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## Chapter 12

# SARS-CoV-2 vaccine development

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### 12.1 Introduction

Vaccine development is the entire process involved in the designing of a vaccine to the post release study period. Vaccines work against viruses, bacteria, fungi and parasites. The design in which an antiviral vaccine is made is in such a way that it boosts the natural human immune response to an incoming virus by priming. In this way, the immune system is able to recognize antigens particular to the virus or for better vaccines, a particular strain of the virus [1]. The antigens have characteristic molecules that are found on the surface of the virus making it easily identifiable within a very short period. The response is that the immune system is ideally releasing immune cells that attack the viruses directly or by the release of antibodies

upon being triggered by the mere presence of the antigens. The antibodies get themselves attached to the virus and then immune cells engulf and destroy it.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a strain that causes coronavirus disease 2019 (COVID-19). One of the biggest challenges that researchers are facing in the development of COVID-19 vaccines is to understand the response of the immune system with both the vaccine itself and the pathogen, an aspect that is crucial in ensuring an effective and safe vaccine [1,2]. Another challenge encountered in vaccine development is antibody-dependent enhancement (ADE) where viruses take hold of the antibodies and use them to enhance infection. This situation is one of the causes of a dysregulated immune response which can clearly be caused by the involvement of the antigens, the antibodies, or both. Despite attention on ADE as the probable cause of dysregulated immune response in COVID-19, there are suggestions that other pathways such as Th2 immunopathology are more responsible than ADE while taking a look at the epidemiology and the general behavior of the disease [1,3]. This was evident in previous studies [4] on SARS where aged mice were reported to have showed high risk of life-threatening Th2 immunopathology.

During the course of vaccine development, it is crucial for developers to determine if the vaccine under development is causing similar malfunction traits as observed in any prior vaccines [1]. From around 60 years ago, vaccine candidate experiments on diseases such as the severe acute respiratory syndrome (SARS), respiratory syncytial virus, and dengue have demonstrated some troubling observations where some animal models and humans in trials who were subjected to the vaccines were later found to be exposed to the virus with the manifestation of more severe disease conditions than those who had not been subjected to the vaccine [5].

There are various approaches that are being taken to develop vaccines against COVID-19. These include small molecule approach that is designed to target RNA polymerase, RNA endonuclease, and 3C-like protease [6]. The other approach is the one that makes use of antibodies obtained from convalescent plasma from patients who successfully recovered from COVID-19 [7]. This is an opportunity that most developing countries are missing out on as they would be able to highly contribute to vaccine development processed against COVID-19 from the plasma of people who have recovered from the disease. This approach, in a way, works mimicking the attainment of individual immunity from prior infection to disease and/or a collective herd immunity from large scale immunity that can be detected from serological analysis in a case of COVID-19 and other related infections. Another way that we propose as a potential approach to be considered for studies is the use of peptides and/or proteins from various animal venoms that have shown activity against some viral strains including COVID-19 stains. [Table 12.1](#) presents some of the venoms from which active peptides can be obtained to consider

**TABLE 12.1** The use of venom in COVID-19 vaccine development.

Drug/chemical	Mechanism	Uses	Dosage	References
Bee venom	Bee venom can have an effect on the body's immune system and also enhance the differentiation of human regulatory T cells; thus, it may serve as a potential treatment for COVID-19 patients.	Though no animal or human study is designed yet to show any potential benefit/harm of bee venom use in COVID-19 patients, this current chapter displays survey result showing that neither beekeepers nor the apitherapists along with their patients receiving apitherapy develop symptoms associated with COVID-19 despite being in contact with COVID-19 patients; thus, there may be a possibility of protection offered due to this venom use. Another common point noted in this survey was that these people develop tolerance to bee sting		[8] [9] [10]

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**TABLE 12.1** The use of venom in COVID-19 vaccine development.—cont'd

Drug/chemical	Mechanism	Uses	Dosage	References
Macrolide	The mechanism of azithromycin/other macrolides against SARS-CoV-2 is unclear at present.	<p>Macrolides, for example, erythromycin, clarithromycin, and azithromycin, demonstrate not only antibacterial activity but also immunomodulatory effects, i.e., antiinflammatory effects.</p> <p>Erythromycin is effective in the treatment of rhinovirus and influenza virus.</p> <p>Clarithromycin and azithromycin are effective for treatment of rhinovirus, respiratory syncytial virus, and influenza virus.</p> <p>Azithromycin use has inhibited Zika and Ebola viruses also.</p> <p>Azithromycin acts as a potential treatment both before and after influenza virus infection.</p>	<p>In a study that enrolled COVID-19 patients into three treatment groups, i.e., hydroxychloroquine only, hydroxychloroquine (200 mg, 3 times per day, for 10 days) in combination with azithromycin (500 mg on day 1, followed by 250 mg per day for the next 4 days), and the control group with patients of COVID-19, the total virological cure (100%) was noted in the combination treatment group only; thus, this combination treatment might be an efficient antiviral therapy for COVID-19.</p>	<p>[11] [12] [13] [14] [15]</p>

<p>Cardiosphere-derived cells (CDCs) (CAP-1002 manufactured by Capricor)</p>	<p>CDCs are stromal/progenitor cells, derived from heart tissue, with a distinctive antigenic profile (CD105<sup>+</sup>, CD45<sup>-</sup>, CD90<sup>low</sup>). These cells exert their effects in a paracrine manner by secreting exosomes (nanosized vesicles with bioactive payload) and also target multiple cytokine pathways (e.g., TNF<math>\alpha</math>, IFN-<math>\gamma</math>, IL-1<math>\beta</math>, IL-6) that are associated with disease progression and poor outcomes in several diseases, i.e., COVID-19. CDCs can polarize macrophages toward an antiinflammatory and healing phenotype.</p>	<p>Immunomodulatory and antiinflammatory effects have been demonstrated with CDC use. Clinical improvement was reported with administration of CAP-1002 in patients with severe COVID-19 and significant comorbidities. It is also reported that not only is the treatment well tolerated and safe (without serious adverse events) but also the survival rate is higher in the critically ill patients receiving CAP-1002 treatment. Preclinical work has demonstrated that majority of IV CDCs are retained in the lungs; thus, this localized effect of CDC administration may be beneficial with further in-depth research.</p>	<p>IV route was used to administer a dose of 150 million allogeneic CDCs in this study (process of administration and preparation of CDCs provided in the referenced article).</p>	<p>[16] [17] [18] [19] [20] [21]</p>
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TABLE 12.1 The use of venom in COVID-19 vaccine development.—cont'd

Drug/chemical	Mechanism	Uses	Dosage	References
Erythropoietin (EPO)	<p>The COVID-19 associated loss of red blood cells and reduction in oxygen binding can be compensated through EPO treatment since its use can stimulate erythropoiesis and heme synthesis. After SARS-CoV-2 infection, EPO treatment could possibly restore hemoglobin levels and improve oxygen delivery to the tissues by targeting erythroid progenitor cells in the bone marrow to stimulate the red blood cell production.</p> <p>EPO also contributes to the regulation of heme production.</p> <p>Animal studies have demonstrated that EPO administration helps not only in the protection of pulmonary endothelium but also in the prevention of pulmonary edema.</p> <p>Antiinflammatory effects have also been demonstrated by EPO administration.</p> <p>EPO is known to counteract the pulmonary vasoconstriction by increasing the endothelial capacity to produce vasodilator nitric oxide.</p> <p>EPO is known to directly affect local brain circuits and cerebral microenvironments, i.e., it is also secreted by neurons and astrocytes; thus, EPO could alleviate general neurological symptoms in severe COVID-19 cases by acting both centrally and peripherally.</p>	<p>Iran has proposed EPO as an effective treatment for severe COVID-19 patients.</p> <p>EPO treatment could be effective for the subsets of COVID-19 patients that have developed hypoxemia in association with low red blood cell counts or low hematocrit.</p>		<p>[22] [23] [24] [25] [26]</p>

<p>IFN-I retinoids</p>	<p>IFN-I not only demonstrates potent antiviral properties but also mediates the early innate immune response to viral infections.</p> <p>Cellular immune actions of IFN-I are mediated through the activation of membrane interferon-<math>\alpha/\beta</math> receptor and the downstream regulation and expression of IFN-stimulated genes (ISGs). This whole process inhibits viral replication and stimulates the adaptive immune responses.</p> <p>In a combination of retinoids and IFN-I, retinoids not only stimulate the secretion of IFN-I but also potentiate its effects. Retinoids can directly stimulate the mRNA expression of ISGs (IFN-stimulated genes), RIG-I (retinoic acid–induced gene I), and IFN regulatory factor 1 (IRF-1).</p> <p>Retinoids also act as effectors of the T cell–mediated adaptive immunity and innate immune responses by stimulation of NK cells, antigen-presenting dendritic cells, and innate lymphoid cells.</p> <p>Also through the activation of RIG-I, retinoids can enhance IFN-I activity. Existing evidence also supports the fact that both IFN-I enhancing and antiviral effect of retinoids occur through direct stimulation of RIG-I mRNA and functions.</p> <p>It has also been reported that activation of retinoid signaling can potently inhibit coronaviruses.</p>	<p>IFN-<math>\alpha</math> has shown the possibility of treating SARS-CoV-2 patients.</p> <p>In vitro, IFN-I is effective in inhibiting SARS-CoV and MERS-CoV, either alone or in combination with other antiviral drugs.</p> <p>In cell and animal models, the IFN-I–potentiating effects of retinoids have been reported and proved beneficial for treatment of several diseases, e.g., cancer, multiple sclerosis. Natural and synthetic retinoids have demonstrated direct inhibitory effects on replication of a number of viruses, for example, hepatitis B virus (HBV), cytomegalovirus, influenza, and norovirus, and thus could be a potential candidate for COVID-19 treatment with further research.</p>	<p>5 million U of IFN-<math>\alpha</math> by vapor inhalation in combination with ribavirin twice per day are recommended for use in treatment of COVID-19 patients.</p>	<p>[27] [28] [29] [30] [31] [32] [33] [34] [35] [36]</p>
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**TABLE 12.1** The use of venom in COVID-19 vaccine development.—cont'd

Drug/chemical	Mechanism	Uses	Dosage	References
Glecaprevir and maraviroc (MVC)	<p>MVC is a C–C chemokine receptor type 5 (CCR5) receptor antagonist with effectiveness in inhibiting the R5-tropic HIV-1 entry into cells.</p> <p>The good pharmacokinetic profile, relatively low protein binding, and high bioavailability of MVC make it a suitable candidate for drug repurposing.</p> <p>Glecaprevir acts on hepatitis C virus (HCV) NS3/4A protease inhibitor, thereby targeting the viral RNA replication.</p> <p>In a study that involved the structure-based drug design approach, it was reported that both MVC and glecaprevir demonstrated a strong fit to the binding pocket of SARS-CoV-2 M<sup>pro</sup>, thus hindering the substrate accessibility and subsequent inhibition.</p> <p>Both glecaprevir and MVC also form many close bonds with the residues of the substrate-binding pocket, thereby locking the inhibitor inside the substrate-binding pocket and inhibiting the SARS-CoV-2 M<sup>pro</sup>.</p>	<p>MVC plays a role in HIV-1 infection.</p> <p>Clinical trial data and animal studies have also suggested the protective role of MVC in different diseases, for example, cancer, graft versus host, and inflammatory diseases.</p> <p>A combination of glecaprevir and pibrentasvir has proven to be a highly effective treatment not only for HCV patients without cirrhosis and with compensated cirrhosis, with a high barrier to resistance, but also for patients with advanced renal disease, HIV, and solid organ transplants.</p> <p>Both MVC and glecaprevir are recommended as potential drug candidates to fight with COVID-19.</p>	N/A	<p>[37]</p> <p>[38]</p> <p>[39]</p> <p>[40]</p> <p>[41]</p> <p>[42]</p>

<p>Melatonin</p>	<p>Melatonin has antiviral actions probably due to its antiinflammatory, antioxidant, and immune enhancing effects despite not being viricidal itself. It is also reported that melatonin suppresses the features of viral infections.</p>	<p>Used to treat sleep disorders, delirium, atherosclerosis, respiratory disease, and viral infections. Its use has been reported in alleviating acute respiratory stress induced by virus, bacteria, etc.</p>	<p>In clinical trials, the oral doses of 3, 6, and 10 mg of melatonin for patients in ICU showed satisfactory safety when compared to placebo. No adverse reports have been reported with melatonin administered at dose of 1 g/d in humans. Adverse effects associated with melatonin use are limited to occasional dizziness, headache, nausea, and sleepiness. In animal studies, no adverse effects were recorded after the use of melatonin in acute lung injury/acute respiratory distress syndrome. Despite the very high safety profile of melatonin in both animal and human studies, there is still a need to monitor its use and effects in COVID-19 patients on administration.</p>	<p>[43] [44] [45] [46] [47]</p>
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studying as potential vaccine sources. The mechanisms of actions have also been briefly stated to enable a better understanding for developers to potentially link them to immunomodulatory systems.

Although there is keen focus to detail in both approaches, the emergence of the challenge of mutation of the COVID-19 strains brings significant complications in the development process. This is so because the genome of the coronavirus is susceptible to genetic drifts. For this reason, vaccine developers are supposed to also consider all possibly known substrains of the virus to make a wider account of potential drifts and possible vaccine leakages due to immune escape.

The development of vaccines in the midst of such projected challenges is required to have sound target product profile (TPP) as early as possible which needs to be flexible enough to allow logical modifications along the way. Chen and other researchers [48] suggested the inclusion of the following parameters in the TPP. The vaccine made should be able to minimize any unwanted immunopotential and should be suitable for adult health workers, stock-piling, and administration in adults older than 60 years or those with underlying diabetic conditions. It is important to understand that a TPP does not necessarily indicate the nature of the vaccine yet at the time of development and early stages of release. These indicate vital properties that the developers should be aiming at to the best of their designs and manufacturing protocols without compromising on some specific conditions such as those stated above. The actual vaccine output is usually not entirely exactly as the TPP had it written down due to challenges and newer sets of knowledge surrounding the disease and the science of the vaccine products being developed, along the way.

## 12.2 Common antiviral vaccine components

There are various types of vaccines. In loose terms, we will discuss largely what is called the traditional vaccine and to a smaller extent, show other modern technologies leading to products that can also mimic vaccines by enhancing immunity against particular infections for a considerable period of time. Vaccines against viruses contain many items, but generally, there are a few components that are always considered to be included. For a traditional vaccine, one of the most important components that is key to its efficiency and efficacy is a weakened or dead target virus (antigens) that triggers the body to produce appropriate antibodies. This is called the active ingredient of the vaccine which ideally should not cause any disease. It is important to understand also that for a leaky vaccine, these weakened antigens might enhance infections in some individuals with certain immuno conditions and sometimes, in a large group of individuals. If this occurs, vaccine developers need to check their protocols again for possible improvements. Preservatives and stabilizers are important as they help to maintain the integrity of the vaccine by

preventing microbial contamination and keeping the vaccine as effective as acceptable. Some materials that remain in trace amounts from various stages of the manufacturing of the vaccine are also found in the end product in amounts that should ideally not cause any harm to humans. Fig. 12.1 presents a summary of the general components of a vaccine.

### 12.3 Types of vaccines related to coronaviruses

Antiviral vaccines are generally categorized into live-attenuated or inactive viruses (traditional), viral vectors, virus-like particles, DNA-based, mRNA-based, and protein-based. There are currently about 363 patents on vaccines developed to prevent diseases from viruses of which 188 directly associate with coronaviruses (SARS and MERS) with evident immune response [49]. Fig. 12.2 shows the relative distribution of the types of vaccines as patented for coronaviruses.

DNA vaccines are the most with the least patents being from mRNA. These patents present a good starting point for the development of vaccines against the current strain of the coronavirus causing COVID-19 as well as any other strains that may emerge in future. Medicinal Chemists and other vaccine/drug discoverers are prudent enough to have backup series that designed and developed to a considerable stage in wait for any emerging strain or a potentially emerging infection or any infection with a potential to go viral. Studying the line of coronaviruses, it has long been known in many circles of scientists that potentially more virulent strains are yet to appear and more will likely keep arising. The same approach is taken in the development and discovery of drugs and vaccines against other diseases such as malaria, leishmaniasis and other diseases caused by parasites, fungi and bacteria. Researchers always keep an eye on the possible evolution of these causative agents and it is never a surprise in many cases to see rising strains appearing.

### 12.4 The use of proteins in vaccine development

Proteins of different types and sizes have been essential in the development of vaccines and drugs for many years. As seen in Tables 12.1 and 12.2, proteins remain central to considerations of material to be used in the development pipeline. The mostly known proteins in vaccine development are antibodies and plasma material. There is little known about possibilities of developing vaccines from animal extracts or their venom as is the case with drug development. Table 12.1 has listed active antiviral venoms that can be explored further in the development of COVID-19 vaccines.

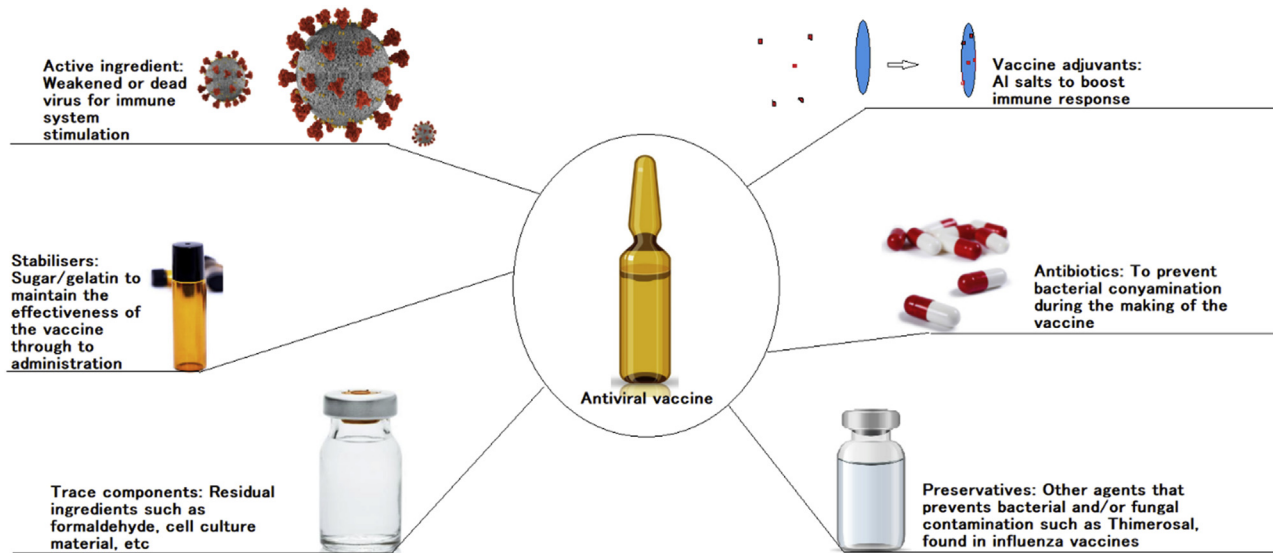


FIGURE 12.1 General components of vaccines.

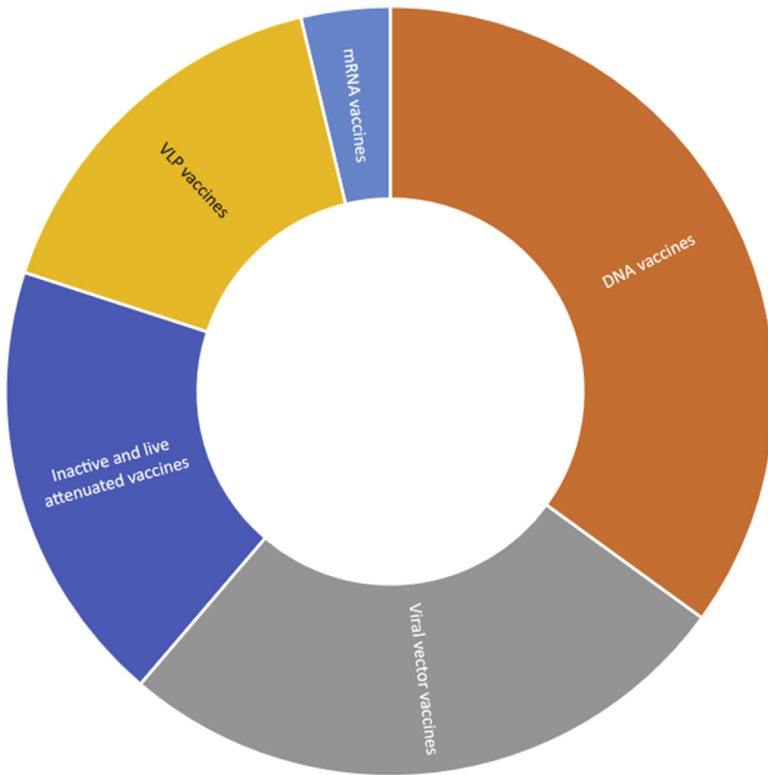


FIGURE 12.2 Relative sizes of vaccines against coronaviruses.

## 12.5 Comparing a drug and a vaccine

Drugs and vaccines are very important agents in medicine and life sciences as they are both categorized as medicinal products (medicines). They both are intended to act on disease agents as they also interact with the physiology of the body in either treating or preventing disease. In essence, the development of drugs and vaccines follows similar stages that are to do with having them be able to be effective, potent, distributed in the body, pass through various membranes, being able to remain in the body for some desired time, and not cause toxicity and adverse events in humans. Despite any differences they may have, both of these can cause adverse events in humans to some acceptable extents if they have been well checked and standardized. They also contain multiple ingredients to make up their final products that are administered to humans where each of the ingredients interacts differently with the disease, the body, and other chemical matter in the body such as other drugs, potentially causing specific individual adverse events.

**TABLE 12.2** Some vaccines under development against COVID-19.

Sponsor	Partners	Vaccine type	Protein expressed or otherwise involved	References
Altimune	N/A	Intranasal replication-defective adenovirus vector vaccine	SARS-CoV-2 S	[2]
BioNTech (Mainz, Germany)	Pfizer, Fosun Pharma	mRNA vaccine	Undisclosed SARS-CoV-2 protein(s)	[2]
(Sichuan) Clover Biopharmaceuticals (Chengdu, China)	GlaxoSmithKline	Recombinant protein trimer subunit vaccine	SARS-CoV-2 S	[2]
Codagenix	Serum Institute of India	Computationally designed and live attenuated vaccine	SARS-CoV-2	[50,51]
CureVac (Tübingen, Germany)	Coalition for Epidemic Preparedness Innovations (CEPI)	Protamine-complexed mRNA vaccine expressing	Undisclosed SARS-CoV-2	[2,52]
GeoVax	BravoVax (Wuhan, China)	Modified Vaccinia Ankara virus-like particle vaccine	Wuhan strain of SARS-CoV-2	[2]
Heat Biologics		Heat shock protein	gp96 complexed with undisclosed SARS-CoV-2 peptide(s)	[2]
iBio	Beijing CC-Pharming	<i>Agrobacterium</i> -transformed tobacco for producing virus-like particle with proteins	Undisclosed SARS-CoV-2 peptide(s)	[2]
Inovio Pharmaceuticals	Beijing Advaccine Biotechnology and Gates Foundation	Electroporated DNA vaccine	SARS-CoV-2 S protein	[3]

Janssen (Johnson & Johnson)	Biomedical Advanced Research Development Authority (BARDA)	Single-dose intranasal recombinant adenovirus vaccine incorporating undisclosed SARS-CoV-2 protein using human retinal cell line (Per.Co6) scale-up technology	[51]	[51]
LineaRx	Takis Biotech (Rome)	Electroporated linear DNA vaccine		[2]
Medicago (Quebec City)	Laval University Infectious Disease Research Centre	Tobacco produced virus-like particles	SARS-CoV-2 protein	[2]
Moderna	National Institute of Allergy and Infectious Diseases (NIAID) and CEPI	mRNA vaccine	SARS-CoV-2 S protein	[53]
Novavax	CEPI	Nanoparticle vaccine	SARS-CoV-2 S	[54]
Sanofi (Paris)	BARDA	Recombinant vaccine	Undisclosed SARS-CoV-2 protein(s)	[2]
Tonix Pharmaceuticals	Non-profit Southern Research	Live attenuated horsepox vaccine	Undisclosed SARS-CoV-2	[2]
University of Queensland (Brisbane, Australia)	CEPI; Dynavax, GlaxoSmithKline CSL (Parkville, Australia)	Recombinant subunit vaccine	SARS-CoV-2 S protein	[55]
Vaxart	N/A	Oral recombinant adenovirus 5 vector vaccine	Undisclosed SARS-CoV-2 protein(s)	[56]
Vaxil Biotherapeutics (Ness Ziona, Israel)	N/A	Human signal peptide domain complex vaccine	Undisclosed SARS-CoV-2 protein(s)	[2]
Zydyus Cadila	N/A	Live attenuated recombinant measles vaccine vector and electroporated DNA vaccine	Undisclosed SARS-CoV-2 protein(s)	[23]



However, there are significant characteristics and behavioral differences that the two have from each other. Just to mention a few, the first difference is the times at which they are administered. A drug is administered after the disease is established in the body while a vaccine is established essentially before the disease gets established [57]. In this sense, the vaccine acts as a preventive agent to the occurrence, progress and any manifestation of disease while a drug comes in as a reactive measure to the occurrence, progression and manifestation of a disease.

Drugs may be chemical or biological entities depending on the nature of the disease target and flexibility of the design process while vaccines are almost always biological entities. Due to their being biological entities, it is usually very difficult to maintain consistency in vaccines across batches of the same vaccine; the products may be similar but not identical [58]. With this in mind, vaccine batches require very close monitoring as one batch may profess differently from the other of the same vaccine. In this regard, every reference to a vaccine needs to be supported with full product safety data sheets among other characteristic test data for easy follow-up. This is usually not the case with most drugs which are chemical products as there is reliable consistency across batches as well as manufacturers for the same chemical drug entity [58]. To avoid denaturing the biological material in vaccines, they mostly have specific cold storage condition requirements, which is less common with drugs that can be stored under room temperature except for a few such as insulin which are biological drug entities. Vaccines are made from large molecules and they still maintain their physiology–drug interactions as they have similar nature. The administration of vaccines is usually en masse with an aim to protect a population, a case that is different from drugs which are administered individually [58,59]. To measure the efficacy of a vaccine is very difficult as there are a lot more factors that the human recipient is exposed to including other drugs over the post-vaccine period. It requires a long time to make a thorough and objective assessment [59]. Sometimes, where necessary, vaccines may be required to be administered repetitively depending on the observations on monitoring.

## 12.6 Safety issues in vaccines

Vaccines usually suffer from low public tolerance for adverse events [60] probably because they are administered en masse and scrutiny is wide. On the other hand, drug adverse events are tolerated more, with less of them reported by consumers. The pharmacology of vaccines is usually very hard to understand and this demands for more resources to be put into vaccine research. There is usually a chance for compromised safety as sometimes politicians and funders may craftily find their way to promote the vaccine's safety profile which is not ethical in its own right. Safety issues in vaccines should always be put ahead of any other factors [59,61] as this is a matter of life and death for

consumers. Looking at parallels with drug safety profiles, drugs are critically examined for safety at every developmental stages. If a drug compound for example is found to be toxic to human cells at preclinical stages in a petri dish, a red alarm is triggered. If a drug proves to be toxic to an experimental mouse, dog or monkey, the drug is pulled off the study and probably revised or completely withdrawn if modifications prove too costly, more so the case in clinical studies. The same critical steps need to be judiciously applied to vaccine development without compromise, to such a point that any single death a vaccine is proven to cause in humans should not be acceptable and should require a tactical withdrawal of the products for reviews, improvements and/or replacement. Legal and ethical frameworks need to be clearly put in place to protect the human population from any potential safety compromise.

## 12.7 Future perspectives

COVID-19 remains a challenging pandemic, more so considering that the world is technologically advanced today, but there is slow progress in the development of successful vaccines against the pandemic with current vaccines facing challenges with efficacy and safety. However, every emerging disease and coronavirus is coming with its own lessons to the drug and vaccine development community from which continued observations and experimentations ensure a future with enough data available for early interventions. The efforts put forward by various research groups and stakeholders are likely to be surgical in dealing with COVID-19 and any other coming pandemics. For the future, the current situation has ensured successful ways of data sharing, collaborative works, and virtual working, a platform which will enable future research to be more effective even in times of limitations and lockdowns. Going forward, developing nations need to be engaged in vaccine development projects more for every part of the world to own vaccine development interventions as their own. A part of the whole development process can be sub contracted to a developing country and this will increase capacity all over with time.

## 12.8 Conclusion

The development of vaccines is generally a very slow, lengthy, and expensive endeavor; however, the effort and resilience put up by various researchers to work on possible vaccines against COVID-19 is almost, if not, unprecedented in this generation to fasten up the process, fund more, and collaborate more. People who have recovered from the disease have provided a good source of plasma material that is being used to study the disease further as well as develop vaccines against the strain and other closely related strains to do away

with possible gene drifting. This along other small molecules in various libraries and animal venom peptides presents a formidable space for potentially successful development of vaccines.

## List of abbreviation

<b>ADE</b>	Antibody-dependent enhancement
<b>ADMET</b>	Absorption, distribution, metabolism, excretion, and toxicity
<b>CD</b>	Cluster of differentiation
<b>CDCs</b>	Cardiosphere-derived cells
<b>CEPI</b>	Coalition for Epidemic Preparedness Innovations
<b>COVID-19</b>	Coronavirus disease 2019
<b>DCs</b>	Dendritic cells
<b>EPO</b>	Erythropoietin
<b>IFN</b>	Interferon
<b>IL</b>	Interleukin
<b>ILCs</b>	Innate lymphoid cells
<b>ISGs</b>	IFN-stimulated genes
<b>MERS</b>	Middle East respiratory syndrome
<b>mRNA</b>	Messenger ribonucleic acid
<b>MVC</b>	Maraviroc
<b>RSV</b>	Respiratory syncytial virus
<b>SARS</b>	Severe acute respiratory syndrome
<b>SARS-COV-2</b>	Severe acute respiratory syndrome coronavirus 2
<b>TNF</b>	Tumor necrosis factor
<b>TPP</b>	Target product profile
<b>VLP</b>	Virus-like particles

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