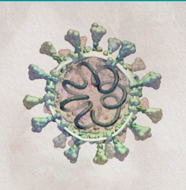

Biology of SARS-CoV-2

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Infection

This is the virus SARS-CoV-2. Its name stands for severe acute respiratory syndrome coronavirus 2.

You may have heard it called just the “coronavirus” or COVID-19.

Coronaviruses are actually a family of viruses that includes SARS-CoV-2.

And COVID-19 is the name of the disease caused by it.

Coronaviruses infect humans and other animals. In humans, they cause the common cold and, in some cases, more serious respiratory diseases.

All coronaviruses, including SARS-CoV-2, have a genome made of a single strand of RNA, which is surrounded by a membrane made of lipids and proteins. This membrane is called an envelope.

Coronaviruses are named after what looks like a crown of protein spikes that stick out of their envelope.

Coronaviruses enter the body mainly through the mouth or nose. The virus then has to get inside a human cell. The protein spikes on the virus’s envelope attach to specific proteins on the surface of a cell.

This causes the virus’s membrane to fuse with the cell’s membrane, releasing the virus’s RNA genome into the cell.

The cell’s ribosomes translate the virus’s RNA into proteins, including viral RNA polymerase.

The RNA polymerase transcribes the virus’s RNA, making more RNA copies that are translated into proteins. It also makes more copies of the virus’s whole genome.

The new viral genome and proteins combine to make a new virus that is packaged into an envelope formed from the cell’s membranes.

Newly formed viruses travel to the cell’s surface and are released outside the cell.

These viruses can infect other cells, or leave the body in mucus and saliva droplets. This can all happen even if a person doesn’t feel sick or show symptoms of disease.

A fever or coughing are usually signs that the immune system is fighting the infection.

The production of new viruses continues, until the body’s immune system is able to eliminate the infection.

Evolution

The SARS-CoV-2 genome is a single strand of RNA, with genes that encode fewer than 30 proteins. This is less than 0.1% of the proteins encoded by the human genome.

The virus’s genome is made of about 30,000 building blocks called nucleotides, which are represented by the letters A, U, C, and G. The unique sequence of nucleotides in a genome determines the proteins it encodes.

When the virus infects a cell, its genome is replicated, or copied. First, the virus makes strands of complementary RNA called template RNAs. The template RNAs are used to produce copies that match the original virus’s genome.

This genome replication process is prone to errors. These errors are called mutations. Mutations can occur at random anywhere in the genome.

For example, in this mutation, a “U” was substituted with an “A.”

A nucleotide can be substituted with a different nucleotide, added in the wrong place, or left out.

When the mutated virus infects another cell, all the new viruses replicated from it will have this same mutation, plus any new mutations that occurred.

Depending on the locations and types of mutations, they may or may not affect a virus’s ability to spread in a population.

Viruses with mutations that help the virus replicate or infect cells have a selective advantage. These viruses usually become more common in a population over time.

Viruses with mutations that make them less effective at replication or infection have a selective disadvantage. These viruses usually become less common in a population over time.

Mutations that have no effect on the virus are called “neutral mutations.” Viruses with neutral mutations replicate just as well as viruses without these mutations.

Tracking mutations in viruses can help determine where an outbreak started and how it spread. Understanding how virus populations change over time can also help scientists develop treatments and vaccines.

Detection

There are several ways to test whether someone has been infected with SARS-CoV-2. Some tests can detect if you have an active infection, or an infection that is happening right now, and others can detect if you’ve had an infection in the past and recovered.

To determine whether you have an active infection, doctors can look for the presence of the virus in your body.

One test uses RT-PCR, or reverse transcriptase polymerase chain reaction, to look for pieces of the virus’s RNA genome. A swab is taken of the inside of your nose or throat to collect cells or saliva in which the virus is likely replicating. If the virus’s RNA is in your cells, it will be detected by the PCR test and give a positive test result.

Another test for detecting an active infection looks for pieces of viral proteins recognized by the immune system, called antigens. If viral antigens are in your sample, they will be detected by the antigen test and give a positive result.

But what if you’ve already recovered and no longer have the virus in your body? In this case, a blood sample is taken to test for the presence of specific types of antibodies that recognize the virus. Antibodies are proteins produced by your body’s immune system to fight off infections.

Studying people who have antibodies to the virus can help scientists understand where a virus is spreading and how our immune system fights the virus.

None of these tests are foolproof. Viral RNA, viral antigens, and antibodies are all produced at different times during an infection, and they won’t always be detected. And, some tests are also less sensitive than others, resulting in false negatives. Doctors may use a combination of tests, or repeat tests at different times, if they’re uncertain.

Vaccination

When you are infected with a virus like SARS-CoV-2, your body gets to work destroying the virus. Your immune system recognizes certain viral proteins, called antigens. Antigens trigger a process called the immune response, which includes the production of many types of immune cells with different roles.

For simplicity, we will focus on B cells. B cells produce antibodies that bind to antigens. When antibodies bind to antigens on a virus, they can keep the virus from infecting other cells and target the virus for destruction by the body. Even after the virus is gone, some B cells that recognize the virus may stay in your body for years and protect you from that virus in the future. These are called memory B cells.

If you haven't come into contact with a particular virus before, it can take weeks for your immune system to produce enough antibodies to fight the unfamiliar virus. In the meantime, the virus can cause serious disease and spread to other people.

Vaccines help prevent disease caused by a virus that is unfamiliar to the body. A vaccine delivers antigens into your body to trigger an immune response without causing disease. Then if you are infected with the real virus in the future, you already have B cells and antibodies to quickly get rid of the virus.

Vaccines against SARS-CoV-2 and other viruses deliver the viral antigens in three main forms: as inactive whole virus, as antigen proteins, or through genetic instructions.

Some vaccines deliver the whole virus, which has been weakened or inactivated. These viruses don't cause disease, but still contain antigens that trigger an immune response.

Other vaccines deliver only the antigen. In the case of SARS-CoV-2, some vaccines deliver the spike protein. These spike proteins are produced in the lab.

And other types of vaccines deliver the genetic instructions, DNA or RNA, for making the antigens. In the case of SARS-CoV-2, some vaccines deliver a messenger RNA (or mRNA) that encodes the spike protein. The mRNA is delivered inside an artificial membrane similar to the cell membrane. When the mRNA enters one of your cells, the cell's ribosomes translate the mRNA into the spike protein antigen, which triggers an immune response.

Other SARS-CoV-2 vaccines deliver spike protein DNA instead of RNA. The DNA is typically delivered using an inactivated adenovirus: a modified virus that can't multiply or cause disease, but *can* bring the DNA into your cells. Your cells then transcribe the DNA into mRNA, which is then translated into spike proteins.

All these types of vaccines help the immune system to develop an immune response against a virus without causing disease. The different parts of each vaccine — such as inactive whole virus, antigens, mRNA or DNA, and molecules that help with delivery — are eliminated from the body. But some of the memory B cells that produce antibodies against the virus may last for years and provide protection from the virus.

Sometimes another dose of a vaccine, called a booster shot, is needed to keep levels of antibodies high. And, over time, if the virus mutates, you might need a new vaccine that delivers antigens matching those of the mutated virus.

As more individuals in a community get vaccinated and have antibodies to destroy a virus, it becomes harder for the virus to spread among people. So, getting a vaccine can help keep you, and those around you, safe from disease.