How to protect yourself and your loved ones from dangerous viruses and germs

Introduction

A **virus** is a biological agent that reproduces inside the cells of living hosts. When infected by a virus, a host cell is forced to produce thousands of identical copies of the original virus at an extraordinary rate. Unlike most living things, viruses do not have cells that divide; new viruses are assembled in the infected host cell. But unlike still simpler infectious agents, viruses contain genes, which gives them the ability to mutate and evolve. Over 5,000 species of viruses have been discovered.

The origins of viruses are unclear: some may have evolved from plasmids—pieces of DNA that can move between cells—while others may have evolved from bacteria. A virus consists of two or three parts: genes, made from either DNA or RNA, long molecules that carry genetic information; a protein coat that protects the genes; and in some viruses, an envelope of fat that surrounds the protein coat and is used, in combination with specific receptors, to enter a new host cell. Viruses vary in shape from the simple helical and icosahedral to more complex structures. Viruses range in size from 20 to 300 nanometres; it would take 33,000 to 500,000 of them, side by side, to stretch to 1 centimetre (0.39 in).

Viruses spread in many ways. Just as many viruses are very specific as to which host species or tissue they attack, each species of virus relies on a particular method for propagation. Plant viruses are often spread from plant to plant by insects and other organisms, known as *vectors*. Some viruses of animals, including humans, are spread by exposure to infected bodily fluids. Viruses such as influenza are spread through the air by droplets of moisture when people cough or sneeze. Viruses such as nor virus are transmitted by the faecal–oral route, which involves the contamination of hands, food and water. Rotavirus is often spread by direct contact with infected children. The human immunodeficiency virus, HIV, is transmitted by bodily fluids transferred during sex. Others, such as the Dengue virus, are spread by blood-sucking insects.

Viral infections can cause disease in humans, animals and even plants. However, they are usually eliminated by the immune system, conferring lifetime immunity to the host for that virus. Antibiotics have no effect on viruses, but antiviral drugs have been developed to treat life-threatening infections. Vaccines that produce lifelong immunity can prevent some viral infections.

Discovery

In 1884 the French microbiologist Charles Chamberland invented a filter, known today as the Chamberland filter or Chamberland–Pasteur filter, that has pores smaller than bacteria. Thus he could pass a solution containing bacteria through the filter and completely remove them from the solution.In the early 1890s the Russian biologist Dmitri Ivanovsky used this filter to study what became known as the tobacco mosaic virus. His experiments showed that extracts from the crushed leaves of infected tobacco plants remain infectious after filtration.

At the same time several other scientists proved that, although these agents (later called *viruses*) were different from bacteria, they could still cause disease, and they were about one hundredth the size of bacteria. In 1899 the Dutch microbiologist Martinus Beijerinck observed that the agent multiplied only in dividing cells. Having failed to demonstrate its particulate nature, he called it a "*contagium vivum fluidum*", a "soluble living germ". In the early 20th century the English bacteriologist Frederick Twort discovered viruses that infect bacteria, and the French-Canadian microbiologist Félix d'Herelle described viruses that, when added to bacteria growing on agar, would lead to the formation of whole areas of dead bacteria. Counting these dead areas allowed him to calculate the number of viruses in the suspension.

With the invention of the electron microscope in 1931 by the German engineers Ernst Ruska and Max Knoll came the first images of viruses. In 1935 American biochemist and virologist Wendell Meredith Stanley examined the tobacco mosaic virus and found it to

be mostly made from protein. A short time later, this virus was separated into protein and RNA parts. A problem for early scientists was that they did not know how to grow viruses without using live animals. The breakthrough came in 1931, when the American pathologist Ernest William Goodpasture and Alice Miles Woodruff grew influenza and several other viruses in fertilised chickens' eggs. Some viruses could not be grown in chickens' eggs, but this problem was solved in 1949 when John Franklin Enders, Thomas Huckle Weller and Frederick Chapman Robbins grew polio virus in cultures of living animal cells. Over 5,000 species of virus have been discovered.

Origins

Viruses co-exist with life wherever it occurs. They have probably existed since living cells first evolved. The origin of viruses remains unclear because they do not form fossils, so molecular techniques have been the most useful means of hypothesising how they arose. However, these techniques rely on the availability of ancient viral DNA or RNA but most of the viruses that have been preserved and stored in laboratories are less than 90 years old. Molecular methods have only been successful in tracing the ancestry of viruses that evolved in the 20th century. Three main theories speculate on the origins of viruses:

Regressive theory

Viruses may have once been small cells that parasitised larger cells. Over time, genes not required by their parasitism were lost. The bacteria rickettsia and chlamydia are living cells that, like viruses, can reproduce only inside host cells. They lend credence to this theory, as their dependence on parasitism is likely to have caused the loss of genes that enabled them to survive outside a cell.

Cellular origin theory

Some viruses may have evolved from bits of DNA or RNA that "escaped" from the genes of a larger organism. The escaped DNA

could have come from plasmids—pieces of DNA that can move between cells—while others may have evolved from bacteria.

Coevolution theory

Viruses may have evolved from complex molecules of protein and DNA at the same time as cells first appeared on earth and would have depended on cellular life for many millions of years.

There are problems with all of these hypotheses: the regressive hypothesis does not explain why even the smallest of cellular parasites do not resemble viruses in any way. The escape hypothesis does not explain the structures of virus particles. The coevolution, or virus-first hypothesis, contravenes the definition of viruses, in that they are dependent on host cells. But viruses are recognised as ancient and to have origins that pre-date the divergence of life into the three domains. This discovery has led modern virologists to reconsider and re-evaluate these three classical hypotheses.

Structure

A virus particle, also known as a virion, consists of genes made from DNA or RNA which are surrounded by a protective coat of protein called a capsid. The capsid is made of many smaller, identical protein molecules which are called capsomers. The arrangement of the capsomers can either be icosahedral (20-sided), helical or more complex. There is an inner shell around the DNA or RNA called the nucleocapsid, which is formed by proteins. Some viruses are surrounded by a bubble of lipid (fat) called an envelope.

Size

Viruses are among the smallest infectious agents, and most of them can only be seen by electron microscopy. Most viruses cannot be seen by light microscopy (in other words, they are sub-microscopic); their sizes range from 20 to 300 nm. They are so small that it would take 30,000 to 750,000 of them, side by side, to stretch to one cm. By contrast bacterial sizes are typically around 1 micrometre (1000 nm) in diameter, and the cells of higher organisms

a few tens of micrometres. Some viruses such as megaviruses and pandoraviruses are relatively large. At around 1 micrometer, these viruses, which infect amoebae, were discovered in 2003 and 2013. They are around a thousand times larger than influenza viruses and the discovery of these "giant" viruses astonished scientists.

Genes

Genes are made from DNA (deoxyribonucleic acid) and, in many viruses, RNA (ribonucleic acid). The biological information contained in an organism is encoded in its DNA or RNA. Most organisms use DNA, but many viruses have RNA as their genetic material. The DNA or RNA of viruses consists of either a single strand or a double helix.

Viruses reproduce rapidly because they have only a few genes compared to humans who have 20,000–25,000. For example, influenza virus has only eight genes and rotavirushas eleven. These genes encode structural proteins that form the virus particle, or non-structural proteins, that are only found in cells infected by the virus.

All cells, and many viruses, produce proteins that are enzymes called DNA polymerase and RNA polymerase which make new copies of DNA and RNA. A virus's polymerase enzymes are often much more efficient at making DNA and RNA than the host cell's. However, RNA polymerase enzymes often make mistakes, and this is one of the reasons why RNA viruses often mutate to form new strains.

In some species of RNA virus, the genes are not on a continuous molecule of RNA, but are separated. The influenza virus, for example, has eight separate genes made of RNA. When two different strains of influenza virus infect the same cell, these genes can mix and produce new strains of the virus in a process called reassortment.

Protein synthesis

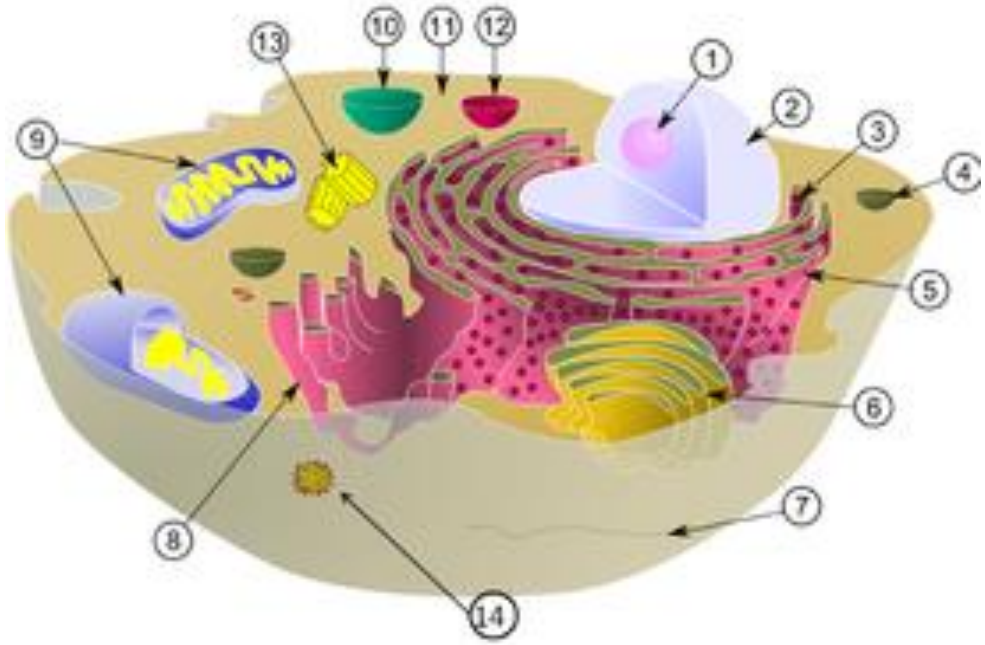


Diagram of a typical eukaryotic cell, showing subcellular components.

Organelles:

(1) nucleolus

(2) nucleus

(3) ribosome

(4) vesicle

(5) rough endoplasmic reticulum (ER)

(6) Golgi apparatus

(7) cytoskeleton

(8) smooth ER

(9) mitochondria

(10) vacuole

(11) cytoplasm

(12) lysosome

(13) centrioles within centrosome

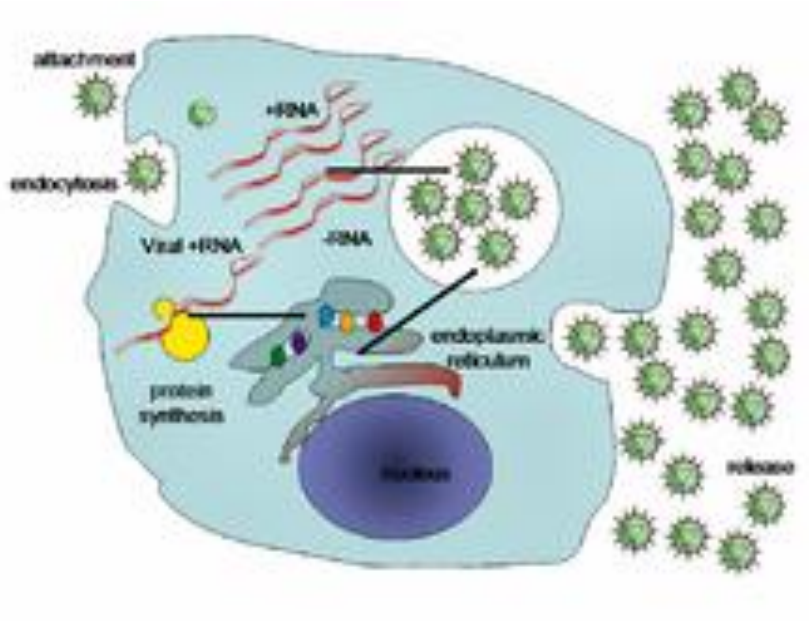
(14) virus particle shown to approximate scale

Proteins are essential to life. Cells produce new protein molecules from amino acid building blocks based on information coded in DNA. Each type of protein is a specialist that usually only performs one function, so if a cell needs to do something new, it must make a new protein. Viruses force the cell to make new proteins that the cell does not need, but are needed for the virus to reproduce. Protein synthesis consists of two major steps: transcription and translation.

Transcription is the process where information in DNA, called the genetic code, is used to produce RNA copies called messenger RNA (mRNA). These migrate through the cell and carry the code to ribosomes where it is used to make proteins. This is called translation because the protein's amino acid structure is determined by the mRNA's code. Information is hence translated from the language of nucleic acids to the language of amino acids.

Some nucleic acids of RNA viruses function directly as mRNA without further modification. For this reason, these viruses are called positive-sense RNA viruses. In other RNA viruses, the RNA is a complementary copy of mRNA and these viruses rely on the cell's or their own enzyme to make mRNA. These are called negative-sense RNA viruses. In viruses made from DNA, the method of mRNA production is similar to that of the cell. The species of viruses called retroviruses behave completely differently: they have RNA, but inside the host cell a DNA copy of their RNA is made with the help of the enzyme reverse transcriptase. This DNA is then incorporated into the host's own DNA, and copied into mRNA by the cell's normal pathways.

Life-cycle



Life-cycle of a typical virus (left to right); following infection of a cell by a single virus, hundreds of offspring are released.

When a virus infects a cell, the virus forces it to make thousands more viruses. It does this by making the cell copy the virus's DNA or RNA, making viral proteins, which all assemble to form new virus particles

There are six basic, overlapping stages in the life cycle of viruses in living cells:

- **Attachment** is the binding of the virus to specific molecules on the surface of the cell. This specificity restricts the virus to a very limited type of cell. For example, the human immunodeficiency virus (HIV) infects only human T cells, because its surface protein, gp120, can only react with CD4 and other molecules on the T cell's surface. Plant viruses can only attach to plant cells and cannot infect animals. This mechanism has evolved to favour those viruses that only infect cells in which they are capable of reproducing.
- **Penetration** follows attachment; viruses penetrate the host cell by endocytosis or by fusion with the cell.

- **Uncoating** happens inside the cell when the viral capsid is removed and destroyed by viral enzymes or host enzymes, thereby exposing the viral nucleic acid.
- **Replication** of virus particles is the stage where a cell uses viral messenger RNA in its protein synthesis systems to produce viral proteins. The RNA or DNA synthesis abilities of the cell produce the virus's DNA or RNA.
- **Assembly** takes place in the cell when the newly created viral proteins and nucleic acid combine to form hundreds of new virus particles.
- **Release** occurs when the new viruses escape or are released from the cell. Most viruses achieve this by making the cells burst, a process called lysis. Other viruses such as HIV are released more gently by a process called budding.

Effects on the host cell

The range of structural and biochemical effects that viruses have on the host cell is extensive. These are called *cytopathic effects*. Most virus infections eventually result in the death of the host cell. The causes of death include cell lysis (bursting), alterations to the cell's surface membrane and apoptosis (cell "suicide"). Often cell death is caused by cessation of its normal activity due to proteins produced by the virus, not all of which are components of the virus particle.

Some viruses cause no apparent changes to the infected cell. Cells in which the virus is latent and inactive show few signs of infection and often function normally. This causes persistent infections and the virus is often dormant for many months or years. This is often the case with herpes viruses.

Some viruses, such as Epstein-Barr virus, often cause cells to proliferate without causing malignancy; but some other viruses, such as papillomavirus, are an established cause of cancer. When a cell's DNA is damaged by a virus, and if the cell cannot repair itself, this often triggers apoptosis. One of the results of apoptosis is destruction

of the damaged DNA by the cell itself. Some viruses have mechanisms to limit apoptosis so that the host cell does not die before progeny viruses have been produced; HIV, for example, does this.

Viruses and diseases

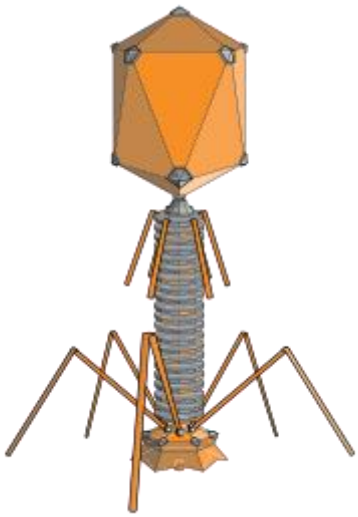
Common human diseases caused by viruses include the common cold, the flu, chickenpox and cold sores. Serious diseases such as Ebola and AIDS are also caused by viruses. Many viruses cause little or no disease and are said to be "benign". The more harmful viruses are described as virulent. Viruses cause different diseases depending on the types of cell that they infect. Some viruses can cause lifelong or chronic infections where the viruses continue to reproduce in the body despite the host's defence mechanisms. This is common in hepatitis B virus and hepatitis C virus infections. People chronically infected with a virus are known as carriers. They serve as important reservoirs of the virus. If there is a high proportion of carriers in a given population, a disease is said to be endemic.

There are many ways in which viruses spread from host to host but each species of virus uses only one or two. Many viruses that infect plants are carried by organisms; such organisms are called vectors. Some viruses that infect animals, including humans, are also spread by vectors, usually blood-sucking insects. However, direct transmission is more common. Some virus infections, such as norovirus and rotavirus, are spread by contaminated food and water, hands and communal objects and by intimate contact with another infected person, while others are airborne (influenza virus). Viruses such as HIV, hepatitis B and hepatitis C are often transmitted by unprotected sex or contaminated hypodermic needles. It is important to know how each different kind of virus is spread to prevent infections and epidemics.

Diseases of plants

There are many types of plant virus, but often they only cause a loss of yield, and it is not economically viable to try to control them. Plant viruses are often spread from plant to plant by organisms (vectors). These are normally insects, but some fungi, nematode worms and single-celled organisms have been shown to be vectors. When control of plant virus infections is considered economical (perennial fruits, for example) efforts are concentrated on killing the vectors and removing alternate hosts such as weeds. Plant viruses are harmless to humans and other animals because they can only reproduce in living plant cells.

Bacteriophages



The structure of a typical bacteriophage

Bacteriophages are viruses that infect bacteria and archaea. The International Committee on Taxonomy of Viruses officially recognises 28 genera of bacteriophages that belong to 11 families.

They are important in marine ecology: as the infected bacteria burst, carbon compounds are released back into the environment, which stimulates fresh organic growth. Bacteriophages are useful in scientific research because they are harmless to humans and can be studied easily. These viruses can be a problem in industries that

produce food and drugs by fermentation and depend on healthy bacteria. Some bacterial infections are becoming difficult to control with antibiotics, so there is a growing interest in the use of bacteriophages to treat infections in humans.

Host resistance

Innate immunity of animals

Animals, including humans, have many natural defences against viruses. Some are non-specific and protect against many viruses regardless of the type. This innate immunity is not improved by repeated exposure to viruses and does not retain a "memory" of the infection. The skin of animals, particularly its surface, which is made from dead cells, prevents many types of viruses from infecting the host. The acidity of the contents of the stomach destroys many viruses that have been swallowed. When a virus overcomes these barriers and enters the host, other innate defences prevent the spread of infection in the body. A special hormone called interferon is produced by the body when viruses are present, and this stops the viruses from reproducing by killing the infected cell and its close neighbours. Inside cells, there are enzymes that destroy the RNA of viruses. This is called RNA interference. Some blood cells engulf and destroy other virus infected cells.

Adaptive immunity of animals

Specific immunity to viruses develops over time and white blood cells called lymphocytes play a central role. Lymphocytes retain a "memory" of virus infections and produce many special molecules called antibodies. These antibodies attach to viruses and stop the virus from infecting cells. Antibodies are highly selective and attack only one type of virus. The body makes many different antibodies, especially during the initial infection; however, after the infection subsides, some antibodies remain and continue to be produced, often giving the host lifelong immunity to the virus.

Plant resistance

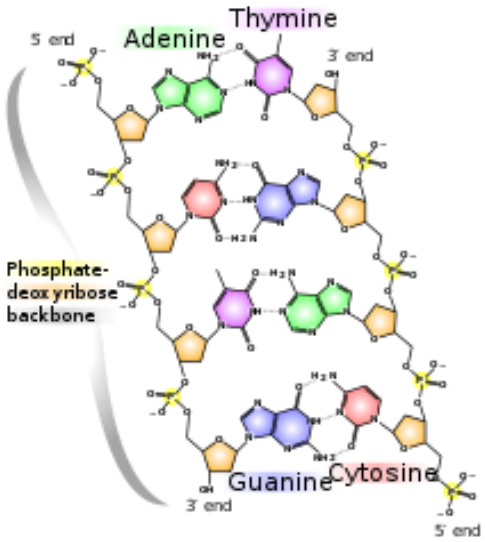
Plants have elaborate and effective defence mechanisms against viruses. One of the most effective is the presence of so-called resistance (R) genes. Each R gene confers resistance to a particular virus by triggering localised areas of cell death around the infected cell, which can often be seen with the unaided eye as large spots. This stops the infection from spreading. RNA interference is also an effective defence in plants. When they are infected, plants often produce natural disinfectants which destroy viruses, such as salicylic acid, nitric oxide and reactive oxygen molecules.

Resistance to bacteriophages

The major way bacteria defend themselves from bacteriophages is by producing enzymes which destroy foreign DNA. These enzymes, called restriction endonucleases, cut up the viral DNA that bacteriophages inject into bacterial cells.

Prevention and treatment of viral disease in humans and other animals

Vaccines



The structure of DNA showing the position of the nucleosides and the phosphorus atoms that form the "backbone" of the molecule

Vaccination is a way of preventing diseases caused by viruses. Vaccines simulate a natural infection and its associated immune response, but do not cause the disease. Their use has resulted in the eradication of smallpox and a dramatic decline in illness and death caused by infections such as polio, measles, mumps and rubella.

Vaccines are available to prevent over fourteen viral infections of humans and more are used to prevent viral infections of animals. Vaccines may consist of either live or killed viruses. Live vaccines contain weakened forms of the virus, but these vaccines can be dangerous when given to people with weak immunity. In these people, the weakened virus can cause the original disease. Biotechnology and genetic engineering techniques are used to produce "designer" vaccines that only have the capsid proteins of the virus. Hepatitis B vaccine is an example of this type of vaccine. These vaccines are safer because they can never cause the disease.

Antiviral drugs

Since the mid 1980s, the development of antiviral drugs has increased rapidly, mainly driven by the AIDS pandemic. Antiviral drugs are often nucleoside analogues, which are molecules very similar, but not identical to DNA building blocks. When the replication of virus DNA begins, some of these fake building blocks are incorporated. As soon as that happens, replication stops prematurely—the fake building blocks lack the essential features that allow the addition of further building blocks. Thus, DNA production is halted, and the virus can no longer reproduce. Examples of nucleoside analogues are aciclovir for herpes virus infections and lamivudine for HIV and hepatitis B virusinfections. Aciclovir is one of the oldest and most frequently prescribed antiviral drugs.

The structure of the DNA base guanosine and the antiviral drug aciclovir

Other antiviral drugs target different stages of the viral life cycle. HIV is dependent on an enzyme called the HIV-1 protease for the virus to become infectious. There is a class of drugs called protease inhibitors, which bind to this enzyme and stop it from functioning.

Hepatitis C is caused by an RNA virus. In 80% of people infected, the disease becomes chronic, and they remain infectious for the rest of their lives unless they are treated. There is an effective treatment that uses the nucleoside analogue drug ribavirin combined with interferon.Treatments for chronic carriers of the hepatitis B virus by a similar strategy using lamivudine and other anti-viral drugs have been developed.In both diseases, the drugs stop the virus from reproducing and the interferon kills any remaining infected cells.

HIV infections are usually treated with a combination of antiviral drugs, each targeting a different stage in the virus's life-cycle. There are drugs that prevent the virus from attaching to cells, others that are nucleoside analogues and some poison the virus's enzymes that it needs to reproduce. The success of these drugs is proof of the importance of knowing how viruses reproduce.

Role in Ecology

Viruses are the most abundant biological entity in aquatic environments —there are about one million of them in a teaspoon of seawater —and they are essential to the regulation of saltwater and freshwater ecosystems. Most of these viruses are bacteriophages, which are harmless to plants and animals. They infect and destroy the bacteria in aquatic microbial communities and this is the most important mechanism of recycling carbon in the marine environment. The organic molecules released from the bacterial cells by the viruses stimulate fresh bacterial and algal growth.

Microorganisms constitute more than 90% of the biomass in the sea. It is estimated that viruses kill approximately 20% of this biomass each day and that there are fifteen times as many viruses in the oceans as there are bacteria and archaea. Viruses are mainly

responsible for the rapid destruction of harmful algal blooms, which often kill other marine life. The number of viruses in the oceans decreases further offshore and deeper into the water, where there are fewer host organisms.

Their effects are far-reaching; by increasing the amount of respiration in the oceans, viruses are indirectly responsible for reducing the amount of carbon dioxide in the atmosphere by approximately 3 gigatonnes of carbon per year.

Marine mammals are also susceptible to viral infections. In 1988 and 2002, thousands of harbour seals were killed in Europe by phocine distemper virus. Many other viruses, including caliciviruses, herpesviruses, adenoviruses and parvoviruses, circulate in marine mammal populations.

More on viruses

Scientists estimate that there are roughly 10^{31} viruses at any given moment. That's a one with 31 zeroes after it! If you were somehow able to wrangle up all 10^{31} of these viruses and line them end-to-end, your virus column would extend nearly 200200 light years into space. To put it another way, there are over ten million times *more* viruses on Earth than there are stars in the entire universe.

Does that mean there are 10^{31} viruses just waiting to infect us? Actually, most of these viruses are found in oceans, where they attack bacteria and other microbes. It may seem odd that bacteria can get a

virus, but scientists think that *every* kind of living organism is probably host to at least one virus!

So what is a virus?

A **virus** is a tiny, infectious particle that can reproduce only by infecting a host cell. Viruses "commandeer" the host cell and use its resources to make more viruses, basically reprogramming it to become a virus factory. Because they can't reproduce by themselves (without a host), viruses are not considered living. Nor do viruses have cells: they're very small, much smaller than the cells of living things, and are basically just packages of nucleic acid and protein.

Still, viruses have some important features in common with cell-based life. For instance, they have nucleic acid genomes based on the same genetic code that's used in your cells (and the cells of all living creatures). Also, like cell-based life, viruses have genetic variation and can evolve. So, even though they don't meet the definition of life, viruses seem to be in a "questionable" zone. (Maybe viruses are actually undead, like zombies or vampires!)

How are viruses different from bacteria?

Even though they can both make us sick, bacteria and viruses are very different at the biological level. Bacteria are small and single-celled, but they are living organisms that do not depend on a host cell to reproduce. Because of these differences, bacterial and viral infections are treated very differently. For instance, antibiotics are only helpful against bacteria, not viruses.

Bacteria are also much bigger than viruses. The diameter of a typical virus is about 20 – 300 nanometres. This is considerably smaller than

a typical *E. coli* bacterium, which has a diameter of roughly 1000 nm! Tens of millions of viruses could fit on the head of a pin.

The structure of a virus

There are a lot of different viruses in the world. So, viruses vary a ton in their sizes, shapes, and life cycles. If you're curious just how much, I recommend playing around with the ViralZone website. Click on a few virus names at random, and see what bizarre shapes and features you find!

Viruses do, however, have a few key features in common. These include:

- A protective protein shell, or **capsid**
- A nucleic acid genome made of DNA or RNA, tucked inside of the capsid
- A layer of membrane called the **envelope** (some but not all viruses)

Let's take a closer look at these features.

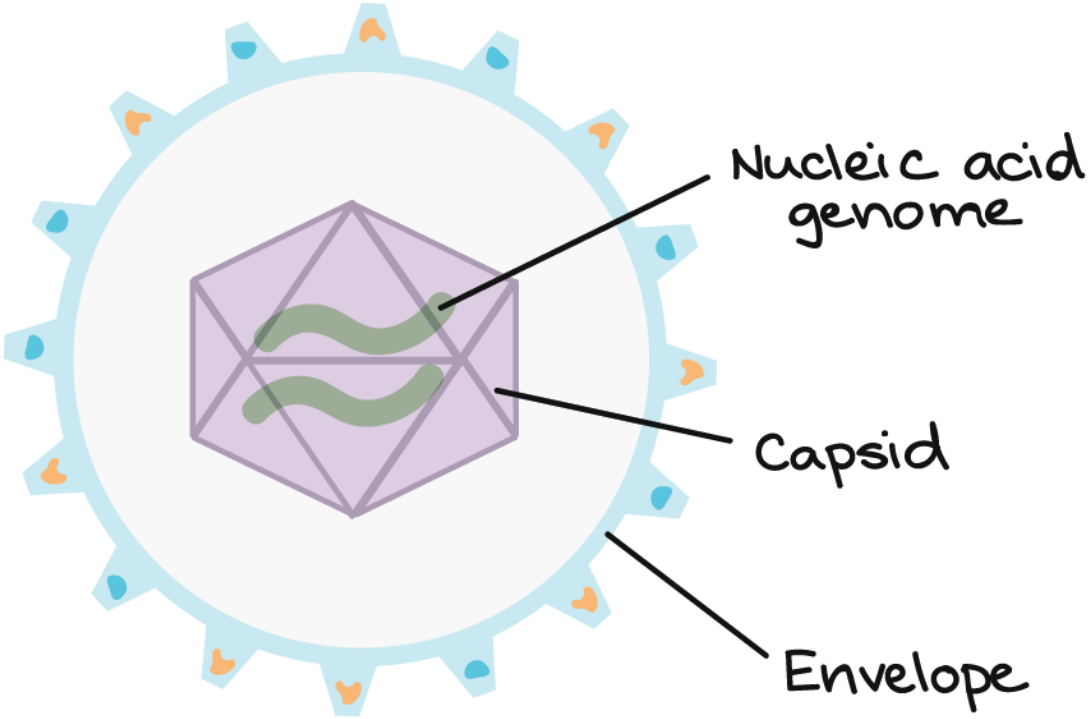
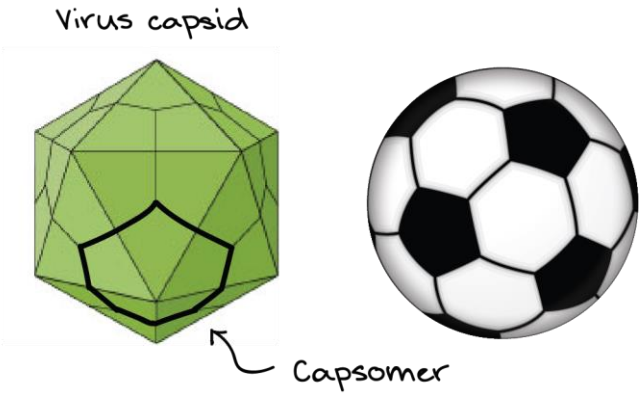


Diagram of a virus. The exterior layer is a membrane envelope. Inside the envelope is a protein capsid, which contains the nucleic acid genome.

Virus capsids

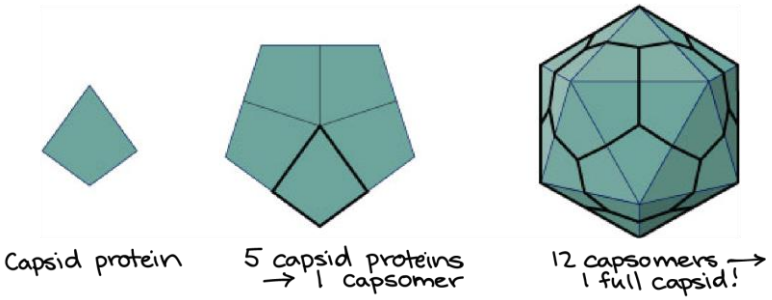
The **capsid**, or protein shell, of a virus is made up of many protein molecules (not just one big, hollow one). The proteins join to make units called **capsomers**, which together make up the capsid. Capsid proteins are always encoded by the virus genome, meaning that it's the virus (not the host cell) that provides instructions for making them.

You can think of the capsid as a soccer ball, and the white hexagons and black pentagons as capsomers.



Comparison of a soccer ball with a virus capsid. The hexagons are one type of capsomer while the pentagon are another type. Both types of capsomer are assembled from individual virus proteins.

The capsids of some viruses are relatively simple and are made from multiple copies of a single protein. Canine parvovirus, a very small virus that infects dogs, has a capsid made from 6060 copies of the same capsid protein. The capsid is organized into 12 capsomers, each of which is made from 5 capsid proteins. The capsids of other viruses are more complex and consist of multiple copies of several different proteins.



Capsid protein

5 capsid proteins = 1 capsomer

12 capsomers = one full capsid

Capsids come in many forms, but they often take one of the following shapes (or a variation of these shapes):

1. **Icosahedral** – Icosahedral capsids have twenty faces, and are named after the twenty-sided shape called an icosahedron.
2. **Filamentous** – Filamentous capsids are named after their linear, thin, thread-like appearance. They may also be called rod-shaped or helical.
3. **Head-tail** –These capsids are kind of a hybrid between the filamentous and icosahedral shapes. They basically consist of an icosahedral head attached to a filamentous tail.

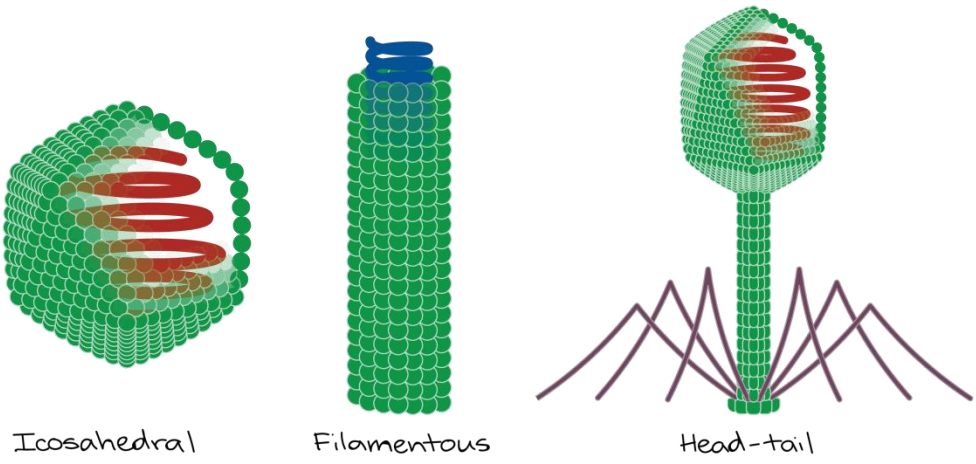


Diagram of icosahedral (roughly spherical), filamentous (rod-like), and head-tail (icosahedral head attached to filamentous tail) virus capsid shapes.

Virus envelopes

In addition to the capsid, some viruses also have an external lipid membrane known as an **envelope**, which surrounds the entire capsid.

Viruses with envelopes do not provide instructions for the envelope lipids. Instead, they "borrow" a patch from the host membranes on their way out of the cell. Envelopes do, however, contain proteins that are specified by the virus, which often help viral particles bind to host cells.

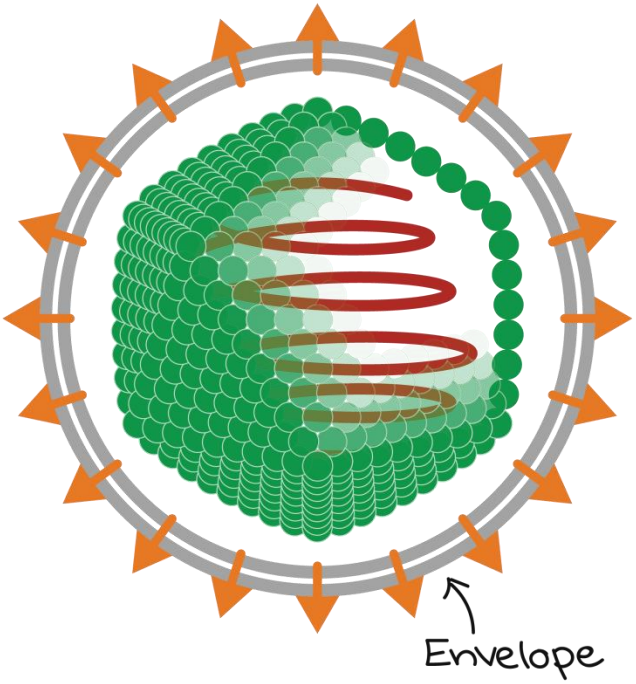


Diagram of enveloped icosahedral virus.

Although envelopes are common, especially among animal viruses, they are not found in every virus (i.e., are not a universal virus feature).

Virus genomes

All viruses have genetic material (a **genome**) made of nucleic acid. You, like all other cell-based life, use DNA as your genetic

material. Viruses, on the other hand, may use either RNA or DNA, both of which are types of nucleic acid.

We often think of DNA as double-stranded and RNA as single-stranded, since that's typically the case in our own cells. However, viruses can have all possible combos of strandedness and nucleic acid type (double-stranded DNA, double-stranded RNA, single-stranded DNA, or single-stranded RNA). Viral genomes also come in various shapes, sizes, and varieties, though they are generally much smaller than the genomes of cellular organisms.

Virus genomes are pretty small! They typically range from 2,2,000000 to several hundred thousand nucleotides in length. (A nucleotide is a "unit" of DNA or RNA).

For comparison, the bacterium *E. coli* has a genome that's 4.6 millionnucleotides long, and you have a genome that's 6.6 billion nucleotides long!

Notably, DNA and RNA viruses always use the same genetic code as living cells. If they didn't, they would have no way to reprogram their host cells!

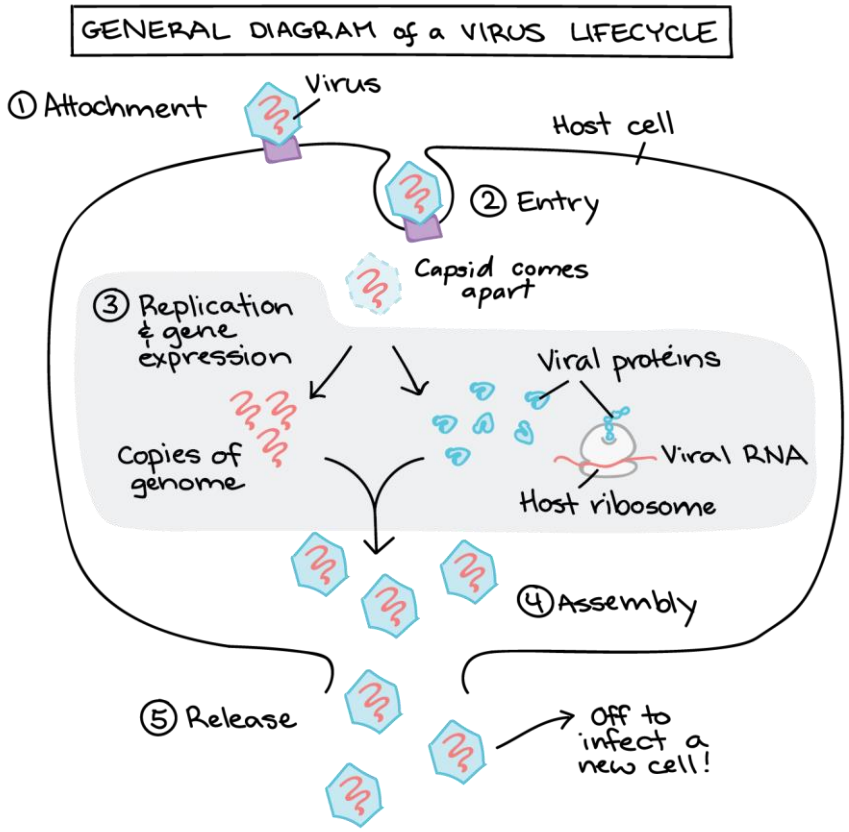
What is a viral infection?

In everyday life, we tend to think of a viral infection as the nasty collection of symptoms we get when catch a virus, such as the flu or the chicken pox. But what's actually happening in your body when you have a virus?

At the microscopic scale, a viral infection means that many viruses are using your cells to make more copies of themselves. The

viral **lifecycle** is the set of steps in which a virus recognizes and enters a host cell, "reprograms" the host by providing instructions in the form of viral DNA or RNA, and uses the host's resources to make more virus particles (the output of the viral "program").

For a typical virus, the lifecycle can be divided into five broad steps (though the details of these steps will be different for each virus):

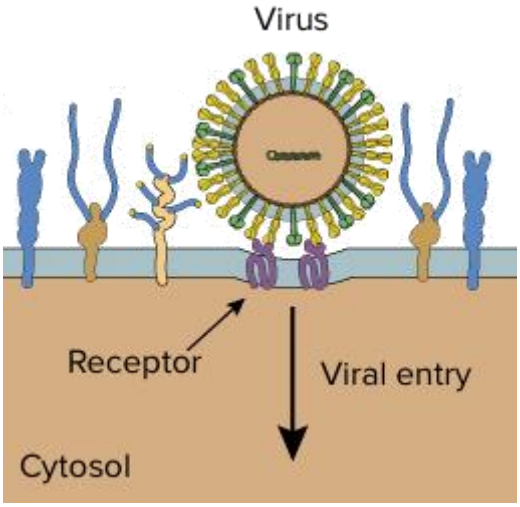


Steps of a viral infection, illustrated generically for a virus with a + sense RNA genome.

1. Attachment. Virus binds to receptor on cell surface.

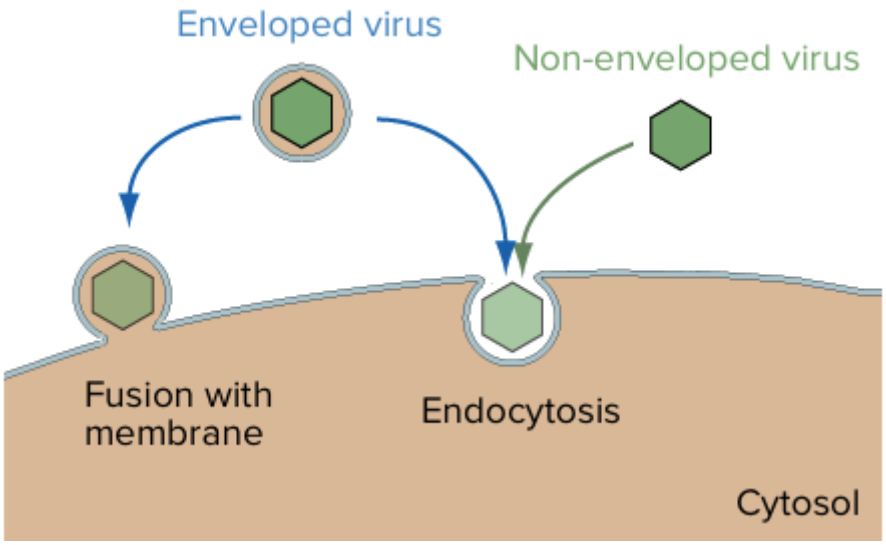
    - In attachment, a specific protein on the capsid of the virus physically "sticks" to a specific molecule on the membrane of the host cell.

- This molecule, called a **receptor**, is usually a protein. A virus recognizes its host cells based on the receptors they carry, and a cell without receptors for a virus can't be infected by that virus.



2. Entry. Virus enters cell by endocytosis. In the cytoplasm, the capsid comes apart, releasing the RNA genome.

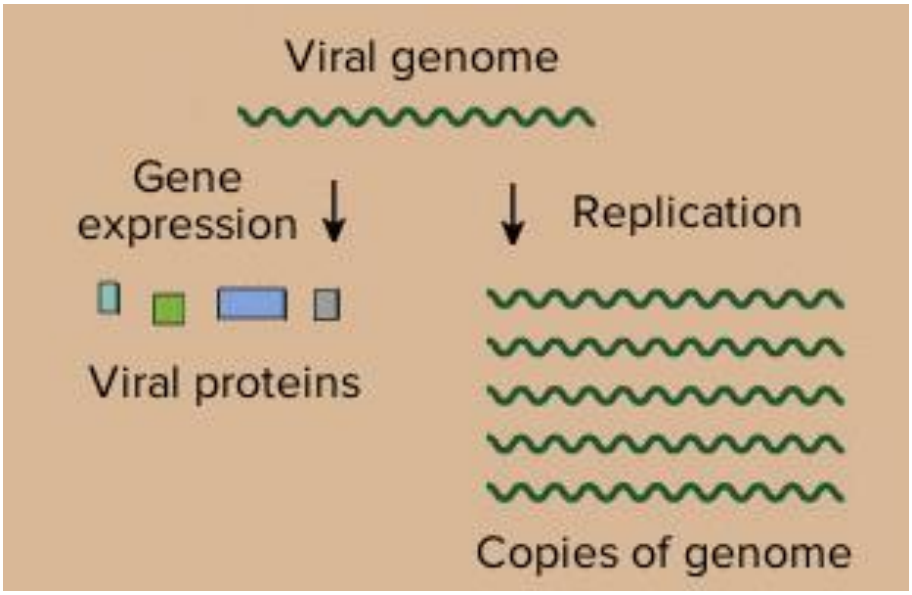
- One typical route for viral entry is fusion with the membrane, which is most common in viruses with envelopes. Viruses may also trick the cell into taking them in by a bulk transport process called endocytosis. Some even inject their DNA into the cell!



3. Replication and gene expression. The RNA genome is copied (this would be done by a viral enzyme, not shown) and translated into viral proteins using a host ribosome. The viral proteins produced include capsid proteins.

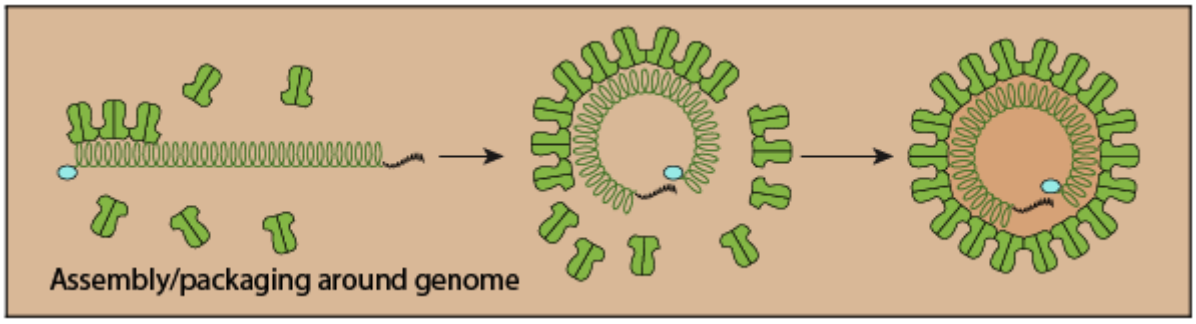
- This step involves copying the viral genome and making more viral proteins, so that new virus particles can be assembled.
- The materials for these processes (such as nucleotides to make new DNA or RNA) come from the host cell, not the virus. Most of the "machinery" for replication and gene expression is also provided by the host cell. For instance, the messenger RNAs (mRNAs) encoding viral genes are translated into viral proteins using the host cell's ribosomes. However, certain steps, such as the copying of an RNA virus's genome, cannot be performed by host cell enzymes. In such cases, the viruses must encode their own enzymes.

- The viral proteins produced vary from virus to virus. All viruses must encode capsid proteins, and enveloped viruses typically also encode envelope proteins (which often aid in host recognition). Viruses may also encode proteins that manipulate the host genome (e.g., by blocking host defenses or driving expression of genes to benefit the virus), help with viral genome replication, or play a role in other parts of the viral lifecycle.



4. Assembly. Capsid proteins and RNA genomes come together to make new viral particles.

    - During assembly, newly synthesized capsid proteins come together to form capsomers, which interact with other capsomers to form the full-sized capsid.
    - Some viruses, like head-tail viruses, first assemble an "empty" capsid and then stuff the viral genome inside. Other viruses build the capsid around the viral genome, as shown below.

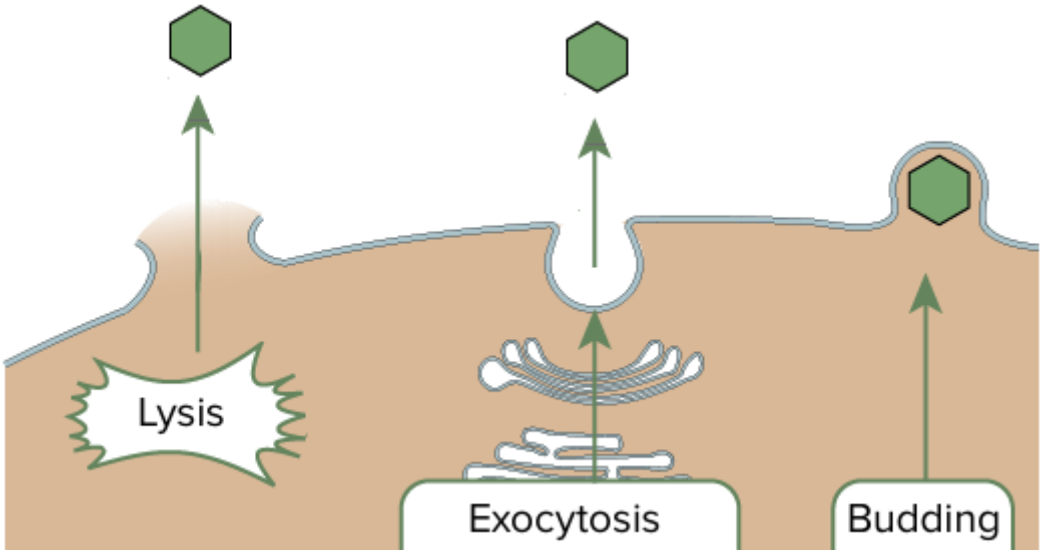


5. Release. The cell lyses (bursts), releasing the viral particles, which can then infect other host cells.

    - The last step in the virus lifecycle is the release of newly made viruses from the host cell. Different types of viruses exit the cell

by different routes: some make the host cell burst (a process called lysis), while others exit through the cell's own export pathways (exocytosis), and others yet bud from the plasma membrane, taking a patch of it with them as they go.

- In some cases, the release of the new viruses kills the host cell. (For instance, a host cell that bursts will not survive.) In other cases, the exiting viruses leave the host cell intact so it can continue cranking out more virus particles.



Bacteria

Bacteria are a type of biological cell. They constitute a large domain of prokaryotic microorganisms. Typically a few micrometres in length, bacteria have a number of shapes, ranging from spheres to rods and spirals. Bacteria were among the first life forms to appear on Earth, and are present in most of its habitats. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep portions of Earth's crust. Bacteria also live in symbiotic and parasitic relationships with plants and animals. Most bacteria have not been characterised, and only about half of

the bacterial phyla have species that can be grown in the laboratory. The study of bacteria is known as bacteriology, a branch of microbiology.

There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a millilitre of fresh water. There are approximately 5×10^{30} bacteria on Earth, forming a biomass which exceeds that of all plants and animals. Bacteria are vital in many stages of the nutrient cycle by recycling nutrients such as the fixation of nitrogen from the atmosphere. The nutrient cycle includes the decomposition of dead bodies; bacteria are responsible for the putrefaction stage in this process. In the biological communities surrounding hydrothermal vents and cold seeps, extremophile bacteria provide the nutrients needed to sustain life by converting dissolved compounds, such as hydrogen sulphide and methane, to energy. Data reported by researchers in October 2012 and published in March 2013 suggested that bacteria thrive in the Mariana Trench, which, with a depth of up to 11 kilometres, is the deepest known part of the oceans. Other researchers reported related studies that microbes thrive inside rocks up to 580 metres below the sea floor under 2.6 kilometres of ocean off the coast of the north-western United States. According to one of the researchers, "You can find microbes everywhere—they're extremely adaptable to conditions, and survive wherever they are."

The famous notion that bacterial cells in the human body outnumber human cells by a factor of 10:1 has been debunked. There are approximately 39 trillion bacterial cells in the human microbiota as personified by a "reference" 70 kg male 170 cm tall, whereas there are 30 trillion human cells in the body. This means that although they do have the upper hand in actual numbers, it is only by 30%, and not 900%.

The largest number exist in the gut flora, and a large number on the skin.The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, though many are beneficial, particularly in the gut flora. However several species of bacteria are pathogenic and cause infectious diseases,

including cholera, syphilis, anthrax, leprosy, and bubonic plague. The most common fatal bacterial diseases are respiratory infections, with tuberculosis alone killing about 2 million people per year, mostly in sub-Saharan Africa. In developed countries, antibiotics are used to treat bacterial infections and are also used in farming, making antibiotic resistance a growing problem. In industry, bacteria are important in sewage treatment and the breakdown of oil spills, the production of cheese and yogurt through fermentation, the recovery of gold, palladium, copper and other metals in the mining sector, as well as in biotechnology, and the manufacture of antibiotics and other chemicals.

Once regarded as plants constituting the class *Schizomycetes*, bacteria are now classified as prokaryotes. Unlike cells of animals and other eukaryotes, bacterial cells do not contain a nucleus and rarely harbour membrane-bound organelles. Although the term *bacteria* traditionally included all prokaryotes, the scientific classification changed after the discovery in the 1990s that prokaryotes consist of two very different groups of organisms that evolved from an ancient common ancestor. These evolutionary domains are called *Bacteria* and *Archaea*.

Etymology

The word *bacteria* is the plural of the New Latin *bacterium*, which is the latinisation of the Greek βακτήριον (*bakterion*), the diminutive of βακτηρία (*bakteria*), meaning "staff, cane", because the first ones to be discovered were rod-shaped

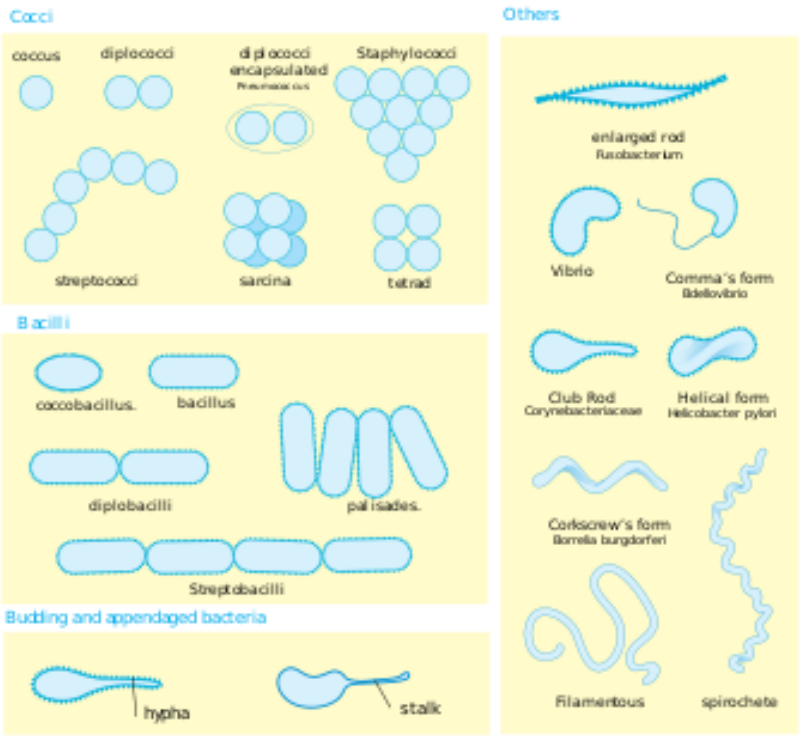
Origin and early evolution

The ancestors of modern bacteria were unicellular microorganisms that were the first forms of life to appear on Earth, about 4 billion years ago. For about 3 billion years, most organisms were microscopic, and bacteria and archaea were the dominant forms of life. Although bacterial fossils exist, such as stromatolites, their lack of distinctive morphology prevents them from being used to examine the history of bacterial evolution, or to date the time of origin

of a particular bacterial species. However, gene sequences can be used to reconstruct the bacterial phylogeny, and these studies indicate that bacteria diverged first from the archaeal/eukaryotic lineage. The most recent common ancestor of bacteria and archaea was probably a hyperthermophile that lived about 2.5 billion–3.2 billion years ago.

Bacteria were also involved in the second great evolutionary divergence, that of the archaea and eukaryotes. Here, eukaryotes resulted from the entering of ancient bacteria into endosymbiotic associations with the ancestors of eukaryotic cells, which were themselves possibly related to the Archaea. This involved the engulfment by proto-eukaryotic cells of alphaproteobacterialsymbionts to form either mitochondria or hydrogenosomes, which are still found in all known Eukarya (sometimes in highly reduced form, e.g. in ancient "amitochondrial" protozoa). Later, some eukaryotes that already contained mitochondria also engulfed cyanobacteria-like organisms, leading to the formation of chloroplasts in algae and plants. This is known as secondary endosymbiosis.

Morphology



Bacteria display many cell morphologies and arrangements

Bacteria display a wide diversity of shapes and sizes, called morphologies. Bacterial cells are about one-tenth the size of eukaryotic cells and are typically 0.5–5.0 micrometres in length. However, a few species are visible to the unaided eye—for example, *Thiomargarita namibiensis* is up to half a millimetre long and *Epulopiscium fishelsoni* reaches 0.7 mm. Among the smallest bacteria are members of the genus *Mycoplasma*, which measure only 0.3 micrometres, as small as the largest viruses. Some bacteria may be even smaller, but these ultramicrobacteria are not well-studied.

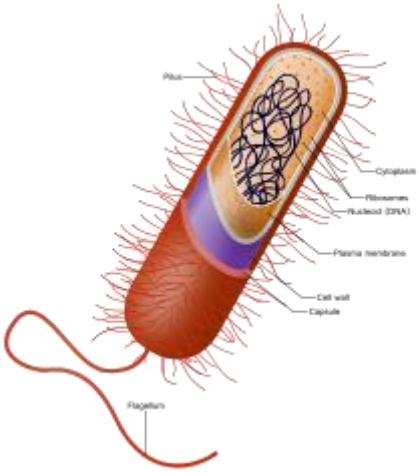
Most bacterial species are either spherical, called *cocci* (*sing.* coccus, from Greek *kókkos*, grain, seed), or rod-shaped, called *bacilli* (*sing.* bacillus, from Latin *baculus*, stick). Some bacteria, called *vibrio*, are shaped like slightly curved rods or comma-shaped; others can be spiral-shaped, called *spirilla*, or tightly coiled, called *spirochaetes*. A small number of other unusual shapes have been described, such as star-shaped bacteria. This wide variety of shapes is determined by the bacterial cell wall and cytoskeleton, and

is important because it can influence the ability of bacteria to acquire nutrients, attach to surfaces, swim through liquids and escape predators.

Many bacterial species exist simply as single cells, others associate in characteristic patterns: *Neisseria* form diploids (pairs), *Streptococcus* form chains, and *Staphylococcus* group together in "bunch of grapes" clusters. Bacteria can also group to form larger multicellular structures, such as the elongated filaments of *Actinobacteria*, the aggregates of *Myxobacteria*, and the complex hyphae of *Streptomyces*. These multicellular structures are often only seen in certain conditions. For example, when starved of amino acids, Myxobacteria detect surrounding cells in a process known as quorum sensing, migrate towards each other, and aggregate to form fruiting bodies up to 500 micrometres long and containing approximately 100,000 bacterial cells. In these fruiting bodies, the bacteria perform separate tasks; for example, about one in ten cells migrate to the top of a fruiting body and differentiate into a specialised dormant state called a myxospore, which is more resistant to drying and other adverse environmental conditions.

Bacteria often attach to surfaces and form dense aggregations called biofilms, and larger formations known as microbial mats. These biofilms and mats can range from a few micrometres in thickness to up to half a metre in depth, and may contain multiple species of bacteria, protistsand archaea. Bacteria living in biofilms display a complex arrangement of cells and extracellular components, forming secondary structures, such as microcolonies, through which there are networks of channels to enable better diffusion of nutrients. In natural environments, such as soil or the surfaces of plants, the majority of bacteria are bound to surfaces in biofilms. Biofilms are also important in medicine, as these structures are often present during chronic bacterial infections or in infections of implanted medical devices, and bacteria protected within biofilms are much harder to kill than individual isolated bacteria.

Cellular structure



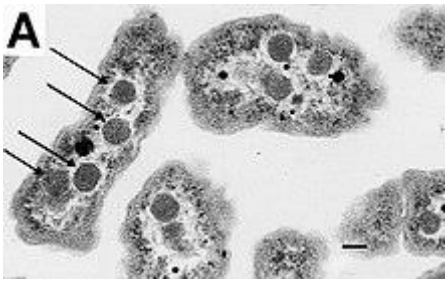
Structure and contents of a typical gram-positive bacterial cell (seen by the fact that only *one* cell membrane is present).

Intracellular structures

The bacterial cell is surrounded by a cell membrane which is made primarily of phospholipids. This membrane encloses the contents of the cell and acts as a barrier to hold nutrients, proteins and other essential components of the cytoplasm within the cell. Unlike eukaryotic cells, bacteria usually lack large membrane-bound structures in their cytoplasm such as a nucleus, mitochondria, chloroplasts and the other organelles present in eukaryotic cells. However, some bacteria have protein-bound organelles in the cytoplasm which compartmentalize aspects of bacterial metabolism, such as the carboxysome. Additionally, bacteria have a multi-component cytoskeleton to control the localisation of proteins and nucleic acids within the cell, and to manage the process of cell division.

Many important biochemical reactions, such as energy generation, occur due to concentration gradients across membranes, creating a potential difference analogous to a battery. The general lack of internal membranes in bacteria means these reactions, such as electron transport, occur across the cell membrane between the cytoplasm and the outside of the cell or periplasm. However, in many

photosynthetic bacteria the plasma membrane is highly folded and fills most of the cell with layers of light-gathering membrane. These light-gathering complexes may even form lipid-enclosed structures called chlorosomes in green sulfur bacteria.



An electron micrograph of *Halothiobacillus neapolitanus* cells with carboxysomes inside, with arrows highlighting visible carboxysomes. Scale bars indicate 100 nm.

Most bacteria do not have a membrane-bound nucleus, and their genetic material is typically a single circular bacterial chromosome of DNAlocated in the cytoplasm in an irregularly shaped body called the nucleoid. The nucleoid contains the chromosome with its associated proteins and RNA. Like all living organisms, bacteria contain ribosomes for the production of proteins, but the structure of the bacterial ribosome is different from that of eukaryotes and Archaea.

Some bacteria produce intracellular nutrient storage granules, such as glycogen, polyphosphate, sulphur or polyhydroxyalkanoates. Certain bacterial species, such as the photosynthetic Cyanobacteria, produce internal gas vacuoles which they use to regulate their buoyancy, allowing them to move up or down into water layers with different light intensities and nutrient levels.

Extracellular structures

Around the outside of the cell membrane is the cell wall. Bacterial cell walls are made of peptidoglycan (also called murein), which is made from polysaccharide chains cross-linked by peptides containing D-amino acids. Bacterial cell walls are

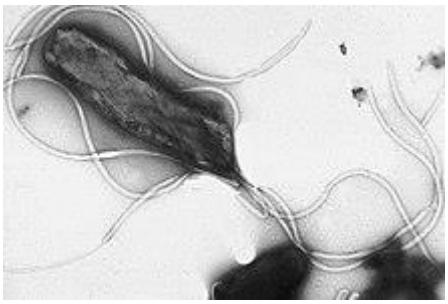
different from the cell walls of plants and fungi, which are made of cellulose and chitin, respectively. The cell wall of bacteria is also distinct from that of Archaea, which do not contain peptidoglycan. The cell wall is essential to the survival of many bacteria, and the antibiotic penicillin is able to kill bacteria by inhibiting a step in the synthesis of peptidoglycan.

There are broadly speaking two different types of cell wall in bacteria, that classify bacteria into gram-positive bacteria and gram-negative bacteria. The names originate from the reaction of cells to the Gram stain, a long-standing test for the classification of bacterial species.

Gram-positive bacteria possess a thick cell wall containing many layers of peptidoglycan and teichoic acids. In contrast, gram-negative bacteria have a relatively thin cell wall consisting of a few layers of peptidoglycan surrounded by a second lipid membrane containing lipopolysaccharides and lipoproteins. Most bacteria have the gram-negative cell wall, and only the Firmicutes and Actinobacteria (previously known as the low G+C and high G+C gram-positive bacteria, respectively) have the alternative gram-positive arrangement. These differences in structure can produce differences in antibiotic susceptibility; for instance, vancomycin can kill only gram-positive bacteria and is ineffective against gram-negative pathogens, such as *Haemophilus influenzae* or *Pseudomonas aeruginosa*. Some bacteria have cell wall structures that are neither classically gram-positive or gram-negative. This includes clinically important bacteria such as *Mycobacteria* which have a thick peptidoglycan cell wall like a gram-positive bacterium, but also a second outer layer of lipids.

In many bacteria, an S-layer of rigidly arrayed protein molecules covers the outside of the cell.This layer provides chemical and physical protection for the cell surface and can act as a macromolecular diffusion barrier. S-layers have diverse but mostly poorly understood functions, but are known to act as virulence factors

in *Campylobacter* and contain surface enzymes in *Bacillus stearothermophilus*.



Helicobacter pylori electron micrograph, showing multiple flagella on the cell surface

Flagella are rigid protein structures, about 20 nanometres in diameter and up to 20 micrometres in length, that are used for motility. Flagella are driven by the energy released by the transfer of ions down an electrochemical gradient across the cell membrane.

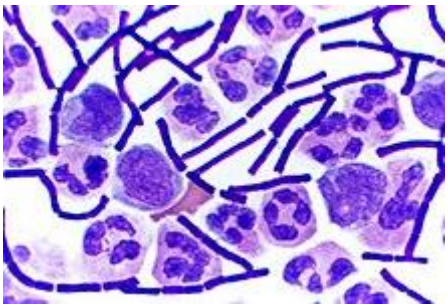
Fimbriae (sometimes called "attachment pili") are fine filaments of protein, usually 2–10 nanometres in diameter and up to several micrometres in length. They are distributed over the surface of the cell, and resemble fine hairs when seen under the electron microscope. Fimbriae are believed to be involved in attachment to solid surfaces or to other cells, and are essential for the virulence of some bacterial pathogens. Pili (*sing*. pilus) are cellular appendages, slightly larger than fimbriae, that can transfer genetic material between bacterial cells in a process called conjugation where they are called conjugation pili or sex pili (see bacterial genetics, below). They can also generate movement where they are called type IV pili.

Glycocalyx is produced by many bacteria to surround their cells, and varies in structural complexity: ranging from a disorganised slime layerof extracellular polymeric substances to a highly structured capsule. These structures can protect cells from engulfment by eukaryotic cells such as macrophages (part of the human immune system). They can also act as antigens and be involved in cell

recognition, as well as aiding attachment to surfaces and the formation of biofilms.

The assembly of these extracellular structures is dependent on bacterial secretion systems. These transfer proteins from the cytoplasm into the periplasm or into the environment around the cell. Many types of secretion systems are known and these structures are often essential for the virulence of pathogens, so are intensively studied.

Endospores



Bacillus anthracis (stained purple) growing in cerebrospinal fluid

Certain genera of gram-positive bacteria, such as *Bacillus*, *Clostridium*, *Sporohalobacter*, *Anaerobacter*, and *Heliobacterium*, can form highly resistant, dormant structures called *endospores*. Endospores develop within the cytoplasm of the cell; generally a single endospore develops in each cell. Each endospore contains a core of DNA and ribosomes surrounded by a cortex layer and protected by a multilayer rigid coat composed of peptidoglycan and a variety of proteins.

Endospores show no detectable metabolism and can survive extreme physical and chemical stresses, such as high levels of UV light, gamma radiation, detergents, disinfectants, heat, freezing, pressure, and desiccation. In this dormant state, these organisms may remain viable for millions of years, and endospores even allow bacteria to survive exposure to the vacuum and radiation in space.Endospore-forming bacteria can also cause disease: for example, anthrax can be contracted by the inhalation of *Bacillus*

*anthracis*endospores, and contamination of deep puncture wounds with *Clostridium tetani* endospores causes tetanus.

Metabolism

Bacteria exhibit an extremely wide variety of metabolic types. The distribution of metabolic traits within a group of bacteria has traditionally been used to define their taxonomy, but these traits often do not correspond with modern genetic classifications. Bacterial metabolism is classified into nutritional groups on the basis of three major criteria: the source of energy, the electron donors used, and the source of carbon used for growth.

Bacteria either derive energy from light using photosynthesis (called phototrophy), or by breaking down chemical compounds using oxidation (called chemotrophy). Chemotrophs use chemical compounds as a source of energy by transferring electrons from a given electron donor to a terminal electron acceptor in a redox reaction. This reaction releases energy that can be used to drive metabolism. Chemotrophs are further divided by the types of compounds they use to transfer electrons. Bacteria that use inorganic compounds such as hydrogren, carbon monoxide, or ammonia as sources of electrons are called lithotrophs, while those that use organic compounds are called organotrophs. The compounds used to receive electrons are also used to classify bacteria: aerobic organisms use oxygen as the terminal electron acceptor, while anaerobic organisms use other compounds such as nitrate, sulfate, or carbon dioxide.

Many bacteria get their carbon from other organic carbon, called heterotrophy. Others such as cyanobacteria and some purple bacteria are autotrophic, meaning that they obtain cellular carbon by fixing carbon dioxide. In unusual circumstances, the gas methane can be used by methanotrophic bacteria as both a source of electrons and a substrate for carbon anabolism.

How to protect yourself against bacteria and viruses

We will present several means and methods to protect yourself. Some may have common points. However, please read and follow them carefully.

Bacteria and viruses can be very contagious and make us ill. No one likes to be sick, so here are 5 things that will help you in your battle against germs!

1. **Wash Your Hands.** Can't say it enough! Hand Hygiene is the #1 way to prevent the spread of infection.
2. **Respiratory Hygiene/Cough etiquette.** You should cover mouth and nose when you cough or sneeze with a tissue or in your elbow. If you did cover with your hand be sure to immediately wash your hands with soap and water for 20 seconds or with an alcohol-based hand rub.
3. **Injection Safety.** These are steps to ensure that one needle, one syringe are used only one time. Outbreaks of Hepatitis B and C have been associated with breaks in injection safety. Don't hesitate to ask your provider if they understand injection safety and if the needle and syringe are only being used once!
4. **Sanitize Your Surroundings.** Always be sure to follow manufacturer instructions regarding cleaning products. Every product has a time frame that determines how long the "surface" must be wet in order to properly clean the surface. Some home products such as Clorox wipes require 4 minutes or longer. Don't forget to protect your hands from these products as well!
5. **ABC's of Antibiotic.** We should all ask the following questions of our healthcare provider when prescribed an antibiotic—Do I really need an antibiotic? Can I get better without this antibiotic? What side effects or drug interactions can I expect? What side effects should I report to you? How do you know what kind of infection I have as I understand antibiotics won't work for viral infections?

Preventing Transmission of Viruses and Bacteria

Get Vaccinated

Vaccination is the best way to protect yourself and others. When a vaccine against an infection or a disease is available, get it.

Apply Recognised Hygiene Measures

- Always keep your hands clean. Follow tips and techniques for washing hands
- Follow tips for Coughing and Sneezing Without Contaminating
- Avoid touching your nose, eyes and mouth. These are entry points for viruses and bacteria
- Avoid contact with people that are sick as they may be contagious. Do not get close to them and do not touch objects they have used, like their utensils for instance
- Clean your surroundings regularly, as well as the sanitary appliances you use. For example, clean your counters and other surfaces that you touch often with your hands. Also wash toilets and sinks in order to keep them clean. Cleaning is very effective in killing viruses, which can survive on hard surfaces.
- Clean with soap and water or use domestic detergents

Learn these healthy habits to protect yourself from disease and prevent germs and infectious diseases from spreading.

1. Handle & Prepare Food Safely

Food can carry germs. Wash hands, utensils, and surfaces often when preparing any food, especially raw meat. Always wash fruits and vegetables. Cook and keep foods at proper temperatures. Don't leave food out - refrigerate promptly.

Learn about Food Safety

2. Wash Hands Often

Learn how to Clean Hands and Help Prevent Flu

3. Clean & Disinfect Commonly Used Surfaces

Germs can live on surfaces. Cleaning with soap and water is usually enough. However, you should disinfect your bathroom and kitchen regularly. Disinfect other areas if someone in the house is ill. You can use an EPA certified disinfectant (look for the EPA registration number on the label), bleach solution, or rubbing alcohol.

4. Cough & Sneeze Into Your Sleeve

Learn how and when to cover your cough and sneeze.

5. Don't Share Personal Items

Avoid sharing personal items that can't be disinfected, like toothbrushes and razors, or sharing towels between washes. Needles should never be shared, should only be used once, and then thrown away properly.

Learn how to guard against germs

6. Get Vaccinated

Vaccines can prevent many infectious diseases. There are vaccines for children and adults designed to provide protection against many communicable diseases. There are also vaccines that are recommended or required for travelto certain parts of the world. Our Immunization Program can advise you on immunizations and clinics where you to get needed shots.

7. Avoid Touching Wild Animals

Be cautious around wild animals as they can spread infectious diseases to you and your pets.

8. Stay Home When Sick

Infectious diseases can be caused by bacteria, viruses, or other organisms that enter the body through a wide range of methods. Because these diseases are often easily passed from person to person, it is relatively easy to see a large outbreak of an illness in a single community. To protect yourself from infectious disease, the "ounce of prevention" adage does hold true. With just a few steps and some healthy habits, you can keep many germs and illnesses at bay.

Preventing Infectious Diseases

1. Wash your hands. Proper hand hygiene is vital when it comes to preventing the spread of infectious diseases. Pathogens (such as viruses, bacteria and fungi) are easily transferred from contaminated surfaces to your skin and from there to your eyes and mouth where

they can gain access to inside your body. Thus, washing your hands is one of the first steps to take to reduce the transfer of infectious agents.

- Wash your hands every time after going to the bathroom, changing a diaper, sneezing or blowing your nose and when coming into contact with bodily fluids.

- Wash your hands before and after working with food.

- When washing your hands, use soap and warm water to wet your hands up to your wrists and scrub the skin for at least 20 seconds or more.

- If water and soap is not available, use an alcohol-based hand sanitizer and rub it from your fingertips to your wrists in order to eliminate pathogens.

2. Avoid touching your face, eyes, and nose. People tend to touch their face several times throughout the day. This is when the infectious agents in your hands gain access to your body. Where an intact skin does not allow transfer of pathogens into the body, the eyes and mucous membranes in the nose and mouth do allow this.

- Besides maintaining a proper hand hygiene, try to avoid touching your face, even with clean hands.

- Avoid direct contact between the palm of your hand and face and use a tissue when you cough or sneeze.

- If a tissue is not available, cover your mouth or nose with your elbow. After using a tissue, discard it immediately into a proper waste receptacle and wash your hands

3. Keep all immunizations up to date. Vaccines are a preventive measure that help prevent or lessen illness caused by infectious pathogens. They work by stimulating an immune response against a specific pathogenic agent and, if you are ever exposed to the pathogen, your immune system can fight it more effectively.

- Get all adult and childhood immunizations on time and keep an accurate vaccination record at home for every family member to ensure everyone remains up to date.

- Because vaccines are designed to activate your immune system to recognize specific pathogens, some vaccines may cause minor symptoms, such as fever, fatigue and muscle aches, that last a day or two.

- Some vaccinations require booster shots (such as tetanus and polio) at certain intervals to maintain immunity.

4. Stay home. When you are sick with infectious disease, it is important to limit exposing other people to the pathogen and spreading the illness. Although some infectious diseases do not spread easily from person-to-person contact, others do and thus, you should stay home when you are symptomatic.

- If you are at public spaces, cover your mouth and nose with your elbow while coughing (and not with your hand) to avoid spreading pathogens airborne and transferring germs with your hands.

- Wash your hands and clean shared surfaces often if you are sick in order to minimize transmission of germs.

5. Prepare and store food safely. Some pathogens can be transferred into your body via food (so called foodborne illnesses or pathogens). Once food is consumed and the pathogen gains access to your body, it

can multiply and cause illness. Thus, it is vital you prepare and store all food appropriately.

- Prepare your food responsibly by limiting cross contamination. Raw food should never be prepared on the same surface as ready-made food to prevent transferring pathogens.

- Clean your work surfaces regularly and keep them clean and dry. Pathogens can thrive on wet environments.

- Wash your hands before and after handling food. You should also wash your hands when you are changing ingredients (eg, from raw food to fresh food).

- Food should be stored at safe temperatures (refrigerated if needed) and thrown out if you doubt their quality. Changes in color and texture and strange odors are signs that your food has spoiled.

- Hot food should be eaten when it is prepared and, if it needs to be stored, kept either hot (as in buffets) or refrigerated as soon as possible to keep pathogens from multiplying.

6. Practice safe sex and do not share personal items. Sexually transmitted diseases (STDs) are spread when bodily secretions come into contact with your genitals, mouth, and eyes. Practice safe sex to limit your risk of catching an STD.

- Always protect yourself by using a condom or dental dam during sexual activity, especially if you are not in a monogamous relationship.

- Do not engage in any sexual activity when you or your partner have a cold sore or genital wart breakout. This can lead to spreading incurable herpes.

- Get tested for STDs before and after engaging in sexual activities with a new partner so that you are aware of your status.

7. Travel wisely. Be aware of the risks of infection that increase when you travel. Some infections may be more common in places you are traveling versus where you live.

- Talk to your doctor about important vaccinations to get when you are traveling. This allows you to build up your immunity and be more prepared to the native pathogens present at the areas where you are travelling to.

- Wash your hands frequently when you are traveling to avoid transferring germs to your body via your hands.

- Protect yourself against infections that are carrier by vectors such as mosquitos by taking precautions, such as sleeping in mosquito netting, using bug spray, and wearing long-sleeved clothing.

Understand different kinds of infectious diseases

1. Understand different kinds of infectious diseases. You should be aware of the different agents that can spread infection. This can help you manage your risk factors.

- Bacteria are the most common infectious agents. They can be transmitted via bodily fluids and food. They are single cell living microorganisms that use your body as a home base to replicate.

- Viruses are pathogens that cannot live outside the host. When a virus enters your body, they hijack your body's cells to multiply and spread to neighboring cells.

- Fungi are simple, plant-like living organisms that may take up residence in your body.

- Parasites are living organisms that hijack the host's body and use their resources to thrive.

2. Treat bacterial infections with antibiotics. Antibiotics are medications that fight off bacterial infections. They work by disabling or killing bacterial cells and thus, fastening the elimination of bacteria by your immune system.

- Use topical antibiotic ointments for small wounds that are infected. Signs of infection include redness, swelling, warmth and pain. Do not use antibiotic ointment for heavily bleeding wounds that are deep. Seek medical attention if you have a wound that does not stop bleeding.

- For systemic bacterial infections, visit your healthcare provider and ask if you should be taking oral antibiotics.

- It is important to understand that antibiotics cannot cure or treat viral infections, such as the cold or flu. Your doctor can diagnose bacterial versus viral infection and treat it appropriately.

- Take antibiotics only as directed. Taking antibiotics when you don't need them (such as when you have a viral infection) increases bacterial resistance to antibiotics.

3. Treat viral infections. Viral infections cannot be treated with antibiotics but there are some antiviral medications that can be used for certain viruses. Some viral infections are treated with at home remedies (such as rest and remaining hydrated).

- Some drugs, known as antiviral or antiretroviral drugs, can fight off certain viruses by taking away their ability to reproduce their DNA inside your cells.

- Some viral infections, such as the common cold, only need to have their symptoms treated to make you more comfortable. Your immune system can fight off the virus as long as you are not immunocompromised and get enough rest and nutrients.

- Many viral illnesses can be prevented with vaccinations. Thus, you should keep your immunizations up to date.

4. Know how to treat fungal infections. Some fungal infections can be treated with medications that help eliminate the fungi and clear the infection. However, there are numerous pathogenic fungi that cause infections and only your doctor can diagnose and prescribe proper treatments.

- Some fungal infections may be treated with a topical ointment if the infected site is on your skin (such as foot fungus).

- Very serious and threatening fungal infections are treated with oral medications or injections.

- Some examples of pathogenic fungi include histoplasmosis, blastomycosis, coccidioidomycosis, and paracoccidioidomycosis, and these infections can be deadly.

5. Know how to treat parasitic infections. As the name implies, parasites are organisms that "hijack" your body's resources in order to live, grow and multiply inside you. Parasites refers to a wide array of pathogenic agents from worms to microscopic cells.

- Many parasites can be transferred into your body via contaminated food or water (such as hookworm), while others enter via broken/compromised skin (such as malaria via mosquito bite).

- You should never drink unfiltered or non-purified water from natural sources as the water may contain parasites.

- Some parasitic infections can be treated with oral or injected medications.

- Your doctor can diagnose a parasitic infection based on your symptoms and specific tests and then treat it appropriately.

Conclusion

The strong selective pressure exerted by phages plays a key role in controlling the number and composition of bacterial populations in most, if not all, ecosystems. Conversely, bacterial strategies to resist phage attack function by controlling phage numbers and composition, thus helping to establish a predator–prey dynamic equilibrium. Many phage resistance strategies depend on the use of horizontally acquired, "selfish" elements (plasmids and prophages) that can provide efficient barriers to phage infection but that do not compromise the physiological integrity of their host cell. Thus, many of the phage resistance strategies outlined here represent competitive advances between mobile parasitic elements that depend equally on their

bacterial host for long-term survival. Regardless of the origin of these systems, the consequences of the interplay between bacteria and phages necessitate molecular characterization of the many antiphage systems that are not fully understood.