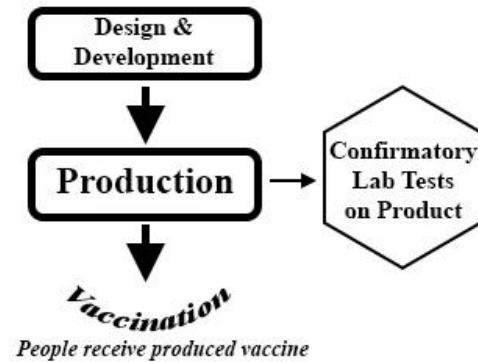


## Update: COVID-19 Vaccine Candidates and Abortion-Derived Cell Lines

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)	<del>Development</del> <del>Discontinued</del> <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>	<i>Operation Warp Speed</i> 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</a> <a href="#">Bangaru et al., 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>	<i>Operation Warp Speed</i> 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="#">Dev 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>
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/>