





<p><b>Analysis of SARS-CoV-2 (COVID-19) Vaccine Candidates</b>                      Last Updated 14 December 2020</p>							
						<p>■ DOES NOT USE abortion-derived cell line</p> <p>▲ DOES USE abortion-derived cell line</p> <p>■ ▲ SOME tests DO NOT use abortion-derived cells, SOME DO.</p> <p>◆ Currently undetermined</p>	
Sponsor(s) <sup>1</sup>	Country	Strategy <sup>2</sup>	Clinical Trial Status <sup>3</sup>	Public Funding <sup>4</sup>	Design & Development	Production	Confirm-atory Lab Tests
<b>WHOLE VIRUS VACCINE - LIVE ATTENUATED or INACTIVATED</b>							
Beijing Institute of Biological Products/ Sinopharm	China	Inactivated virus "BBIBP-CorV" Given: Intramuscular	Phase 3 Phase 3		■ Vero monkey cells	■ Vero monkey cells	■ Cytopathic test
Wuhan Institute of Biological Products/ Sinopharm	China	Inactivated virus Unnamed Given: Intramuscular	Phase 3 Phase 1/2		■ 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 "BBV152" Given: Intramuscular	Phase 3 Phase 1/2 Phase 1/2 Phase 1/2		■ 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>
John Paul II Medical Research Institute	USA	Live attenuated virus	Pre-clinical		■ Ethical cell lines as a matter of policy	■ Perinatal human cells (term umbilical cord and placental)	◆

Sinovac Biotech Co., Ltd.	China	Inactivated virus "PiCoVacc" Given: Intramuscular	Phase 3 Phase 3 Phase 1/2 Phase 1/2 Phase 1/2		■ 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	Pre-clinical		■ Vero monkey cells	■ Vero monkey cells <a href="#">Same platform as IXIARO, Valneva press release, 22April2020</a>	◆
<b>VIRAL VECTOR-BASED VACCINE</b>							
Altimmune	USA	Replication-deficient Adenovirus vector "AdCOVID" Given: Intranasal	Pre-clinical		▲ 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	Phase 3 Phase 3 Phase 3 Phase 2/3 Phase 2/3 Phase 1/2 Phase 1/2	<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 preprint, 30July2020</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	Phase 3 Phase 3 Phase 2 Phase 2 Phase 1 Phase 1		▲ HEK293 cells	▲ HEK293 cells <a href="#">Biospace, 12May2020</a>	▲
Gamaleya Research Institute	Russia	Replication-deficient Adenovirus vectors (rAd26-S+rAd5-S) "Sputnik V" Given: Intramuscular	Phase 3 <i>Early approval in Russia August 2020</i>		▲ HEK293 cells	▲ HEK293 cells	▲

			Phase 1/2 Phase 1/2				
ImmunityBio and NantKwest	USA	Replication-deficient Adenovirus vector recombinant "hAd5 S-Fusion + N-ETSD" Given: Subcutaneous	Phase 1		▲ 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 "TMV-083" Given: Intramuscular	Phase 1	CEPI up to \$4.9 Million	◆	■ Vero monkey cells	◆
Israel Institute for Biological Research (IIBR)	Israel	Replication-competent recombinant vesicular stomatitis virus (VSVΔG) "IIBR-100" Given: Intramuscular	Phase 1		■ 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 "Ad26" Given: Intramuscular	Phase 3 Phase 1/2	<i>Operation Warp Speed</i> HHS-BARDA \$1,457,887,081 total	▲ PER.C6 cells	▲ PER.C6 cells <a href="#">Tostanoski et al., Nature Medicine, 3Sept2020; J&amp;J, 30March2020; Janssen Vaccine Technologies</a>	▲
Merck and IAVI	USA	Replication-competent recombinant vesicular stomatitis virus (VSVΔG) "V590" Given: Intramuscular	Pre-clinical	<i>Operation Warp Speed</i> HHS-BARDA \$38,033,570	■ Vero monkey cells	■ Vero monkey cells <a href="#">Use rVSV Ervebo platform Ervebo uses Vero cell culture-11 Description</a>	◆
Shenzhen Geno-immune	China	Lentivirus minigenes +	Phase 1		◆	■	◆

Medical Institute		Adult human APC (antigen-presenting cells)					
Shenzhen Geno-immune Medical Institute	China	Lentivirus minigenes + Adult human CD/T cells (dendritic cells and T cells) "LV-SMENP-DC"	Phase 1/2			◆	◆
Vaxart	USA	Replication-deficient Adenovirus vector "VXA-CoV2-1" plus dsRNA adjuvant Given: Oral	Phase 1			▲ HEK293 cells	▲ HEK293 cells <i>Moore et al., bioRxiv 6Sept2020</i>
<b>PROTEIN-BASED VACCINE</b>							
Anhui Zhifei Longcom Biopharmaceutical/Institute of Microbiology, Chinese Academy of Sciences	China	Protein vaccine Recombinant RBD dimer plus adjuvant Given: Intramuscular	Phase 2 Phase 1/2 Phase 1			▲ HEK293T cells <i>Dai et al., Cell 6Aug2020</i>	▲ Pseudovirus HEK293T cells <i>Dai et al., Cell 6Aug2020</i>
Clover Biopharmaceuticals, Inc.	China	Protein vaccine "SCB-2019" plus adjuvant CpG 1018 Given: Intramuscular	Phase 1	CEPI up to \$69.5 Million		■ cDNA in expression vector; transfect CHO hamster cells <i>Liang et al., bioRxiv, 24Sept2020</i> Trimer-Tag system; <i>Liu et al., Scientific Reports 2017</i>	■ ▲ Pseudovirus HEK293 cells <i>Ref'd: Nie et al., Emerging Microbes &amp; Infections 24Mar2020</i> Cytopathic effect Vero monkey cells <i>Liang et al., bioRxiv, 24Sept2020</i>
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	Early approval in Russia Oct 2020 Phase 1 Phase 1			◆	◆ chemically synthesized peptide antigens

John Paul II Medical Research Institute	USA	Recombinant Protein Perinatal human cells (term umbilical cord and placental)	Pre-clinical		 Ethical cell lines as a matter of policy	 Perinatal human cells (term umbilical cord and placental)	
Kentucky BioProcessing, Inc. (British American Tobacco)	USA	Protein vaccine "KBP-201" Plant-expressed RBD Given: Intramuscular		Phase 1/2	 Recombinant DNA sequence for RBD of SARS-CoV-2	 Plant expression of RBD peptide	
Medicago	Canada	Protein on Virus-Like Particle "CoVLP" Plant-expressed spike protein particle with adjuvant, CpG1018 or AS03 Given: Intramuscular	Phase 1		 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>
Novavax	USA	Protein vaccine "NVX-CoV2373" Baculovirus expression plus Matrix M adjuvant Given: Intramuscular	Phase 3 Phase 2 Phase 1	Operation Warp Speed HHS-BARDA \$1,600,434,523 CEPI up to \$388 Million		 Sf9 insect cells <a href="#">Bangaru et al., bioRxiv preprint, 6Aug2020</a> ; <a href="#">Graphical view</a>	  Pseudovirus HEK293 cells <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	Phase 1/2	Operation Warp Speed HHS-BARDA \$2,072,775,336 total		 Sf9 insect cells Baculovirus expressed recombinant protein ;	
Sorrento	USA	Protein vaccine "T-VIVA-19" SARS-Cov-2 spike protein S1 domain fused with human IgG-Fc Given: Intramuscular	Pre-clinical			 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	Pre-clinical			 K562 cells <a href="#">Concept: Ji et al.,</a>	

		protein expressed on K562 cells				<a href="#">Medicine in Drug Discovery</a> March2020	
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</a> , 2April2020	▲
University of Queensland and CSL Ltd.	Australia	Protein vaccine "V451" Recombinant protein with proprietary molecular clamp Given: Intramuscular	Phase 1 Phase 1 Phase 1	CEPI up to \$4.5 Million	■	■ expiCHO hamster cells	◆
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<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	Phase 1/2		■ Sequence designed on computer	■ No cells used <a href="#">de Alwis et al., bioRxiv</a> 3Sept2020	■ ▲ protein test HEK293 <a href="#">de Alwis et al., bioRxiv</a> 3Sept2020
CureVac	Germany	mRNA vaccine non-replicating "CVnCoV" <i>in vitro</i> transcription lipid nanoparticle encapsulated Given: Intramuscular	Phase 2 Phase 1	CEPI up to \$15.3 Million	■ Sequence designed on computer	■ No cells used <a href="#">Rauch et al., bioRxiv</a> 23Oct2020	■ Protein test Reticulocyte lysate, HeLa cells <a href="#">Rauch et al., bioRxiv</a> 23Oct2020
Moderna, Inc. with National Institutes of Health	USA	mRNA vaccine non-replicating "mRNA-1273" T7 RNA polymerase-mediated transcription from DNA plasmid	FDA Emergency Use Authorization Requested Phase 3	Operation Warp Speed HHS-BARDA \$2,479,894,979 total CEPI up to \$1	■ Sequence designed on computer	■ No cells used <a href="#">Corbett et al., Nature</a> , 5Aug2020	■ ▲ protein test & pseudovirus HEK293 cells <a href="#">Corbett et al., Nature</a> , 5Aug2020

		template LNP (lipid nanoparticle) encapsulated Given: Intramuscular	Phase 2 Phase 1	Million			
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	FDA Emergency Use Authorization Requested UK EUA granted Phase 2/3 Phase 1/2 Phase 1/2 Phase 1 Phase 1	Operation Warp Speed 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 <a href="#">Vogel et al., bioRxiv 8Sept2020</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	Pre-clinical		Sequence designed on computer	No cells used <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., bioRxiv 14Oct2020</a>
<b>DNA VACCINE</b>							
Genexine	Korea	DNA vaccine "GX-19" DNA synthesized in <i>in vitro</i> , placed in plasmid vector Given: Intramuscular and Electroporation	Phase 1/2		Sequence designed on computer	No cells used <a href="#">Seo et al., bioRxiv 10Oct2020</a>	◆
Inovio Pharmaceuticals	USA	DNA vaccine "INO-4800" DNA synthesized in <i>in vitro</i> , placed in plasmid vector	Phase 1/2 Phase 1	Operation Warp Speed CEPI up to \$22.5 Million	Sequence designed on computer	No cells used <a href="#">Smith et al., Nature 20May2020</a>	protein test & pseudovirus HEK293 cells <a href="#">Smith et al., Nature</a>

		Given: Intradermal Electroporation					20May2020
Symvivo Corporation	Canada	DNA vaccine Genetically engineered <i>Bifidobacterium longum</i> "bacTRL-spike" Given: Oral, bacteria bind to gut lining	Phase 1	◆		■ No cells used	◆

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/>

