concentrated genetic material), and plasmids (small, circular pieces of DNA, some of which carry genes that control resistance to various drugs). All living cells have ribosomes, but those of bacteria are smaller than those found in any other cell. Some antibacterial medicines have been made that attack the ribosomes of a bacterium, leaving it unable to produce proteins, and therefore killing it. Because the ribosomes are different, the cells of the host are left unharmed by the antibiotic. Other antibiotics target certain portions of the cell wall. Some bacteria have long, whip-like structures called "flagella" that they use for movement.




Bacteria can occur in three basic shapes:



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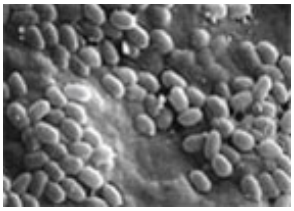
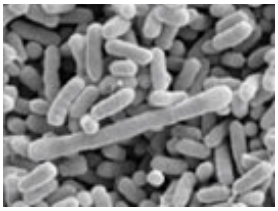
- Coccus (spheres)
- Bacillus (rods)
- Spirillum (spirals)

| Bacterial Shapes | | |
|---|---|---|
| **Name** | **Basic Shape** | **Example (electron micrograph)** |
| Coccus (sphere) | |  *Staphylococcus aureus* |
| Bacillus (rod) | (starting to divide) |  *Salmonella typhi* |
| Spirillum (spiral) | | *Campylobacter jejuni* |

Reproduction: Bacteria undergo a type of asexual reproduction known as "binary fission." This simply means they divide in two, and each new bacterium is a clone of the original – they each contain a copy of the same DNA. Bacteria can reproduce very quickly. In fact, in an ideal laboratory situation, an entire population of bacteria can double in only twenty minutes. At this enormous growth rate, one bacterium could become a BILLION (1,000,000,000) bacteria in just 10 hours! Luckily, there are neither enough nutrients nor space available to support this rapid growth, or the world would be overrun with bacteria. As it is, bacteria can be found living on almost any surface and in almost any climate in the world.

Hosts and resistance: As stated, bacteria can grow nearly everywhere. These microbes have been around for billions of years because they are able to adapt to the ever-changing environment. They can find a home anywhere, and some of them live in places where it was once thought 'nothing' could survive. There are bacteria in the soil, at the depths of the ocean, living in the mouth of volcanoes, on the surfaces of teeth, and in the digestive tracts of humans and animals. They are everywhere and are very numerous. For example, a single teaspoon of soil is said to contain at least 1,000,000,000 bacteria. Most often, bacteria are thought of as a bad thing, but most bacteria are not pathogenic (disease-causing). In fact, many bacteria are very helpful to us. There are species that decompose trash, clean up oil spills, and even produce medicines. The few species that are pathogenic, however, give the rest of the bacteria a bad name.

Pathogens are rated on two characteristics – invasiveness and toxigenicity. Invasiveness is a measure of the bacterium's ability to grow inside the host, and toxigenicity measures the capacity of the bacterium to produce toxins (chemical substances that cause damage to the host). The combination of these two characteristics gives the final rating of the bacteria's virulence (ability to cause disease). A species does not necessarily need to have both high invasiveness and high toxigenicity to be rated highly virulent. One or the other can be high enough to cause the bacterium to be very virulent. For example, the bacterium *Streptococcus pneumoniae* (causes pnuemonia) does not produce a toxin, but it is so highly invasive that it causes the lungs to fill up with fluid from the immune response. In contrast, the bacteria *Clostridium tetani* (causes tetanus) is not very invasive, but it produces a potent toxin that causes damage at a very small concentration.

How does the body fight off a bacterial infection? Again, the body mounts an immune response to the foreign invader, producing antibodies for immediate help and future protection. Since this process takes about a week, antibiotics are usually



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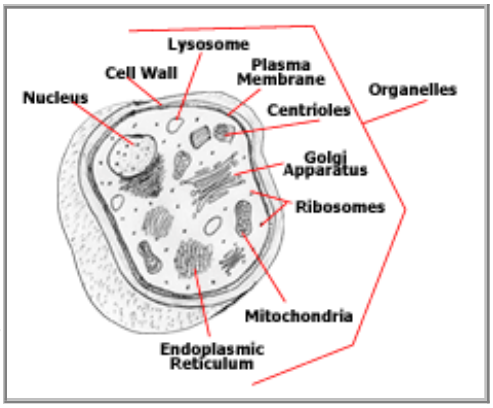
employed in the meantime. Antibiotic drugs are usually only successful in treating bacterial infections, not viral, or fungal infections. Professionals are becoming concerned that the overuse of antibiotics when they are not needed may lead to the mutation of normal bacteria into antibiotic-resistant bacteria. Bacteria are very resilient and have already developed resistance to many antibiotics. Another concern is that the helpful bacteria that live in the digestive tract may also fall prey to the antibiotics. These bacteria, known as "natural flora," produce vitamins that the host organism uses and needs, as well as help in the digestion of food.

What is a fungus?

Fungi (plural for fungus) are different from both viruses and bacteria in many ways. They are larger, plant-like organisms that lack chlorophyll (the substance that makes plants green and converts sunlight into energy). Since fungi do not have chlorophyll to make food, they have to absorb food from whatever they are growing on. Fungi can be very helpful – brewing beer, making bread rise, decomposing trash – but they can also be harmful if they steal nutrients from another living organism. When most people think of fungi they picture the mushrooms that we eat. True, mushrooms are important fungi, but there are other forms such as molds and yeasts.




Structure: The main identifying characteristic of fungi is the makeup of their cell walls. Many contain a nitrogenous substance known as "chitin," which is not found in the cell walls of plants, but can be found in the outer shells of some crabs and mollusks. Most fungi are multicellular (made up of many cells), with the exception of the yeasts. The cells make up a network of branching tubes known as "hyphae," and a mass of hyphae is called a "mycelium." The insides of the cells look a little different than bacterial cells. First of all, the genetic material is gathered together and enclosed by a membrane in what is called the "nucleus." Also, there are other structures called "organelles" in the cell that help the cell to function, such as mitochondria (converts energy), endoplasmic reticulum (ER) (makes complex proteins), and other organelles. The Golgi apparatus forms many types of proteins and enzymes. Lysosomes contain enzymes and help digest nutrients. Centrioles are necessary for proper division of the cell. Both bacteria and fungi have ribosomes, but those of the bacteria are smaller in size and also reproduce differently.

Reproduction: Fungi can reproduce in multiple ways depending upon the type of fungus and the environmental conditions:

- Budding
- Fragmentation
- Production of spores asexually
- Production of spores sexually

Budding occurs in yeasts, which are only made up of one cell. Budding is somewhat similar to binary fission in bacteria, in that the single cell divides into two separate cells.

Fragmentation is a mode of reproduction used by those fungi that form hyphae. During fragmentation, some of the hyphae break off and simply start growing as new individuals.

Spores are tiny single cells that are produced by fungi that have hyphae. They can be produced asexually by a process in which the tips of the hyphae form specially encased cells – the spores. Some fungi also produce spores sexually. Two types of special cells called "gametes" are produced. One of each type unite to produce a new individual spore. Spores are tiny single cells that are usually very resistant to environmental changes. They can remain dormant for long periods of time until the conditions are right for them to develop into mature individuals.

Hosts and resistance: Fungi are heterotrophs, meaning that they secrete digestive enzymes and absorb the resulting soluble nutrients from whatever they are growing on. For this reason they are great decomposers in the ecosystem, but they can also cause problems when they begin to absorb nutrients from a living organism. They most commonly are breathed in or have contact with the skin. If conditions are right and they start to reproduce, disease can result. Some antifungal agents are available to treat these infections, but it has been much more difficult for scientists to create successful antifungal drugs than antibacterial drugs because the cells of fungi are much closer in structure to the cells of animals than are bacteria. In creating drugs, it is hard to find an agent that will kill the fungal cells and leave the animal cells unharmed. The most successful drugs that have been created prevent the formation of chitin, and therefore prevent the fungus from creating new cell walls and spreading. The cell wall is the only structure that is not shared by the animal and fungal cells. Other drugs bind to specific fungal proteins and prevent growth. Unfortunately, many of the drugs available are only fungistatic, meaning they can only prevent further growth rather than fungicidal, meaning to kill the fungus. Many of the drugs used for serious fungal infections have potentially toxic side effects.

Which diseases are which?

When a pet or a human contracts an infection, it is important to understand how the disease works, and where it came from. This is important for treatment, as well as to protect other animals or humans from becoming ill. The following table



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categorizes some common diseases in various species of animals as viral, bacterial, or fungal.

| **Germs – Causing Common Diseases or Infections in Various Animal Species** | | |
|---|---|---|
| **Viral** | **Bacterial** | **Fungal** |
| **Humans** | **Humans** | **Humans** |
| Influenza (flu) | Tuberculosis | Athlete's foot |
| Measles | Whooping cough | Candidiasis (thrush) |
| Rhinovirus (cold) | Strep throat | Cryptococcosis |
| **Dogs** | **Dogs** | **Dogs** |
| Parvovirus | Lyme disease | Blastomycosis |
| Distemper | Leptospirosis | Malassezia (yeast infection) |
| Hepatitis | Brucellosis | Histoplasmosis |
| **Cats** | **Cats** | **Cats** |
| Feline leukemia | *Mycoplasma haemofelis*, formerly *Haemobartonella* | Coccidioidomycosis |
| Panleukopenia | Plague | Ringworm |
| **Fish** | **Fish** | **Fish** |
| Lymphocystis | Tuberculosis | Cotton wool disease |
| Spring Viremia of Carp (SVC) | Vibriosis | Egg fungus |
| **Birds** | **Birds** | **Birds** |
| Newcastle disease | Psittacosis | Aspergillosis |
| Psittacine Beak & Feather | Campylobacter infections | Candidiasis |
| **Ferrets** | **Ferrets** | **Ferrets** |
| Aleutian disease | Helicobacter | Crytococcosis |
| Epizootic Catarrhal Enteritis | *Clostridium perfringens* | Coccidiomycosis |
| **Reptiles** | **Reptiles** | **Reptiles** |
| Caiman pox | Salmonella | Candidiasis |
| Iguana herpesvirus | Red leg disease | *Aspergillus* |
| **Small Pets** | **Small Pets** | **Small Pets** |
| Viral hemorrhagic disease | Pasteurella (snuffles) | Ringworm |



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| | | |
|---|---|---|
| Mouse pox | Enterotoxemia | Histoplasmosis |



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