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PROPHYLACTIC VACCINATIONS AND THEIR MICROBIOLOGICAL FOUNDATIONS

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Abstract: This article examines the importance of prophylactic vaccinations, their microbiological principles, and various types of vaccines. Vaccines prepare the immune system to mount a defensive response against disease-causing microorganisms, significantly reducing the spread of infectious diseases over the years. The paper also discusses the efficacy and safety of immunization, its role in global public health (WHO strategies), and its contribution to combating antibiotic resistance.

Keywords: Prophylactic vaccination,microbiological mechanisms,immune memory,WHO,antibiotic resistance

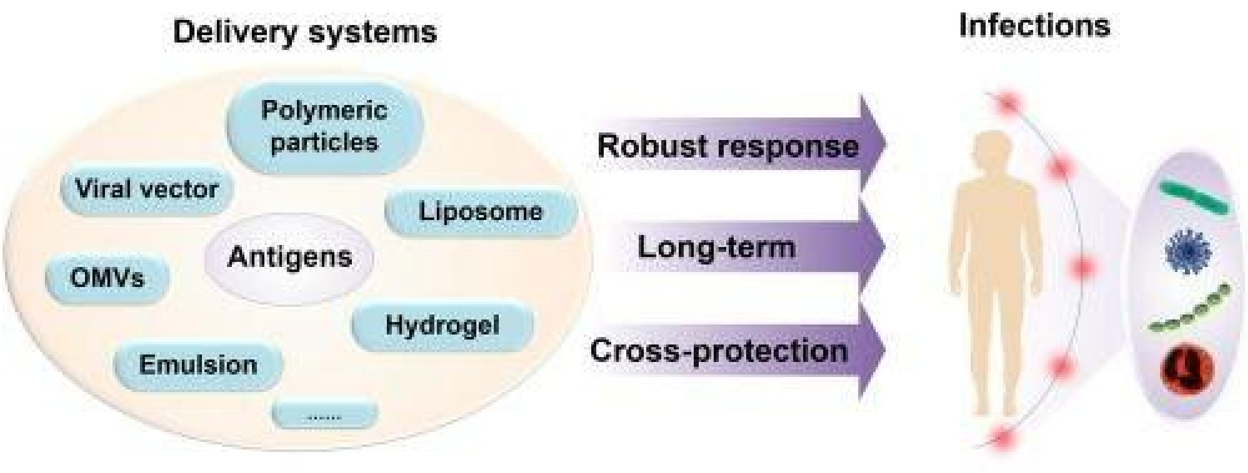
INTRODUCTION

At the beginning of the 20th century, infectious diseases were the leading cause of death worldwide. For example, in 1900, the average life expectancy in the United States was only 47 years, and infections accounted for about 30% of deaths among children under five. Later, due to improved hygiene, food safety, and especially vaccination, mortality from infections decreased significantly, and average life expectancy rose to 78 years. A large portion of this improvement resulted from vaccination programs that brought diseases such as measles, poliomyelitis, and hepatitis B under control — some even eradicated.

History and Development of Prophylactic Vaccination

Prophylactic vaccines emerged in the late 18th and early 19th centuries. Benjamin Jesty and Edward Jenner studied smallpox transmission and, in 1796, introduced the first cowpox-based inoculation method, earning Jenner the title "Father of Vaccinology." Later, in 1885, Louis Pasteur developed the world's first experimental rabies vaccine. The 20th century witnessed rapid vaccine development: in the 1950s, Jonas Salk and Albert Sabin created the first poliomyelitis vaccines, followed by vaccines against diphtheria, pertussis, and others in the 1970s.

In 1974, the World Health Organization (WHO) launched the Expanded Programme on Immunization (EPI), prioritizing six key diseases including diphtheria, measles, polio, hepatitis B, and others. By 1980, WHO declared smallpox eradicated worldwide. Further successes followed — the Americas were certified polio-free in 1994, and Europe in 2002. Thus, prophylactic vaccination has played a vital role in halting major infectious epidemics and even eradicating certain diseases.

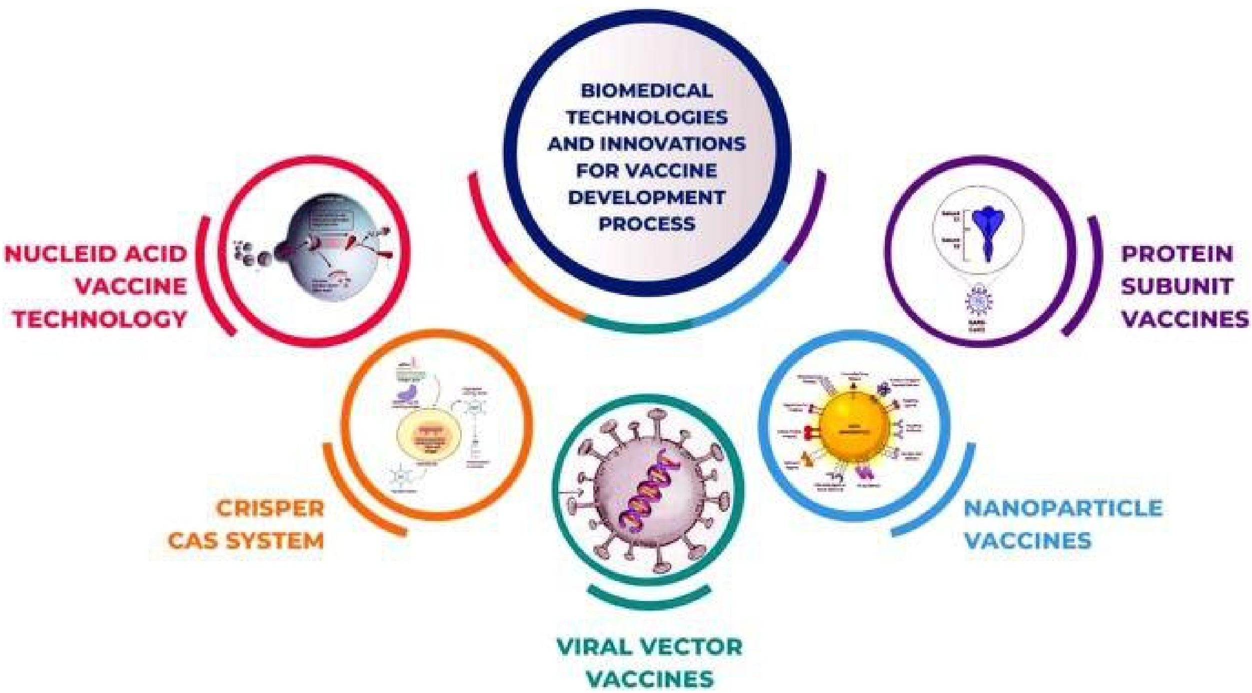


Microbiological Mechanisms of Vaccination

Vaccines train the immune system to recognize pathogens without causing disease. The antigens present in vaccines (proteins, toxoids, or genetic material from the pathogen) are identified by immune cells as foreign, triggering an immune response. B lymphocytes produce antibodies, while T lymphocytes initiate cellular immunity.

After initial exposure, memory B cells form and persist for years in the bone marrow and bloodstream. Upon re-exposure, these memory cells rapidly produce antibodies, preventing disease development. Hence, vaccination provides immunity safely, without natural infection.

TYPES OF VACCINES: LIVE, INACTIVATED, SUBUNIT, MRNA, DNA, AND VECTOR VACCINES



1. Live attenuated vaccines

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These contain weakened but still viable pathogens. They typically provide long-term immunity after one or two doses. Examples include BCG (tuberculosis), OPV (oral polio), and MMR (measles, mumps, rubella). However, they are not recommended for immunocompromised individuals or pregnant women due to a minimal risk of reversion to virulence.

2. Inactivated (killed) vaccines

Pathogens are chemically or thermally inactivated. These vaccines are very safe, even for immunocompromised individuals, but require booster doses to maintain protection. Examples include the inactivated polio vaccine (Salk), hepatitis A, and some influenza vaccines.

3. Subunit (purified antigen) vaccines

These use specific pathogen components (proteins or polysaccharides) to trigger immunity. For instance, the hepatitis B vaccine contains the viral surface antigen, and the Hib vaccine includes bacterial polysaccharides. They are highly safe and effective.

4. Genetic vaccines (mRNA and DNA)

These modern vaccines contain genetic material encoding a pathogen's antigen. Once introduced into host cells, the antigen is produced internally, inducing immunity. The Pfizer and Moderna COVID-19 vaccines are prime examples of mRNA-based vaccines. They are fast to develop but require ultra-cold storage conditions.

5. Vector vaccines

These use harmless carrier viruses (vectors) to deliver genetic material from the pathogen. Once injected, the vector introduces the genetic information, leading to immune activation. Examples include adenovirus-based COVID-19 vaccines such as AstraZeneca and Sputnik V.

Efficacy and Safety of Vaccines

WHO data show that vaccines save an estimated 3.5–5 million lives annually by preventing diseases such as diphtheria, measles, pertussis, hepatitis B, and poliomyelitis. For example, two doses of the MMR vaccine provide approximately 97% protection against measles.

Vaccine safety is rigorously monitored at every stage — from laboratory testing and early clinical phases to large-scale human trials. Even after approval, vaccines undergo ongoing post-marketing surveillance. Adverse events such as mild fever or injection-site pain are typically minor and self-limiting, while serious complications are extremely rare. Thus, vaccines remain one of the safest public health interventions.

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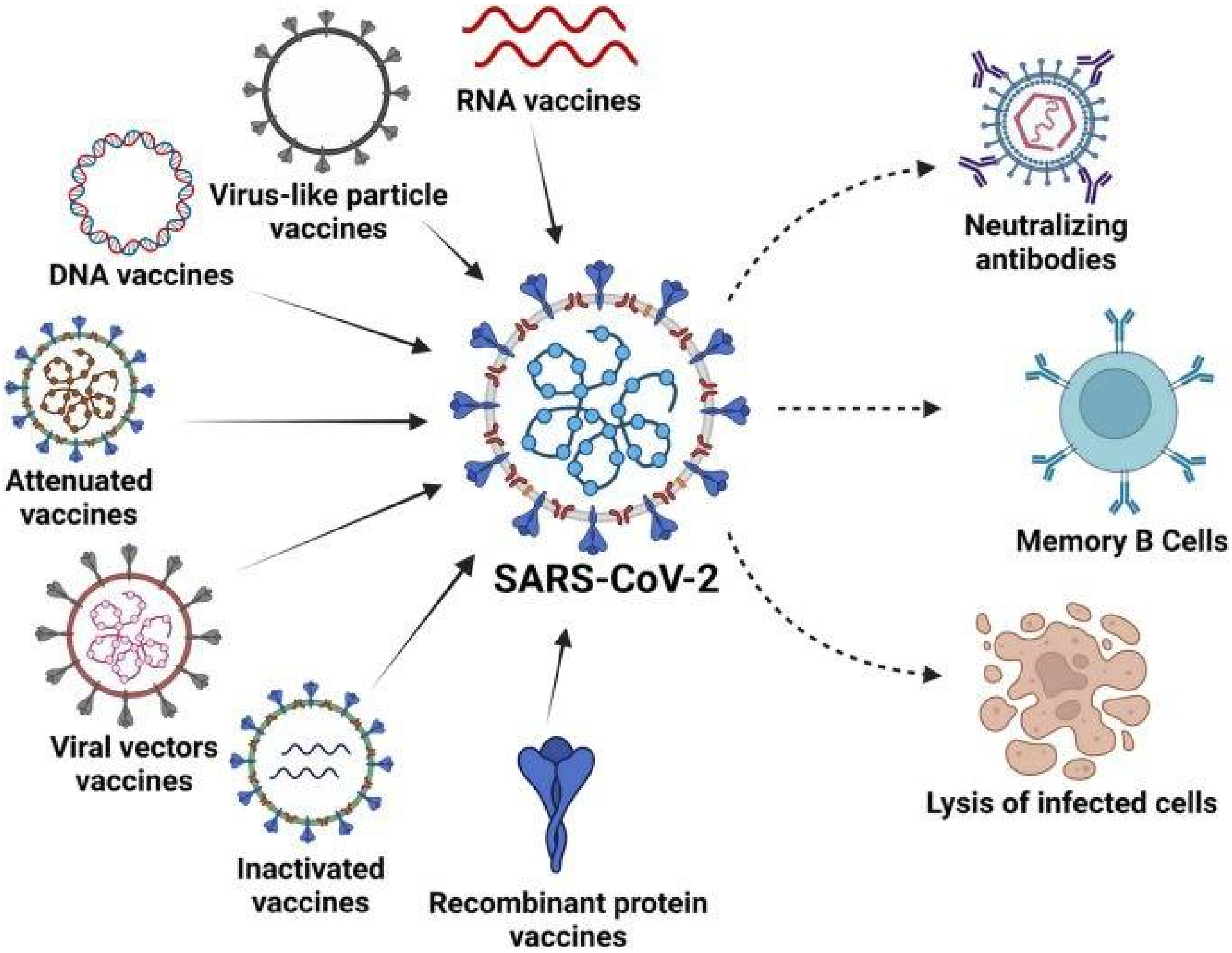

Role in Global Public Health (WHO Perspective)

WHO regards vaccination as a cornerstone of health systems. According to WHO, vaccines currently prevent around 20 life-threatening diseases and significantly extend global life expectancy. The Immunization Agenda 2030 (IA2030), launched in 2020, aims to expand global immunization coverage, strengthen pandemic preparedness, and save 50 million lives by 2030.

However, WHO reports that over 20 million infants annually remain unvaccinated, heightening the risk of disease resurgence. Therefore, WHO continues to emphasize vaccine accessibility, equity, and sustainability as central to global health strategies.

Role in Combating Antibiotic Resistance

Vaccines are also a critical tool in the fight against antimicrobial resistance (AMR). By preventing infections, they reduce unnecessary antibiotic use, slowing the emergence of resistant strains. WHO estimates that vaccines against 23 pathogens could reduce annual antibiotic consumption by approximately 22%, equivalent to 2.5 billion doses per year. For example, pneumococcal, Hib, and typhoid vaccines each save hundreds of thousands of antibiotic treatments annually. Hence, vaccination contributes directly to global AMR control strategies.

CONCLUSION

Prophylactic vaccination, grounded in immunological and microbiological principles, remains the most effective method to prevent infectious diseases. Over two centuries, vaccines have nearly eradicated or controlled smallpox, poliomyelitis, hepatitis, and many other diseases.

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Their proven efficacy and safety, confirmed through extensive trials and continuous monitoring, make them a central component of global health policy. Through WHO-led initiatives, vaccines continue to prevent epidemics, mitigate pandemics, and reduce antibiotic resistance. Owing to their reliability, broad coverage, and safety, prophylactic vaccinations will remain a vital tool for safeguarding global health in the future.

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