have been administered globally since the 19th century. We described aspects of the vaccine production process that may not be well-publicized, and the ingredients in vaccines. We discussed the classes of vaccines and their production steps. Before vaccines are approved for use, they go through rigorous safety tests, and quality control and improvement continue at all stages of production and beyond. Furthermore, we showed some benefits and challenges of vaccines. Vaccines prevent 3.5 to 5 million deaths from vaccine-preventable diseases annually. They are second only to clean drinking water in reducing infectious disease worldwide (Plotkin, 2009). They are the cheapest and fastest way to generate communal and global immunity to disease, as shown in the curbing of the COVID-19. Not only do they help to prevent a disease in the present, but also the memory that they give the body in recognizing the pathogen and preventing the same infection in the future distinguishes them from other drugs. Though they have some disadvantages and challenges, but their advantages far outweigh the disadvantages. Think for instance how having a clinical COVID-19 infection would compare with the sting of an injection, or how paralysis from poliomyelitis would compare with a short fever from the polio vaccine. In conclusion, we strongly recommend continuous and all-inclusive vaccination as a way to minimize and potentially eradicate infectious diseases.

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References

1. Centers for Disease Control and Prevention (2022). How vaccines work.
2. World Health Organization (2022). WHO Coronavirus (COVID-19) Dashboard.
3. Moore R, Willis DE, Shah SK, Purvis RS, Shields X & McElfish PA. "The risk seems too high": thoughts and feelings about COVID-19 vaccination. International Journal of Environmental Research and Public Health 18 (2021): 8690.
4. Chayinska M, Uluğ ÖM, Ayanian AH, Gratzel JC, Brik T, Kende A. et al. Coronavirus conspiracy beliefs and distrust of science predict risky public health behaviours through optimistically biased risk perceptions in Ukraine, Turkey, and Germany. Group Processes & Intergroup Relations 25 (2021): 1616-1634.
5. Kollewe J. From Pfizer to Moderna: who's making billions from COVID-19 vaccines? The Guardian (2021).
6. Plotkin SA. Vaccines: the fourth century. Clinical and Vaccine Immunology: CVI 16 (2009): 1709–1719.
7. Lewiecki M. Biological therapy: chronicling 15 years of progress. Expert Opinion on Biological Therapy, 15 (2015): 619-621.
8. Case CL, & Chung K-T. Montagu and Jenner: the campaign against smallpox. SIM News 47 (1997): 58-60.
9. Breman J. Smallpox. Journal of Infectious Diseases 224 (2021): S379-S386.
10. Thurston L & Williams G. An examination of John Fewster's role in the discovery of smallpox vaccination. The Journal of the Royal College of Physicians of Edinburgh 45 (2015): 173-179.
11. Little M. Antibodies for treating cancer: basics, development and applications. Springer Nature, Switzerland (2021).
12. Plett PC. Peter Plett und die übrigen Entdecker der Kuhpockenimpfung vor Edward Jenner [Peter Plett and other discoverers of cowpox vaccination before Edward Jenner]. Sudhoffs Archives 90 (2006): 219-232.
13. Tizard I. Grease, anthraxgate, and kennel cough: a revisionist history of early veterinary vaccines. Advances in Veterinary medicine 41 (1999): 7-24.
14. Behbehani A. The smallpox story: life and death of an old disease. Microbiological Reviews 47 (1983): 455-509.
15. Riedel S. Edward Jenner and the history of smallpox and vaccination. BUMC Proceedings 18 (2005): 21-25.
16. Cavaillon J-M, & Legout S. Louis Pasteur: between myth and reality. Biomolecules 12 (2022): 596.
17. Duclaux E. Pasteur: Histoire d'un esprit. Imprimerie Charaire et Cie: Paris, France (1896).
18. Pasteur L. De l'attenuation du virus du cholera des poules. Comptes Rendus de l'Academie des Sciences 91 (1880): 673-680.
19. Entrican G & and Francis MJ. Applications of platform technologies in veterinary vaccinology and the benefits for one health. Vaccine 40 (2021): 2833-2840.
20. Newman L. Maurice Hilleman: Microbe hunter, pioneering virologist, and the 20th century's leading vaccinologist. The British Medical Journal 330 (2005): 1028.
21. World Health Organization (2022). Thiomersal.
22. Schlingmann B, Castiglia KR, Stobart CC & Moore ML. Polyvalent vaccines: high-maintenance heroes. PLoS Pathogens 14 (2018): e1006904.

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

23. European Medicines Agency (2022). EMA recommends approval of second adapted Spikevax vaccine.

24. Pfizer-BioNTech. Pfizer-BioNTech COVID-19 vaccine, bivalent (2022).

25. Centers for Disease Control and Prevention (2022). Adjuvanted flu vaccine.

26. Centers for Disease Control and Prevention (2022c). Overview of COVID-19 vaccines.

27. Centers for Disease Control and Prevention (2022d). Combination vaccines.

28. Kallerup RS, & Foged C. Classification of vaccines. In: Foged, C, Rades, T, Perrie, Y. & Hook, S. (Eds). Subunit vaccine delivery. Advances in Delivery Science and Technology. Springer, New York, NY (2015).

29. Vos A, Neumann G, Hundt B & Neubert A. Attenuated vaccines for veterinary use. Current Laboratory Techniques in Rabies Diagnosis & Prevention 1 (2014): 237-244.

30. Mak T & Saunders M. Vaccines and clinical Immunization. In: Mak, T. & Saunders, M. (Eds). The immune response. Academic Press (2006): 695-749.

31. Pasteur L. Méthode pour prevenir la rage après morsure. Comptes Rendus des Séances de l'Academie des Sciences (1885): 765-772.

32. Plotkin S. History of vaccination. Proceedings of the National Academy of Sciences USA 111 (2014): 12283-12287.

33. Pfeiffer R & Kolle W. Experimentelle untersuchungen zur frage der schutzimpfung des menschen gegen typhus abdominalis. Deutsche Medizinische Wochenschrift 22 (1896): 735-737.

34. Wright AE & Semple D. Remarks on vaccination against typhoid fever. British Medical Journal 1 (1897): 256-259.

35. Vishweshwaraiah YL & Dokholyan NV. Towards rational vaccine engineering. Advanced Drug Delivery Reviews 183 (2022): 114142.

36. Pollard AJ & Bijker EM. A guide to vaccinology: from basic principles to new developments. Nature Reviews Immunology 21 (2021): 83-100.

37. Qin F, Xia F, Cheng H, Cui B, Feng Y, Zhang P. et al. A guide to nucleic acid vaccines in the prevention and treatment of infectious diseases and cancers: from basic principles to current applications. Frontiers in Cell and Developmental Biology 9 (2021).

38. Glenny AT & Hopkins BE. Diphtheria toxoid as an immunizing agent. British Journal of Experimental Pathology 4 (1923): 283-288.

39. Plotkin SA & Plotkin SL. The development of vaccines: how the past led to the future. Nature Reviews Microbiology 9 (2011): 889-893.

40. Ramon G. Sur le pouvoir floculant et sur les propriétés immunisantes d'une toxine dipthérique rendue anatoxique (anatoxine). Comptes Rendus de l'Académie des Sciences Paris 177 (1923): 1338-1340.

41. Vaccine Knowledge Project (2022). Vaccine ingredients.

42. Gotschlich EC, Goldschneider I & Artenstein, M. Human immunity to meningococcus: IV. Immunogenicity to Group A and Group C meningococcal polysaccharides in human volunteers. The Journal of Experimental Medicine 129 (1969): 1367-1384.

43. Kim C, Kim JD. & Seo SU. Nanoparticle and virus-like particle vaccine approaches against SARS-CoV-2. Journal of Microbiology 60 (2022): 335-346.

44. Balke I & Zeltins A. Use of plant viruses and virus-like particles for the creation of novel vaccines. Advanced Drug Delivery Reviews 145 (2019): 119-129.

45. Rappuoli R, De Gregorio E & Constantino P. On the mechanisms of conjugate vaccines. The Proceedings of the National Academy of Sciences 116 (2019): 14-16.

46. Avery OT & Goebel WF. Chemo-immunological studies on conjugated carbohydrate-proteins: V. The immunological specificity of an antigen prepared by combining the capsular polysaccharide of Type III Pneumococcus with foreign protein. Journal of Experimental Medicine 54 (1931): 437-447.

47. Li M, Zhou H, Yang C, Wu Y, Zhou X, Liu H. et al. Bacterial outer membrane vesicles as a platform for biomedical applications: an update. Journal of Controlled Release 323 (2020): 253-268.

48. Zhu Z, Antenucci F, Villumsen KR & Bojesen, AM. Bacterial outer membrane vesicle as a versatile tool in vaccine research and the fight against antimicrobial resistance. mBio 12 (2021): e01707-01721.

49. Cheng K, Zhao R, Li Y, Qi Y, Wang Y, Zhang, Y, et al. Bioengineered bacteria-derived outer membrane vesicles as a versatile antigen display platform for tumor vaccination via Plug-and-Display technology. Nature Communications 12 (2021).

50. Kulp A & Kuehn MJ. Biological functions and biogenesis of secreted bacterial outer membrane vesicles. Annual Review of Microbiology 64 (2010): 163-184.

51. Electronic Medicines Compendium (2021). Infanrix hexa, powder and suspension for suspension for injection.

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

52. Electronic Medicines Compendium (2021). HBVAXPRO 10 micrograms, suspension for injection in pre-filled syringe.

53. Electronic Medicines Compendium (2022). Gardasil 9 suspension for injection.

54. Abinaya RV. & Viswanathan, P. Biotechnology-based therapeutics. In: Hasija, Y. (Ed). Translational Biotechnology. Academic Press (2021): 27-52.

55. Jackson DA, Symons RH & Berg P. Biochemical method for inserting new genetic information into DNA of Simian Virus 40: circular SV40 DNA molecules containing lambda phage genes and the galactose operon of Escherichia coli. The Proceedings of the National Academy of Sciences 69 (1972): 2904-2909.

56. Daian e Silva DSDO & da Fonseca FG. The rise of vectored vaccines: a legacy of the COVID-19 global crisis. Vaccines (Basel) 9 (2021): 1101.

57. Kumar S. Live-attenuated bacterial vectors for delivery of mucosal vaccines, DNA vaccines, and cancer immunotherapy. In: Arora, D, Sharma, C, Jaglan, S. & Lichtfouse, E. (Eds). Pharmaceuticals from microbes: the bioengineering perspective. Springer (2019): 39-73.

58. Henao-Restrepo AM, Camacho A, Longini IM, Watson CH, Edmunds WJ, Egger M, et al. Efficacy and effectiveness of an rVsV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomised trial (Ebola Ça Suffit!). The Lancet 389 (2016): P505-P518.

59. Mahony TJ. The role of adjuvants in the application of viral vector vaccines. In: Vanniasinkam, T, Tikoo, S.K. & Samal, S.K. (Ed). Viral vectors in veterinary vaccine development. Springer Cham (2021): 37-50.

60. Milicic A, Rollier CS, Tang CT, Longley R, Hill AVS & Reyes-Sandoval A. Adjuvanting a viral vectored vaccine against pre-erythrocytic malaria. Scientific Reports 7(2017): 7284.

61. Reyes-Sandoval A, Rollier CS, Milicic A, Bauza K, Cottingham MG, Tang C-K, et al. Mixed vector immunization with recombinant adenovirus and MVA can improve vaccine efficacy while decreasing anti-vector immunity. Molecular Therapy 20 (2012): 1633-1647.

62. Travieso T, Li J, Mello JDFRE & Blasi M. The use of viral vectors in vaccine development. Npj Vaccines 7 (2022).

63. Ura T, Okuda K & Shimada M. Developments in viral vector-based vaccines. Vaccines 2 (2014): 624-641.

64. European Medicines Agency (2022b). Jcovden (previously COVID-19 Vaccine Janssen.

65. Centers for Disease Control and Prevention (2021a). Understanding and explaining viral vector COVID-19 vaccines.

66. Liu MA. DNA vaccines: an historical perspective and view to the future. Immunological Reviews 239 (2011): 62-84.

67. Yankauckas MA, Morrow JE, Parker SE, Abai A, Rhodes GH, Dwarkim VJ, et al. Long-term anti-nucleoprotein cellular and humoral immunity is induced by intramuscular injection of plasmid DNA containing NP gene. DNA and Cell Biology 12 (1993): 771-776.

68. Rodríguez-Gascón A, Pozo-Rodríguez AD & Solinís MA. Development of nucleic acid vaccines: use of self-amplifying RNA in lipid nanoparticles. International Journal of Nanomedicine 9 (2014):1833-1843.

69. Shan C, Xie X & Shi P-Y. Zika virus vaccine: progress and challenges. Cell Host & Microbe 24 (2018): 12-17.

70. Wolff JA, Malone RW, Williams P, Chong W, Acsadi G, Jani A. et al. Direct gene transfer into mouse muscle in vivo. Science 247 (1990): 1465-1468.

71. European Medicines Agency (2022c). Comirnaty.

72. European Medicines Agency (2022d). Spikevax (previously COVID-19 vaccine Moderna.

73. Sheridan C. First COVID-19 DNA vaccine approved, others in hot pursuit. Nature Biotechnology 39 (2021): 1479-1482.

74. Blakney AK & Bekker L-G. DNA vaccines join the fight against COVID-19. Lancet 399 (2022): 1281-1282.

75. Cardoso FMC, Petrovajová D & Horňáková T. Viral vaccine stabilizers: status and trends. Acta virologica 61 (2017): 231-239.

76. Domachowske J. Vaccine additives and excipients In: Domachowske, J. & Suryadevara, M. (Eds). Vaccines. Springer, Cham (2020): 49-76.

77. The Immunization Advisory Center, New Zealand (2022). Vaccine components.

78. Genzel Y. Designing cell lines for viral vaccine production: where do we stand?. Biotechnology Journal. 10 (2015): 728-740.

79. Aşi Içeriği. Vaccine contents. Current Literature 12 (2018): e83-e85.

80. Scholar E. Neomycin. In: Enna SJ & Bylund DB. (2011). xPharm: The Comprehensive Pharmacology Reference. Elsevier (2007): 1-5.

81. United States Food and Drug Administration. Common licensed ingredients in U.S. licensed vaccines (2019).

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

82. Centers for Disease Control and Prevention (2022e). What's in vaccines?.

83. Finn TM & Egan W. Vaccine additives and manufacturing residuals in the United States: licensed vaccines. Vaccines: Sixth Edition (2012): 71-79.

84. Mahler V & Junker A-C. Anaphylaxis to additives in vaccines. Allergo Journal International 31 (2022): 123-136.

85. World Health Organization (2022c). Thiomersal.

86. Food and Drugs Administration. Common ingredients used in U.S. licensed vaccines (2018).

87. Centers for Disease Control and Prevention (2022f). Thimerosal FAQs.

88. Escudero C, Prieto-Montaño & Audicana MT. Adverse reactions to anti-infective vaccines: an emerging problem in the COVID-19 era 9 (2022): 250-272.

89. Powell D, Weisman K & Marman E. Modeling and leveraging intuitive theories to improve vaccine attitudes. PsyArXiv Preprint (2022).

90. World Health Organization (2020). How are vaccines developed?.

91. Kang MS, Jang H, Kim MC, Kim MJ, Joh SJ, Kwon JH, et al. Development of a stabilizer for lyophilization of an attenuated duck viral hepatitis vaccine. Poultry Science 89 (2010): 1167-1170.

92. Belew M, Yan M & Caldwell KD. Purification of recombinant human serum albumin (rHSA) produced by genetically modified Pichia pastoris. Separatation Science and Technology 43 (2008): 3134-3153.

93. Chuang VTG & Otagiri M. Recombinant human serum albumin. Drugs Today (Barc) 43 (2007): 547-561.

94. Liauw S & Saibil F. Sorbitol: often forgotten cause of osmotic diarrhea. Canadian Family Physician 65 (2019): 557-558.

95. Islam MS & Sakaguchi E. Sorbitol-based osmotic diarrhea: possible causes and mechanism of prevention investigated in rats. World Journal of Gastroenterology 12 (2006): 7635-7641.

96. Mukhopadhyay E, Brod F, Angell-Manning P, Green N, Tarrant RD, Detmers FJ. et al. Production of a high purity, C-tagged hepatitis B surface antigen fusion protein VLP vaccine for malaria expressed in Pichia pastoris under cGMP conditions. Biotechnology and Bioengineering 119 (2022): 2784-2793.

97. Sampath V, Rabinowitz G, Shah M, Jain S, Diamant Z, Jesenak M, et al. Vaccines and allergic reactions: the past, the current COVID-19 pandemic, and future perspectives. Allergy 76 (2021): 1640-1660.

98. Naini A, Bartetzko MP, Sanapala SR, Broecker F, Wirtz V, Lisboa MP, Parameswarappa SG. Semisynthetic glycoconjugate vaccine candidates against Escherichia coli O25B induce functional IgG antibodies in mice. Journal of the American Society 2 (2022): 2135-2151.

99. Schmidt LK, Orne CE, Shaffer TL, Wilson SM, Khakhum N, Torres AG, et al. Development of melioidosis subunit vaccines using an enzymatically inactive Burkholderia pseudomallei AhpC 90 (2022): e00222-22.

100. Kosten T, Domingo C, Orson F & Kinsy B. Vaccines against stimulants: cocaine and MA. British Journal of Clinical Pharmacology 77 (2013): Pp 368-374.

101. Pulendran B, Arunachalam PS, O'Hagan DT. Emerging concepts in the science of vaccine adjuvants. Nature Reviews Drug Discovery 20 (2021): 454-475.

102. Fan J, Jin S, Gilmartin L, Toth I, Hussein WM, & Stephenson RJ. Advances in infectious disease vaccine adjuvants. Vaccines 10 (2022): 1120.

103. Awate S, Babiuk LA & Mutwiri G. Mechanisms of action of adjuvants. Frontiers in Immunology 4 (2013):

104. Ramon G. Sur la toxine et sur l'anatoxine diphtheriques. Annales de l'Institut Pasteur 38 (1924): 1-10.

105. Hoebe K, Janssen E, & Butler B. The interface between innate and adaptive immunity. Nature Immunology. Nature Immunology 5 (2004): 971-974.

106. Fraser CK, Diener KR, Brown MP & Hayball JD. Improving vaccines by incorporating immunological coadjuvants. Expert Review of Vaccines 6 (2007): 559-578.

107. Tetsuani K & Ishii KJ. Adjuvants in influenza vaccines. Vaccines 30 (2012): 7658-7661.

108. Calabro S, Tritto E, Pezzotti A, Taccone M, Muzzi A, Bertholet S. et al. The adjuvant effect of MF59 is due to the oil-in-water emulsion formulation, none of the individual components induce a comparable adjuvant effect. Vaccine 31 (2013): 3363-3369.

109. Ko E-J, & Kang S-M. Immunology and efficacy of MF-59 adjuvanted vaccines. Human Vaccines and Immunotherapeutics 14 (2018): 3041-3045.

110. HogenEsch H, O'Hagan DT. & Fox CB. Optimizing the utilization of aluminum adjuvants in vaccines: you might just get what you want. NPJ Vaccines 3 (2018).

111. Principi N & Esposito S. Aluminum in vaccines: does it create a safety problem?. Vaccine 36 (2018): 5825-5831.

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

112. HogenEsch H. Mechanisms of the stimulation of the immune response by aluminum adjuvants. Vaccine. 20 (2002): S34-S39.

113. Goullé J-P & Grangeot-Keros L. Aluminum and vaccines: current state of knowledge. Medicine and Infectious Diseases 50 (2020): 16-21.

114. Verdier F, Burnett R, Michelet-Habchi C, Moretto P, Fievet-Groyne F. & Sauzeat E. Aluminium assay and the evaluation of the local reaction at several time points after intramuscular administration of aluminium containing vaccines in the Cynomolgus monkey. Vaccine 23 (2004): 1359-1367.

115. Rosenblatt AE. & Stein SL. Cutaneous reactions to vaccinations. Clinics in Dermatology 33 (2015): 327-332.

116. Avcin S, Jazbec J & Jancar J. Subcutaneous nodule after vaccination with an aluminum-containing vaccine. Acta Dermatovenerol APA 17 (2008): 182-184.

117. Feng H, Yamashita M, Wu L, Lopes, da Silva Lopes J, Watanabe T & Kawaoka Y. Food additives as novel influenza vaccine adjuvants. Vaccines 7 (2019): 127.

118. World Health Organization Immunization Action Coalition. The Immunization Action Coalition (IAC) works to increase immunization rates and prevent disease by creating and distributing educational materials for healthcare professionals and the public (2020).

119. Chung EH. Vaccine allergies. Clinical and Experimental Vaccine Research 3 (2014): 50-57.

120. Allen CW, Kemp AS. Dietary advice, dietary adherence and the acquisition of tolerance in egg-allergic children: a 5-yr ffollow-up. Pediatric Allergy and Immunology 20 (2009): 213-218.

121. Lajeunesse ME, Braithwaite N, Lucas JSA & Warner JO. Recommendations for the administration of influenza vaccine in children allergic to egg. The Biomedical Journal 339 (2009): b3680.

122. Centers for Disease Control and Prevention (2022g). Flu vaccines and people with egg allergies.

123. Aytekin ES, Şekerel BE, & Şahiner UM. Allergic reactions during childhood vaccination and management. The Turkish Journal of Pediatrics 63 (2021): 941-954.

124. Russell M, Pool V, Kelso JM, Tomazic-Jezic VJ. Vaccination of persons allergic to latex: a review of safety data in the Vaccine Adverse Event Reporting System (VAERS). Vaccine 23 (2004): 664-667.

125. World Health Organization (2022d). COVID-19 vaccines with WHO emergency use listing.

126. VIPER Group COVID-19 Vaccine Tracker (2022).

127. drugs.com (2022). Comirnaty.

128. Wu S, Huang J, Zhang Z, Wu J, Zhang J, Hu H, et al. Safety tolerability, and immunogenicity of an aerosolised adenovirus type-5 vector-based COVID-19 vaccine (Ad5-nCoV) in adults: preliminary report of an open-label and randomised phase 1 clinical trial. The Lancet Infectious Diseases 21 (2021): P1654-P1664.

129. World Health Organization (2022e). Vaccines: Convidecia.

130. World Health Organization (2021a). A quick guide: vaccination against COVID-19 with the Sinovac-CoronaVac COVID-19 vaccine.

131. World Health Organization (2022f). Vaccines: CoronaVac.

132. Bharat Biotech (No Date). Covaxin Fact Sheet.

133. World Health Organization (2021b). WHO recommendation Bharat Biotech International Ltd—COVID-19 vaccine (Whole Virion Inactivated Corona Virus).

134. Pan American Health Organization (2022). Sinopharm/BIPB COVID-19 vaccine.

135. Serum Institute of India LTD (No Date). Fact sheet for vaccine recipient approved for restricted use in emergency.

136. Serum Institute of India LTD (2021). Health FAQ.

137. World Health Organization (2021c). Vaccines: Nuvaxovid.

138. World Health Organization (2021d). COVID-19 vaccine AstraZeneca WHO summary of product characteristics.

139. Aars OK, Clark M & Schwalbe N. Increasing efficiency in vaccine production: a primer for change. Vaccine X 8 (2021): 100104.

140. Russo AA & Johnson J. Research use exemptions to patent infringement for drug discovery and development in the United States. Cold Springs Harbor Perspectives in Medicine 5 (2015): a020933.

141. Ahmad J, Johnson C, Edwards V & Rees N. Chapter 1- Does regulation drive science or does science drive regulation?. In: Doan, T, Renz, C, Bhattachrya, M, Lievano, F. & Scarazzini, L. (Eds). Pharmacovigilance: a practical approach. Elsevier (2019): 1-11.

142. Thomas D, & Klika C. Chapter 15- Pharmacovigilance systems. In: Thomas, D. (Ed). Clinical pharmacy education, practice and research. Elsevier (2019): 215-225.

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

143. Gomez PL & Robinson JM. Vaccine manufacturing. Plotkin's Vaccines (2018): 51-60.

144. AstraZeneca (2021). Vaccine production and manufacturing at scale and pace.

145. Robinson JM. Chapter 5- Vaccine production: main steps and considerations. In: Bloom, B.R. & Lambert, P.-H. (Eds). The Vaccine Book (Second Edition). Academic Press (2016): 77-96.

146. Régnier SA & Huels J. Drug versus vaccine investment: a modelled comparison of economic incentives. Cost Effectiveness and Resource Allocation 11 (2013): 23.

147. Centers for Disease Control and Prevention (2020b). Bioterrorism.

148. Rappuoli R, Pizza M, Del Giudice G & De Gregorio E. Vaccines, new opportunities for a new society. Proceedings of the National Academy of Sciences of the United States 111 (2014): 12288-12293.

149. United Nations Development Project (2021). Impact of vaccine inequity on economic recovery.

150. Nahm FS, Lee PB, Park SY, Kim YC, Lee SC, Shin HY, et al. Pain from intramuscular vaccine injection in adults. Revista Medica de Chile 140 (2012): 192-197.

151. Taddio A, Ilersich AF, Ilersich AN. & Wells J. From the mouth of babes: getting vaccinated doesn't have to hurt. Canadian Journal of Infectious Diseases and Medical Microbiology 25 (2014): 196-200.

152. Taddio A, McMurtry CM, Shah V, Riddell RP, Chambers CT, Noel M, et al. Reducing pain during vaccine injections: clinical practice guideline. Canadian Medical Association Journal 187 (2015): 975-982.

153. Shah V, Taddio A, McMurtry, C.M, Halperin, S.A, Noel, M, Pillai Riddell R, et al. Pharmacological and combined interventions to reduce vaccine injection pain in children and adults: systematic review and meta-analysis. The Clinical Journal of Pain 31 (2015): S38-S63.

154. Vela Ramirez JE, Sharpe LA & Peppas NA. Current state and challenges in developing oral vaccines. Advanced Drug Delivery Reviews 114 (2017): 116-131.

155. Marasini N, Skwarczynski M & Toth I. Oral delivery of nanoparticle-based vaccines. Expert Review of Vaccines 13 (2014): 1361-1376.

156. Stecula DA, Kuru O, Albarracin D & Jamieson KH. Policy views aínd negative beliefs about vaccines in the United States. The American Journal of Public Health 110 (2020): 1561-1563.

157. Gidengil C, Chen C, Parker AM, Nowak S & Matthews L. Beliefs around childhood vaccines in the United States: a systematic review. Vaccine 37 (2019): 6793-6802.

158. Gatrad AR & Sheikh A. Medical ethics and Islam: principles and practice. Archives of Disease in Childhood. 84 (2001): 72-75.

159. Kuru O, Chan MS, Lu H, Stecula DA, Jamieson KH, & Albarracín D. Religious affiliation and philosophical and moral beliefs about vaccines: a longitudinal study. Journal of Health Psychology 27 (2022): 3059-3081.

160. Feizollah A, Anuar NB, Mehdi R, Firdaus A & Sulaiman A. Understanding COVID-19 halal vaccination discourse on Facebook and Twitter using aspect-based sentiment analysis and text emotion analysis. International Journal of Environmental Research and Public Health 19 (2022): 6269.

161. Attum B, Hafiz S, Malik A & Shamoon Z. Cultural competence in the care of Muslim patients and their families. In: StatPearls. TreasureIsland (2022).

162. Ahmed A, Lee KS, Buksh A, Al-Worafi YM, Sarker MMR, Ming LC. et al. Outbreak of vaccine-preventable diseases in Muslim majority countries. Journal of Infection and Public Health 11 (2018): 153-155.

163. Maravia MU. Vaccines: religio-cultural arguments from an Islamic perspective. Journal of the British Islamic Medical Association 6 (2021).

164. Muravsky NL, Betesh GM & McCoy RG. Religious doctrine and attitudes towards vaccination in Jewish Law. Journal of Religion and Health 27 (2021): 1-16.

165. Pontifical Academy for Life. Moral reflections on vaccines prepared from cells derived from aborted human fetuses, National Catholic Bioethics Quarterly 6 (2006): 541-548.

166. Ladaria LF. Note on the morality of using some anti-COVID-19 vaccines (2020).

167. Gerend MA, & Shepherd JE. Correlates of HPV knowledge in the era of HPV vaccination: a study of unvaccinated young adult women. Women's Health 51 (2011): 25-40.

168. Guidry JPD, Miller CA, Perrin PB, Laestadius LI, Zurlo G, Savage MW, et al. Between healthcare practitioners and clergy: Evangelicals and COVID-19 hesitancy. International Journal of Environmental Research and Public Health 19 (2022): 11120.

169. Whitehead AL, & Perry SL (2020a). How culture wars delay herd immunity: Christian nationalism and anti-vaccine attitudes. Quantitative Health Research. 6: 1485-1494. DOI: 10.1177/1049732309348366

Sokefun OE and Olasehinde GI., Arch Microbiol Immunology 2023
DOI:10.26502/ami.936500135

170. Whitehead AL & Perry SL. Taking America back for God: Christian nationalism in the United States. Oxford University Press (2020b).

171. Kibongani Volet A, Scavone C, Catalán-Matamoros D & Capuono A. Vaccine hesitancy among religious groups: reasons underlying this phenomenon and communication strategies to rebuild trust. Frontiers in Public Health 10 (2022): 824560.

172. Centers for Disease Control and Prevention (2020). Possible side effects from vaccines.

173. Centers for Disease Control and Prevention (2021b). Chickenpox VIS.

174. World Health Organization (2002). Bell's palsy following intranasal vaccination.

175. Centers for Disease Control and Prevention (2022h). COVID-19: Possible side effects.

176. Obermann M, Kraniqi M, Ewers N, Fayad J & Haeberle U. Bell's palsy following COVID-19 vaccination with high CSF antibody response. Neurological Sciences 42 (2021): 4397-4399.

177. Kennedy RB, Ovsyaannikova IG, Palese P & Poland G. Current challenges in vaccinology. Frontiers in Immunology (2020).

178. Heaton PM. Challenges of developing novel vaccines with particular global health importance. Frontiers in Immunology (2020).

179. Poland GA & Barry MA. Common cold, uncommon variation. The New England Journal of Medicine 360 (2009): 2245-2246.

180. Hanage WP, Finkelstein JA, Huang SS, Pelton SI, Stevenson AE, Kleinman K, et al. Evidence that pneumococcal serotype replacement in Massachusetts following conjugate vaccination is now complete. Epidemics 2 (2010): 80–84.

181. Sokefun E and Akinnola O. Cancer-inducing mechanisms of representative sexually-transmitted infection pathogens. Cell Biology. Special Issue: Cell Death and Mechanisms in Cancer 8 (2020): 12-21.