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Vaccine strategies

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Remerciements

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1 Introduction

Vaccines represent an amazing invention which saved millions of lives in the world since 2000 [2]. Even if vaccination is not new, the recent pandemic of COVID-19 brought to the forefront this field, generating great advances but also important debates about safety, ethics and politics. It is necessary to take into account all these changes and to adapt to be avoid a backward step and the rejection of these opportunities.

Therefore it would be interesting to better understand the recent evolutions in vaccine strategies and technologies and the consequences it may have on society.

Firstly, I will briefly recall the history of vaccination, detailing the different types of vaccines which have been developed. Secondly, I will present the technology of mRNA (messenger ribonucleic acid) vaccines which are currently the main source of progress. Thirdly, I will observe how society is integrating these developments and what issues remain to be solved.

This theme is closely linked to the mechanics of the immune system, in medicine, which will not be detailed in this article due to the needed knowledge in medicine. In any case, I would like to thank Ms. Stoven for her molecular biology course and her help in the writing of this article.

2 A brief history of vaccines

2.1 Discovery of the principle

The principle of vaccination could come from the idea of mithridatism, that is to say the ability to gain protection against a poison by taking several benign amounts.

Variolization, which corresponds to injecting smallpox pustules to gain immunity against smallpox, began in China around the 10th century [1]. Before the scientist Jenner, several persons realized variolization in England. However, in 1798, this is Jenner who made a link between cowpox and smallpox: cowpox could an attenuated version of smallpox.

The idea of vaccination is to create an individual, long-term and efficient protection against a pathogen (like a virus or a bacteria), without causing serious symptoms. This is made possible thanks to the memory of human's immune system.

The word "vaccination" comes from the Latin word "vacca", which means "cow".

2.1.1 A quick look on the immune system

2.2 First generation of vaccines

It is only between 1870 and 1885 with Pasteur's works (helped by Emile Roux and Emile Duclaux, and based on Robert Koch's findings), that the first vaccines were developed [3]. The first official vaccines that he conceived were against chicken cholera, anthrax, swine erysipelas and then rabies.

The first generation of vaccines consists in pathogens which are live, weakened or killed. Live weakened vaccines are the most immunogenic, but they should be prepared carefully. Despite being efficient, there are still high risks using them if virus are not attenuated enough: one can develop the disease and transmit it to an immunocompromised person. Otherwise, vaccines can be killed for example with heat/chemical treatment, and they are less dangerous, however there is a need for adjuvants (from the Latin word "adjurvare", which means "to help") to make them immunogenic, and the response is mainly humoral and less cellular.

Adjuvants can be very diverse and numerous as well as their mechanism of action: killed mycobacteria, oils, aluminium salts, microparticles, squalanes, ligands of PRRs... They aim at amplifying the reaction for a whole population and each individual (especially old people whose immune system is less dynamic) and at reducing the quantity of active substance needed (dose sparing). The dosage should be very cautious not to hide the active substance.

To prepare a live weakeaned vaccine, the virus or the bacteria is replicated in adverse conditions several times.

To prepare those vaccines, cell culture is often needed before weakening the virus with different techniques such as

Thanks to the development of immunology and microbiology, in particular the ability to isolate pathogens, vaccines were better understood and it led to the development of a new type of vaccines.

The method of production of these vaccines also evolved over time. With genetic engineering and reverse genetics, that is to say, contrary to forward genetic, the ability to know which phenotypes can be controlled by different genetic sequences, it allows a better treatment of viruses to select inactivated vaccines.

2.3 Second generation of vaccines

This generation demands more development and technological advances, to use subunits of viruses such as protein antigens or recombinant protein components (antigens for instance). There is also the need for adjuvant, which are substances which trigger a powerful immune response ; otherwise the vaccine would not be effective. The response is again mainly humoral: sometimes it cannot activate Toll-Like Receptors on dentritic cells needed for a complete response.

An anatoxin is a toxin which has lost his toxic power thanks to heat and formaldehyde, but not totally its immunogenic ability.

2.4 Towards a third generation

3 mRNA vaccines: a promising technology

3.1 Principle

3.2 Development

3.3 Advantages and drawbacks

4 New stakes for vaccines in the 21st century

4.1 World inequalities

4.2 Public policies

Firstly it is an individual protection.

Secondly it protects the whole population thanks to herd immunity: the pathogen is less likely to be transmitted ; otherwise it would be exponential, as people observed for the Covid-19 pandemic.

4.3 New uses and technical challenges

5 Conclusion

A Source code

The source code of this document is available at https://github.com/florian6973/biology-report.

References

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