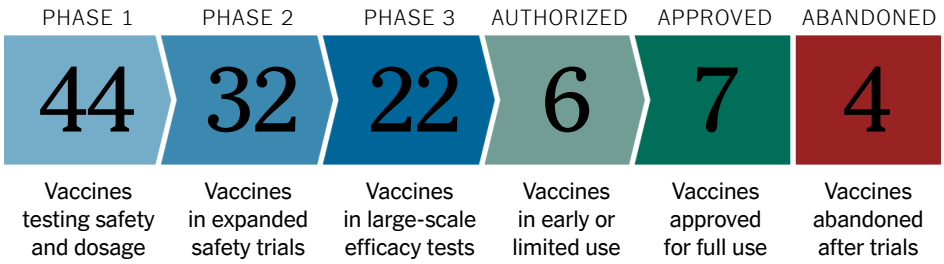
Coronavirus Vaccine Tracker

By Carl Zimmer, Jonathan Corum and Sui-Lee Wee Updated March 16, 2021



Vaccines typically require years of research and testing before reaching the clinic, but in 2020, scientists embarked on a race to produce safe and effective coronavirus vaccines in record time. Researchers are currently testing **78 vaccines** in clinical trials on humans, and 22 have reached the final stages of testing. At least 77 preclinical vaccines are under active investigation in animals.

New additions and recent updates

March 16 Canada's **Medicago** begins a Phase 3 trial of a plant-derived vaccine.

March 16 **Meissa Vaccines** begins a Phase 1 trial of an intranasal vaccine.

March 16 Iran's **Ministry of Defence** announces a new Phase 1 vaccine.

March 15 China authorizes a vaccine by **Anhui Zhifei Longcom** and **IMCAS**.

March 15 Germany, France and Italy are the latest countries to suspend use of the **Oxford-AstraZeneca** vaccine.

March 13 Brazil gives full approval to the **Oxford-AstraZeneca** vaccine.

March 12 A vaccine from **Sanofi** and **Translate Bio** enters Phase 1/2.

March 11 **Novavax** reports strong trial results.

March 11 Italy's **ReiThera** moves to Phase 2/3.

March 11 The European Union authorizes **Johnson & Johnson**'s vaccine.

March 11 Denmark, Iceland and Norway suspend the use of the **Oxford-AstraZeneca** vaccine because of concerns about blood clots.

Leading vaccines

Developer	How It Works	Phase	Status
Pfizer-BioNTech	mRNA	2 3	Approved in several countries. Emergency use in U.S., E.U., other countries.
Moderna	mRNA	3	Approved in Switzerland. Emergency use in U.S., U.K., E.U., others.
Gamaleya	Ad26, Ad5	3	Early use in Russia. Emergency use in other countries.

Oxford-AstraZeneca	ChAdOx1	**2**	**3**	Approved in Brazil. Emergency use in U.K., E.U., other countries.
CanSino	Ad5		**3**	Approved in China. Emergency use in Mexico, Pakistan.
Johnson & Johnson	Ad26		**3**	Emergency use in U.S., E.U., Bahrain.
Vector Institute	Protein		**3**	Early use in Russia.
Novavax	Protein		**3**	
Sinopharm	Inactivated		**3**	Approved in China, U.A.E., Bahrain. Emergency use in other coutries.
Sinovac	Inactivated		**3**	Approved in China. Emergency use in other countries.
Sinopharm-Wuhan	Inactivated		**3**	Approved in China. Limited use in U.A.E.
Bharat Biotech	Inactivated		**3**	Emergency use in India, Iran, Zimbabwe.

Below is a list of all vaccines that have reached trials in humans, along with a selection of promising vaccines being tested in animals. For an explanation of virus variants and mutations, see our Coronavirus Variant Tracker. For treatments for Covid-19, see our Coronavirus Drug and Treatment Tracker. For an explanation of leading vaccines, see How Nine Covid-19 Vaccines Work.

The Vaccine Testing Process

The development cycle of a vaccine, from lab to clinic.

PRECLINICAL TESTING : Scientists test a new vaccine on cells and then give it to **animals** such as mice or monkeys to see if it produces an immune response.

PHASE 1 SAFETY TRIALS : Scientists give the vaccine to a **small number of people** to test safety and dosage, as well as to confirm that it stimulates the immune system.

PHASE 2 EXPANDED TRIALS : Scientists give the vaccine to **hundreds of people** split into groups, such as children and the elderly, to see if the vaccine acts differently in them. These trials further test the vaccine's safety.

PHASE 3 EFFICACY TRIALS : Scientists give the vaccine to **thousands of people** and wait to see how many become infected, compared with volunteers who received a placebo. These trials can determine if the vaccine protects against the coronavirus, measuring what's known as the efficacy rate. Phase 3 trials are also large enough to reveal evidence of relatively rare side effects.

EARLY OR LIMITED APPROVAL : Many countries have given emergency authorization based on preliminary evidence that they are safe and effective. China, Russia and other countries have begun administering vaccines before detailed Phase 3 trial data has been made public. Experts have warned of serious risks from jumping ahead of these results.

APPROVAL : Regulators review the complete trial results and plans for a vaccine's manufacturing, and decide whether to give it full approval.

COMBINED PHASES : One way to accelerate vaccine development is to combine phases. Some vaccines are now in Phase 1/2 trials, for example, which this tracker would count as both Phase 1 and Phase 2.

PAUSED or **ABANDONED** : If investigators observe worrying symptoms in volunteers, they can pause the trial. After an investigation, the trial may resume or be abandoned.

Filter the list of vaccines:

All vaccines Preclinical Phase 1 2 3 Approved Abandoned

Genetic Vaccines

Vaccines that deliver one or more of the coronavirus's own genes into our cells to provoke an immune response.

RNA vaccine DNA vaccine

PHASE 2 PHASE 3 COMBINED PHASES
APPROVED IN SEVERAL COUNTRIES EMERGENCY USE IN U.S., ELSEWHERE

VACCINE NAME: Comirnaty (also known as tozinameran or BNT162b2)
EFFICACY: 95%
DOSE: 2 doses, 3 weeks apart
TYPE: Muscle injection
STORAGE: Freezer storage only at −13°F to 5°F (−25°C to −15°C)

On Nov. 9, New York-based **Pfizer** and the German company **BioNTech** made history by announcing that their coronavirus vaccine had an efficacy rate of over 90 percent, far surpassing expectations. It was the first time anyone had found such evidence. Just over a month later, on Dec. 11, the Food and Drug Administration granted it the first emergency use authorization ever given by the United States to a coronavirus vaccine.

The work on the vaccine began in January 2020, when BioNTech researchers started fashioning a genetic molecule called messenger RNA (mRNA). They created the genetic instructions for building a coronavirus protein, known as spike. When injected into cells, the vaccine causes them to make spike proteins, which then get released into the body and provoke a response from the immune system. In March, BioNTech partnered with Pfizer to scale up the research, launching a clinical trial in May. They gave the vaccine the generic name tozinameran and the brand name Comirnaty

In Phase 1 trials, the researchers found that Comirnaty caused volunteers to produce antibodies against SARS-CoV-2, as well as immune cells called T cells that respond to the virus. On July 27, the companies announced the launch of a Phase 2/3 trial with 30,000 volunteers. On Sept. 12, Pfizer and BioNTech announced that they would seek to expand the trial to 44,000 participants.

Through the summer and into the fall, the world focused more and more of its attention on the Pfizer-BioNTech trial. In September, Dr. Albert Bourla, the chief executive of Pfizer, said the Phase 3 trial would deliver enough results as soon as October to show if the vaccine worked or not. President Trump touted their progress, hinting that a vaccine would be available before the election. But on Oct. 27, Dr. Bourla announced that the volunteers in the trial had yet to experience enough cases of Covid-19 to determine if the vaccines work. Finally, on Nov. 9, Pfizer and BioNTech released preliminary analysis of the first 94 cases.

Over the next month, Pfizer and BioNTech released more data on more cases. On Dec. 8 the FDA released their independent analysis of the clinical trials. They determined that the Comirnaty has an efficacy rate of 95 percent. While Comirnaty caused no serious side effects, it frequently caused short-lived fatigue, fever, and muscle aches.

These impressive results led rapidly to authorizations across the world. On Dec. 2, the United Kingdom gave emergency authorization to Pfizer and BioNTech's vaccine, becoming the first Western country to give such an approval to a coronavirus vaccine. In the weeks that followed, many more countries authorized Comirnaty, and on Dec. 31, the World Health Organization

gave the vaccine an Emergency Use Listing, which will speed up its authorization across the world. In Israel, which took the lead in mass vaccination, researchers found that the vaccine was as effective in the real world as the trials had indicated.

As the trials progressed, Pfizer and BioNTech also scaled up factories to produce Comirnaty in huge amounts. They currently expect to manufacture 2 billion doses worldwide by the end of 2021. The Trump administration awarded a $1.9 billion contract in July for 100 million doses, but The New York Times reported in December that the administration passed up the chance over the summer to secure another 100 million doses. Since then, the Trump and Biden administrations reached agreements for a total of 300 million doses by the summer.

While Comirnaty has proven highly effective, it was initially a challenging vaccine to distribute because it had to be kept frozen at –94°F (–70°C). On Feb. 19, Pfizer and BioNTech announced that they could keep the vaccine stable at -25°C to -15°C (-13°F to 5°F).

In January, scientists grew concerned about the emergence of fast-spreading variants that might be able to evade antibodies. Pfizer and BioNTech found that the antibodies are somewhat less effective against another variant called B.1.351. On Feb. 26, the companies announced a study to develop a B.1.351-specific booster. Still, a March 8 study showed that the vaccine could effectively neutralize a Brazilian variant known as P.1.

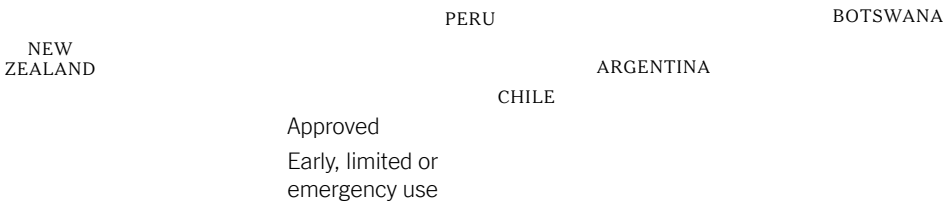
In their initial trial, Pfizer and BioNTech did not include pregnant women among their participants. On Feb. 15 they registered a trial specifically for pregnant women. The trial will determine whether the vaccine provides as much protection for them as for women who aren't pregnant, and also gather information on its safety. Currently, the Centers for Disease Control says pregnant women who become eligible may choose to get vaccinated, while pointing out the lack of data from trials.

For more details, see **How the Pfizer-BioNTech Vaccine Works** and **Inside the B.1.1.7 Coronavirus Variant**.

APPROVED FOR USE IN: Bahrain, Brazil, New Zealand, Saudi Arabia, Switzerland.
EMERGENCY USE IN: Argentina, Australia, Botswana, Canada, Chile, Colombia, Costa Rica, Ecuador, European Union, Hong Kong, Iceland, Iraq, Israel, Japan, Jordan, Kuwait, Lebanon, Liechtenstein, Malaysia, Mexico, Moldova, Mongolia, Norway, Oman, Panama, Peru, Philippines, Qatar, Serbia, Singapore, South Korea, Tunisia, United Arab Emirates, United Kingdom, United States. Emergency use validation from the World Health Organization.

Updated March 9

Pfizer-BioNTech vaccine



PHASE 3

APPROVED IN SWITZERLAND EMERGENCY USE IN U.S., E.U., ELSEWHERE

moderna NIH National Institutes of Health *Turning Discovery Into Health*

VACCINE NAME: mRNA-1273
EFFICACY: 94.5%
DOSE: 2 doses, 4 weeks apart
TYPE: Muscle injection
STORAGE: 30 days with refrigeration, 6 months at –4°F (–20°C)

On Dec. 18., the F.D.A. gave emergency use authorization for a vaccine made by the Boston-based company **Moderna**. The Moderna vaccine is the second one authorized by the F.D.A., coming a week after the vaccine made by Pfizer and BioNTech.

Like Pfizer and BioNTech, Moderna makes its vaccine from mRNA. In recent years, the company has tested mRNA vaccines for a number of diseases, but they have yet to bring one to market. Last January, they began developing a vaccine for the coronavirus.

The United States government bankrolled Moderna's efforts, providing nearly $1 billion in support. In partnership with **National Institutes of Health**, they found that the vaccine protects monkeys from the coronavirus. Last March, the scientists were the first to put a Covid-19 vaccine into human trials. After those studies yielded promising results, Phase 3 testing on 30,000 volunteers began on July 27.

On Nov. 16, Moderna announced the first preliminary data from the trial, followed by the complete data on Nov. 30. Out of 196 cases of Covid-19 among trial volunteers, 185 were in people who received the placebo. And of the 11 vaccinated volunteers who got Covid-19, none suffered from severe disease. The researchers estimated that the vaccine had an efficacy rate of 94.1 percent, far higher than experts had expected when vaccine testing began. While it's not clear how long this efficacy will last, Moderna has found that after three months the trial participants still have a strong immune defense against the coronavirus. On Dec. 2, Moderna registered a trial to test the vaccine on adolescents between 12 and 18 years of age.

Meanwhile, the company entered deals with several countries to supply the vaccine pending its approval. On Aug. 11 last year, the United States government awarded the company an additional $1.5 billion in exchange for 100 million doses if the vaccine proves safe and effective, following up in December with a deal for another 100 million doses in the second quarter of 2021. In February, the agreed supply rose to 300 million. On Nov. 25, the company reached an agreement with the European Commission to supply up

to 160 million doses. Moderna has made similar deals with other countries including Canada, Japan, Qatar and South Korea.

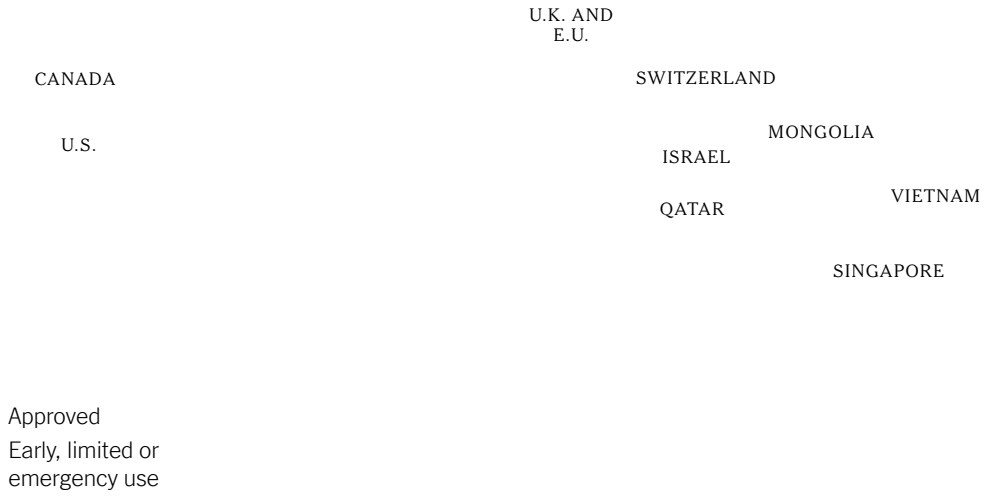
On Feb. 25, Moderna announced they were working to produce between 600 million and a billion doses for 2021. They are making investments to expand capacity up to 1.4 billion doses in 2022.

In March, Moderna began a Phase 1 trial of a vaccine made specifically for the B.1.351 variant and a Phase 1 trial of a new, refrigerator-stable vaccine.

For more details, see **How Moderna's Vaccine Works**.

APPROVED FOR USE IN: Switzerland.
EMERGENCY USE IN: Canada, European Union, Iceland, Israel, Mongolia, Norway, Qatar, Singapore, United Kingdom, United States, Vietnam.
Updated March 15

Moderna vaccine



PHASE 3

VACCINE NAME: CVnCoV
EFFICACY: Unknown
DOSE: 2 doses, 4 weeks apart
TYPE: Muscle injection
STORAGE: Stable at least 3 months at 36–46°F (2–8°C)

Last March, the Trump administration unsuccessfully tried to entice **CureVac** to move its research on a mRNA vaccine from Germany to the United States. The company plowed ahead with its work in Germany, seeing responses to the vaccine in mice and monkeys before launching clinical trials in July. In December, CureVac launched a Phase 3 trial, recruiting up to 36,500 volunteers in Germany. The European Union began a rolling review in February, intended to speed up approval if the Phase 3 trial delivers positive results. CureVac expects the trial to show if the vaccine is safe and effective in April or early May.

In November, CureVac negotiated a deal to provide the European Union with up to 225 million doses of their vaccine. They project manufacturing up to 300 million doses in 2021 and up to a billion doses the following year. CureVac has collaborated with Elon Musk's company Tesla on creating mRNA "micro-factories," which could potentially be deployed around the world to make billions of doses of the vaccine. On Nov. 12, the company announced that its vaccine could be kept in a refrigerator at 41 degrees. Other RNA vaccines made by Pfizer and Moderna have to be kept frozen at chillier temperatures.

Starting in January 2021, CureVac forged a series of partnerships with pharmaceutical giants Bayer, GSK, and Novartis, to support the production of their vaccine and develop new ones against coronavirus variants.

Updated March 5

PHASE 3

VACCINE NAME: ZyCoV-D
EFFICACY: Unknown
DOSE: 3 doses, 4 weeks apart
TYPE: Skin injection
STORAGE: Stable at room temperature for three months

In July, the Indian vaccine-maker **Zydus Cadila** began testing a DNA-based vaccine delivered by a skin patch. They launched a Phase 2 trial on ZyCoV-D on Aug. 6 and announced at the end of December that it was complete. On Jan. 3 the Indian government gave Zydus Cadila permission to advance to a Phase 3 trial with 30,000 volunteers. In a Dec. 11 interview, company's chairman Pankaj Patel, the company's chairman, said the company expects to have their vaccine ready for distribution by March 2021.

Updated Jan. 3

PHASE 2 PHASE 3 COMBINED PHASES

VACCINE NAME: AG0302-COVID19
EFFICACY: Unknown
DOSE: 2 doses, 2 weeks apart
TYPE: Skin injection
STORAGE: Over a year at room temperature

On June 30, the Japanese biotechnology company **AnGes** launched a Phase 1 trial to test a DNA-based vaccine, developed in partnership with **Osaka University** and **Takara Bio**. The company moved on to a Phase 2/3 trial in December.

Updated Dec. 8

PHASE 2

INOVIO
POWERING DNA MEDICINES

VACCINE NAME: INO-4800
EFFICACY: Unknown
DOSE: To be determined
TYPE: Skin injection
STORAGE: Over a year at room temperature

Before the pandemic, the Pennsylvania-based company **Inovio** developed DNA-based vaccines that are delivered into the skin with electric pulses from a hand-held device. They are running clinical trials for vaccines against a number of diseases, including HIV, Zika, and several forms of cancer. At the start of the pandemic, Inovio developed a DNA vaccine against the spike protein on the coronavirus. A Phase 1 trial, published in December, did not uncover any serious adverse effects, and measured an immune response in all 38 volunteers.

Inovio became embroiled in several lawsuits with stockholders and a company partner. On Sept. 28, the F.D.A. put the vaccine on a partial hold due to questions about the delivery device. On Nov. 16, Inovio said that the F.D.A. had given them permission to move forward.

They are now running Phase 2 trials in the United States as well as in China and South Korea. In March, the company said results could come as early as the second quarter of 2021. They also began testing versions of their vaccine tailored against new variants.

Updated March. 2

PHASE 2

ARCTURUS therapeutics DukeNUS Medical School

The California-based company **Arcturus Therapeutics** and **Duke-NUS Medical School** in Singapore have developed an mRNA vaccine. It has a "self-replicating" design that leads to a greater production of viral proteins. Tests on animals showed that it protected them against infection. In August, Arcturus launched a Phase 1/2 trial at Singapore General Hospital. On Nov. 9, the company announced that an interim analysis of the trial showed that the vaccine produced an immune response that's in the range of responses seen in people who recovered from Covid-19. On Jan. 6 Arcturus announced that they had permission to start the Phase 2 portion of the trial in both Singapore and the United States. Singapore reached an agreement with Arcturus to spend up to $175 million to acquire vaccines when they're ready.

Updated Jan. 12

PHASE 2


In June, Chinese researchers at the **Academy of Military Medical Sciences**, **Suzhou Abogen Biosciences** and **Walvax Biotechnology** announced they would start their country's first safety trials on a mRNA-based vaccine, called ARCoV. Earlier studies on monkeys reportedly showed protective effects, and in the Phase 1 trial indicated it was safe in people. On Dec. 21, Xinhua reported that China was building a factory to produce 120 million doses per year. Researchers registered a Phase 2 trial for the vaccine on Jan. 8.

Updated March 9

PHASE 1 PHASE 2 COMBINED PHASES

Gennova Biopharmaceuticals in India and Seattle-based **HDT Bio** partnered to develop a vaccine based on self-amplifying RNA. The vaccine, known as HGC019, was able to safely provoke animals to make antibodies to the coronavirus, leading India to grant the companies approval in December to start Phase 1/2 trials.

Updated Dec. 12

PHASE 1 PHASE 2 COMBINED PHASES

GeneOne Life Science, a South Korean biotech company, developed a DNA-based vaccine that encodes two proteins from the coronavirus. In December they launched a Phase 1/2 trial with 345 participants.

Updated Dec. 17

PHASE 1 PHASE 2 COMBINED PHASES

The South Korean company **Genexine** started testing the safety of a DNA-based vaccine in June. In December, the Korea Biomedical Review reported that Genexine got disappointing results from their initial formulation and decided to restart their trials with a modified vaccine. On Jan. 20, the company registered a Phase 1/2 trial.

Updated Jan. 20

PHASE 1 PHASE 2 COMBINED PHASES

The French pharmaceutical company **Sanofi** is developing an mRNA vaccine in partnership with **Translate Bio**. They have found that it produces a strong antibody response in mice and monkeys. On March 12, they announced the start of a Phase 1/2 trial. It is Sanofi's second Covid-19 vaccine candidate in clinical trials, along with their protein-based vaccine.

Updated March 12

PHASE 1 PHASE 2 COMBINED PHASES

Takis Biotech and **Rottapharm Biotech,** two vaccine companies in Italy, developed a vaccine called COVID-eVax. A special device uses a tiny electric pulse to deliver DNA through the skin. The DNA enters cells, which use the genetic instructions to make spike proteins. In February, Takis and Rottapharm launched a Phase 1/2 trial. COVID-eVax can remain stable at room temperature.

Updated March 15

PHASE 1

Researchers at Thailand's **Chulalongkorn University** have been developing several potential vaccines for the coronavirus. The furthest along is an mRNA-based vaccine known as ChulaCov19. On Sept. 29, the **Chula Vaccine Research Center** registered a Phase 1 trial to test it in humans. Due to delays in funding and manufacturing, the trial is expected to begin in April or May 2021. In an interview with the Bangkok Post, the leader of the project said that up to 30 million doses might be produced for Thailand and six other Asian countries if the vaccine proved to be safe and effective.

Updated Feb. 23

PHASE 1

The Canadian company **Entos Pharmaceuticals** has created a DNA vaccine for the coronavirus. Most other genetic vaccines carry the gene for the spike protein on the surface of the virus. Entos instead chose the gene for nucleocapsid, a protein that sits inside the virus's membrane. They are betting

it can offer long-lasting immunity. In October, Entos launched a Phase 1 trial in Canada for their vaccine, called Covigenix VAX-001.

Updated Oct. 20

PHASE 1

symvivo

On Nov. 2, the Canadian company **Symvivo** announced they had administered a DNA vaccine to their first volunteer in a Phase 1 trial. The DNA is inserted into harmless bacteria, which volunteers swallow in a frozen liquid (the company is working on putting the bacteria into a pill). When the bacteria reach the intestines, the DNA slips into cells in the gut lining, which then make viral proteins.

Updated Nov. 3

PHASE 1

oncosec™
IMMUNOTHERAPIES

New Jersey-based **OncoSec Immunotherapies** has developed experimental cancer treatments that deliver genes into tumors. There, the injected genes produce a natural signalling molecule called IL-12, which attracts the attention of immune cells that attack the cancer. In the spring, OncoSec began adapting their technology to make a vaccine for the coronavirus. The vaccine, called CORVax12, consists of a loop of DNA that encodes both the spike protein and IL-12. Causing the body to make extra IL-12 could potentially enhance the immune system's ability to make antibodies to the spike protein. On Nov. 13, the company registered a Phase 1 trial to test the safety of the CORVax12.

Updated Nov. 13

PHASE 1

PROVIDENCE
therapeutics

Canada's **Providence Therapeutics** specializes in messenger RNA vaccines to treat cancer. In response to the pandemic, they developed an mRNA vaccine against the coronavirus. They launched a Phase 1 study of an RNA vaccine in late January. The company expects to move into Phase 2 trials by May.

Updated Jan. 28

PHASE 1

Using a delivery system from PharmaJet, researchers at **BioNet-Asia** and Australia-based **Technovalia** have developed a DNA vaccine called COVIGEN that can be pushed through the skin without a needle. Instead, the dose is loaded into a handheld device and shot directly into cell tissue through a jet spray of fluid. Vaccines for the flu already use the device, which PharmaJet says is a safer alternative to needle injections. The researchers registered a Phase 1 trial in Australia on Feb. 8.

Updated March 4

ABANDONED

Imperial College London researchers have developed a "self-amplifying" RNA vaccine, which boosts production of a viral protein to stimulate the immune system. They began Phase 1/2 trials on June 15, partnering with **Morningside Ventures** to manufacture and distribute the vaccine through a new company called VacEquity Global Health. On Dec. 18, the researchers announced a collaboration with Enesi Pharma to formulate a solid version of the vaccine that can be implanted in the skin without a needle.

On Jan. 27, Robin Shattuck, the leader of the project, announced that "it is not the right time to start a new efficacy trial for a further vaccine in the U.K." Instead of competing with authorized vaccines, they are turning their efforts to making candidates that will work well emerging variants of the coronavirus.

Updated Jan. 28

PRECLINICAL

Other genetic vaccines in active preclinical development include vaccines from: Applied DNA Sciences, EvviVax and Takis Biotech; DIOSynVax; Elixirgen Therapeutics; ETheRNA; Globe Biotech; Greenlight Biosciences; Infectious Disease Research Institute and Amyris; Mediphage Bioceuticals; National institute of Chemistry of Slovenia and Kemijski Inštitut; National Research Centre, Egypt; the OPENCORONA Consortia; Providence Therapeutics; Scancell; the Spanish National Center for Biotechnology and the Spanish National Research Council; Vaccibody.

Updated Jan. 14

Viral Vector Vaccines

Vaccines that contain viruses engineered to carry coronavirus genes. Some viral vector vaccines enter cells and cause them to make viral proteins. Other viral vectors slowly replicate, carrying

coronavirus proteins on their surface.

PHASE 3 EARLY USE IN RUSSIA EMERGENCY USE IN OTHER COUNTRIES

МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ

VACCINE NAME: Sputnik V (also known as Gam-Covid-Vac)
EFFICACY: 91.6%
DOSE: 2 doses, 3 weeks apart
TYPE: Muscle injection
STORAGE: Freezer storage. Developing an alternative formulation that can be refrigerated.

The **Gamaleya Research Institute**, part of Russia's Ministry of Health, has created a vaccine with an efficacy rate of 91.6 percent. The creators of the vaccine published the results of their Phase 3 trial on Feb. 2 in the Lancet.

Gamaleya produced the vaccine, initially called Gam-Covid-Vac, from a combination of two adenoviruses called Ad5 and Ad26. Both kinds have been tested as vaccines over a number of years. By combining them, the Russian researchers hoped to avoid a situation in which the immune system could learn to recognize the vaccine as a foreign object that needed to be destroyed. The researchers launched clinical trials in June.

By the end of the summer, the trial became bogged down in controversy. On Aug. 11, President Vladimir V. Putin announced that a Russian health care regulator had approved the vaccine, renamed Sputnik V. Yet the Phase 3 trials had not even begun. Vaccine experts decried the move as risky, and Russia later walked back the announcement, saying that the approval was a "conditional registration certificate," which would depend on positive results from Phase 3 trials. In addition to Russia, volunteers for the trial were recruited in Belarus, the United Arab Emirates, and Venezuela. On Oct. 17, a Phase 2/3 trial was launched in India.

On Sept. 4, three weeks after Putin's announcement, Gamaleya researchers published the results of their Phase 1/2 trial. They found that Sputnik V yielded antibodies to the coronavirus and mild side effects. On Nov. 11, the Russian Direct Investment Fund announced the first preliminary evidence from their Phase 3 trial indicating that the vaccine is effective. Based on 20 cases of

Covid-19 among the trial participants, Russian scientists estimated that the vaccine demonstrated 92 percent efficacy.

By December, the trial had reached its final total of 78 cases. The full details of the trial came out in February, demonstrating a high efficacy after two doses. The trial did not encover serious side effects and showed no significant difference between groups of volunteers. No one who got the vaccine experienced a serious case of Covid-19.

In an unprecedented move in the coronavirus vaccine field, the Gamaleya Institute joined forces in December with the drugmaker AstraZeneca, which makes a vaccine with human adenoviruses. The two teams combined their vaccines to see if the mixture can increase the efficacy of the AstraZeneca vaccine. The trial began in February. In January, Gamaleya researchers also started a trial on a single-dose version of the vaccine, which they dubbed "Sputnik Light." On Feb. 12, the director of the Gameleya center said in a television interview that it would likely provide only four to five months of protection.

In November, the Russian government began offering Sputnik V within Russia in a mass vaccination campaign. But worry that the vaccine was rushed to approval led to widespread hesitancy. On Dec. 22, Belarus became the first country outside of Russia to register Sputnik V, and since then a number of other countries have followed suit. In Europe, where the vaccine rollout faltered badly, regulators began a rolling view of Sputnik V on March 4. If the European Medicines Agency approved it, many European countries might take up the vaccine.

For more details, see **How Gamaleya's Vaccine Works**.

EARLY USE IN: Russia.
EMERGENCY USE IN: Algeria, Angola, Argentina, Armenia, Azerbaijan NEW, Bahrain, Belarus, Bolivia, Bosnian Serb Republic, Congo Republic, Djibouti, Egypt, Honduras, Gabon, Ghana, Guatemala, Guinea, Guyana, Hungary, Iran, Iraq, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Laos, Lebanon, Mexico, Moldova, Mongolia, Montenegro, Morocco, Myanmar, Namibia, Nicaragua, North Macedonia, Pakistan, Palestinian Authority, Paraguay, San Marino, Slovakia, Sri Lanka, St. Vincent and the Grenadines, Serbia, Syria, Tunisia, Turkmenistan, United Arab Emirates, Uzbekistan, Venezuela, Vietnam, Zimbabwe.
Updated March 15

Gamaleya's Sputnik V vaccine

Approved
Early, limited or

PHASE 2 PHASE 3 COMBINED PHASES
APPROVED IN BRAZIL EMERGENCY USE IN BRITAIN, E.U., ELSEWHERE

UNIVERSITY OF OXFORD AstraZeneca

VACCINE NAME: AZD1222 (also known as Covishield in India)
EFFICACY: 82.4% for doses separated by 12 weeks.
DOSE: 2 doses
TYPE: Muscle injection
STORAGE: Stable in refrigerator for at least 6 months

On Dec. 8, researchers with the **University of Oxford** and the British-Swedish company **AstraZeneca** published the first scientific paper on a Phase 3 clinical trial of a coronavirus vaccine. The trial demonstrated that the vaccine can protect people from Covid-19, but it left many questions unresolved about the results.

Early in the pandemic, Oxford researchers developed the vaccine by genetically engineering an adenovirus that normally infects chimpanzees. When they gave the vaccine to monkeys, they found that it protected the animals from the disease. Last April they followed up with a Phase 1/2 trial. The vaccine developers did not detect any severe side effects in the trial, while observing that the vaccine raised antibodies against the coronavirus as well as other immune defenses. The vaccine began Phase 2/3 trials in the United Kingdom and India, and (where it's known as Covishield). In addition, AstraZeneca later launched Phase 3 trials in Brazil, South Africa, and the United States.

On Nov. 19, researchers published the first findings from the Phase 2/3 trials in the United Kingdom. They didn't observe any serious side effects at any age. Encouragingly, the older volunteers produced about as many antibodies against the coronavirus as the younger ones.

On Nov. 23, AstraZeneca and Oxford announced that the vaccine had good efficacy, based on a study of the first 131 cases of Covid-19 in the trials in the United Kingdom and Brazil. The volunteers all got two doses, but in some cases the first dose was only half strength. Surprisingly, an initial half-strength dose led to 90 percent efficacy, while two standard-dose shots led only to 62 percent efficacy. The researchers speculated that the lower first dose did a better job of mimicking the experience of an infection, promoting a stronger immune response. But only after the initial announcement did it become clear that the low dose version was the result of a mistake in how the vaccines were measured out, not part of the original plan for the trial.

AstraZeneca continued to analyze data from their trials and released another report on Feb. 2, which has yet to appear in a medical journal. They found that two doses separated by 12 weeks had an efficacy rate of 82.4%. The vaccine not only protected people from getting sick but also reduced transmission of the virus — a promising sign that vaccines may be able to curb the pandemic.

On Feb. 7, South Africa halted plans for a rollout of 1 million doses of the

AstraZeneca vaccine. A small trial failed to demonstrate that it protected South Africans against the variant B.1.351, which has become predominant in the country. Meanwhile, AstraZeneca are Oxford said they are working on a new version of the vaccine tailored to the variant.

The United Kingdom and Argentina were the first countries to give the vaccine emergency authorization, on Dec. 30, and since then a number of other countries have also done the same. On Jan. 3, India, approved a version called Covishield, made by the Serum Institute of India. On Feb. 16 the World Health Organization recommended the vaccine for emergency use in adults 18 or older. In March, Covax began delivering millions of doses of the vaccine to low- and middle-income countries. AstraZeneca is expected to submit an application for an emergency use authorization from the F.D.A. when its Phase 3 trial in the United States delivers results, possibly in March. The company expects a total annual manufacturing capacity of two billion doses.

AstraZeneca and Oxford are continuing to run new trials on their vaccine. In an unprecedented move in the coronavirus vaccine field, they announced on Dec. 11 that they would collaborate with the Russian creators of the Sputnik V vaccine, which is also made from adenoviruses, to see if a combination with Sputnik V might increase the efficacy of the Oxford-AstraZeneca vaccine. The trial started in February 2021. On Feb. 14, Oxford announced they would start trials on children as young as six.

Denmark, Iceland and Norway suspended the use of the vaccine on March 11 because of concerns about a possible increased risk of blood clots. Germany, France, Italy and several other countries followed shortly after. Brazil gave full approval to the vaccine on March 13.

For more details, see **How the Oxford-AstraZeneca Vaccine Works**.

APPROVED FOR USE IN: Brazil NEW.
EMERGENCY USE IN: Algeria, Argentina, Australia, Bahamas NEW, Bangladesh, Bahrain, Bhutan, Botswana, Brazil, Canada, Chile, Colombia, Dominican Republic, Egypt, El Salvador, European Union, Iceland, India, Indonesia, Iran, Iraq, Kuwait, Liechtenstein, Malaysia, Maldives, Mexico, Moldova, Mongolia, Morocco, Nepal, Nigeria, Norway, Pakistan, Papua New Guinea, Philippines, Saudi Arabia, Seychelles, Sri Lanka, South Africa, South Korea, Thailand, Ukraine, United Kingdom, Vietnam. Emergency use validation from the World Health Organization. Endorsed by the Africa Regulatory Taskforce NEW.

Updated March 15

Oxford-AstraZeneca vaccine

Early, limited or emergency use

PHASE 3

APPROVED IN CHINA EMERGENCY USE IN MEXICO, PAKISTAN

VACCINE NAME: Convidecia (also known as Ad5-nCoV)
EFFICACY: 65.28%
DOSE: Single dose
TYPE: Muscle injection
STORAGE: Refrigerated

The Chinese company **CanSino Biologics** developed Convidecia in partnership with the Institute of Biology at the country's **Academy of Military Medical Sciences**. The one-shot vaccine is based on an adenovirus called Ad5. Last May, researchers published promising results from a Phase 1 safety trial on Convidecia, and in July they reported that their Phase 2 trials demonstrated the vaccine produced a strong immune response. In an unprecedented move, the Chinese military approved the vaccine on June 25 for a year as a "specially needed drug." On Nov. 28, the Chief Executive of CanSino Biologics said in an interview that about 40,000 to 50,000 people had received Convidecia.

Starting in August 2020, CanSino began running Phase 3 trials in a number of countries, including Pakistan, Russia, Mexico and Chile. On Feb. 25, China announced the approval of the CanSino vaccine for general use. The company announced that its one-shot vaccine had an efficacy rate of 65.28 percent at preventing all symptomatic Covid-19 cases. The details of the trial have yet to be published.

APPROVED FOR USE IN: China.
EMERGENCY USE IN: Mexico, Pakistan.
Updated Feb. 26

CanSino vaccine

CHINA

PAKISTAN

MEXICO

Approved

Early, limited or emergency use

PHASE 3 EMERGENCY USE IN U.S., E.U., ELSEWHERE

VACCINE NAME: Ad26.COV2.S
EFFICACY: 72% in United States, 64% in South Africa, 61% in Latin America
DOSE: 1 dose
TYPE: Muscle injection
STORAGE: Up to two years frozen at −4° F (−20° C), and up to three months refrigerated at 36–46° F (2–8° C).

On Feb. 27, the F.D.A. issued an emergency use authorization for **Johnson & Johnson**'s vaccine, making it the third coronavirus vaccine available in the United States. It was also the first to be shown to be safe and effective with just one dose rather than two.

The work that led to the vaccine started a decade ago at **Beth Israel Deaconess Medical Center** in Boston, where researchers developed a method for making vaccines out of a virus called Adenovirus 26, or Ad26 for short. Johnson & Johnson used Ad26 to develop vaccines for Ebola and other diseases with Ad26. Last January, the company and Beth Israel researchers collaborated on creating a coronavirus vaccine. Last March they received $456 million from the United States government to support their move towards production. After the vaccine provided protection in experiments on monkeys, Johnson & Johnson began Phase 1/2 trials in July.

Based on promising results in these studies, Johnson & Johnson launched a Phase 3 trial in September using just one dose rather than two. Although Johnson & Johnson initially set out to recruit 60,000 volunteers, it capped the trial at 45,000 in December as cases rose.

On Jan. 29, Johnson & Johnson announced that the trial had proven that the vaccine was safe and effective. On Feb. 24, the F.D.A. released their own analysis of the trial, concluding that the vaccine had an efficacy of 72 percent in the United States, 64 percent in South Africa, and 61 percent in Latin America. The next day, Bahrain became the first country to authorize the vaccine for emergency use. Two days later, the United States followed suit.

South Africa dropped plans to use AstraZeneca's vaccine for their health care workers after a small trial failed to show it was effective against the B.1.351 variant that had grown dominant across the country. They began using Johnson & Johnson's instead.

In August, the federal government agreed to pay Johnson & Johnson $1 billion for 100 million doses if the vaccine was authorized. In their initial rollout, the company only provided 4 million doses, and another 16 million or so doses by the end of March--far fewer than the 37 million doses called for in its contract. The company said it would meet its requirement of delivering 100 million doses by June. On March 2, Merck announced it would assist Johnson & Johnson with manufacturing the vaccine.

The European Union reached a similar deal on Oct. 8 for 200 million doses. COVAX, an international collaboration to deliver the vaccine equitably across the world, secured 500 million doses. The company is aiming for production of

a billion doses in 2021.

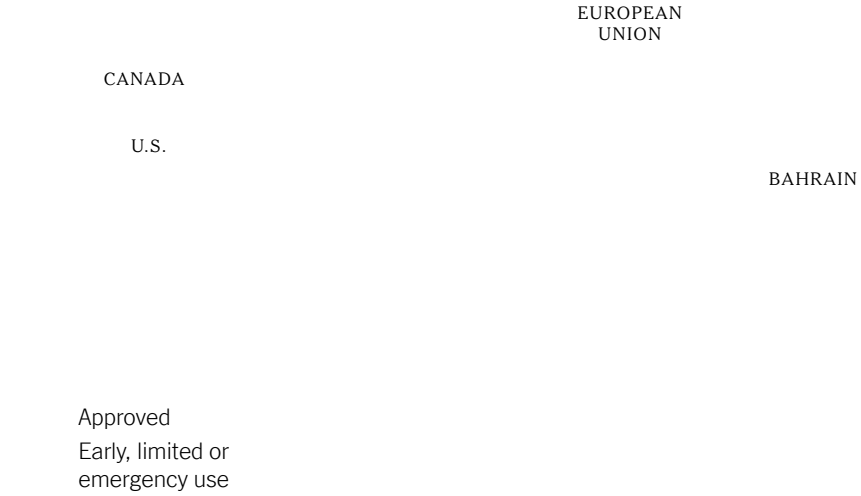
On Nov. 16, Johnson & Johnson announced that they were also launching a second Phase 3 trial to observe the effects of two doses of their vaccine, instead of just one. The results are expected in late 2021. In February, the company also launched a trial for pregnant women and in March it announced it would soon start trials on children. The chief executive said in a March 4 interview that the vaccine could become available for children by September.

The vaccine is being developed by **Janssen Pharmaceutica**, a Belgium-based division of Johnson & Johnson. For more details, see **How the Johnson & Johnson Vaccine Works**.

EMERGENCY USE IN: Bahrain, Canada, European Union, Iceland, Liechtenstein, Norway, United States. Emergency use validation from the World Health Organization NEW.

Updated March 15

Johnson & Johnson vaccine



PHASE 2 PHASE 3 COMBINED PHASES

REITHERA

SISTEMA SANITARIO REGIONALE
IRCCS LAZZARO SPALLANZANI

The Italian biotechnology company **ReiThera** has developed a Covid-19 vaccine, called GRAd-COV2, that is based on an adenovirus that infects gorillas. Working in collaboration with the **Lazzaro Spallanzani National Institute for Infectious Diseases** in Rome, they launched a Phase 1 trial at the end of July. In November, they announced that the vaccine was well tolerated and produced antibodies. They registered a Phase 2/3 trial on March 10.

Updated March 11

PHASE 2

In the spring, the **Israel Institute for Biological Research** started work on a coronavirus vaccine based on vesicular stomatitis viruses. They engineered the viruses to carry the gene for the coronavirus spike protein. On Oct. 25, the Israeli government announced that the vaccine, called Brilife, would be going into a Phase 1 trial. The Phase 2 trial, which is recruiting up to 1,000 volunteers, started on Jan. 5. It's not clear how the trial will fare now that Israel is aggressively vaccinating its citizens with authorized vaccines by Pfizer.

Updated Jan. 14

PHASE 1

While many vaccines are given as injections, some vaccines can be taken as a pill. Oral vaccines have been approved for diseases including polio, cholera, and typhoid fever. The small San Francisco company **Vaxart** specializes in developing oral vaccines. They have created and tested pills for influenza and other diseases. Last spring Vaxart began work on an oral vaccine for Covid-19. It contains an adenovirus called Ad5 (the same viral vector in CanSinoBio's vaccine and in Russia's Sputnik V).

When Vaxart gave the pill to mice, they produced antibodies against the coronavirus. Mice don't suffer symptoms of Covid-19, however, so the researchers then switched to hamsters, which do. In an unpublished study, they found that the vaccine pill not only dramatically reduced the amount of coronavirus in sick hamsters, but also protected them from two important symptoms of the disease: weight loss and swollen lungs. In October, the company began giving the pill to volunteers in a Phase 1 clinical trial. On Feb. 3, Vaxart announced that the trial revealed no serious safety concerns. While the pill produced a response from T cells, it didn't produce encouraging neutralizing antibodies. Its stock price plunged 60 percent on the news. On Feb. 25, the company announced it would advance to a Phase 2 trial in the second quarter of 2021. .

Although none of Vaxart's vaccines have yet been licensed, the company's stock price increased 3,600 percent in the first half of 2020. In June, The New York Times reported, a hedge fund that partly controlled the company sold off most of its shares, netting over $200 million in profits. In the wake of that reporting, the Department of Justice began investigating the company, while a number of shareholder lawsuits were brought against Vaxart, its executives and its board.

Updated Feb. 25

PHASE 1

香 港 大 學
THE UNIVERSITY OF HONG KONG

厦門大學
XIAMEN UNIVERSITY

万泰生物
WANTAI BioPharm

In 2019, researchers at the **University of Hong Kong** and **Xiamen University** created a nasal-spray vaccine for the flu based on a genetically weakened form of the influenza virus. Earlier this year, they engineered the vaccine to produce part of the coronavirus spike protein as well. On Sept. 9, they received approval to start clinical trials in partnership with **Beijing Wantai Biological Pharmacy**.

Updated Sept. 9

PHASE 1

DZIF
German Center
for Infection Research

Three decades ago, the **German Center for Infection Research** developed a smallpox vaccine from a harmless virus called Modified Vaccinia Ankara, or MVA for short. In recent years, they adapted it to create a vaccine for MERS, a disease caused by another coronavirus.

This spring, they made an MVA-based vaccine for SARS-CoV-2, the coronavirus that is causing the Covid-19 pandemic. It carries the gene for the spike protein, which is produced inside cells that it invades. On Sept. 29, the center and a consortium of German universities registered a Phase 1 trial. In January the center announced that their initial formulation provided disappointing results and are postponing the trial until they update it.

Updated Jan. 13

PHASE 1

ImmunityBio

The California-based company **ImmunityBio** created a vaccine using the Ad5 adenovirus, the same one used by CanSinBio and the Gamaleya Institute in Russia. ImmunityBio engineered the Ad5 virus to carry genes for two genes from the coronavirus. In addition to the spike protein, it also carries the gene for a protein called nucleocapsid. The company hopes that this combination will provoke a strong immune response.

The company found that the vaccine protects monkeys from the coronavirus. ImmunityBio launched a Phase 1 trial of a Covid-19 vaccine in October in the United States and another in South Africa in January. In February the company registered a Phase 1 trial of an oral version of the vaccine.

The chairman and C.E.O. of ImmunityBio is billionaire Patrick Soon-Shiong, the owner of the Los Angeles Times.

Updated Feb. 18

PHASE 1

Researchers at **City of Hope**, a California biomedical research institute, created a vaccine based on a weakened form of a virus called Modified Vaccinia Ankara, or MVA for short. They added two coronavirus genes to the virus — one for the spike protein, and one for another protein called nucleocapsid. They hope the combination will enable the vaccine to produce immunity that's both fast and long-lasting. On Nov. 24 they announced the start of a Phase 1 trial, with hopes for a Phase 2 trial to start in the second quarter of 2021.

Updated Nov. 24

PHASE 1

In April, the South Korean biotech company **Cellid** began to develop a vaccine for Covid-19. The vaccine is based on a combination of two strains of adenoviruses, called Ad5 and Ad35. After testing the vaccine out on monkeys, Cellid entered into a partnership with the South Korean chemical manufacturer **LG Chem** to manufacture the vaccine. In December, they registered a Phase 1 trial.

Updated Dec. 14

PHASE 1

VACCINE NAME: AdCOVID
EFFICACY: Unknown
DOSE: 1 dose
TYPE: Nasal spray
STORAGE: Refrigerated

Maryland-based **Altimmune** is a biopharmaceutical company that focuses on developing vaccines delivered by nasal spray. Recently, they've tackled influenza and anthrax using this technology. They have now used it to make a nasal spray vaccine for Covid-19, delivering the Ad5 adenovirus to the airway. The company says its nasal spray may be more effective for blocking the transmission of the virus than vaccines given by injection. On Dec. 22, the company registered a Phase 1 clinical trial for adults and began recruiting volunteers on Feb. 25.

Updated Feb. 25

PHASE 1

On Feb. 11, Indian regulators gave **Bharat Biotech** approval to launch a Phase 1 trial of a vaccine delivered as a nasal spray. The spray, called BBV154, contains a chimpanzee adenovirus developed by researchers at Washington University. They found that it could produce coronavirus antibodies in mice with just a single dose. BBV154 is Bharat Biotech's second foray into coronavirus vaccine clinical trials. Their vaccine Covaxin, made of inactivated coronaviruses, is already in emergency use in India.

Updated Feb. 16

PHASE 1

In 2020, researchers at the **Icahn School of Medicine at Mount Sinai** in New York developed a Covid-19 vaccine based on a virus called Newcastle Disease Virus, or NDV for short. NDV is a bird pathogen and does not cause symptoms in humans. The researchers engineered NDV to carry the gene for the coronavirus spike protein and then grew the modified virus in chicken eggs. They then inactivated the NDVs with chemicals. Combining the inactivated viruses with immune-boosting chemicals called adjuvants, the researchers found that the vaccine produced coronavirus antibodies in mice. They published the results of their experiments in November.

On Feb. 22, **Mahidol University** in Thailand registered a Phase 1 trial of the vaccine, called NDV-HXP-S. They are running the trial in collaboration with the **Government Pharmaceutical Organization**, a Thai state-run drug manufacturer. The vaccine could potentially be very useful in lower income countries, because the virus can be safely grown in large quantities in chicken eggs, the same way influenza vaccines have been produced since the 1950s. As a result, the cost of the vaccine could be as low as two dollars a dose.

Updated Feb. 23

PHASE 1

Gritstone Oncology has developed experimental vaccines in recent years that teach the immune system to attack tumors. Last year they constructed a vaccine for Covid-19 that presents a number of targets in the coronavirus for attack.

The researchers constructed a piece of DNA that encodes the entire spike protein of the coronavirus. In addition, it encodes instructions for building small pieces of other viral proteins called nucleocapsid and ORF3a. They then inserted this cassette into the genes of a chimpanzee adenovirus. The spike protein provoked the body to make antibodies, while the pieces of other proteins train the immune system to recognize infected cells and kill them.

In addition, the researchers created an RNA molecule with the same genetic instructions, which they put in a shell. Once the shell slips into a cell, the RNA molecule can make copies of itself, and the cell then makes proteins from those copies.

In a Phase 1 trial launched in March, the **National Institute of Allergy and Infectious Diseases** is testing how well these two vaccines work together, with the chimpanzee adenovirus serving as the first dose and the self-amplifying RNA as the second. The researchers hope that this combination will produce a better immune response than two doses of either vaccine.

Updated March 4

PHASE 1

Meissa Vaccines

Meissa Vaccines has developed a vaccine that can be delivered as a spray or drops into the nose. To make the intranasal vaccine, researchers outfitted a live attenuated vaccine against a different respiratory virus with the coronavirus spike protein. On March 15, Meissa registered a Phase 1 trial for the vaccine and will begin enrolling later this month.

Updated March 16

ABANDONED

MERCK THEMIS INSTITUT PASTEUR

The American company **Merck** acquired the Austrian firm **Themis Bioscience** in June to develop their vaccine, which had been originally developed at **Institut Pasteur**. The vaccine used a weakened measles virus that carries a gene for the coronavirus spike protein. Researchers launched a Phase 1 trial in August. On Jan. 25, Merck announced it was abandoning the effort, because the vaccine provoked a response that was weaker than a natural infection. In March they entered into a partnership with Johnson & Johnson to help produce their vaccine instead.

Updated March 4

ABANDONED

In addition to its project with Themis, **Merck** partnered with **IAVI** on a second viral vector vaccine. It was based on vesicular stomatitis viruses, the same approach Merck successfully used to produce the first approved vaccine for Ebola. They designed their coronavirus vaccine as a pill, which could have made it easier to distribute than syringes for injections. Merck and IAVI received $38 million from the United States government to support their research, and on September 30 they registered a Phase 1 trial. But on Jan. 25, they announced they were abandoning the effort because the vaccine failed to trigger an immune system comparable to what happens in a natural infection of Covid-19.

Updated Jan. 25

PRECLINICAL

Other viral vector vaccines in active preclinical development include vaccines from: Ankara University; ID Pharma; Institut Pasteur Lille; KU Leuven; Ohio State University and Kazakh National Agrarian University; the Spanish National Center for Biotechnology and the Spanish National Research Council; TheraVectys and Institut Pasteur; Thomas Jefferson University and Bharat Biotech; Tonix Pharmaceuticals; University of Georgia; University of Helsinki, University of Eastern Finland, and Rokote Laboratories Finland; University of Pittsburgh; University of Western Ontario; Valo Therapeutics and University of Helsinki; Vivaldi Biosciences; Walvax Biotechnology, Tsinghua University, and Tianjin Medical University; Zydus Cadila.

Updated Feb. 18

Protein-Based Vaccines

Vaccines that contain coronavirus proteins but no genetic material. Some vaccines contain whole proteins, and some contain fragments of them. Some pack many of these molecules on nanoparticles.

PHASE 3 EARLY USE IN RUSSIA

BEKTOP

VACCINE NAME: EpiVacCorona
EFFICACY: Unknown
DOSE: 2 doses, 3 weeks apart
TYPE: Muscle injection
STORAGE: Stable in refrigerator for up to two years

On Aug. 26, the **Vector Institute**, a Russian biological research center, registered a Phase 1/2 trial for a coronavirus vaccine they call EpiVacCorona. The vaccine contains small portions of viral proteins, known as peptides. Less than two months later, on Oct. 14, Vladimir Putin announced that Russia has granted regulatory approval to the vaccine, making it the second one to receive that designation after the Gamaleya Institute's Sputnik V vaccine.

A Phase 3 trial began in November, and as of Dec. 15, the Interfax News Agency reported that 1,438 volunteers had received the vaccine.

In January, Russia launched a mass vaccination campaign that included EpiVacCorona. But the Vector Institute has yet to present results from its Phase 3 trial demonstrating that their vaccine is safe and effective. In February, Tass reported that the immune response from EpiVacCorona lasted "for approximately a year." On March 3, the Vector Institute registered their trial on an international registry, indicating that they expected to deliver preliminary results in August 2021.

EARLY USE IN: Russia.

Updated March 4

Vector Institute vaccine

RUSSIA

Approved
Early, limited or emergency use

PHASE 3 EMERGENCY USE IN CHINA, UZBEKISTAN

ZFSW The Biologics Company

INSTITUTE OF MEDICAL BIOLOGY
CHINESE ACADEMY OF MEDICAL SCIENCES

VACCINE NAME: ZF2001
EFFICACY: Unknown

DOSE: 3 doses, 4 weeks apart

TYPE: Muscle injection

The Chinese company **Anhui Zhifei Longcom** and the **Institute of Medical Biology at the Chinese Academy of Medical Sciences** partnered to make a vaccine. Their candidate is composed of an adjuvant, along with a section of the spike protein called the receptor-binding domain. They launched Phase 2 trials in July, followed by a Phase 3 trial with 29,000 volunteers in December. China authorized the vaccine for emergency use on March 15.

EMERGENCY USE IN: China NEW, Uzbekistan.

Updated March 15

Anhui Zhifei Longcom and IMCAS vaccine

CHINA

UZBEKISTAN

Approved

Early, limited or emergency use

PHASE 3

NOVAVAX

Creating Tomorrow's Vaccines Today

VACCINE NAME: NVX-CoV2373

EFFICACY: 96% against original coronavirus, 86% against most variants

DOSE: 2 doses, 3 weeks apart

TYPE: Muscle injection

STORAGE: Stable in refrigerator

Maryland-based **Novavax** makes vaccines by sticking proteins onto microscopic particles. They've taken on a number of different diseases this way; their flu vaccine finished Phase 3 clinical trials last March. The company launched trials for a Covid-19 vaccine in May, and the Coalition for Epidemic Preparedness Innovations invested $384 million to support research on the vaccine. In July the U.S. government awarded Novavax another $1.6 billion to support the vaccine's clinical trials and manufacturing.

After getting promising results from preliminary studies in monkeys and humans, Novavax launched a Phase 2 trial on 2,900 people in South Africa in August, and the next month it launched a Phase 3 trial with up to 15,000 volunteers in the United Kingdom.A 30,000-person Phase 3 trial in the United States was delayed because of problems with manufacturing the doses

required for the study. It finally launched on Dec. 28 and is expected to deliver results in April. In March, the chief executive of Novavax said their vaccine might get authorized by the F.D.A. in May.

On March 11, Novavax reported that their United Kingdom trial determined an efficacy rate of 96 percent against the original coronavirus. But in South Africa, where volunteers were exposed to a more contagious variant, the result was roughly 55 percent. The company is developing a new version of the vaccine that is tailored to emerging variants.

In September, Novavax reached an agreement with the Serum Institute of India, a major vaccine manufacturer, that could enable them to produce as many as 2 billion doses a year. On its current course, Novavax may be able to supply 110 million doses to the United States by June. They also have an agreement with other countries, including the United Kingdom, Canada, Australia and South Korea. On Feb. 18, Novavax announced it would supply 1.1 billion doses to COVAX, a consortium that seeks to distribute vaccines to all countries across the world.

For more details, see **How the Novavax Vaccine Works**.

Updated March 11

PHASE 3

IFV INSTITUTO FINLAY DE VACUNAS

Cuba's **Finlay Vaccine Institute** developed a vaccine known as Soberana 2. It contains a part of the coronavirus spike protein, fused to a standard tetanus vaccine to make it stable. Soberana 2 also contains aluminum hydroxide as an adjuvant to boost the immune system.

After testing Soberana 2 in animals, Finlay researchers started a Phase 1 trial in October, followed by a Phase 2 trial in December. In January Cuba reached an agreement with Iran to test their vaccines in a Phase 3 trial. On March 3, the Finlay Vaccine Institute registered a Phase 3 trial for Soberana 2, with plans to recruit 44,010 participants in Havana.

Cuba is planning to make 100 million doses of Soberana 2 in order to vaccinate its entire population. Cuba is pinning hopes on the vaccine as a source of economic benefit to the island.

Updated Feb. 18

PHASE 3

medicago gsk

VACCINE NAME: CoVLP
EFFICACY: Unknown
DOSE: 2 doses, 3 weeks apart
TYPE: Muscle injection

STORAGE: Stable in refrigerator

Canada-based **Medicago**, partly funded by the cigarette maker Philip Morris, grows vaccines in a plant called Nicotiana benthamiana, a wild species related to tobacco. They deliver virus genes into leaves, and the plant cells then create protein shells that mimic viruses.

In July, Medicago launched Phase 1 trials on a plant-based Covid-19 vaccine in combination with adjuvants to boost the immune system's response to the viral proteins. In that study, they found that an adjuvant made by GSK produced promising levels of antibodies in volunteers. On Oct. 23, the company announced it had reached an agreement with the government of Canada to supply 76 million doses. A Phase 2/3 trial of the vaccine began on Nov. 12. Medicago launched a Phase 3 trial on March 16.

Updated March 16

PHASE 2 **PHASE 3** **COMBINED PHASES**

三叶草生物制药 Clover Biopharmaceuticals DYNAVAX INNOVATING IMMUNOLOGY

Clover Biopharmaceuticals developed a vaccine containing the spike protein from coronaviruses. To further stimulate the immune system, the company is testing so-called adjuvants made by British drugmaker **GSK** and the American company **Dynavax**. Investments from the Coalition for Epidemic Preparedness supported the development of manufacturing that could lead to the production of a billion doses a year. Clover's formula looks to be especially durable; the vaccine can sit out at room temperature for a month and remain viable.

Clover launched a Phase 1 trial last June, and in December the company announced that the vaccine triggered a high level of antibodies. It registered a Phase 2/3 trial with the GSK adjuvant, but in February the company announced it was cancelling the study. Instead, it will move forward with a trial with the Dynavax adjuvant.

Updated Feb. 2

PHASE 2

West China School of Medicine
West China Hospital of Sichuan University

In July, researchers at **West China Hospital of Sichuan University** published a study in Nature describing a vaccine made from the RBD region of the spike protein that could protect mice and monkeys from the coronavirus. To make the vaccine, researchers encode the RBD region in a gene, which they insert into a virus. They then infect insect cells with the virus, causing them to make the molecule in huge amounts. On Aug. 24, they launched a Phase 1 trial, and on Nov. 16 they moved to Phase 2 with a study on 960 volunteers. On Jan. 22 they registered another Phase 2 trial with 4000 volunteers.

Updated Jan. 24

PHASE 2

Taiwan-based vaccine maker **Medigen** is making a vaccine made of a combination of spike proteins and an adjuvant from **Dynavax**. After a series of promising experiments on animals, they began injecting volunteers for a Phase 1 trial in early October. On Dec. 30, Medigen announced that it had received permission to commence a Phase 2 trial. The first volunteers in the trial were injected in late January.

Updated Jan. 26

PHASE 2

The **Center for Genetic Engineering and Biotechnology of Cuba** launched a trial at the end of November on a coronavirus vaccine called Abdala. The name is from a poem by the nineteenth-century poet José Marti. The Abdala vaccine consists of a piece of the coronavirus spike protein called the receptor-binding domain. On Feb. 1, the center held a press conference to announce the start of a Phase 2 trial.

Updated Feb. 2

PHASE 2

New York-based **COVAXX**, a subsidiary of United Biomedical, has created a vaccine containing parts of several viral proteins. On Sept. 11 they registered a Phase 1 trial in Taiwan which led to 100 percent of volunteers producing antibodies without any serious side effects. In February COVAXX launched a Phase 2 trial, also in Taiwan. A Phase 2/3 trial is planned to launch in Brazil. On Nov. 25, Covaxx announced agreements with countries including Brazil, Ecuador, and Peru to deliver more than 140 million doses for $2.8 billion. In January, the company announced they were also starting preclinical research on a vaccine tailored specifically to newly emerged coronavirus variants that could potentially evade conventional vaccines.

Updated Feb. 10

PHASE 2

In addition to their mRNA vaccine, **Sanofi** developed a Covid-19 vaccine based on viral proteins. They produced the proteins with engineered viruses that grow inside insect cells. **GSK** supplemented these proteins with adjuvants that stimulate the immune system. The vaccine is based on the same design Sanofi

used to create Flublok, an approved vaccine for influenza. The companies launched a Phase 1/2 clinical trial in September.

Sanofi's vaccine was widely expected to play a major role in tackling the pandemic. In the United States, Operation Warp Speed selected it as one of six vaccines to secure in large quantities, reaching a $2.1 billion agreement for 100 million doses. On Sept. 18 Sanofi closed another deal with the European Union for 300 million doses for an unspecified amount, and later reached an agreement with Canada for up to 72 million doses. In addition, Sanofi agreed to provide 200 million doses to COVAX, an international collaboration to deliver the vaccine equitably across the world. The company expected to move to a Phase 3 trial in December and potentially seek emergency use authorization in the United States by spring. The company announced plans to make up to one billion doses in 2021.

But on Dec. 11, Sanofi and GSK announced that their vaccine was proving disappointing. While it provided promising levels of antibodies in people under 50, older people did not respond as strongly as they had hoped. The company halted the trial. In January Sanofi decided in January to help Pfizer and BioNTech make 100 million doses of their vaccine, and they reached a similar agreement with Johnson & Johnson in February.

Meanwhile, Sanofi developed a stronger formulation of their own vaccine. On Feb. 22, the company launched a new Phase 2 trial. If they can get sufficiently high antibodies with the new vaccine, they will move on to Phase 3 studies. That could be a challenge, because they may not be able to test it against a placebo. Instead, they may have to test against a vaccine that has already received emergency use authorization. Sanofi and GSK do not expect the vaccine to become available before the end of 2021.

Updated Feb. 23

PHASE 2

NANOGEN BIOPHARMACEUTICAL

On Dec. 10, **Nanogen Biopharmaceutical** in Vietnam began recruiting 60 volunteers for a Phase 1 trial of their protein-based vaccine Nanocovax. Nikkei Asia reported that Nanogen is considering Phase 3 trials in Bangladesh, India, and Indonesia. The company projects the vaccine will become available in Vietnam in mid-2021. Vietnam news agencies announced that Nanocovax entered Phase 2 trials in February.

Updated March 9

PHASE 1 PHASE 2 COMBINED PHASES

IFV INSTITUTO FINLAY DE VACUNAS

On Aug. 18, the head of epidemiology at Cuba's public health ministry announced the country's first trial of a vaccine of Covid-19. The **Finlay Vaccine Institute** in Havana began testing a vaccine called Soberana 1. It contains a part of the spike protein, called RBD, along with two extra ingredients:

proteins from a bacteria and aluminum hydroxide. These ingredients, known as adjuvants, boost the immune system's response to the coronavirus RBD.

Updated Dec. 18

PHASE 1 PHASE 2 COMBINED PHASES

SpyBiotech, a company spun off from the University of Oxford, announced in September that the first volunteers in an Australian Phase 1/2 trial were receiving their Covid-19 vaccine. The researchers created the vaccine from a mixture of proteins. Some of the proteins, from hepatitis B viruses, assemble themselves into hollow shells. The researchers decorated these shells with part of the coronavirus spike protein. The Serum Institute of India, which licensed the technology from SpyBiotech, is running the trials.

Updated Sept. 24

PHASE 1 PHASE 2 COMBINED PHASES

After the SARS epidemic in 2002, **Baylor College of Medicine** researchers began developing a vaccine that could prevent a new outbreak. Despite promising early results, support for the research disappeared. Because the coronaviruses that cause SARS and Covid-19 are very similar, the researchers revived the project in partnership with the **Texas Children's Hospital**. The researchers have found that the Covid-19 vaccine produces antibodies in mice.

The Indian company **Biological E** licensed it in August and launched a Phase 1/2 trial in November, combining the viral proteins with an adjuvant made by **Dynavax**. On Dec. 29, Biological E and the Coalition for Epidemic Preparedness Innovations announced a partnership to advance the development and manufacturing of the vaccine, with CEPI initially contributing $5 million to the effort. If trials confirm that the vaccine works, Biological E hopes to make a billion doses a year.

Updated Dec. 29

PHASE 1 PHASE 2 COMBINED PHASES

Shionogi, a Japanese pharmaceutical giant, launched a Phase 1/2 trial of a

coronavirus vaccine on Dec. 16. The company developed it in collaboration with the **National Institute of Infectious Diseases** and **Kyushu University**. The vaccine is based on a coronavirus protein which is produced in insect cells by genetically altered viruses.

Updated Dec. 17

PHASE 1 PHASE 2 COMBINED PHASES

South Korean vaccine producer **EuBiologics** launched a Phase 1/2 trial of a protein-based vaccine in late January. Known as EuCorVac-19, the vaccine combines the spike protein with an adjuvant that stimulates the immune system.

Updated Feb. 23

PHASE 1 PHASE 2 COMBINED PHASES

Last spring, researchers at the **University of Washington** developed a nanoparticle studded with pieces of the coronavirus spike protein. Experiments on mice showed a strong immune response. The South Korean vaccine company **SK Bioscience** licensed the vaccine, called GBP510. After partnering with GSK, they launched a Phase 1/2 trial of the vaccine in February. It is the second vaccine SK Bioscience has put into trials, after launching a study on another protein-based vaccine called NBP2001.

Updated Feb. 8

PHASE 1 PHASE 2 COMBINED PHASES

The Massachusetts-based company **VBI Vaccines** developed a coronavirus vaccine that is based on hollow, virus-like protein shells. The company added pieces of coronavirus vaccines to the shells, selected for their potential both to produce antibodies and to train T cells to attack infected cells. In February, they registered a placebo-controlled Phase 1/2 trial in Canada on 780 volunteers, comparing the effects from using one or two doses. The vaccine, called VBI-2902a, is a combination of protein shells and aluminum phosphate as an adjuvant.

VBI Vaccines is also experimenting with vaccines that combine proteins from the three coronaviruses that cause severe disease in humans: Covid-19, SARS, and MERS. They are exploring the possibility that such a vaccine could someday protect against a wide swath of coronaviruses, including ones that have yet to spill over from animal hosts.

Updated March 1

PHASE 1 PHASE 2 COMBINED PHASES

As part of the European Union-funded **PREVENT-nCoV** consortium, a team of biotechnology companies and research laboratories has developed a vaccine that uses a nucleocapsid protein to mimic a virus in the human body. The vaccine, called ABCoV2, uses technology from consortium members AdaptVac and ExpreS^{2}ion, among others. After promising preclinical results in primates, **Bavarian Nordic** announced that it would proceed with a Phase 1/2 trial of the vaccine with and without an adjuvant in the Netherlands. Dosing in humans is planned for March 12.

Updated March 9

PHASE 1

The Australian company **Vaxine** developed a vaccine that combines viral proteins with an adjuvant that stimulates the immune system. A Phase 1 trial began over the summer.

Updated Jan. 2

PHASE 1

A second plant-based vaccine is in development at **Kentucky BioProcessing**, an American subsidiary of British American Tobacco, the maker of Lucky Strike and other cigarettes. Like Medicago, Kentucky BioProcessing engineers a wild relative of tobacco called Nicotiana benthamiana to make viral proteins. The company previously used this technique to make a drug called Zmapp for Ebola. A Phase 1 trial launched in December.

Updated Dec. 17

PHASE 1

Taiwan-based vaccine manufacturer **Adimmune** got permission to launch a Phase 1 trial on Aug. 20. The vaccine contains the RBD section of the virus's spike protein. In December, the Taiwan press reported that Adimmune failed to find the right dose of their vaccine and needed to try a new formulation.

Updated Dec. 31

PHASE 1

In the spring, researchers at the **University of Tübingen** in Germany created a vaccine made of eight parts of two viral proteins, along with an immune-stimulating adjuvant. In September they launched a Phase 1 trial.

Updated Sept. 15

PHASE 1

SK Bioscience, a South Korean vaccine maker, won approval on Nov. 23 from the country's Ministry of Food and Drug Safety for a vaccine called NBP2001. The vaccine contained fragments of the spike protein. In a Phase 1 trial, researchers are now testing the vaccine on 50 volunteers.

Updated Feb. 23

PHASE 1

In addition to their Abdala vaccine, the **Center for Genetic Engineering and Biotechnology of Cuba** announced on Nov. 26 that it was beginning a Phase 1 trial of a second vaccine, this one delivered as a nasal spray. Known as Mambisa, the vaccine contains a piece of the coronavirus spike protein called the receptor-binding domain, along with a protein from the hepatitis B virus that stimulates the immune system. The name refers to women who fought in Cuba's nineteenth-century wars of independence.

Updated Feb. 10

PHASE 1

VACCINE NAME: COVAC
EFFICACY: Unknown
DOSE: 2 doses, 4 weeks apart
TYPE: Muscle injection

The **Vaccine and Infectious Disease Organization** at the University of Saskatchewan has developed a vaccine candidate which uses protein subunits to develop immunity against the coronavirus. It was cleared for human testing late last year by the Canadian government. VIDO registered a Phase 1/2 trial

on Jan. 8. If trials proceed as expected, researchers predict that at least one of their candidates will be ready by late 2021.

Updated Jan. 12

PHASE 1

On Feb. 7, Iran announced that it was launching a clinical trial of a second vaccine, known as Cov-Pars Razi and developed by the **Razi Vaccine & Serum Research Institute**. The vaccine contains fragments of coronavirus spike proteins and is delivered in three doses: two injections and one nasal spray.

Updated Feb. 10

PHASE 1 ?

On July 18, **North Korea**'s State Commission of Science and Technology announced on their web site that they had started clinical trials on a vaccine based on part of the coronavirus spike protein. It's hard to independently evaluate the claim from the isolated dictatorship. The commission claimed to have tested the vaccine on animals, but provided no data. Four months after their announcement, South Korean lawmakers said they had foiled an attempt by North Korea to hack South Korean companies developing coronavirus vaccines. So far, North Korea has not released any further information about the trials they supposedly are running.

Updated Dec. 2

ABANDONED

The University Of Queensland AUSTRALIA CSL

On Dec. 10, a vaccine from Australia's **University of Queensland** was the first to be abandoned after entering a clinical trial. Cancelling the vaccine meant the collapse of a $1 billion deal with the Australian government for 51 million doses.

The vaccine studies offered great promise at first. Experiments on hamsters showed that the vaccine protected them from the coronavirus. The university launched a Phase 1 trial in July, combining coronavirus spike proteins with an adjuvant made by **CSL**. The trial delivered encouraging results: volunteers produced a high level of antibodies with no evidence of harmful side effects.

But then the researchers made an unwelcome discovery: some volunteers were getting positive tests for HIV, even though they were not actually infected with that virus. In a report released in February, the researchers explained the

false positives came about due to the way the researchers designed the vaccine.

To ensure that spike proteins can stimulate a strong immune response, the researchers had to prevent the molecules from unfolding and changing their shape. The researchers held the proteins in place with a molecular clamp, which was based on a segment of an HIV protein.

HIV tests use antibodies to probe for the presence of the virus's proteins in people's blood. The researchers thought that the antibodies would not grab the clamp. That assumption turned out to be wrong. Worried that false positive HIV test results would fuel hesitancy over getting Covid-19 vaccines, the Australian government decided to halt the trial.

"It will no longer feature in Australia's vaccine plan," said Prime Minister Scott Morrison at a press conference to announce the cancellation.

Updated Feb. 23

PRECLINICAL

University of Pittsburgh

A vaccine in development by the **University of Pittsburgh**, called PittCoVacc, is a skin patch tipped with 400 tiny needles made of sugar. When placed on the skin, the needles dissolve and deliver virus proteins into the body. At the end of 2020, its creators applied to the F.D.A. for permission to begin clinical trials.

Updated Dec. 22

PRECLINICAL

Other protein-based vaccines in active preclinical development include vaccines from: Akston Biosciences; Applied Biotechnology Institute; Artes Biotech; Baiya Phytopharm; BiOMVis and University of Trento; BioVaxys Technology; Chulalongkorn University; City College of New York and TechnoVax; EpiVax; Generex; GeoVax; Heat Biologics; Icosavax and University of Washington; ImmunoPrecise Antibodies; IMV; Instituto Buntantan; Intravacc; IrsiCaixa; Izmir Biomedicine and Genome Center; MIGAL Galilee Research Institute; Nanografi Nano Technology, Middle East Technical University, and Ankara University; Navarrabiomed; NidoVax; OncoGen; Oragenics Osaka University, BIKEN, and National Institutes of Biomedical Innovation, Japan; OSE Immunotherapeutics; Osivax; PDS Biotechnology; Quadram Institute; Saiba; Soligenix; Ufovax; University of Alberta; University of San Martin and CONICET, Argentina; University of Sao Paulo; University of Virginia; Vabiotech; VBI Vaccines and Coalition for Epidemic Preparedness Innovations; Vaxform; Verndari; Voltron Therapeutics; Walter Reed Army Institute of Research.

Updated March 10

Inactivated or Attenuated Coronavirus Vaccines

Vaccines created from weakened coronaviruses or coronaviruses that have been killed with chemicals.

Inactivated virus

PHASE 3
APPROVED IN CHINA, BAHRAIN, U.A.E.
EMERGENCY USE IN OTHER COUNTRIES

VACCINE NAME: BBIBP-CorV
EFFICACY: 79.34%
DOSE: 2 doses, 3 weeks apart
TYPE: Muscle injection

The **Beijing Institute of Biological Products** created an inactivated coronavirus vaccine that was put into clinical trials by the state-owned Chinese company **Sinopharm.** On Dec. 30, Sinopharm announced that the vaccine had an efficacy of 79.34 percent, leading the Chinese government to give it approval. The company has yet to publish the detailed results of their Phase 3 trial.

Last June, Beijing Institute researchers reported that the vaccine produced promising results in monkeys. A Phase 1/2 trial then showed that the vaccine didn't cause any serious side effects and enabled people to make antibodies against the coronavirus. In July a Phase 3 trial began in the United Arab Emirates in July, and in Morocco and Peru the following month.

On Sept. 14, the U.A.E. gave emergency approval for Sinopharm's vaccine to use on health care workers, and soon government officials and others were also receiving it. Less than two months later, on Dec. 9, the U.A.E. gave full approval to BBIBP-CorV, announcing it had an efficacy rate of 86 percent. Since then a number of countries in the Near East have authorized it; on Jan. 29, Hungary authorized BBIBp-CorV, making the country the first European nation to use a Chinese vaccine.

In China, meanwhile, the government gave Sinopharm emergency approval over the summer to inject its vaccine candidates into government officials, health care workers, and other select groups. By November, the chairman of Sinopharm said, almost a million people in China had received the vaccines.

Sinopharm did not initially comment on the U.A.E.'s announcement that BBIBP-CorV had an efficacy rate of 86 percent. When an executive with the company was later asked about the difference between the U.A.E. estimate and Sinopharm's own analysis, he said that both were "real and valid." The difference was the result of differences in how the trials were run. Sinopharm plans to raise its annual output of its two vaccines to three billion doses a year.

In February, as concerns grew about new mutations in the coronavirus, Chinese researchers tested BBIBP-CorV against a variant called B.1.351, which was first found in South Africa. They reported that the antibody response created by the vaccine was only modestly weaker against B.1.351. The study has not yet been published in a medical journal.

For more details, see **How the Sinopharm Vaccine Works**.

APPROVED FOR USE IN: Bahrain, China, United Arab Emirates.
EMERGENCY USE IN: Argentina, Cambodia, Egypt, Guyana, Hungary, Iran NEW, Iraq, Jordan, Nepal, Pakistan, Peru, Venezuela, Zimbabwe.
LIMITED USE IN: Serbia, Seychelles.
Updated March 12

Sinopharm and Beijing Institute vaccine

PHASE 3
APPROVED IN CHINA EMERGENCY USE IN OTHER COUNTRIES

sinovac

VACCINE NAME: CoronaVac (formerly PiCoVacc)
EFFICACY: 50.38% in Brazil trial, 83.5% in Turkey trial
DOSE: 2 doses, 2 weeks apart
TYPE: Muscle injection
STORAGE: Refrigerated

Sinovac Biotech, a private Chinese company, developed an inactivated vaccine called CoronaVac in early 2020. In early 2021, trials in Brazil and Turkey showed that it could protect against Covid-19, but they delivered strikingly different results--in part because they designed the trials differently. In Brazil, the efficacy against Covid-19 with or without symptoms was 50 percent. In

Turkey, the efficacy against Covid-19 with at least one symptom was 83.5 percent. Sinovac has yet to publish the details of the trials as a preprint or in a medical journal. Nevertheless, Sinovac announced on Feb. 6 that China had given CoronaVac conditional approval. Other countries are also beginning to use the vaccine.

After creating their vaccine last spring, Sinovac ran a Phase 1/2 trial on 743 volunteers that revealed no severe adverse effects. Sinovac published the details of the trial in November in a medical journal, showing a comparatively modest production of antibodies. In July, Sinovac launched a Phase 3 trial in Brazil, followed by others in Indonesia and Turkey.

In that same month, Chinese government gave CoronaVac an emergency approval for limited use. In October, authorities in the eastern Chinese city of Jiaxing announced they were giving CoronaVac to people in relatively high-risk jobs, including medical workers, port inspectors and public service personnel.

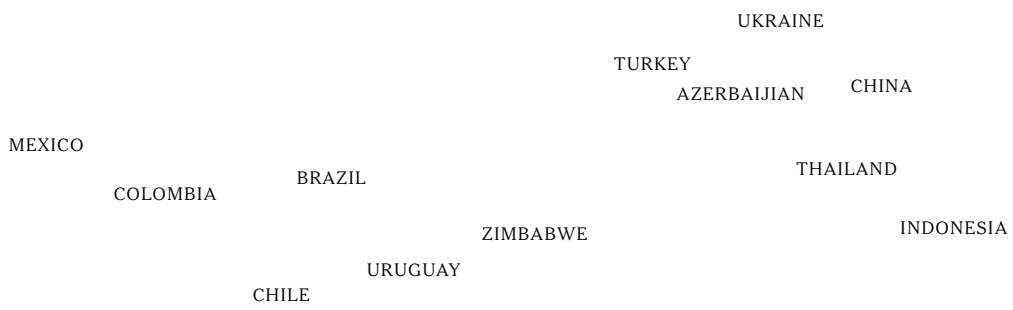
The scientists running the Phase 3 trials began announcing early results at the end of December and continued to update them as new cases of Covid-19 arose. It is still unclear just how much protection CoronaVac provides against Covid-19 in general. But the trials do suggest that CoronaVac--like several other coronavirus vaccines--does a much better job at protecting people against severe disease. On March 3, the scientists running the Turkish trial reported that no vaccinated participants ended up in the hospital for Covid-19, while six in the placebo group did.

Sinovac has struck deals with at least 11 countries and regions to supply them with SinoVac. Indonesia gave the vaccine emergency authorization on Jan. 11, and two days later the president of Indonesia received an injection of CoronaVac on live television. Turkey authorized the vaccine on Jan. 13, and its president got vaccinated the next day. Brazil authorized CoronaVac on Jan. 17. After building a second production line, Sinovac said in February that its manufacturing capacity was up to a billion doses.

For more details, see **How the Sinovac Vaccine Works**.

APPROVED FOR USE IN: China.
EMERGENCY USE IN: Azerbaijan, Brazil, Cambodia, Chile, Colombia, Ecuador, Hong Kong, Indonesia, Laos, Malaysia, Mexico, Philippines, Thailand, Turkey, Ukraine, Uruguay, Zimbabwe.
Updated March 10

Sinovac vaccine



Approved
Early, limited or emergency use

PHASE 3

APPROVED IN CHINA LIMITED USE IN U.A.E.

武汉生物制品研究所有限责任公司
WUHAN INSTITUTE OF BIOLOGICAL PRODUCTS CO.,LTD.

Along with their Beijing Institute vaccine, **Sinopharm** also tested an inactivated virus vaccine developed by the **Wuhan Institute of Biological Products**. The Phase 1/2 trial showed that the vaccine produced antibodies in volunteers, some of whom experienced fevers and other side effects. Sinopharm said the vaccine's efficacy was 72.51 percent. The Wuhan version of the vaccine is undergoing Phase 3 trials in several countries. In December, Peru briefly paused their Sinopharm trial to investigate neurological problems that one volunteer experienced, but determined that it had nothing to do with the vaccines. On Feb. 25, China announced the approval of the Wuhan vaccine for general use. The efficacy determined from the Phase 3 trials has yet to be published.

APPROVED FOR USE IN: China.
LIMITED USE IN: United Arab Emirates.
Updated March 4

Sinopharm and Wuhan Institute vaccine

CHINA

U.A.E.

Approved
Early, limited or emergency use

PHASE 3 EMERGENCY USE IN INDIA

VACCINE NAME: Covaxin (also known as BBV152 A, B, C)
EFFICACY: 80.6%
DOSE: 2 doses, 4 weeks apart
STORAGE: At least a week at room temperature

In collaboration with the **Indian Council of Medical Research** and the **National Institute of Virology**, the Indian company **Bharat Biotech** designed Covaxin, a vaccine based on an inactivated form of the coronavirus. Studies on monkeys and hamsters found that it provided protection against infection. Last June, Covaxin became the first coronavirus vaccine created in India to go into clinical trials.

The phase 1/2 trial showed that the vaccine didn't cause any serious side effects while producing antibodies to the coronavirus, and a follow-up study confirmed these results. On Oct. 23, the company announced they were initiating a Phase 3 trial, eventually recruiting over 25,800 volunteers. On Dec. 22, the company announced a partnership with Pennsylvania-based Ocugen to develop Covaxin for the United States market.

On Jan. 3, the Indian government granted Covaxin emergency authorization. The authorization came despite the fact that Bharat had yet to release Phase 3 data showing the vaccine is safe and effective. Two months later on March 3, the company announced an early analysis of the trial results, finding that Covaxin has an efficacy of 80.6 percent. Of the first 43 volunteers to get Covid-19, only 7 had received the vaccine. Bharat said that they would update their estimate of Covaxin's efficacy up to 130 cases. The early analysis also revealed no serious adverse events.

EMERGENCY USE IN: India, Iran, Zimbabwe.

Updated March 12

Bharat Biotech's Covaxin vaccine

IRAN

INDIA

ZIMBABWE

Approved
Early, limited or emergency use

PHASE 3

INSTITUTE OF MEDICAL BIOLOGY
CHINESE ACADEMY OF MEDICAL SCIENCES

Researchers at the **Institute of Medical Biology at the Chinese Academy of Medical Sciences**, which has invented vaccines for polio and hepatitis A, created an inactivated coronavirus vaccine. Last May, they launched a Phase 1 trial on 192 volunteers which indicated the vaccine was safe and produced an immune response. A Phase 2 trial followed on 750 volunteers, which led the researchers to select a two-week spacing between the two doses of the vaccine.

In December the researchers launched a Phase 3 trial on up to 34,020 volunteers in Brazil and Malaysia.

Updated June 23

PHASE 3

RIBSP
Research Institute for Biological Safety Problems

The central Asian nation of Kazakhstan began research on a vaccine made from inactivated coronaviruses over the summer. On August 28, their **Research Institute for Biological Safety Problems** registered a Phase 1 trial on the vaccine, known as QazCovid. On Dec. 19, Kazinform reported that Phase 2 had been completed, showing that the vaccine was safe and produced a promising immune response. The researchers commenced a Phase 3 trial, anticipating approval by March.

Updated Dec. 27

PHASE 2

ERCİYES ÜNİVERSİTESİ 1978

On Nov. 5, Turkey's **Erciyes University** announced they had begun injecting volunteers with an inactivated coronavirus vaccine called ERUCOV-VAC. It is the first clinical trial of a coronavirus vaccine developed in Turkey. On Dec. 14, the president of the university said that the Phase 1 trial was complete. Sabah Today reported the following month that Phase 2 trials had begun.

Updated Jan. 21

PHASE 2

康泰生物 BIOKANGTAI

Shenzhen Kangtai Biological Products is a Chinese company that makes vaccines for diseases such as hepatitis B and measles. In August, AstraZeneca reached an agreement with Shenzhen to supply China with their adenovirus vaccine, despite the reports of corruption and scandals that have the company. In October Shenzhen Kangtai launched a Phase 1 trial on 180 volunteers of its own vaccine, based on inactivated coronaviruses. In February they added a Phase 2 trial to a U.S. registry, where they indicated the trial included 1,000 people and that the study would be completed by the end of the month.

Updated Feb. 18

PHASE 1 PHASE 2 COMBINED PHASES EARLY USE IN RUSSIA

The **Chumakov Center** at the **Russian Academy of Sciences** developed an inactivated coronavirus vaccine called CoviVac. On Oct. 14, the TASS news agency reported that clinical trials of the vaccine would begin in Kirov and St. Petersburg on Oct. 19. On Feb. 20, Russia approved the vaccine for domestic use, despite the fact that the Chumakov Center had yet to start a Phase 3 trial. By the end of the year, Russia planned on producing 20 million doses.

EARLY USE IN: Russia.

Updated Feb. 23

PHASE 1 PHASE 2 COMBINED PHASES

The French vaccine maker **Valneva** created a vaccine from chemically inactivated coronaviruses, using an adjuvant from **Dynavax**. It's currently the only Western company to be using this traditional method, which is also being pursued in China and India. On Dec. 16, it launched a Phase 1/2 trial in the United Kingdom. The company expects initial results from the trial in April, and hopes to reach authorization in the second half of 2021. The British government has already reached an agreement to purchase 100 million doses of the vaccine should it prove safe and effective, with an option to acquire a further 90 million.

Updated Feb. 26

PHASE 1

New York-based **Codagenix** develops vaccines based on live attenuated viruses, but with a twist: they create the viruses from scratch. Researchers rewrite the genome of viruses, introducing hundreds of mutations. Then they manufacture RNA molecules encoding the rewritten genes. In special host cells, the molecules can give rise to full-blown viruses. But thanks to their numerous mutations, they are too weak to cause Covid-19 when they're delivered in a vaccine. After successful experiments in animals, a Phase 1 trial was launched in the United Kingdom in January.

Updated Jan. 12

PHASE 1

Shafa Pharmed Pars, an Iranian pharmaceutical company, developed a vaccine made of inactivated coronaviruses. Known as COVIran Barekat, it entered a Phase 1 trial at the end of December. COVIran Barekat is the first vaccine developed in Iran to go into clinical testing.

Updated Dec. 29

PHASE 1

On March 16, Iran's **Ministry of Defence** announced another vaccine made of inactivated coronaviruses. Known as Fakhravac, the vaccine is named after Mohsen Fakhrizadeh, Iran's top nuclear scientist who was killed in November. The vaccine is now in a Phase 1 trial.

Updated March 16

PRECLINICAL

Other inactivated or attenuated coronavirus vaccines in active preclinical development include vaccines from: Indian Immunologicals and Griffith University; KM Biologics; and Osaka University.

Updated Nov. 7

Repurposed Vaccines

Vaccines already in use for other diseases that may also protect against Covid-19. Repurposed vaccines are not included in our vaccine count.

PHASE 3

The Bacillus Calmette-Guerin vaccine was developed in the early 1900s as a protection against tuberculosis. The **Murdoch Children's Research Institute** in

Australia is conducting a Phase 3 trial called the BRACE to see if the vaccine partly protects against the coronavirus.

Updated

OTHER CLINICAL TRIALS

Other repurposed vaccines are in clinical trials being conducted by: the Bandim Health Project; Crown Coronation (Washington University and partner universities); Hôpitaux de Paris; Louisiana State University Health Sciences Center New Orleans; the BADAS Study (Texas A&M University, Baylor College of Medicine, M.D. Anderson Cancer Center and Cedars-Sinai Medical Center); India's National Institute for Research in Tuberculosis; BCG-CORONA (UMC Utrecht and Radboud University); University of Campinas; University Health Network, the Serum Institute of India, the Max Planck Institute for Infection Biology and Verity Pharmaceuticals; Oklahoma Medical Research Foundation and the University of Oklahoma; Vakzine Projekt Management.

Updated Sept. 25

Note: Vaccines will be added to the tracker when they reach **Phase 1**, and tracked until they succeed or fail.

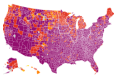
Did we miss something? To notify The Times of new developments, send updates to vaccinetracker@nytimes.com.

Tracking the Coronavirus

United States

Latest Maps and Data
Cases and deaths for every county

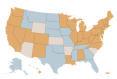
Vaccinations
How many have been vaccinated, and who's eligible



Your County's Risk
See guidance for your local area

Your Places
Build your own dashboard to track cases

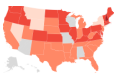
Hospitals Near You
Patients hospitalized and I.C.U. beds remaining



Restrictions
What is open and closed in each state

Deaths Above Normal
The true toll of the pandemic in the U.S.

Cities and Metro Areas
Where it is getting better and worse



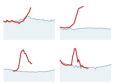
Nursing Homes
The hardest-hit states and facilities

Colleges and Universities
Cases at more than 1,800 schools

World

Latest Maps and Data
Cases and deaths for every country

Global Vaccinations
How many have been vaccinated, by country



Deaths Above Normal
The true toll of coronavirus around the world

Health

Vaccines
Track their development

Treatments
Rated by effectiveness and safety

Countries

Brazil
Canada
France
Germany
India
Italy
Mexico
Spain
U.K.
United States

States, Territories and Cities

Alabama
Alaska
Arizona
Arkansas
California
Colorado
Connecticut
Delaware
Florida
Georgia
Hawaii
Idaho
Illinois
Indiana
Iowa
Kansas
Kentucky
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Maryland
Massachusetts
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Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New Mexico
New York
New York City
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Puerto Rico
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Utah
Vermont
Virginia
Washington
Washington, D.C.
West Virginia
Wisconsin
Wyoming

Data

Frequently Asked Questions About the Covid Data

Access the Open Source Covid Data

Additional reporting by Farnaz Fassihi, Denise Grady, Andrew E. Kramer, Matthew Kristoffersen, Hari Kumar, Cao Li, Jess Ruderman and Carlos Tejada.

Notes and corrections: Early versions of the tracker combined two vaccines by Sinopharm into one entry, before subsequent reporting confirmed they were two different vaccines. A previous version of the tracker stated that Pfizer had reached a deal with the E.U., when in fact the deal was made by AstraZeneca. A previous version of the tracker listed Canadian approval of the Pfizer-BioNTech and Moderna vaccines, when in fact they were conditional authorizations.

Sources: World Health Organization, National Institute of Allergy and Infectious Diseases, National Center for Biotechnology Information, New England Journal of Medicine, Rollins School of Public Health at Emory University. Cahill-Keyes map projection by Gene Keyes.