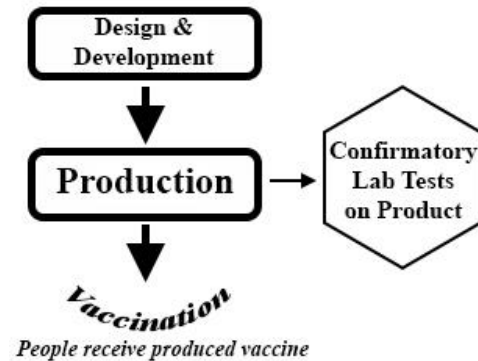


## Update: COVID-19 Vaccine Candidates and Abortion-Derived Cell Lines

Accurate information about the development and production of COVID-19 vaccines is essential, especially because many proposed candidates use newer molecular technologies for production of a viral vaccine. One concern regarding the ethical assessment of viral vaccine candidates is the potential use of abortion-derived cell lines in the development, production or testing of a vaccine. This analysis utilizes data from the primary scientific literature when available, along with data from clinical trial documents, reputable vaccine tracking websites, and published commercial information.<sup>1</sup> It is the hope that by providing accurate data, recipients can make well-informed decisions regarding vaccine choices.

### For additional background and guidance, please see:

- \* [A Visual Aid to Viral Infection and Vaccine Production](#) for a visual primer on the various strategies for viral vaccine production.
- \* [COVID-19 Vaccines & Fetal Cell Lines](#) for an infographic description of how fetal cell lines are sometimes used to produce vaccines.
- \* [Chart of Operation Warp Speed Vaccines](#) streamlined view of the leading vaccine candidates.



### Flow Chart for Creation and Testing of Vaccines



Design & Development: conceptualization, preparatory experiments, and specification for how vaccine will be constructed and produced.







Production: process used to manufacture final vaccine to be given to people.













Confirmatory Lab Tests on Product: tests to analyze quality, nucleic acid or protein sequence, protein confirmation, antibody reactivity, etc. of final vaccine product.














Vaccination: giving final produced vaccine to people.

















<b><u>Analysis of SARS-CoV-2 (COVID-19) Vaccine Candidates</u></b>					DOES NOT USE abortion-derived cell line DOES USE abortion-derived cell line SOME tests DO NOT use abortion-derived cells, SOME DO. Currently undetermined		
Sponsor(s) <sup>1</sup>	Country	Strategy <sup>2</sup>	Clinical Trial Status <sup>3</sup>	Public Funding <sup>4</sup>	Design & Development	Production	Confirmatory Lab Tests
<b>WHOLE VIRUS VACCINE – LIVE ATTENUATED or INACTIVATED</b>							
Beijing Institute of Biological Products/ Sinopharm	China	Inactivated virus “BBIBP-CorV” Given: Intramuscular	WHO granted Emergency		 Vero monkey cells	 Vero monkey cells	 Cytopathic test

		2 doses (3 weeks apart)	<i>Use Listing (EUL)</i> 7May2021 <b>Phase 3</b> Early approval in China <b>Phase 3</b> <b>Phase 1/2</b>		<a href="#">Wang et al., Cell 182, P713, 6Aug2020</a>	<a href="#">Wang et al., Cell 182, P713, 6Aug2020</a>	Vero monkey cells <a href="#">Wang et al., Cell 182, P713, 6Aug2020</a>
Wuhan Institute of Biological Products/ Sinopharm	China	Inactivated virus “New Crown COVID-19” Given: Intramuscular 2 doses (3 weeks apart)	<b>Phase 3</b> <b>Phase 3</b> <b>Phase 3</b> Early approval in China <b>Phase 1/2</b>		 Vero monkey cells <a href="#">Xia et al., JAMA 324, 951, 13Aug2020</a>	 Vero monkey cells <a href="#">Xia et al., JAMA 324, 951, 13Aug2020</a>	 Plaque reduction neutralization test Vero monkey cells <a href="#">Xia et al., JAMA 324, 951, 13Aug2020</a>
Bharat Biotech/Indian Council of Medical Research	India	Inactivated virus “COVAXIN” “BBV152” Given: Intramuscular 2 doses (2 weeks apart)	India EUA granted <b>Phase 3</b> <b>Phase 3</b> <b>Phase 1/2</b> <b>Phase 1/2</b> <b>Phase 1/2</b>		 Vero monkey cells <a href="#">Yadav et al., ResearchSquare 10Sept2020</a>	 Vero monkey cells <a href="#">Yadav et al., ResearchSquare 10Sept2020</a>	 Antibody ELISA Plaque reduction Vero monkey cells <a href="#">Yadav et al., ResearchSquare 10Sept2020</a>
Institute of Medical Biology, Chinese Academy of Medical Sciences	China	Inactivated virus “SARS-CoV-2 vaccine” Given: Intramuscular 2 doses (4 weeks apart)	<b>Phase 3</b> <b>Phase 1/2</b> <b>Phase 1/2</b>		 Vero monkey cells <a href="#">Pu et al., medRxiv, 6Oct2020</a>	 Vero monkey cells <a href="#">Pu et al., medRxiv, 6Oct2020</a>	 Antibody ELISA Neutralizing antibody cytopathic effect Vero monkey cells <a href="#">Pu et al., medRxiv, 6Oct2020; Supplement</a>
John Paul II Medical Research Institute	USA	Live attenuated virus	Pre-clinical		 <a href="#">Ethical cell lines as a matter of policy</a>		














						<a href="#">Perinatal human cells (term umbilical cord and placental)</a>	
Research Institute for Biological Safety Problems	Kazakhstan	Inactivated virus “QazCovid-in” Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 3</a> <a href="#">Phase 1/2</a>		?	?	?
Sinovac Biotech Co., Ltd.	China	Inactivated virus “CoronaVac” (formerly PiCoVacc) Given: Intramuscular 2 doses (2 weeks apart)	<i>WHO granted Emergency Use Listing (EUL) 1June2021</i> <a href="#">Phase 4</a> <i>China granted conditional marketing authorization 8Feb2021 Chile, Brazil, Turkey, Indonesia</i> <i>EUA granted</i> <a href="#">Phase 3</a> <i>Early approval in China</i> <a href="#">Phase 3</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a>		 Vero monkey cells	 Vero monkey cells <a href="#">Gao et al., Science 369, 77, 3July2020</a>	  protein test HEK293 cells <a href="#">Supplement Gao et al., Science 369, 77, 3July2020</a>
Valneva and Dynavax	France USA UK	Inactivated Virus “VLA2001” plus adjuvant CpG1018 Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 3</a> <a href="#">Phase 1/2</a>		 Vero monkey cells	 Vero monkey cells <a href="#">Same platform as IXIARO, Valneva press release, 22April2020</a> <a href="#">Valneva COVID-19 – VLA2001</a>	?
<b>VIRAL VECTOR-BASED VACCINE</b>							

Altimmune	USA	Replication-deficient Adenovirus vector “AdCOVID” Given: Intranasal 1-2 doses	<a href="#">Phase 1</a>		 PER.C6 cells	 PER.C6 cells <a href="#">Same platform as NasoVAX</a> <a href="#">NasoVAX uses PER.C6</a> <a href="#">Licensed PER.C6 from Janssen</a>	
AstraZeneca University of Oxford	USA UK	Replication-deficient Adenovirus vector “AZD1222” “ChAdOX1nCoV-19” Given: Intramuscular 2 doses (4 weeks apart)	<i>WHO granted Emergency Use Listing (EUL) on 15Feb2021</i> <a href="#">UK EUA granted</a> <i>India EUA granted</i> <a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 2/3</a> <a href="#">Phase 2/3</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a>	<i>Operation Warp Speed</i> HHS-BARDA \$1.2 Billion  CEPI up to \$384 Million	 HEK293 cells	 HEK293 cells <a href="#">van Doremalen et al., Nature, 30July2020</a>	 HEK293 cells <a href="#">van Doremalen et al., Nature, 30July2020</a> MRC-5 cells <a href="#">Almuqrin et al., ResearchSquare 20Oct2020</a>
CanSino Biologics, Inc. Beijing Institute of Biotechnology, Academy of Military Medical Sciences, PLA of China	China	Replication-deficient Adenovirus vector “Ad5-nCoV” Given: Intramuscular 1 dose	EUA in Chile, Hungary, Pakistan, Mexico <a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 2</a> <a href="#">Phase 2</a> <a href="#">Phase 1</a> <a href="#">Phase 1</a>		 HEK293 cells	 HEK293 cells <a href="#">Biospace, 12May2020</a>	
Gamaleya Research Institute	Russia	Replication-deficient Adenovirus vectors (rAd26-S+rAd5-S) “Gam-COVID-Vac” “Sputnik V” Given: Intramuscular	<a href="#">Phase 3</a> <a href="#">Phase 3</a> <i>EUA in 39 countries as of Mar2021</i>		 HEK293 cells	 HEK293 cells Gamaleya has not published details on this vaccine, but has posted <a href="#">information</a>	






















		2 doses (3 weeks apart)	<i>Early approval in Russia August 2020</i> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a>			<a href="#">on use of cell lines for their other adenoviral vaccines</a>	
ImmunityBio and NantKwest	USA	Replication-deficient Adenovirus vector recombinant “hAd5 S-Fusion + N-ETSD” Given: Subcutaneous	<a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1</a> <a href="#">Phase 1</a> <a href="#">Phase 1</a>		 E.C7 cells (derivative of HEK293 cells) <a href="#">Rice et al., bioRxiv 30July2020</a>	 E.C7 cells (derivative of HEK293 cells) <a href="#">Rice et al., bioRxiv 30July2020</a>	 Protein and antibody tests HEK293T cells <a href="#">Rice et al., bioRxiv 30July2020</a> <a href="#">Seiling et al., medRxiv 6Nov2020</a>
Institut Pasteur and Themis and Merck	USA France	Replication-competent recombinant measles virus “V591” (formerly “TMV-083”) Given: Intramuscular 1 or 2 doses (4 weeks apart)	<b>Development Discontinued</b> <a href="#">Phase 1/2</a> <a href="#">Phase 1</a>	CEPI up to \$4.9 Million	 HEK293T Development and rescue of recombinant measles virus <a href="#">Hörner et al., PNAS 22Dec2020</a> <a href="#">Hörner et al. Supplement</a> “SARS-CoV-2 S-encoding vaccine candidates... were generated <a href="#">as described previously</a> ”	 Vero monkey cells <a href="#">Hörner et al., PNAS 22Dec2020</a> <a href="#">Hörner et al. Supplement</a>	  Lentiviral vectors for antigenic DC Fusogenic test HEK293T Fusogenic test S protein expression Vero monkey cells <a href="#">Hörner et al., PNAS 22Dec2020</a> <a href="#">Hörner et al. Supplement</a>
Israel Institute for Biological Research (IIBR)	Israel	Replication-competent recombinant vesicular stomatitis virus (VSVΔG) “IIBR-100” Given: Intramuscular 1 dose	<a href="#">Phase 1/2</a>		 BHK hamster cells Vero monkey cells <a href="#">Yahalom-Ronen et al., bioRxiv 19June2020</a>	 Vero monkey cells <a href="#">Yahalom-Ronen et al., bioRxiv 19June2020</a>	 Plaque reduction; immunofluorescence Vero monkey cells <a href="#">Yahalom-Ronen et al., bioRxiv 19June2020</a>
Janssen Research & Development, Inc. Johnson & Johnson	USA	Replication-deficient Adenovirus vector	<a href="#">FDA Emergency Use</a>	<i>Operation Warp Speed</i> HHS-BARDA	 PER.C6 cells	 PER.C6 cells	

















		“Ad26.COV2-S” Given: Intramuscular 1 dose (some trials use 2 doses, 8 weeks apart)	<a href="#">Authorization</a> <a href="#">Approved</a> <a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 1/2</a>	\$1,457,887,081 total		<a href="#">Tostanoski et al., Nature Medicine, 3Sept2020;</a> <a href="#">Mercado et al., Nature 30July2020</a> <a href="#">J&amp;J, 30March2020;</a> <a href="#">Janssen Vaccine Technologies</a>	
Laboratorio Avi-Mex	Mexico	Live recombinant Newcastle Disease Virus Expressing spike-fusion chimeric protein “Patria” Given: Intramuscular or Intranasal 2 doses (3 weeks apart)	<a href="#">Phase 1</a>		 Bacterial cells BSRT7 hamster cells Per <a href="#">Sun et al., Vaccines 17Dec2020</a>	 Chicken eggs Per <a href="#">Sun et al., Vaccines 17Dec2020</a>	 Neutralization Assay Vero monkey cells Per <a href="#">Sun et al., Vaccines 17Dec2020</a>
Meissa Vaccines, Inc.	USA	Live attenuated recombinant RSV viral vector “MV-014-210” Given: Intranasal 1-3 doses (5 weeks apart)	<a href="#">Phase 1</a>			 Vero monkey cells Spike expressing, <a href="#">Based on recombinant RSV platform</a>	
Rega Institute, KU Leuven	Belgium	Replication-competent attenuated yellow fever vaccine (YF17D) vector “YF-S0” 1 dose	Pre-clinical		 BHK-21J hamster cells <a href="#">Sanchez-Felipe et al., Nature 1Dec2020</a>	 BHK-21J hamster cells <a href="#">Sanchez-Felipe et al., Nature 1Dec2020</a>	  Antibody titer Pseudovirus HEK293T cells Immunoblot BHK-21J hamster cells <a href="#">Sanchez-Felipe et al., Nature 1Dec2020</a>
ReiThera	Italy	Replication-deficient simian adenovirus encoding S “GRAd COV2” Given: Intramuscular 1 dose	<a href="#">Phase 2/3</a> <a href="#">Phase 1</a>		 HEK293T cells Development and rescue of recombinant <a href="#">Capone et al., bioRxiv 22Oct2020</a>	 HEK293T cells <a href="#">Capone et al., bioRxiv 22Oct2020</a>	 HEK293T cells <a href="#">Capone et al., bioRxiv 22Oct2020</a>
Merck and IAVI	USA	Replication-competent recombinant vesicular stomatitis virus (VSVΔG) “V590”	<a href="#">Development Discontinued</a> <a href="#">Phase 1</a>	<i>Operation Warp Speed</i> HHS-BARDA \$38,033,570	 Vero monkey cells	 Vero monkey cells <a href="#">Use rVSV Ervebo platform</a>	
















		Given: Intramuscular				<a href="#">Ervebo uses Vero cell culture-11 Description</a>	
Shenzhen Geno-immune Medical Institute	China	Lentivirus minigenes + Adult human APC (antigen-presenting cells) “COVID-19/aAPC” Given: Subcutaneous 3 doses (2 weeks apart)	<a href="#">Phase 1</a>		?		?
Shenzhen Geno-immune Medical Institute	China	Lentivirus minigenes + Adult human CD/T cells (dendritic cells and T cells) “LV-SMENP-DC” Given: Subcutaneous and Intravenous 1 dose	<a href="#">Phase 1/2</a>		?		?
Vaxart	USA	Replication-deficient Adenovirus vector “VXA-CoV2-1” plus dsRNA adjuvant Given: Oral 2 doses (4 weeks apart)	<a href="#">Phase 1</a>		 HEK293 cells	 HEK293 cells <a href="#">Moore et al., bioRxiv 6Sept2020</a>	
<b>PROTEIN-BASED VACCINE</b>							
Anhui Zhifei Longcom Biopharmaceutical/Institute of Microbiology, Chinese Academy of Sciences	China	Protein vaccine Recombinant RBD dimer plus adjuvant “ZF2001” Given: Intramuscular 2 or 3 doses (28 days apart)	<a href="#">Phase 3</a> <a href="#">Phase 2</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1</a>		 HEK293T cells <a href="#">Dai et al., Cell 6Aug2020</a>	 CHO hamster cells <a href="#">Dai et al., Cell 6Aug2020</a>	 Pseudovirus HEK293T cells <a href="#">Dai et al., Cell 6Aug2020</a>
Clover Biopharmaceuticals, Inc.	China	Protein vaccine “SCB-2019” plus adjuvant CpG 1018 Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 2/3</a> <a href="#">Phase 1</a>	CEPI up to \$69.5 Million	 cDNA in expression vector; transfect CHO hamster cells <a href="#">Liang et al., bioRxiv, 24Sept2020</a> <a href="#">Trimer-Tag system; Liu et al., Scientific Reports 2017</a>	 CHO hamster cells <a href="#">Liang et al., bioRxiv, 24Sept2020</a>	 Pseudovirus HEK293 cells Ref'd: <a href="#">Nie et al., Emerging Microbes &amp; Infections 24Mar2020</a> Cytopathic effect













							Vero monkey cells <a href="#">Liang et al., bioRxiv, 24Sept2020</a>
COVAXX and United Biomedical	USA Taiwan	Protein vaccine “UB-612” S1-RBD-protein; Multitope Peptide-Based Vaccine (MVP) Given: Intramuscular 2 doses (4 weeks apart)	<a href="#">Phase 2/3</a> <a href="#">Phase 1</a>		 cDNA in expression vector; transfect CHO hamster cells <a href="#">Guirakhoo et al., bioRxiv, 30Nov2020</a>	 CHO hamster cells <a href="#">Guirakhoo et al., bioRxiv, 30Nov2020</a>	  Antibody-blocked binding to hACE2 HEK293 <a href="#">Guirakhoo et al., bioRxiv, 30Nov2020</a>
Federal Budgetary Research Institution State Research Center of Virology and Biotechnology “Vektor”	Russia	Protein vaccine “EpiVacCorona” chemically synthesized peptide antigens of SARS-CoV-2, conjugated to a carrier protein adsorbed on an aluminum-containing adjuvant Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 3</a> <i>Early approval in Russia Oct 2020</i> <a href="#">Phase 1/2</a>			 chemically synthesized peptide antigens	
Instituto Finlay de Vacunas	Cuba	Protein vaccine “Finlay-FR-1” (“Soberana 01”) Receptor-Binding Domain (RBD) SARS-CoV-2 spike + adjuvant Given: Intramuscular 2 doses (4 weeks apart)	<a href="#">Phase 1/2</a> <a href="#">Phase 1</a>		 RBD produced in mammalian cells <a href="#">Garcia-Rivera, MEDICC Review, 30Oct2020</a>	 RBD produced in mammalian cells <a href="#">Garcia-Rivera, MEDICC Review, 30Oct2020</a>	
Instituto Finlay de Vacunas	Cuba	Protein vaccine “Finlay-FR-2” (“Soberana 02”) Receptor-Binding Domain (RBD) SARS-CoV-2 spike chemically bound tetanus toxoid + adjuvant Given: Intramuscular	<a href="#">Phase 2</a> <a href="#">Phase 1</a>		 RBD produced in mammalian cells <a href="#">Garcia-Rivera, MEDICC Review, 30Oct2020</a>	 RBD produced in mammalian cells <a href="#">Garcia-Rivera, MEDICC Review, 30Oct2020</a>	



















		2 doses (4 weeks apart)					
John Paul II Medical Research Institute	USA	Recombinant Protein Perinatal human cells (term umbilical cord and placental)	Pre-clinical		 <a href="#">Ethical cell lines as a matter of policy</a>	 <a href="#">Perinatal human cells (term umbilical cord and placental)</a>	
Kentucky BioProcessing, Inc. (British American Tobacco)	USA	Protein vaccine “KBP-201” Plant-expressed RBD Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 1/2</a>		 Recombinant DNA sequence for RBD of SARS-CoV-2	 <a href="#">Plant expression of RBD peptide</a>	
Medicago	Canada	Protein on Virus-Like Particle “CoVLP” Plant-expressed spike protein particle with adjuvant, CpG1018 or AS03 Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 2/3</a> <a href="#">Phase 2</a> <a href="#">Phase 1</a>		 Recombinant DNA sequence in <i>Agrobacterium</i> , transformation of plant cells	 Plant expression of protein and VLP <a href="#">Ward et al., medRxiv 6Nov2020</a>	  Pseudovirus HEK293 cells <a href="#">Ward et al., medRxiv 6Nov2020</a>
Migal Galilee Research Institute	Israel	Protein vaccine  <i>E. coli</i> expressed chimeric S and N proteins Given: Oral	Pre-clinical			 Bacterial production system <a href="#">MigVax’s corona subunit vaccine</a>	
Novavax	USA	Protein vaccine “NVX-CoV2373” Baculovirus expression plus Matrix M adjuvant Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 3</a> <a href="#">Phase 3</a> <a href="#">Phase 2</a> <a href="#">Phase 1</a>	Operation Warp Speed HHS-BARDA \$1,600,434,523  CEPI up to \$388 Million		 Sf9 insect cells <a href="#">Bangaru et al., Science, 27Nov2020</a> <a href="#">Bangaru et al., Supplement 27Nov2020</a> <a href="#">Bangaru et al., bioRxiv preprint, 6Aug2020; Graphical view</a>	  Pseudovirus HEK293 cells <a href="#">Bangaru et al., Science, 27Nov2020 Supplement 27Nov2020</a> <a href="#">Bangaru et al., bioRxiv preprint, 6Aug2020</a>
Sanofi and GSK Protein Sciences	USA France	Protein vaccine Baculovirus expression plus AS03 adjuvant Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">Phase 3</a> <a href="#">Phase 2</a> <a href="#">Phase 1/2</a>	Operation Warp Speed HHS-BARDA \$2,072,775,336 total	 Recombinant baculovirus <a href="#">Francica et al., bioRxiv 2Mar2021</a>	 Sf9 insect cells <a href="#">Francica et al., bioRxiv 2Mar2021</a> <a href="#">Baculovirus expressed recombinant protein</a>	  Pseudovirus HEK293T cells

							<a href="#">Francica et al., bioRxiv 2Mar2021</a>
Sorrento	USA	Protein vaccine “T-VIVA-19” SARS-Cov-2 spike protein S1 domain fused with human IgG-Fc Given: Intramuscular	Pre-clinical		 DNA fragment developed in lab <a href="#">Herrmann et al., bioRxiv preprint, 30June2020</a>	 CHO cells <a href="#">Herrmann et al., bioRxiv preprint, 30June2020</a>	 Antibody ELISA; Neutralization assays Vero monkey cells <a href="#">Herrmann et al., bioRxiv preprint, 30June2020</a>
Sorrento	USA	Protein vaccine “STI-6991” SARS-Cov-2 spike protein expressed on K562 cells	Pre-clinical			 K562 cells Concept: <a href="#">Ji et al., Medicine in Drug Discovery March2020</a>	
University of Pittsburgh	USA	Protein vaccine Adenovirus-expressed recombinant proteins “PittCoVacc” Given: Microneedle arrays	Pre-clinical		 HEK293 cells	 HEK293 cells <a href="#">Kim et al., EBioMedicine, 2April2020</a>	
University of Queensland and CSL Ltd.	Australia	Protein vaccine “V451” Recombinant protein with proprietary molecular clamp Given: Intramuscular	<b>HALTED</b> <a href="#">Phase 1</a> <a href="#">Phase 1</a> <a href="#">Phase 1</a>	CEPI up to \$4.5 Million		 expiCHO hamster cells	
Walter Reed Army Institute of Research (WRAIR) / U.S. Army Medical Research and Development Command	USA	Protein vaccine “SpFN” Spike-Ferritin nanoparticle with ALFQ adjuvant Given: Intramuscular 2-3 doses (4 weeks apart; plus 6 months after initial)	<a href="#">Phase 1</a>		 Expi293 cells <a href="#">Carmen et al., bioRxiv 28April2021</a>	 Expi293 cells <a href="#">Carmen et al., bioRxiv 28April2021</a>	  Pseudovirus, HEK293 cells Virus neutralization Vero monkey cells <a href="#">Joyce et al., bioRxiv 25Mar20</a> <a href="#">21</a>

							& <u>Supplement</u>
<b>RNA VACCINE</b>							
Arcturus Therapeutics	USA	mRNA vaccine self-transcribing, replicating “LUNAR-CoV19” (“ARCT-021”) <i>in vitro</i> transcription reaction with T7 RNA polymerase from STARR plasmid template LUNAR proprietary lipid nanoparticle encapsulated Given: Intramuscular 1 dose	<a href="#">Phase 2</a> <a href="#">Phase 2</a> <a href="#">Phase 1/2</a>		 Sequence designed on computer	 No cells used <a href="#">de Alwis et al., bioRxiv 3Sept2020</a>	  protein test HEK293 Protein expression Hep3b cells Plaque reduction neutralization Vero monkey cells <a href="#">de Alwis et al., bioRxiv 3Sept2020</a>
CureVac	Germany	mRNA vaccine non-replicating “CVnCoV” <i>in vitro</i> transcription lipid nanoparticle encapsulated Given: Intramuscular 2 doses (4 weeks apart)	<a href="#">Phase 3</a> <a href="#">Phase 2/3</a> <a href="#">Phase 2</a> <a href="#">Phase 1</a>	CEPI up to \$15.3 Million	 Sequence designed on computer	 No cells used <a href="#">Rauch et al., bioRxiv 9Feb2021</a>	 Protein test Reticulocyte lysate, HeLa cells <a href="#">Rauch et al., bioRxiv 9Feb2021</a>
Imperial College London	UK	mRNA vaccine Self-amplifying “LNP-nCoVsaRNA” <i>in vitro</i> transcription lipid nanoparticle encapsulated Given: Intramuscular 2 doses	<a href="#">Phase 1</a>		 Expression plasmid HEK293 cells <a href="#">McKay et al., bioRxiv, 25April2020</a>	 No cells used <a href="#">McKay et al., bioRxiv, 25April2020</a>	  Pseudovirus HEK293T cells <a href="#">McKay et al., bioRxiv, 25April2020</a>
Moderna, Inc. with National Institutes of Health	USA	mRNA vaccine non-replicating “mRNA-1273” T7 RNA polymerase-mediated transcription	<a href="#">FDA Emergency Use Authorization Approved Phase 3</a>	<i>Operation Warp Speed</i> HHS-BARDA \$2,479,894,979 total	 Sequence designed on computer	 No cells used <a href="#">Corbett et al., Nature, 5Aug2020</a>	  protein test & pseudovirus HEK293 cells

		from DNA plasmid template LNP (lipid nanoparticle) encapsulated Given: Intramuscular 2 doses (4 weeks apart)	<a href="#">Phase 2</a> <a href="#">Phase 1</a>	CEPI up to \$1 Million			Plaque reduction neutralization Vero monkey cells <a href="#">Corbett et al., Nature, 5Aug2020</a>
Pfizer and BioNTech	USA Germany	mRNA vaccine non-replicating “BNT-162a1,b1,b2,b3,c2” nucleoside-modified mRNA <i>in vitro</i> transcribed by T7 polymerase from a plasmid DNA template LNP (lipid nanoparticle) encapsulated Given: Intramuscular 2 doses (3 weeks apart)	<a href="#">FDA Emergency Use Authorization Approved</a> UK EUA granted <a href="#">Phase 2/3</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1</a> <a href="#">Phase 1</a>	<i>Operation Warp Speed</i> HHS-BARDA \$1.95 Billion	 Sequence designed on computer	 No cells used <a href="#">Vogel et al., bioRxiv 8Sept2020</a>	  protein test & pseudovirus HEK293 cells Neutralization Vero monkey cells <a href="#">Vogel et al., bioRxiv 8Sept2020</a>
Providence Therapeutics	Canada	mRNA vaccine “PTX-COVID19-B” mRNA <i>in vitro</i> transcription from plasmid template using T7 RNA polymerase LNP (lipid nanoparticle) encapsulated Given: Intramuscular 2 doses (4 weeks apart)	<a href="#">Phase 1</a>		 HEK293T cells used to select mRNA candidate <a href="#">Liu et al., bioRxiv 12May2021</a>	 No cells used <a href="#">Cision, 5Aug2020</a> <a href="#">Providence Therapeutics</a> <a href="#">Liu et al., bioRxiv 12May2021</a>	  Pseudovirus, serum neutralization HEK293T cells Vero monkey cells <a href="#">Liu et al., bioRxiv 12May2021</a>
Sanofi Pasteur and Translate Bio	USA France	mRNA vaccine non-replicating “MRT5500” synthesized by <i>in vitro</i> transcription employing RNA polymerase with a plasmid DNA template LNP (lipid nanoparticle) encapsulated Given: Intramuscular	<a href="#">Phase 1/2</a>		 HEK293T cells used to select mRNA candidate <a href="#">Kalnin et al., npj Vaccines 19Apr2021</a>	 No cells used <a href="#">Kalnin et al., npj Vaccines 19Apr2021</a> <a href="#">Kalnin et al., bioRxiv 14Oct2020</a> mRNA production in the lab ; Translate Bio scientific platform	  protein test & pseudovirus HEK293 cells <a href="#">Kalnin et al., npj Vaccines 19Apr2021</a> <a href="#">Kalnin et al., bioRxiv 14Oct2020</a>

		2 doses (3 weeks apart)					
<b>DNA VACCINE</b>							
Genexine	Korea	DNA vaccine “GX-19” DNA synthesized in vitro, placed in plasmid vector Given: Intramuscular and Electroporation 2 doses (4 weeks apart)	<a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a>		 Sequence designed on computer	 No cells used <a href="#">Seo et al., Vaccines</a> <a href="#">24March2021</a>	 Neutralization assay Vero monkey cells <a href="#">Seo et al., Vaccines</a> <a href="#">24March2021</a>
Inovio Pharmaceuticals	USA	DNA vaccine “INO-4800” DNA synthesized in vitro, placed in plasmid vector Given: Intradermal Electroporation 2 doses (4 weeks apart)	<a href="#">Phase 2/3</a> <a href="#">Phase 2</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1</a>	<i>Operation Warp Speed</i>  CEPI up to \$22.5 Million	 Sequence designed on computer	 No cells used <a href="#">Smith et al., Nature</a> 20May2020	  protein test & pseudovirus HEK293 cells <a href="#">Smith et al., Nature</a> 20May2020
Osaka University, AnGes, Takara Bio	Japan	DNA vaccine “AG0301-COVID19” “AG0302-COVID19” Chemically synthesized plasmid vector grown in <i>E. coli</i> Pressure injector Given: Intramuscular 2 doses (2 weeks apart)	<a href="#">Phase 2/3</a> <a href="#">Phase 1/2</a> <a href="#">Phase 1/2</a>		 Sequence designed on computer	 No cells used <i>E. coli</i> <a href="#">Nishikawa et al., bioRxiv</a> , 14Jan2021	 Virus neutralization Vero E6 monkey cells <a href="#">Nishikawa et al., bioRxiv</a> , 14Jan2021
Symvivo Corporation	Canada	DNA vaccine “bacTRL-spike” Genetically engineered <i>Bifidobacterium longum</i> Given: Oral, bacteria bind to gut lining 1 dose	<a href="#">Phase 1</a>			 No cells used	
Zydus Cadila	India	DNA vaccine “ZyCov-D” Chemically synthesized plasmid vector grown in <i>E. coli</i> Given: Intradermal	<a href="#">Phase 3</a> <a href="#">Phase 1/2</a>		 Sequence designed on computer	 No eukaryotic cells used <i>E. coli</i> <a href="#">Dey et al., bioRxiv</a> <a href="#">26Jan2021</a>	 Expression analysis Plaque reduction Vero monkey cells

		3 doses (4 weeks apart)					<a href="#">Dey et al., bioRxiv 26Jan2021</a> <a href="#">Yadav et al., bioRxiv 3Feb2021</a>
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1. Data accumulated from primary literature as referenced in the Chart; AND “COVID-19 Treatment and Vaccine Tracker,” Milken Institute, <https://covid-19tracker.milkeninstitute.org/> ; AND “Draft landscape of COVID-19 candidate vaccines,” World Health Organization (WHO), <https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines>

NOTE that patents are not considered because they are unreliable sources; even the most relevant patents are prospective documents that provide examples of potential use, but do not provide information about actual, current application of an invention or technology.

2. Prentice, DA and Sander Lee, T. June 15, 2020. A Visual Aid to Viral Infection and Vaccine Production. *On Science Series 1*. Accessed 19 June 2020 at: <https://lozierinstitute.org/a-visual-aid-to-viral-infection-and-vaccine-production/>

3. Phases of Clinical Trials: Pre-clinical- laboratory and animal studies; Phase I- 10-100 people, study safety and dosage; Phase II- tens to hundreds of people, study efficacy, dosage, side effects; Phase III- hundreds to thousands of people, study efficacy and adverse reactions.

4. HHS-BARDA = U.S. Health and Human Services-Biomedical Advanced Research and Development Authority; CEPI = Coalition of Epidemic Preparedness Innovations; BARDA’s rapidly-expanding COVID-19 medical countermeasure portfolio. Accessed 29 Sept 2020 at <https://www.medicalcountermeasures.gov/app/barda/coronavirus/COVID19.aspx>; CEPI’s COVID-19 Vaccine Portfolio, Accessed 29 Sept 2020 at <https://cepi.net/COVAX/>