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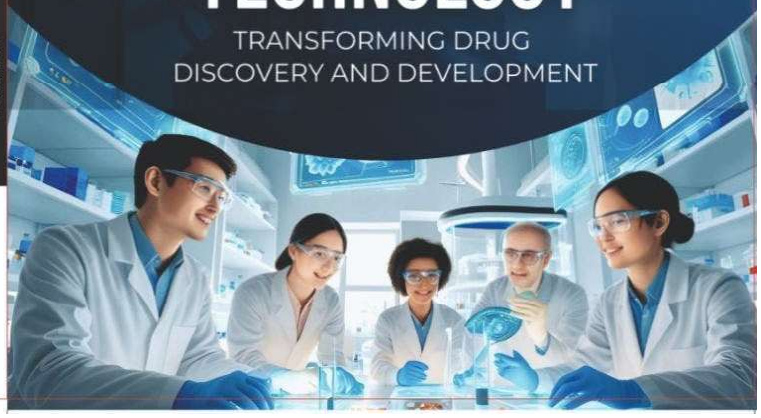

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ADVANCEMENT IN VACCINE DEVELOPMENT AND DELIVERY

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ABSTRACT : The field of vaccinology is undergoing rapid scientific advancements and an urgent need for faster, more effective immunization strategies. Traditional vaccines, including live attenuated, inactivated, toxoid and subunit vaccines, have played a crucial role in controlling infectious diseases for over a century. This chapter explores cutting-edge vaccine technologies, including nucleic acid-based platforms (mRNA and DNA vaccines), peptide vaccines and protein-based formulations, highlighting their mechanisms, advantages and clinical implications. Recent breakthroughs in reverse vaccinology, CRISPR-based gene editing and nanoparticle-based delivery systems have revolutionized antigen discovery and vaccine development, enabling precision-targeted immunization strategies. The success of mRNA vaccines against COVID-19 has underscored the transformative potential of synthetic biology and genomics in accelerating vaccine production. Despite these advancements, challenges persist, including cold chain logistics, immune response variability, and global accessibility. This chapter critically examines these emerging technologies, offering a comprehensive perspective on the future of vaccines, where personalized immunization, rapid deployment and enhanced efficacy will define the next generation of disease prevention.

Key words : DNA vaccine, mRNA vaccine, gene editing, nanoparticle- based gene editing, CRISPR-based gene editing.

Introduction

Vaccines are essential for global health, preventing infections and the spread of numerous diseases across the world. Vaccinations have significantly decreased the prevalence of disease, disability, and mortality caused by various infectious illnesses (Orenstein and Ahmed, 2017). They stand as a major public health success of the past century, sparing an estimated 2–3 million lives every calendar year. Since their development and widespread governmental implementation, vaccines based on live attenuated or killed whole organisms have eradicated or eliminated several major threats to mankind, including tetanus, measles, mumps, rubella, diphtheria, polio, pertussis, and smallpox (Ho *et al*, 2021; Vetter *et al*, 2018). Even so, the rise of rapidly spreading infections namely SARS-CoV-2 and H1N1, along with fast-adapting deadly illnesses such as Ebola, presents significant obstacles for traditional vaccine approaches, including live attenuated viral (LAV) and inactivated viral vaccines. Developing these vaccines typically takes over a decade, even with accelerated efforts like those for Ebola which required around five years (Le *et al*, 2020). Moreover, the time required for large-scale manufacturing and stockpiling further complicates timely preparedness. Vaccines have a significant impact