## What is a vaccine?

Vaccines are substances that are used to stimulate the production of antibodies (a specialized protein produced by the body's immune system to kill a virus or bacteria) and provide immunity against one or several diseases. It is prepared from the causative pathogen (a disease-causing organism), its products or a synthetic substitute, and treated to act as an antigen (foreign substance that stimulates an immune response) without inducing the disease. A vaccine stimulates your immune system to produce antibodies in the same way you would if you had the disease. After getting vaccinated, you develop immunity to that disease, without having to get the disease first.

## How do viruses make you sick?

When a virus enters your body it will attach itself to one of your cells and inject its DNA (genetic material) into your cell, this causes the cells to become factories for the virus and the cell starts producing more of the virus. The immune system attacks any foreign protein, virus of tissues however it takes a few days for the immune system to learn how to attack the intruder, in the meantime the virus is multiplying in the body and you start to experience symptoms of whatever has infected you. After a few days the immune system learns how to attack the intruder and produces antibodies which attach themselves to the virus preventing them from infecting more cells and this marks them for destruction. The immune system is very good at killing intruders but it's slow to attack.

## How does a vaccine work?

To give the immune system a helping hand we give the body a vaccine which helps train the immune system on how to attack the intruder without you getting sick.

A vaccine can result in active immunity (results after exposure to a disease organism which triggers the immune system to produce antibodies to that disease) against a specific harmful pathogen by stimulating the immune system to attack the pathogen. Once stimulated by a vaccine, the antibody-producing cells, called B cells (or B lymphocytes), remain sensitized and ready to respond to the agent should it ever gain entry to the body. Once the immune system has been trained to recognise this,if the body is later exposed to the pathogen, it will be removed from the body. Specifically, the immune system recognises foreign 'antigens', parts of the pathogen on the surface or inside the pathogen, that are not normally found in the body. A vaccine may also cause passive immunity (providing antibodies or lymphocytes already made by an animal or human donor).

When studying a new vaccine efficacy and effectiveness of the vaccines are determined. Efficacy refers to how something performs under ideal and controlled circumstances, such as in clinical trials. Effectiveness, on the other hand, describes the performance of something in "real world" situations.

## Types of vaccines?

There are several different types of vaccines. Each type is designed to teach your immune system how to fight off certain kinds of pathogens and the serious diseases they cause. There are 6 main types of vaccines:

- Live-attenuated vaccines
- Inactivated vaccines
- Subunit, recombinant, polysaccharide, and conjugate vaccines
- Toxoid vaccines
- Messenger RNA vaccines
- Viral vector vaccine

### Live-attenuated vaccines

Live vaccines use a weakened (or attenuated) form of the pathogen that causes a disease.

Because these vaccines are so similar to the natural infection that they help prevent, they create a strong and long-lasting immune response. Just 1 or 2 doses of most live vaccines can give you a lifetime of protection against a pathogen and the disease it causes.

They need to be kept cool, so they don't travel well. That means they can't be used in countries with limited access to refrigerators.

Live vaccines are used to protect against:

- Measles, mumps, rubella (MMR combined vaccine)
- Rotavirus
- Smallpox
- Chickenpox
- Yellow fever
- BCG vaccine against TB

## Inactivated vaccines

Inactivated vaccines use the killed version of the pathogen that causes a disease. Inactivated vaccines usually don't provide immunity (protection) that's as strong as live vaccines. So you may need several doses over time (booster shots) in order to get ongoing immunity against diseases. Inactivated vaccines are used to protect against:

- Hepatitis A
- Flu (shot only)
- Polio (shot only)
- Rabies

## Subunit, recombinant, polysaccharide, and conjugate vaccines

Subunit, recombinant, polysaccharide, and conjugate vaccines use specific pieces of the pathogen — like its protein, sugar, or capsid (a casing around the pathogen). Because these vaccines use only specific pieces of the pathogen, they give a very strong immune response that's targeted to key parts of the pathogen. They can also be used on almost everyone who needs them, including people with weakened immune systems and long-term health problems. One limitation of these vaccines is that you may need booster shots to get ongoing protection against diseases.

These vaccines are used to protect against:

- Hib (Haemophilus influenzae type b) disease
- Hepatitis B
- HPV (Human papillomavirus)
- Whooping cough (part of the DTaP combined vaccine)
- Pneumococcal disease
- Meningococcal disease
- Shingles

## Toxoid vaccines

Toxoid vaccines use a toxin (harmful product) made by the pathogen that causes a disease. They create immunity to the parts of the pathogen that cause a disease instead of the pathogen itself. That means the immune response is targeted to the toxin instead of the whole pathogen. Like some other types of vaccines, you may need booster shots to get ongoing protection against diseases. Toxoid vaccines are used to protect against:

- Diphtheria

- Tetanus

### Messenger RNA vaccines:

Messenger RNA (mRNA) vaccines are the most recently discovered type of vaccine. They teach our cells how to make a protein or a piece of a protein by using the mRNA to turn the cells into your body into manufactures of the protein which show up on the cells surface. The proteins are then detected by the immune system and this triggers an immune response inside our bodies. That immune response, which produces antibodies, protects us from getting infected if the real virus enters our bodies. Since just a piece of a virus is used it does not make you sick. The mRNA is destroyed once the protein has been made and leave no trace in your body.

### Viral vector vaccine

Viral vector vaccines use a modified version of a different virus (adenovirus) such as the common cold as a vector to deliver instructions (mRNA), in the form of genetic material (a gene), to a cell. The virus used as a viral vector vaccine poses no threat of causing illness because it has been modified. Once the instructions have been delivered to the cells it makes the cell into a manufacturer of the pathogen proteins. The cell then produces the proteins which the immune system the detects and forms an immune response. The viral vector itself plays an additional role by booting our immune response. This leads to a more robust reaction than if the pathogens genetic sequence was delivered on its own. Viral vector vaccines have been used resecntly used to resond to Ebola outbreaks.

## What COVID-19 vaccines are currently available?

### Pfizer-BioNTech vaccine:

Cornona virus are so named due to their spikes found on their surface which makes them resemble a crown. These spikes attach to a cell in your body and infect them. Researchers took the RNA that manufactures the spikes on a COVID-19 virus cell and changed it into mRNA with has the blueprints on how to create the spikes, used that as a vaccine, which attaches to a cell in your body and passes the RNA into the cell causing the cell to manufacture and produce the spikes. The immune system then detects the spikes as intruders and attacks them and produces antibodies which block the spikes and destroys them. As part of your immune system you have memory cells called B cells, these remember how to attack the virus and if you are exposed to the virus in the future your immune system knows how to attack the virus straight away and produces antibodies which attach themselves to the spikes preventing them from infecting the cells in your body.

The vaccine uses messenger RNA, genetic material that our cells read to make proteins. The molecule — called mRNA for short — is fragile and would be chopped to pieces by our natural enzymes if it were injected directly into the body. To protect their vaccine, Pfizer and BioNTech wrap the mRNA in oily bubbles made of lipid nanoparticles. Messenger RNA is very sensitive to warm temperatures and must be kept at -70 °C. The vaccine can be given to individuals 16 years and older. Two doses are given 21 days apart, the first vaccine provides a 52% protection and the second provides a 92% protection.

## Moderna

The Moderna vaccine is also an mRNA vaccine. The body produces antibodies and develops longer lasting immunity that can fight off the SARS-CoV-2 virus should it enter the body at a later stage. Two separate doses are given 28 days apart. The FDA state that staff must store the Moderna COVID-19 vaccine frozen, between -25ºC and -15ºC. Staff can store the vaccine in the refrigerator between 2°C and 8°C for up to 30 days before use. Once staff withdraw the first dose from a multidose vial, they should keep the vial at between 2°C to 25°C. They should discard the vial after 6 hours because this vaccine does not contain any preservatives. A large 2020 trial, involving 30,420 adult volunteers at various sites across the U.S., reports that the Moderna vaccine has a 94.1% efficacy rate against COVID-19, including against severe disease. According to the World Health Organization (WHO), the evidence so far indicates that the Moderna vaccine is effective against the new variants of COVID-19. These new variants include those that scientists first identified in the U.K. and South Africa.

## Johnson and Johnson

This vaccine works similarly to the Pfizer and Moderna vaccines, instead of using mRNA to deliver the instructions to make your cells to make the spike proteins, it uses a DNA construct that produces the RNA in people's cells . Janssen Pharmaceutica, a Belgium-based division of Johnson & Johnson, has developed the vaccine in collaboration with Beth Israel Deaconess Medical Center. The Johnson & Johnson vaccine is based on the virus's genetic instructions for building the spike protein. But unlike the Pfizer-BioNTech and Moderna vaccines, which store the instructions in single-stranded RNA, the Johnson & Johnson vaccine uses double-stranded DNA. The researchers added the gene for the coronavirus spike protein to another virus called Adenovirus 26. Adenoviruses are common viruses that typically cause colds or flu-like symptoms. The Johnson & Johnson team used a modified adenovirus that can enter cells but can't replicate inside them or cause illness.

Adenovirus-based vaccines for Covid-19 are more robust than mRNA vaccines from Pfizer and Moderna. DNA is not as fragile as RNA, and the adenovirus's tough protein coat helps protect the genetic material inside. As a result, the Johnson & Johnson vaccine can be refrigerated for up to three months at 36–46°F (2–8°C). After the vaccine is injected into a person's arm, the adenoviruses bump into cells and latch onto proteins on their surface. The cell engulfs the virus in a bubble and pulls it inside. Once inside, the adenovirus escapes from the bubble and travels to the nucleus, the chamber where the cell's DNA is stored. The adenovirus pushes its DNA into the nucleus. The adenovirus is engineered so it can't make copies of itself, but the gene for the coronavirus spike protein can be read by the cell and copied into a molecule called messenger RNA, or mRNA. The mRNA leaves the nucleus, and the cell's molecules read its sequence and begin assembling spike proteins. Some of the spike proteins produced by the cell form spikes that migrate to its surface and stick out their tips. The vaccinated cells also break up some of the proteins into fragments, which they present on their surface. These protruding spikes and spike protein fragments can then be recognized by the immune system.

The adenovirus also provokes the immune system by switching on the cell's alarm systems. The cell sends out warning signals to activate immune cells nearby. By raising this alarm, the Johnson & Johnson vaccine causes the immune system to react more strongly to the spike proteins. When a vaccinated cell dies, the debris contains spike proteins and protein fragments that can then be taken up by a type of immune cell called an antigen-presenting cell. Johnson & Johnson's vaccine is given as a single dose, unlike the two-dose coronavirus vaccines from Pfizer, Moderna and AstraZeneca. Researchers don't yet know how long the vaccine's protection might last. It's possible that the number of antibodies and killer T cells will drop in the months after vaccination. But the immune system also contains special cells called memory B cells and memory T cells that might retain information about the coronavirus for years or even decades. Clinical trials showed that a single dose of the vaccine had an efficacy rate of up to 72 percent.

### AstraZeneca

This is a viral vector vaccine as well. It is made from a weakened version of a common cold virus (known as an adenovirus) from chimpanzees. It has been modified to look more like coronavirus - although it can't cause illness. Our cells than transcribe this gene into mRNA which promts our cellular machine to make the spike protein in your cells, which then appear at the cell surface triggering an immune response.

Research has shown it is highly effective. No one given the vaccine in trials developed severe Covid or needed hospital treatment. Unlike Pfizer's vaccine - which has to be kept at an extremely cold temperature (-70C) - the Oxford vaccine can be stored in a normal fridge. This makes it much easier to distribute. Large trials showed the Pfizer vaccine was 95% effective, while the figure for the Oxford one was 62%. It's important to remember that even the lower 62% figure is a better result than the best flu jab, which is about 50% effective. No-one who received the Oxford vaccine was hospitalised or became seriously ill due to Covid. A recent study found a single dose of the Oxford vaccine offered 76% protection for three months, and this went up to 82% after the second dose.

## Sinopharm

The Beijing-based biopharmaceutical company Sinovac is behind the CoronaVac, an inactivated vaccine. It works by using killed viral particles to expose the body's immune system to the virus without risking a serious disease response. By comparison the Moderna and Pfizer vaccines being developed in the West are mRNA vaccines. "CoronaVac is a more traditional method of vaccine that is successfully used in many well known vaccines like rabies.

On paper, one of Sinovac's main advantages is that it can be stored in a standard refrigerator at 2-8 degrees Celsius, like the Oxford vaccine, which is made from a genetically engineered virus that causes the common cold in chimpanzees. Moderna's vaccine needs to be stored at -20C and Pfizer's vaccine at -70C. It means that both Sinovac and the Oxford-AstraZeneca vaccine are a lot more useful to developing countries which might not be able to store large amounts of vaccine at such low temperatures. Sinopharm announced on 30 December 2020 that phase three trials of the vaccine showed that it was 79% effective - lower than that of Pfizer and Moderna. However, the United Arab Emirates, which approved a Sinopharm vaccine earlier this month, said the vaccine was 86% effective, according to interim results of its phase three trial.

## Sputnik V vaccine

Sputnik V is also a viral vector vaccine, it is made up of two different viruses belonging to the adenovirus family, Ad26 and Ad5. These adenoviruses have been modified to contain the gene for making the SARS-CoV-2 spike protein; they cannot reproduce in the body and do not cause disease. The two adenoviruses are given separately: Ad26 is used in the first dose and Ad5 is used in the second to boost the vaccine’s effect.

Once it has been given, the vaccine delivers the SARS-CoV-2 gene into cells in the body. The cells will use the gene to produce the spike protein. The person’s immune system will treat this spike protein as foreign and produce natural defences − antibodies and T cells − against this protein.

If, later on, the vaccinated person comes into contact with SARS-CoV-2, the immune system will recognise the spike protein on the virus and be prepared to attack it: antibodies and T cells can work together to kill the virus, prevent its entry into the body's cells and destroy infected cells, thus helping to protect against COVID-19.

| Company | Country | Type of vaccine | Dosage | Ages deemed safe | Effectiveness | Storage |
|---|---|---|---|---|---|---|
| AstraZeneca (Oxford University) | United Kingdom | Viral vector | X2 (8-12 weeks apart) | 18+<br>(6-17 trials underway) | 63.09% (WHO) | 2-8°C<br>(6 months) |
| Moderna | USA | RNA | X2 (28 days apart) | 18 years + | 84.1% | -25 to -15°C<br>(7 months) |
| Pfizer-BioNTech | USA and Pathogenany | RNA | X2 (21-28 days apart) | 16 years + | 95% (TheLancet) | -80 to -60°C<br>(6 Months) |
| Gamalega (Sputnik V) | Russia | Viral vector | X2 (21 days apart) | 18-60 years | 92% (BBC news) | -18.5°C (liquid form)<br>2-8°C (Dry form) |
| Sinovac (CoronaVac) | China | Inactivated virus (weakened virus) | X 2 (1 month apart) | | 50% (BBC new) | 2-8°C |
| Janssen (Johnson and Johnson) | USA | Viral vector | X1 (3 weeks apart) | 18+ | Ranges from 64% to 86% | 2-8 °C<br>(3 months) |