

Vaccine



Figure 1: The DPT vaccine, which protects against diphtheria, pertussis, and tetanus, is routinely given to children in the first year of life.

In 1921 there were 206,939 cases of diphtheria reported in the United States, mostly among children. In 1983 only five people came down with the disease. In 1941 measles claimed 894,134 victims; in 1983 there were only 1,497 cases. The main reason for the dramatic decline in these serious diseases has been the development and use of vaccines.

A vaccine is a substance administered to humans or animals to protect them from serious diseases. The process of administering a vaccine is called vaccination. The process of protecting a person or animal from diseases is called immunization. Through the use of vaccines, humanity has been able to protect itself against many deadly and crippling diseases. Researchers are working to develop new vaccines against other health threats such as AIDS (Acquired Immune Deficiency Syndrome).

The first vaccine was developed by the English physician Edward Jenner in 1796 to protect against smallpox, a disease that disfigured and killed thousands of people each year. Jenner knew that dairy workers who caught the mild disease cowpox did not get smallpox. Jenner took material from a cowpox sore and scratched it into the arm of a healthy 8-year-old boy. As expected, the child developed cowpox. Jenner then scratched material from a smallpox sore into the boy's arm. The child remained healthy. Jenner named the material from the cowpox sore vaccine, and the process in which he used it, vaccination. Both words are from the Latin *vaccinus*, meaning "from cows." Use of the vaccine spread quickly; within 200 years smallpox had been eliminated from the world.

Vaccines are now available for a variety of diseases. The list is likely to grow as new techniques are used to develop safer, less costly vaccines.

Vaccines are used for several purposes. Their widest use is to immunize large groups of people or animals against serious diseases common in areas where they live. Travelers often receive vaccines to protect them from diseases found in the countries they will be visiting. A third use of vaccines is to protect high-risk groups, such as the elderly and the very young, who are at greater risk should they contract a contagious disease.

The principle of vaccination is to cause the immune system to behave as if the body has contracted a disease. This sets in motion the body's defense system without risking the damage that may be caused by the disease itself. Immunization can be either active or passive.



In active immunization, the components of the vaccine teach the individual's immune system to recognize a specific toxin, virus, or bacteria. Each pathogen, or disease-causing agent, is identified by antigens, or marker molecules, on its surface. The immune system has cells called B-lymphocytes that detect these antigens and respond by manufacturing molecules called antibodies. Each antibody is made specifically to attack one type of antigen. The antibody combines with the antigen—like a key fitting a lock—and enables the immune system to destroy it. If the same type of pathogen enters the body again in the future, its antigens will be recognized, specific antibodies will be rapidly manufactured, and the organism that could cause a disease will be destroyed.

The protection against specific diseases conferred by active immunization generally lasts for years. If the antibodies formed after a vaccination decrease significantly over time, the individual can be revaccinated. So-called booster shots cause antibodies to be formed more quickly than they are by the first shot.

Passive immunization involves injecting antibodies made by one person or animal into the bloodstream of another. This type of immunization may be used if active immunization is not available; if an individual has already been exposed to a disease and does not have time to manufacture antibodies; or if an individual's own immune system is not working properly. Passive immunization protects an individual for only a few weeks or months.

There are still many diseases for which it has not been possible to create vaccines. In some cases, this is because of the complexity of the pathogen. Other diseases, such as influenza, are caused by organisms that have the ability to change their antigens from time to time. A new influenza vaccine must be prepared each year to protect against the forms of the flu viruses that researchers predict will strike the population during the flu season.

A third category of organisms has the capacity to hide from the immune system. Some members of the herpes virus family, which cause cold sores, genital sores, shingles, chicken pox, and mononucleosis, live in nerve roots where they can avoid detection by the blood-borne B-lymphocytes. The body's immune system cannot distinguish between the nerve root and the pathogen.

Technical problems have also hindered the development of vaccines. Research is expensive. Vaccines have side effects that can be quite serious for some individuals. Drug companies may be reluctant to produce vaccines because of the threat of lawsuits from those who may be harmed by these side effects. Even many existing vaccines have not been widely used in developing countries because of problems with storing and administering the doses.

Many vaccines can be given only by injection, because passage through the gastrointestinal tract would destroy them. The vaccine may be injected into a muscle, or intramuscularly; beneath the skin, or subcutaneously; or between the skin layers, or intradermally. Some vaccines are effective when given orally, such as the Sabin polio vaccine, and some are sprayed into the nose or mouth.

Vaccines made with live organisms generally need to be given only once to confer lifelong immunity. Vaccines made from inactivated or killed organisms or toxoids, substances from disease-causing organisms that have been treated so as to induce formation of antibodies when injected into a person, often must be given several times to stimulate an immune response. Even then antibody production may decline after a time, leaving the individual vulnerable to the disease again. Booster shots may be required at regular intervals to raise immunity to protective levels. For instance, the diphtheria and tetanus immunizations are given initially at two-month intervals for a total of three doses. Immunity begins to decline after a few months, and booster shots are then administered periodically.

Not every individual will respond to vaccination by developing long-lasting immunity. Much depends on the person's age, state of health, and ability to manufacture antibodies. Physicians believe, however, that if most of the population is immunized against common diseases, these illnesses will occur less frequently.

Adverse reactions, or side effects, have been reported for all existing vaccines. These reactions may range from a sore arm at the injection site to mild fever, joint pains, rash, or nausea, normally lasting only a short time. In extremely rare cases, however, severe reactions may occur.

Oral polio vaccines, in which live virus is used, have been known to cause mild to crippling paralysis in some people who received the vaccines. However, the incidence of serious problems is rare—approximately one case of paralytic polio per 9 million doses of vaccine. Vaccines are still among the safest and most beneficial preventive drugs available.

Until recently, vaccines have been made from naturally occurring viruses or bacteria or from the products of these pathogens. Vaccines may be prepared from live pathogens that have been weakened, or attenuated, in some way. This technique prevents the pathogen from causing serious disease while still stimulating the immune system to produce antibodies. The antibodies formed against live pathogens last longer; however, the vaccine may not be as safe as one made from killed microorganisms. Vaccines made from weakened microorganisms include those for measles, mumps, rubella, and yellow fever.

The second type of vaccine may consist of dead viruses or bacteria. If the pathogens can be killed so that their chemical makeup changes very little, they will still cause the body to produce antibodies. While these vaccines are among the safest, the antibodies may not be as numerous as with live-pathogen vaccines and may not last very long. Diseases in which killed pathogens are used for the vaccine include typhoid fever, rabies, and whooping cough.

A third type of vaccine produces antibodies that fight against the poisons, or toxins, generated by pathogens. These vaccines contain chemically changed toxins, called toxoids, and are considered safe and highly effective. The diphtheria and tetanus vaccines are made in this manner.

Finally, some vaccines, like Jenner's vaccine, consist of viral or bacterial particles that do not cause serious disease but resemble their disease-causing counterparts. These impostors can fool the immune system into producing antibodies against both diseases.

The advent of genetic engineering has enabled scientists to apply new techniques to the manufacture of vaccines. One approach is to use the recombinant DNA method to remove the disease-causing portion of a microbe without affecting its ability to stimulate antibody production. A recombinant vaccine against hepatitis B has been in common use since 1986. A second approach is simply to manufacture antigens artificially, without using any portion of the pathogen. Antigens are composed of building blocks called amino acids, assembled in a specific order. Scientists have learned how to string together amino acids in the proper order to elicit an antibody response without risking disease.

Genetic engineering has modified Jenner's original vaccine, which was made from the vaccinia virus. This large and fast-growing organism can be changed, using the recombinant DNA method, so that it produces antigens against not one but a number of diseases. If successful, it could be the basis of a so-called supervaccine with a number of advantages. It would be cheap and easy to produce, because many countries have experience in producing the smallpox vaccine. It could be freeze-

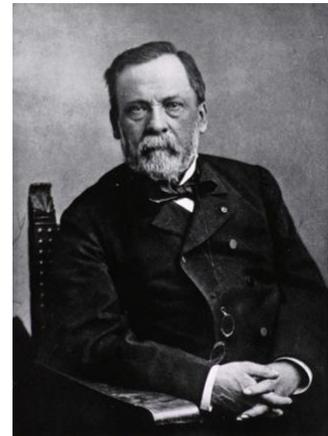
dried and thus easy to store without refrigeration; one inoculation could provide protection against many diseases; and administration of the supervaccine, like the smallpox vaccine, would leave a small scar, identifying protected individuals without requiring written records.

The new genetic techniques may provide ways to create vaccines for previously resistant diseases, such as malaria and herpes viruses, and perhaps for noninfectious diseases, such as those caused by parasites.

When Jenner performed his historic vaccination in 1796, he did not know why the process prevented smallpox. It was left to other scientists to discover the mechanisms of infection and immunity. Over the next 100 years, Robert Koch, a German physician, and others demonstrated that disease was caused by microbes. In 1879 French chemist Louis Pasteur was growing the microbes that caused fowl cholera. He left the cultures in his laboratory while he went on vacation. On his return, he injected some chickens with the old cultures and found that they became only slightly ill. Furthermore, on recovery, they were immune to fowl cholera. He named his attenuated culture vaccine in honor of Jenner. Pasteur eventually developed an effective vaccine against rabies. The French scientist was the first to apply scientific principles to the manufacture of vaccines.

After Pasteur published his findings, other researchers began to develop vaccines. In the late 19th century, Émile Roux, a student of Pasteur, and Emil von Behring, a German physician, found that the killer in diphtheria was not the disease microbe itself but a toxin it produced. They laid the groundwork for the tetanus and diphtheria toxoid vaccines in the early 20th century.

Wilhelm Kolle, a German bacteriologist, developed the typhoid and cholera vaccines in 1896. His method employed killed organisms that nonetheless were able to stimulate an immune response and to protect against disease. In the mid-20th century, Jonas Salk, an American physician, used the techniques of culturing viruses in living tissue in the laboratory to produce a vaccine against poliomyelitis. The polio vaccine, licensed in 1955, has virtually ended a disease that once killed or crippled thousands of children around the world each year. In the future the names of genetic engineers will undoubtedly be added to the list of those who have made significant contributions to the prevention of disease through the use of vaccines.



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