How Vaccines Work

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Introduction to How Vaccines Work

Medicine has come a long way over the years. The development of the **vaccine** kicked off an era of illness prevention unlike anything the world had ever seen. In fact, vaccinations are largely viewed as the most successful medical advancement in the history of public health. Before vaccines were introduced, smallpox killed millions, nearly 20,000 were paralyzed by polio, and rubella (German measles) caused serious birth defects in about 20,000 newborns.

In this article, we'll learn about the inspiration for vaccines, the basic science behind how they prevent illness and the diseases they keep at bay. We'll also go head-to-head with some of the common myths circulated about vaccines.

The Inspiration for Vaccines

Who knew that cows would save the lives of countless humans? In 1796, a physician named Edward Jenner decided to prove a theory that had been circulating for some time. Smallpox once killed millions of people worldwide. Cowpox was a less serious disease related to smallpox that milkmaids often caught through exposure to infected cows. Jenner noticed that milkmaids who had contracted cowpox were later immune to smallpox. Jenner tested this theory when he took some infected cowpox matter and exposed an otherwise healthy boy through a cut in his arm. After the boy caught and recovered from cowpox, Jenner exposed him to smallpox via an injection. The boy remained healthy, and the world's first vaccine was born. The cows, for their part, were honored when the term "vaccine" was coined -- "vacca" is Latin for cow. According to the national Centers for Disease Control and Prevention (CDC) the world's last case of naturally occurring smallpox was in 1977. The disease has since been eliminated from natural occurrences in the world, so the vaccine is no longer given.

On the next page, we'll learn about how vaccines work in your body to destroy diseases.

Vaccine Basics

Jenner was operating on the now widely accepted principle that once a person catches a certain disease, he or she is immune to it for the rest of their life. For example, once you've had the chickenpox, it's extremely unlikely that you'll ever catch it again. This is because your body, when exposed again, will recognize the disease and fight it off. The beauty of vaccines is that they help the body develop disease-fighting abilities without making you sick. Vaccines accomplish this amazing feat by tricking the body into believing it already has the full-blown disease. Here are the steps in this process, known as the "immune response":

The vaccine is administered. It contains weakened or dead forms of the disease.

1. The immune system identifies these foreign substances (viruses and bacteria), also known as **antigens**.
2. Once antigens are identified, the immune system develops proteins that circulate in the blood. These proteins are called **antibodies**. They fight the infection by killing the antigens. Antibodies are made by white blood cells called lymphocytes, also known as B cells. The main purpose of B cells is to create antibodies to fight infection.
3. The body stockpiles these antibodies so they are available to fight off the disease if exposed later on. Unfortunately, antibodies are disease-specific, so previously acquired chickenpox antibodies will be useless if faced with other diseases.

It's very important to note that when the actual disease infects a person, the antigens multiply thousands and thousands of times until a raging infection is under way. The vaccine provides just enough of these antigens for the body to recognize them and complete the immune response process, therefore protecting them from exposure to the disease in the future.

Next, we'll discuss the two types of vaccines.

Vaccine Types

Vaccines are usually given via a hypodermic injection, but some are given through the mouth or nose. There are two main groups of vaccines: live-attenuated vaccines and inactivated vaccines.

Live-attenuated vaccines: Live-attenuated basically means alive, but very weak. These vaccines are made when the virus is weakened to such a level that they reproduce only about 20 times in the body. By comparison, natural viruses reproduce thousands of times. When the vaccine is made, the virus or bacteria is weakened in a laboratory to the point where it's still alive and able to reproduce, but can't cause serious illness. Its presence is enough to cause the immune system to produce antibodies to fight off the particular disease in the future. "Live-attenuated vaccines can cause very mild illness in a small proportion of people," says John Bradley, M.D., member of the committee on infectious diseases of the American Academy of Pediatrics (AAP). "However, these side effects are usually very mild and limited to a low-grade fever or runny nose." Dr. Bradley also notes that about 5 to 10 percent of children who receive the varicella (chickenpox) vaccine develop a few pox spots, but it's nothing compared to the full-blown illness.

To weaken the virus, scientists must isolate it through a specimen from an infected person. They then grow the virus in a test tube. They "pass" the virus into a second test tube, then a third, a fourth and so on. Scientists perform this "passage" many times -- the measles virus was passed 77 times! The virus is periodically taken out of the test tube to see if it has mutated. Eventually, the virus gets so used to living in the comfortable test-tube environment that it loses its capacity to produce illness in humans. These passages are performed in a very controlled environment in exactly the same way each time. This discovery was considered the "hallelujah" of vaccine development, according to William Schaffner, M.D., professor and chair of the Department of Preventive Medicine at Vanderbilt University School of Medicine.

Examples of live-attenuated vaccines are MMR (measles, mumps and rubella combination vaccine), varicella and the intranasal form of influenza.

Inactivated vaccines: When inactivated vaccines are made, the bacteria is completely killed using a chemical, usually formaldehyde. Dead pieces of disease-causing microorganisms (usually bacteria) are put into the vaccine.

Because the antigens are dead, the strength of these vaccines tend to wear off over time, resulting in less long-lasting immunity. So, multiple doses of inactivated vaccines are usually necessary to provide the best protection. The benefit of inactivated vaccines is that there is zero chance of developing any disease-related symptoms -- allergic reactions are possible but extremely rare. Examples of inactivated vaccines are hepatitis A, hepatitis B, poliovirus, haemophilus influenzae type b (Hib), meningococcal, pneumococcal and the injected form of influenza.

Why are some vaccines live and some dead?

"The bottom line is that the decision is entirely driven by the science," says Dr. Schaffner. "If scientists can make a killed vaccine that is effective, that is what they will do. It's all about trial and error." Most viral diseases, he says, require live-attenuated vaccines, but the vast majority of bacterial illnesses are prevented with inactivated vaccines. There are some exceptions to this rule, though. For example:

- Some travelers to less-developed countries get the vaccine to prevent typhoid fever. There are live and killed forms of this vaccine.
- Rabies is a viral infection that is 100 percent fatal once it has progressed. The disease is simply too dangerous to give, even in a weakened state. Fortunately, science allowed the development of an inactivated rabies vaccine.

So what, exactly, are the ingredients of a vaccine? Read on to find out.

Vaccine Components

Other than the antigen, a couple of things have to be included in the vaccine in order for it to be effective. The requirements vary depending on the specific vaccine, but the gist is the same.

The vaccine has to be stable because it leaves the manufacturing plant, gets bounced around on trucks and so forth. Sometimes small chemicals are added to act as stabilizers so that the vaccine material remains potent. These chemicals are thoroughly regulated by the Food and Drug Administration (FDA) to ensure their safety and are usually present only in trace amounts.

In multidose vials, a disinfectant is required. This is so that each time a dose is removed, any foreign matter that intrudes is killed instantly. Traditionally, Thimerosol has been the most popular among scientists. However, the industry has largely abandoned its use because of concerns that the chemical causes adverse reactions (see sidebar about vaccine myths). In fact, multidose vials are being phased out in favor of single-dose vials, even though these are more expensive. Thimerosol is currently present only in trace amounts in the influenza vaccine, but that will be a thing of the past in a few years. "We would like to put the controversy behind us," says Dr. Schaffner. "None of us associated with vaccines believe there is merit to that belief, but we are going the extra hundred miles to reassure parents."

The process of creating, testing and producing a vaccine in mass quantities can take many years from start to finish because the industry is highly regulated. Before scientists even begin to formulate a vaccine, researchers have to study the particular virus or bacteria. Basically, they have to isolate it in a laboratory setting and figure out how it causes the disease. Then they develop the vaccine as either a live-attenuated or inactivated vaccine, depending on the type of virus or bacteria.

Once they have a good grip on that, researchers study the best ways to protect people from the disease using the vaccine they have developed. They figure out the best dosage amounts, whether or not one shot is good enough, or if more is necessary. They also estimate how long protection from the vaccine lasts to determine if booster shots will be necessary. Most of this early research is conducted in laboratories in an academic setting and is paid for by foundation or government grants.

Once the vaccine has been developed, the testing process is conducted over four phases and a period of many years. This testing is funded by pharmaceutical companies and can rack up hundreds of millions of dollars in bills.