

[MUSIC PLAYING]

Let's think of the cell like a factory. The nucleus is the boss's office, where the manufacturing instructions for the factory's products, our genes, are stored safely and permanently as digital files on the boss's computer. To initiate building a product, the boss first prints out these instructions, making a paper copy of the instructions using a special printer. These mRNA prints are sent to the factory floor. The workers in the factory take these instructions and build the requested product.

Protein products can be tagged to stay in the factory or shipped out for external use. These factory processes can be exploited by viruses, which require them to manufacture copies of themselves. First, they break into the factory using a special key to pick the lock on one of the factory doors. In the case of the virus that causes COVID-19, the key is the viral spike protein. And the lock is a receptor called ACE2.

Once inside, different viruses have different tactics. Some directly leave their own paper instructions on the factory floor. Others sneak into the office and print out paper instructions from their own digital files using the office printer before leaving those on the factory floor. They achieve this without needing to use the boss's computer.

The cell workers then unwittingly start making the virus's own products. When the viral products come together, they form new viruses. Soon, the factory is overwhelmed by these viruses, which destroy the factory so they can escape and then go on to take over other factories. But don't worry. Your body's cell factories are protected by your immune system. Once it notices the presence of viral products left behind from destroyed factories or the viruses themselves, it sets up a task force to intercept and stop the viruses from causing further damage.

There are two main components of our immune system responsible for this task. T cells destroy factories compromised by the viruses, which stops viruses inside spreading to further factories. Alternatively, antibodies, produced by B cells, stop viruses before they get into factories in the first place. They do this by blocking the interaction of the viral keys with the factory locks. Once our immune system has learned what to look for, it can provide long-term protection for our factories.

The purpose of a vaccine is to train our immune system so it can stay one step ahead of the viruses. Vaccines work by turning one or more of the virus's own products against it. For vaccines targeting coronavirus, we use the spike protein key to train our immune system.

Some of the new COVID-19 vaccines harness the power of our cell factories to achieve this goal. These are called nucleic acid vaccines. And this is how two different examples of this approach work.

One method is to recruit a friendly virus as a courier, a viral vector, to deliver the vaccine instructions to the cell factory. In the case of the Oxford/AstraZeneca COVID-19 vaccine, this viral vector is known as chadox1.

Our courier makes its way to the factory office of the cell and uses the office printer to print out the paper instructions from its personal digital files, again, without needing to use the boss's computer. However, our courier only carries one printable file containing instructions for the coronavirus spike protein. The file does not contain instructions to make the rest of the coronavirus or to make other courier viruses. This means no viruses are made within the factory, and the factory remains safe.

An alternative to hiring a courier is to post the paper instructions for the spike protein directly to the factory, wrapped in a padded envelope to ensure it gets there safely. These instructions are delivered directly to the factory floor without needing to print them off first. These approaches, known as RNA vaccines, are used by Pfizer/BioNTech for their COVID-19 vaccine.

For both viral vector and RNA vaccines, our cell factory manufactures harmless spike protein that is used to teach our immune system how to recognise the spike protein on the actual virus so it can stop the virus if it makes an appearance in future. The instructions provided by the vaccines are not permanent. Over time, they're removed from the office and factory floor, and the factory stops production. Because of this removal, we need to resend the instructions in the form of a second courier or envelope to ensure our immune system remains vigilant. This repeat service is the booster vaccination that is required for most of the COVID-19 vaccines available. By temporarily reactivating the factory in this way, we ensure that our immune system remains vigilant for an extended period of time.