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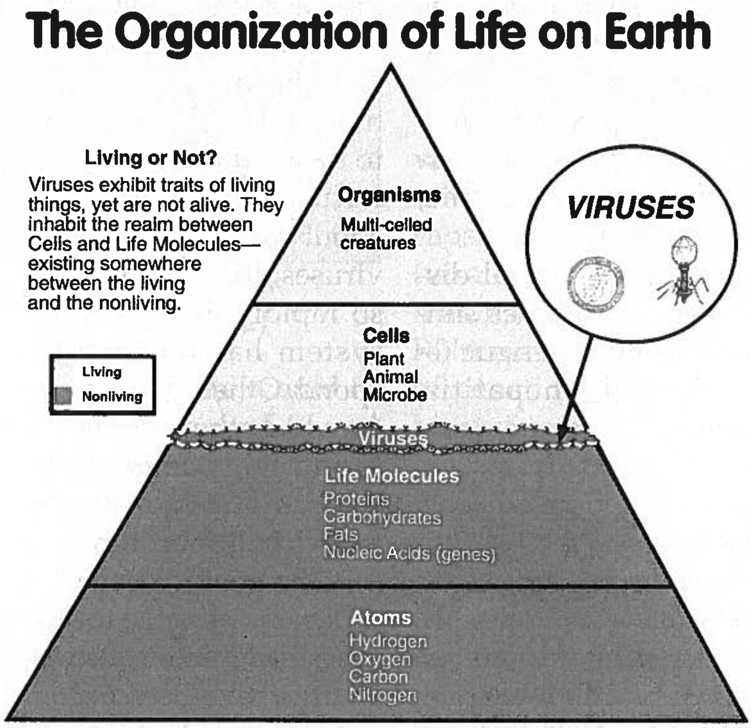
VIRUSES: PARISITIC PARTICLES



The chart above shows the organization of life on Earth. **(See page 32 for full-size chart.)**

We have identified 92 kinds of atoms (elements), but only four play a major role in life. These atoms are arranged into life molecules—proteins for building structures, carbohydrates for quick energy, fats for stored energy, and nucleic acids for regulation and control.

The molecules of life are, in turn, arranged into living units known as cells. Animal and plant cells contain the same basic parts, but plant cells possess several additional structures that animal cells do not—green "food factories" called chloroplasts and rigid box-like coverings called cell walls. Microbial cells (bacteria) lack many cell parts and will be explained in more detail further on in this book.

Viruses—powerful particles that can have a tremendous impact on living things even though they themselves are not alive—have changed the course of human history numerous times.

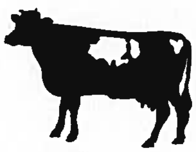
The great influenza pandemic of 1918–9 resulted in the death of an estimated 20 million people worldwide—more than were killed during all of World War I.

In our own time, AIDS hysteria has shaken legal, social, and medical tenets to their very core.

Effects of Viruses

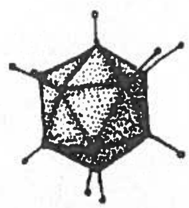
Viruses normally have harmful effects on their host cells and are associated with disease. Viral plant diseases of tobacco, cucumber, tomato, lettuce, cabbage, potato, sugar cane—along with potato leaf curl, curly top in beets, and aster yellow—cause great loss of crops and food each year.

Animals also suffer. Many livestock and other economically important animals as well as pets perish each year from such diseases as hog cholera, foot-and-mouth disease, distemper, rabies, swine flu, carp pox, myxomatosis in rabbits, Newcastle disease in fowl, fowl leukemia, and psittacosis in birds.



Humans are plagued by such viral diseases as smallpox, chicken pox, herpes simplex I and II, rabies, yellow fever, dengue fever, rubella, influenza, colds, hepatitis, mumps, hanta, and certain types of cancer.

Disease occurs as viruses damage and kill the cells they invade. However, our bodies are not defenseless against viruses. Viruses must have a weakness or our immune systems could not attack and defeat them. In some cases, our immune system recognizes foreign invaders and manufactures antibodies to attack them. Scientists discovered they could fight certain viral infections by boosting the natural workings of our immune system. Vaccines containing a weakened strain of a virus were created. The vaccine was then injected, stimulating the immune system's manufacturing of antibodies that remain in the blood to attack any further invasions by that specific type of virus. Vaccines have been effective against viruses like polio and smallpox.



Common Cold Virus

Viral infections must run their course once they occur because no cure has yet been invented. Antibiotics are not effective against viruses because the antibiotics are looking for something viruses don't have: life processes. Scientists have developed a few drugs to slow viral replication, but natural immunity is still about our only defense. Some viruses, like Ebola, multiply so rapidly that the immune system has no time to respond. Others, like herpes, lie dormant in cells to which the immune system does not respond. Still others, like influenza and cold viruses, mutate quickly, making vaccines ineffective in a short time.

Flu Virus

One positive aspect of viruses is that because it is possible to study the genes that viruses bring into cells when they infect them, viruses have been extremely valuable in genetic research. Many of the major breakthroughs in genetics and molecular biology have been made by studying viral genes. Furthermore, attempts are being made to correct genetic defects by using human-created viruses to insert proper-functioning genes in cells.

(See related student activities p. 17–25)

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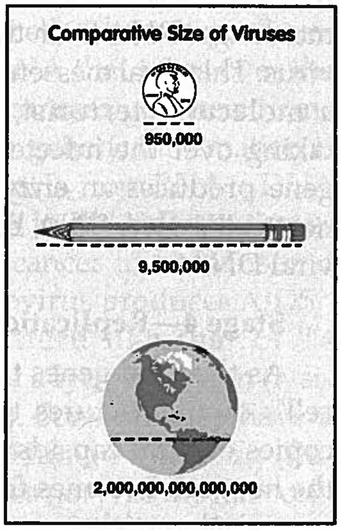
Characteristics of Viruses

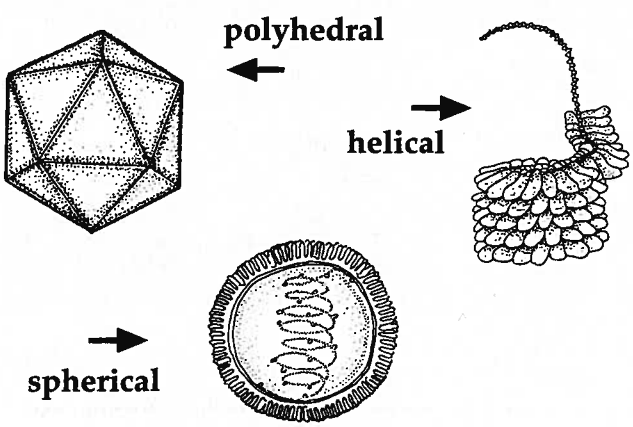
As virologists delve deeper into the mysteries of viruses, the following facts have emerged:



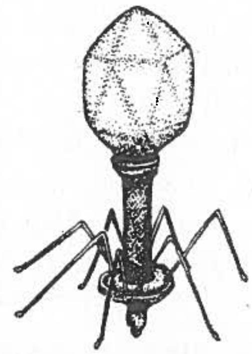
(See page 33 for full-size chart.)

- **Size**—Viruses are so small that special size scales have been developed to measure them. Virologists describe their size in nanometers (1 nanometer [nm] = one billionth of a meter). To help us to visualize such small sizes, let us compare the size of viruses to the sizes of common objects: 950,000 viruses end-to-end would fit across a penny, 9,500,000 viruses end-to-end would fit along the length of a new pencil, and to lay viruses end-to-end around the world at the equator would require about two quadrillion viruses. Ponder this: If all the people in the United States were shrunk to the size of viruses, they would fit on the eraser ends of two pencils with plenty of room left over for future generations.

- **Shape**—Viruses come in a variety of shapes, including helical, polyhedral, and spherical.



The most complex-looking viruses are the **bacteriophages**, which, as their name suggests, attack bacteria. Resembling little lunar spacecraft, these tiny protein landers have a hollow modular head and spindly legs for grasping the surface of bacteria.



- **Structure**—Whatever their shape, all viruses have the same basic structure. They are nothing more than a protein coat (called a capsid) surrounding a tiny strand(s) of DNA (viral genes) or RNA (chemical codes for making new viruses). The strands of DNA or RNA may be single or double, but the amount of genetic information they carry is small. Most viruses have only about 10 genes; even the largest viruses have only about 100 genes. By comparison, an *E. coli* bacterium has about 2,000 genes, and a human has at least 100,000 genes. Viruses contain no cell parts and are not cellular in nature. Furthermore, they do not require energy. Hence, they take in or make no food and give off no waste products. By these definitions, viruses are not living things.

- **Specificity**—Usually, specific viruses will infect specific organisms. For example, a plant virus cannot infect an animal. There are some viruses that will infect only humans. Others, such as the rabies virus, infect all mammals and some birds. Still others infect only cold-blooded animals. Some infect only closely related species of animals. For example, viruses that infect mice may infect rats. Even the tiniest of creatures, bacteria, many of whom are themselves disease-causers, are infected by bacteriophages (phage from Greek *to eat*).

• **Replication**—Because viruses are not alive, the terms replication and / or duplication are used instead of reproduction to describe the production of new virus particles.

New virus particles are produced when a virus invades a host cell and uses the enzymes and organelles of that cell to make new viruses. They are, therefore, **obligate intracellular parasites,** which means they require a host cell to replicate. The replication of viruses occurs in stages. The T4 bacteriophage will serve to illustrate.

Stage 1—Attachment of host

A virus is activated by chance contact with the right kind of host cell. In the case of T4, molecules on the tail fibers have the proper shape to fit into molecules on the surface of a bacterium. This molecular matching process explains why most viruses recognize and infect only one kind of host cell.

Stage 2—Infection of host

The virus then injects its DNA into the host cell. In most cases, the complete virus particle itself never enters the cell. However, in some cases the whole virus enters, and then the capsid is destroyed.

Stage 3—Sabotage of host's DNA

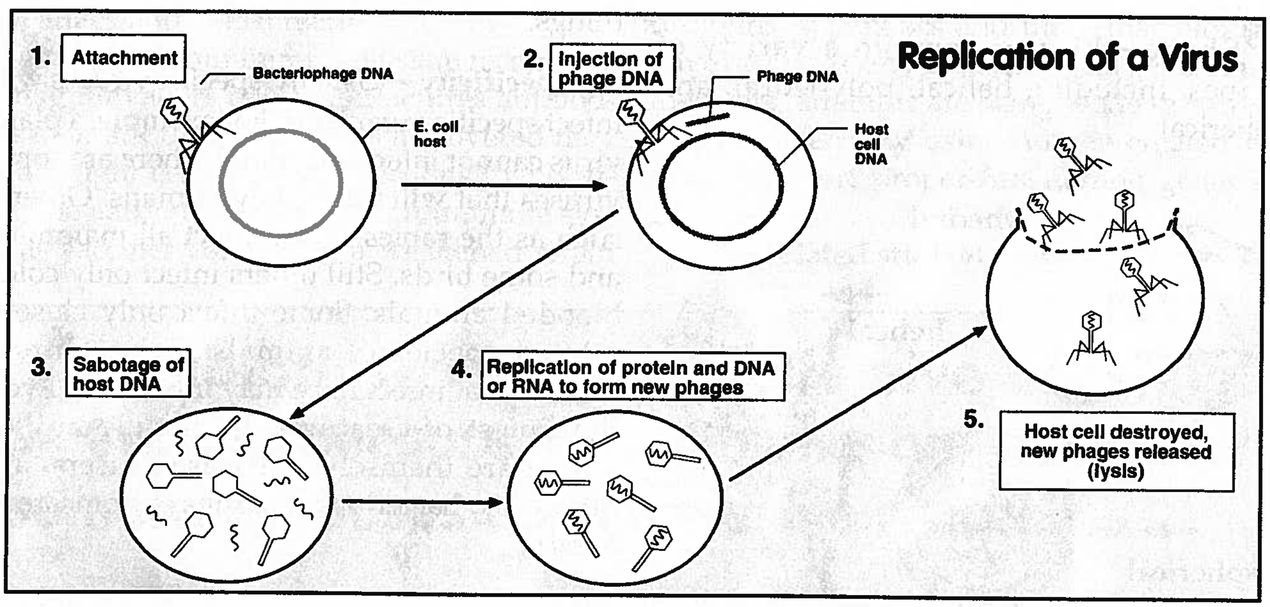
After entering the host cell, the DNA of the virus goes into action. In most cases, the host cell cannot tell the difference between its own DNA and the DNA of the virus. Consequently, the very same enzyme that makes messenger RNA from the cell's DNA begins to make messenger RNA from the DNA (genes) of the virus. This viral messenger RNA now acts like a molecular terrorist, shutting down and taking over the infected host cell. One viral gene produces an enzyme that destroys the host cell's own DNA but does not harm the viral DNA!

Stage 4—Replication of virus

As the viral genes take over, they use the cell's own structures to make thousands of copies of viral capsids and viral DNA. Soon the host cell becomes filled with hundreds of new viral particles.

Stage 5—Release of virus

The host cell is instructed to make an enzyme that digests the cell wall from the inside. The cell bursts open, releasing hundreds of new viruses. Within three-quarters of an hour as many as 200 new viral particles may burst forth from the microbe. These young phages drift off to infect more bacteria; the unfortunate host, blown to bits, rapidly dies.



(See page 34 for full-size chart.)

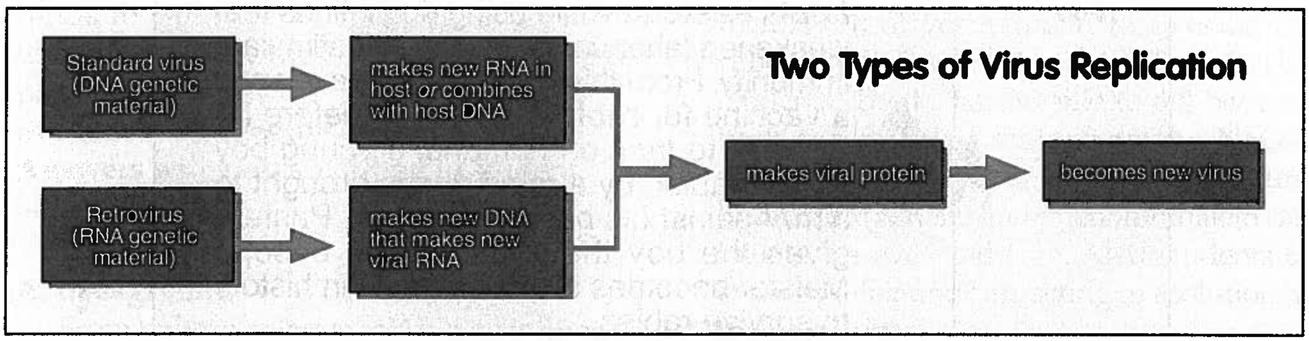
One group of viruses, known as **retroviruses,** do things differently. Retroviruses contain RNA as their genetic material. When retroviruses infect a cell, they produce a DNA copy of their genes. This DNA is inserted into the DNA of the host cell, where it produces the viral messenger RNA that takes over the cell machinery. Retroviruses get their name from the fact that their genetic information is copied backwards—that is, from RNA to DNA rather than from DNA to RNA. Retroviruses cause some types of cancer in humans and animals, and one retrovirus produces AIDS.

A replication pattern like that of T4 bacteriophage is called a **lytic infection** (lysis means to burst open). Some viruses have a modified lytic cycle. Human influenza (flu) virus, for example, does not lyse the host cell. Rather, it exits the host cell by pushing out through the cell membrane of the host. The outer envelope of the virus then consists partly of the host cell membrane and partly of viral protein embedded in the membrane.

Not all viruses cause lysis immediately after entering a cell. Some enter the host cell and become inactive. The viral DNA becomes part of the DNA of the host cell but does not take over the metabolism of the cell right away. When the host cell replicates its DNA, the viral genes are also duplicated. Quietly, the viral DNA may be passed through many generations of the cell with no harm. In this form, the viral DNA is called a **prophage.** Viral inactivity such as this is called a **lysogenic infection.** Eventually, the sleeper awakens and the host cell is destroyed.

Virologists believe some outside influence such as temperature change, certain chemicals, or radiation triggers the prophage.

(See related student activity, p. 17)



(See page 34 for full-size chart.)

Sources of Viruses

No fossil evidence of viruses has ever been found. Because they are obligate intracellular parasites, viruses probably did not arise until cells appeared, since their existence requires cells. If this is so, then viruses probably either formed spontaneously from existing nonliving organic material or developed as simplification of previously existing cells.

This matter has been further complicated by the discovery of certain disease-causing particles that are even smaller and simpler than viruses. One of these is the **viroid.** A viroid is a short, single strand of RNA with no surrounding capsid. Virologists suggest that somehow this RNA strand interferes with normal cell function and causes production of new viral strands. Diseases caused by viroid infection damage potatoes, coconuts, chrysanthemums, and citrus crops.

Even smaller and simpler than a viroid is a **prion.** A prion doesn't even contain true DNA or RNA but only about 250 amino acids. Yet these tiny molecules have been implicated in **scrapie**, a slow degeneration of the nervous system in sheep and goats; in **kuru**, a degenerative nerve disease contracted by touching the brains of dead individuals; and **mad cow disease**.

(See related student activities, p. 26–7)

Researchers theorized the existence of viruses and even developed vaccines against them long before they were actually seen. The graphic below details some of the history of virus study and vaccines.

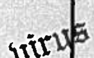
Viruses and Vaccines through History

1796 — English doctor **Edward Jenner** develops a vaccine against the dreaded scourge of **smallpox** after noticing that milkmaids who contracted cowpox never got smallpox. He correctly surmised that the milkmaids had developed an immunity to smallpox as a result. Taking material from a cowpox sore on the hand of a milkmaid, he inoculated his own son with the first viral vaccine in history.

1885 — **Louis Pasteur**, while using dogs, finds that weakened (attenuated) viruses will stimulate immunity. From this work, he has developed a vaccine for **rabies**. However, before he is ready to try it on humans, a young boy badly mauled by a rabid dog is brought to him. Against his better judgment, Pasteur gives the boy the inoculations. Joseph Meister becomes the first person in history to survive rabies.

1892 — Russian biologist **Dmitri Iwanowski** discovers the virus that causes **tobacco mosaic disease** in plants.

1898 — Dutch biologist **Martinus Beijernick** coins the term virus (from Latin for *poison*) and shows viruses to be infectious "germs" by transferring viral diseases from sick to healthy plants.



1930s — The first electron microscope is perfected.

1940s — The first virus is actually seen through the newly developed electron microscope.