

NEWS | 16 December 2021

## How COVID vaccines shaped 2021 in eight powerful charts

The extraordinary vaccination of more than four billion people, and the lack of access for many others, were major forces this year – while Omicron’s arrival complicated things further.

Smriti Mallapaty , Ewen Callaway , Max Kozlov , Heidi Ledford , John Pickrell & Richard Van Noorden



A mobile vaccination team at work during a house call in a remote region of Turkey. Credit: Chris McGrath/Getty

A year ago, vaccine drives against COVID-19 were just beginning. Now, more than 4.4 billion people have had one or more dose – about 56% of the world population. The vaccination of so many in such a short space of time, so soon after the unparalleled rapid development of the vaccines, has saved huge numbers of lives and is a triumph for science and research.

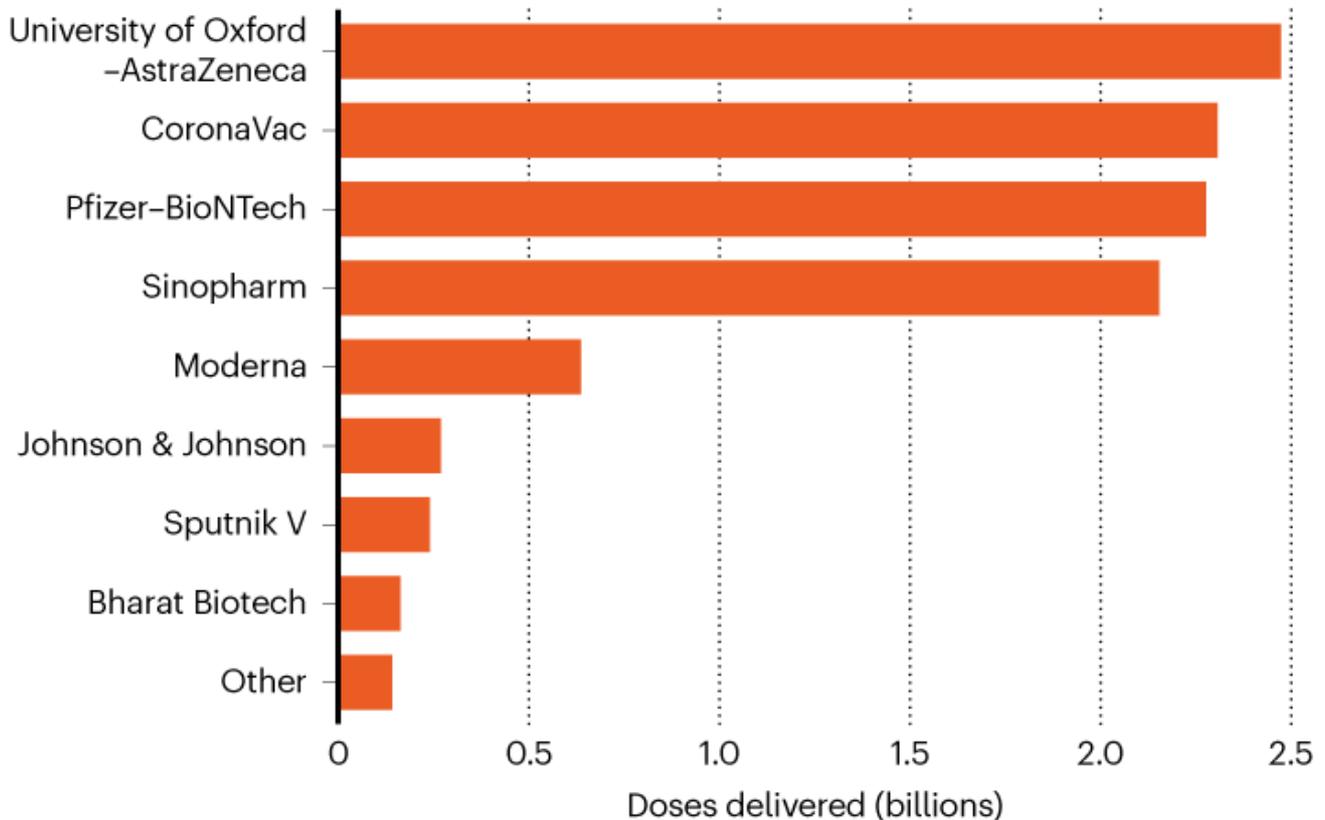
Sadly, the vaccines have not been shared or taken up equitably across the world, nor even, sometimes, within nations. But the extraordinary roll-out of a plethora of COVID-19 vaccines – or the lack thereof – has been a major force shaping politics, science and everyday human experience in 2021. In this graphic-led story, *Nature* offers a guide to the successes, failures and impact of COVID-19 vaccines in 2021.

## **Winning the vaccine race**

More than eight billion doses, mostly of eight front-runner vaccines, have now been administered around the world, the vast majority in 2021 (see ‘The race to vaccinate’). “Just making that much vaccine has been the standout success,” says Gagandeep Kang, a virologist at the Christian Medical College in Vellore, India.

## THE RACE TO VACCINATE

Nearly 10 billion doses of COVID-19 vaccine have been delivered around the world since mid-2020, 8.5 billion of which had been administered by late 2021. Eight different vaccines make up the vast majority of doses\*.



©nature

\*Data as of 14 December 2021.

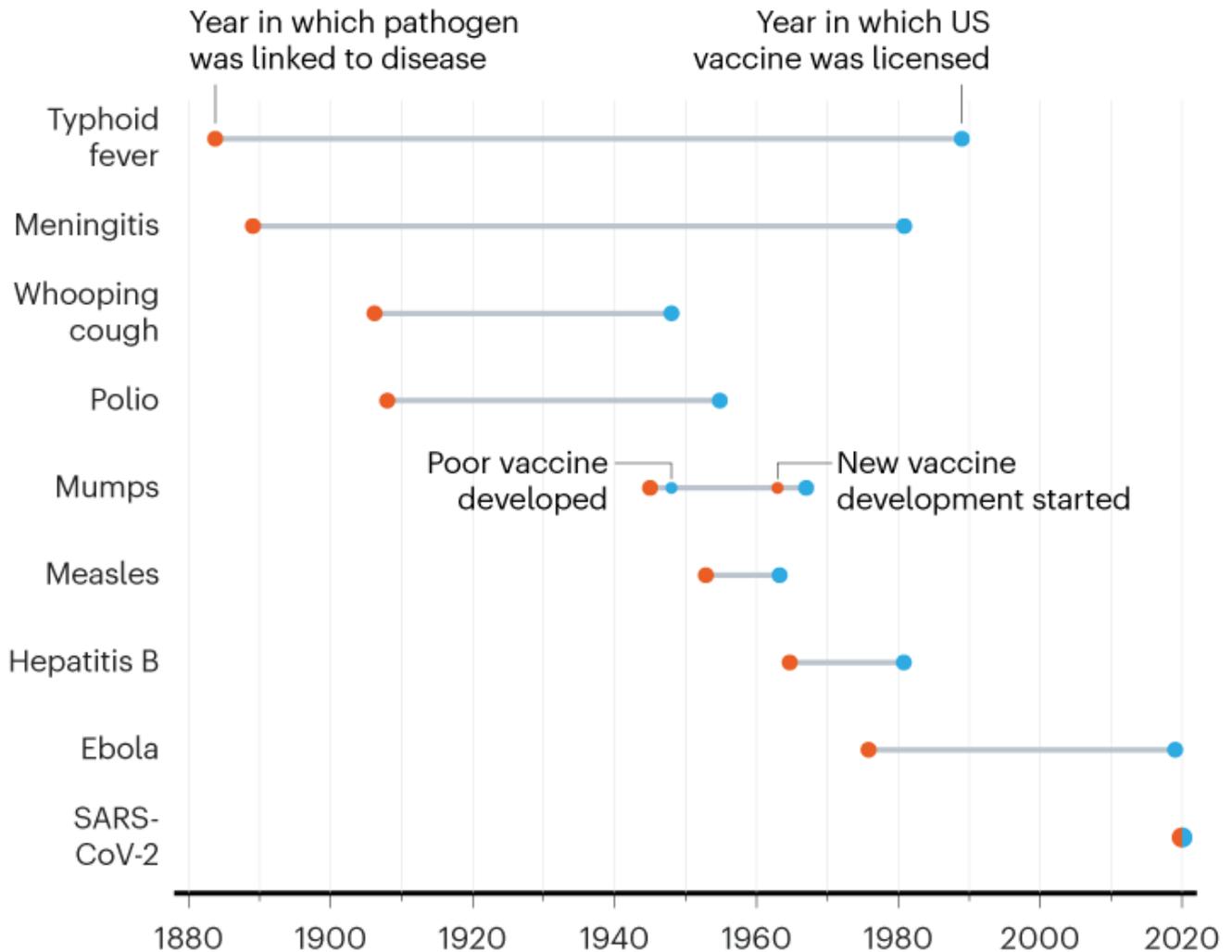
Source: Data from Airfinity

“The vaccines have had a huge impact on averting deaths and helping country’s economies return to normal,” says Soumya Swaminathan, chief scientist at the World Health Organization (WHO) in Geneva, Switzerland. “In countries with high coverage, infections have been uncoupled from deaths, so that even with new surges of infection, deaths have stayed low.”

Also noteworthy is the [speed of the development of the vaccines](#) (see ‘Vaccine innovation’). No vaccines in history have been developed so fast, yet 23 different vaccines against SARS-CoV-2 have already been approved for use around the world – and hundreds more are in development.

# VACCINE INNOVATION

Most vaccines take years to develop, but scientists created multiple vaccines for SARS-CoV-2 within a year.



©nature

Source: Our World in Data; *Nature* analysis

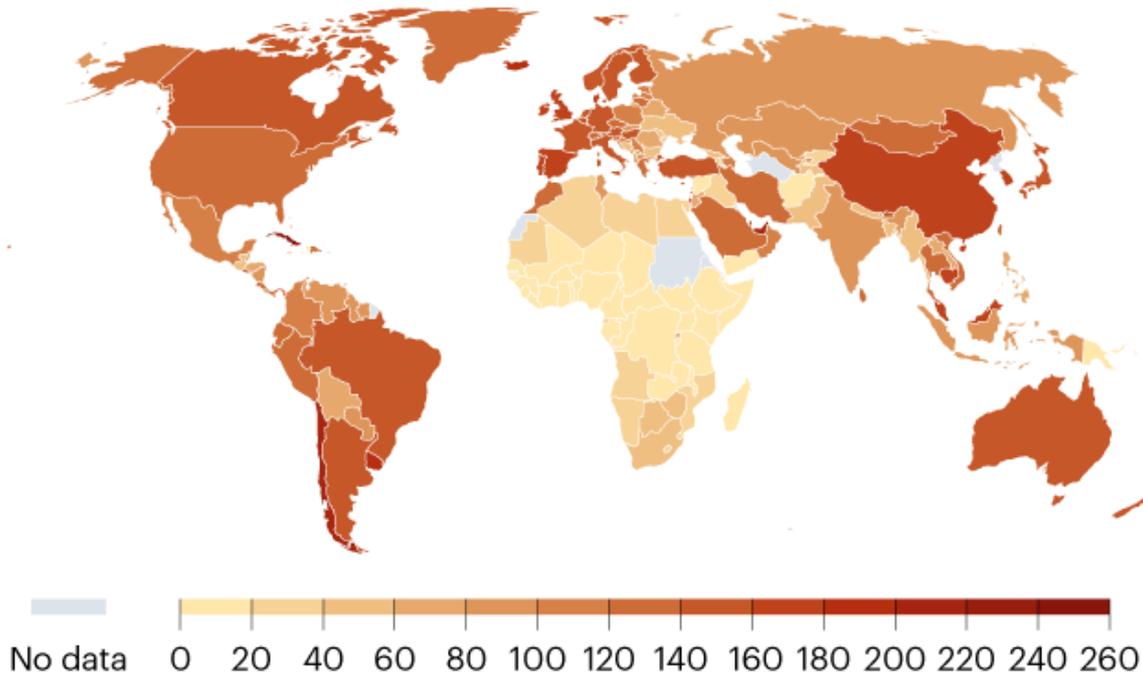
It is estimated that this astonishingly rapid development and deployment has saved at least 750,000 lives in the United States and Europe alone – and probably many more globally, although researchers are as yet unwilling to commit to a number. A study from the WHO and the European Centre for Disease Prevention and Control in Solna, Sweden, published last month<sup>1</sup> estimated that 470,000 deaths had been averted across 33 European countries in those aged 60 and over alone. Another [modelling study](#), which is yet to be peer reviewed, from epidemiologists at Yale University in New Haven, Connecticut, estimated that 279,000 lives had been saved by late June by the vaccination drive in the United States.

## Vaccine haves and have-nots

But despite the astonishing success of the vaccines, it's a story of haves and have-nots and the roll-out has been anything but equitable. "We were so together and so divided," says Kang. "Very together on the science, very divided on the access."

### GLOBAL DOSES

Vaccine roll-outs are uneven across the world, as shown by the number of COVID-19 vaccine doses administered per 100 people in the total population\*.



\*Data as of 29 November 2021. Data don't reflect the number of people who have been vaccinated because some people have received two doses of a vaccine. Nature publications remain neutral with regard to contested jurisdictional claims in published maps.

©nature

Source: Our World in Data

In the world's most-vaccinated nations, such as the United Arab Emirates, Chile and Cuba, more than 200 doses have been administered per 100 people – but at the opposite end of the scale, in places such as Tanzania, Afghanistan and Papua New Guinea, fewer than 20 people per 100 have received at least one dose (see 'Global doses').

"Vaccine inequity has been one of the most painful experiences of the pandemic," says Swaminathan, who notes that there now exist two parallel worlds. In some regions, infections have been uncoupled from deaths and life is normalizing. But in

others, there is “fear in opening up, schools remain shut, long-term plans cannot be made, and surges in infections translate soon into higher deaths”, she says.

On average, in high-income countries, 83% of the eligible populations have had at least one shot, but in low-income countries that falls to 21%. These figures “never cease to amaze”, says Andrew Azman, an infectious-disease epidemiologist at Johns Hopkins University in Baltimore, Maryland, who co-authored an analysis on the inequities in doses, posted as a preprint<sup>2</sup> in October.

It was expected that poorer nations would get **increased supplies** once demand began to fall in wealthy nations, but most of them are now **administering boosters**. This, combined with the fact that many countries are stockpiling doses, could be contributing to a lack of access to those who really need them, says Kang.

Disparities exist not just between countries, but also within them. One study in the United States found lower vaccination coverage in areas that had larger numbers of people on low incomes, or who were single parents, or who had disabilities<sup>3</sup>. Other studies show disparities in vaccination coverage along racial or ethnic lines<sup>4</sup>.

## **Waning immunity and variants**

2021 was the year of COVID-19 vaccines, but it was also the year of variants. Researchers identified a trio of SARS-CoV-2 ‘variants of concern’ in late 2020 and early 2021, **now called Alpha, Beta and Gamma**. They seemed to spread faster than earlier circulating viral lineages, and scientists worried that these variants might also blunt the effectiveness of vaccines.

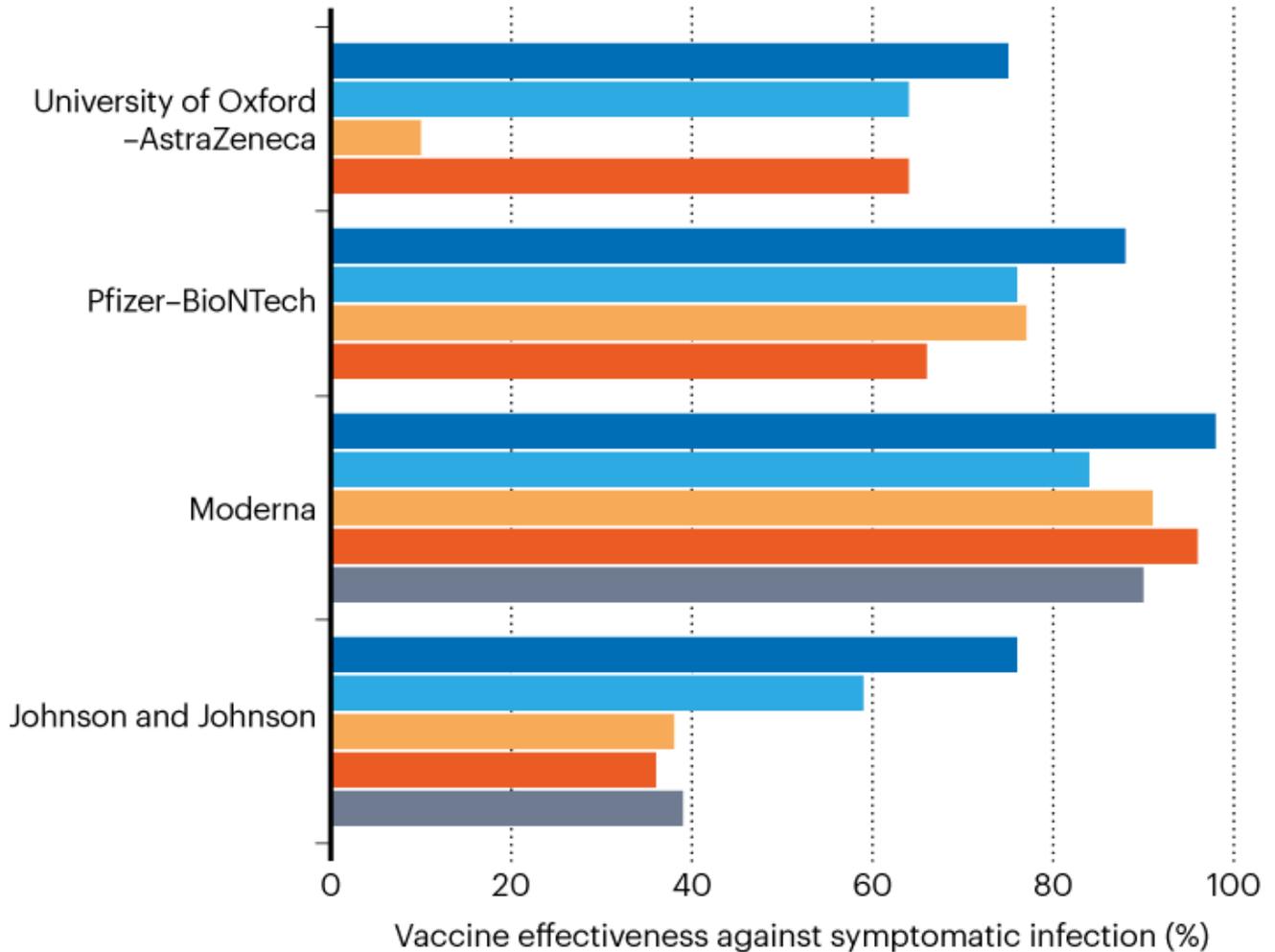
Laboratory studies and real-world epidemiology confirmed that vaccines remained highly effective against the most widespread of the three, Alpha, which was identified in the United Kingdom. But Beta and Gamma – first spotted in South Africa and Brazil, respectively – were linked to reduced effectiveness of some vaccines, particularly those based on viral vectors, such as the Oxford–AstraZeneca vaccine, or on inactivated viruses, such as those developed in China and India (see ‘Variants and vaccines’).

# VARIANTS AND VACCINES

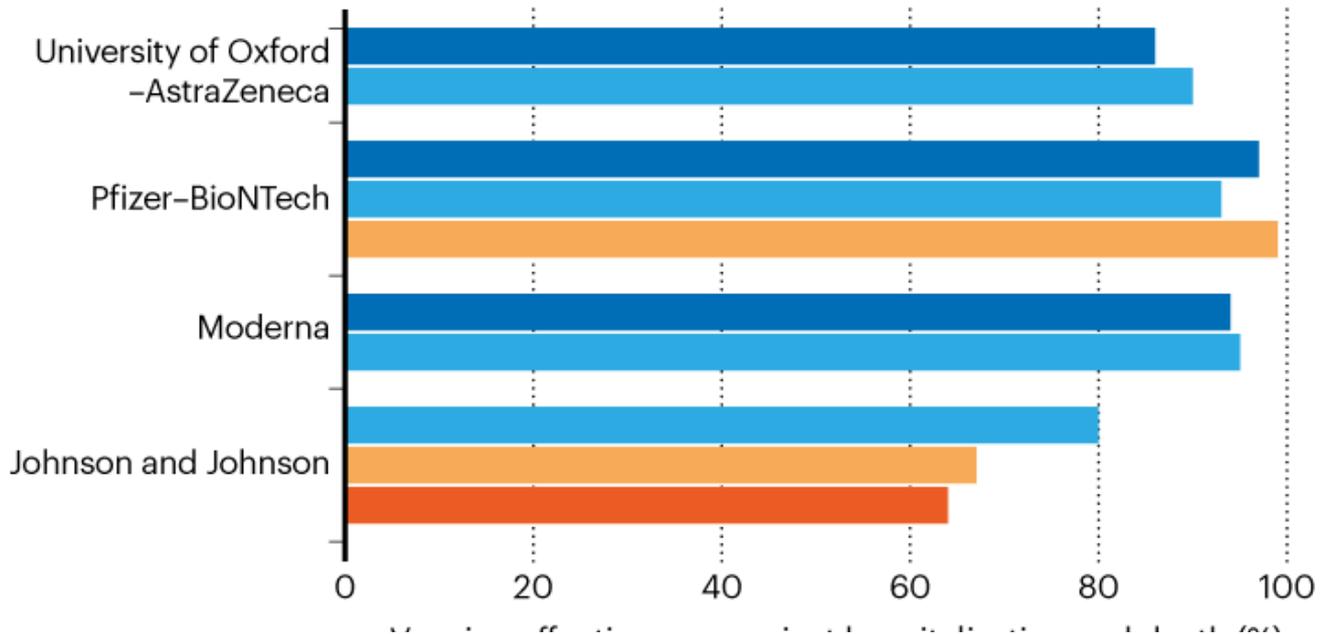
Over the course of the past year, the emergence of SARS-CoV-2 variants Alpha, Beta, Gamma, Delta and Mu has challenged the effectiveness of vaccines, although most have held their ground. How vaccines will fare in the face of highly mutated Omicron is yet to be determined\*.

■ Alpha ■ Delta ■ Beta ■ Gamma ■ Mu

## Symptomatic infection



## Hospitalization/death



## Vaccine effectiveness against hospitalization and death (%)



Data as of 25 November. Estimates of vaccine effectiveness modelled by Airfinity, based on available data. Figures on effectiveness against hospitalization and death not available for all variants.

Source: Data from Airfinity

---

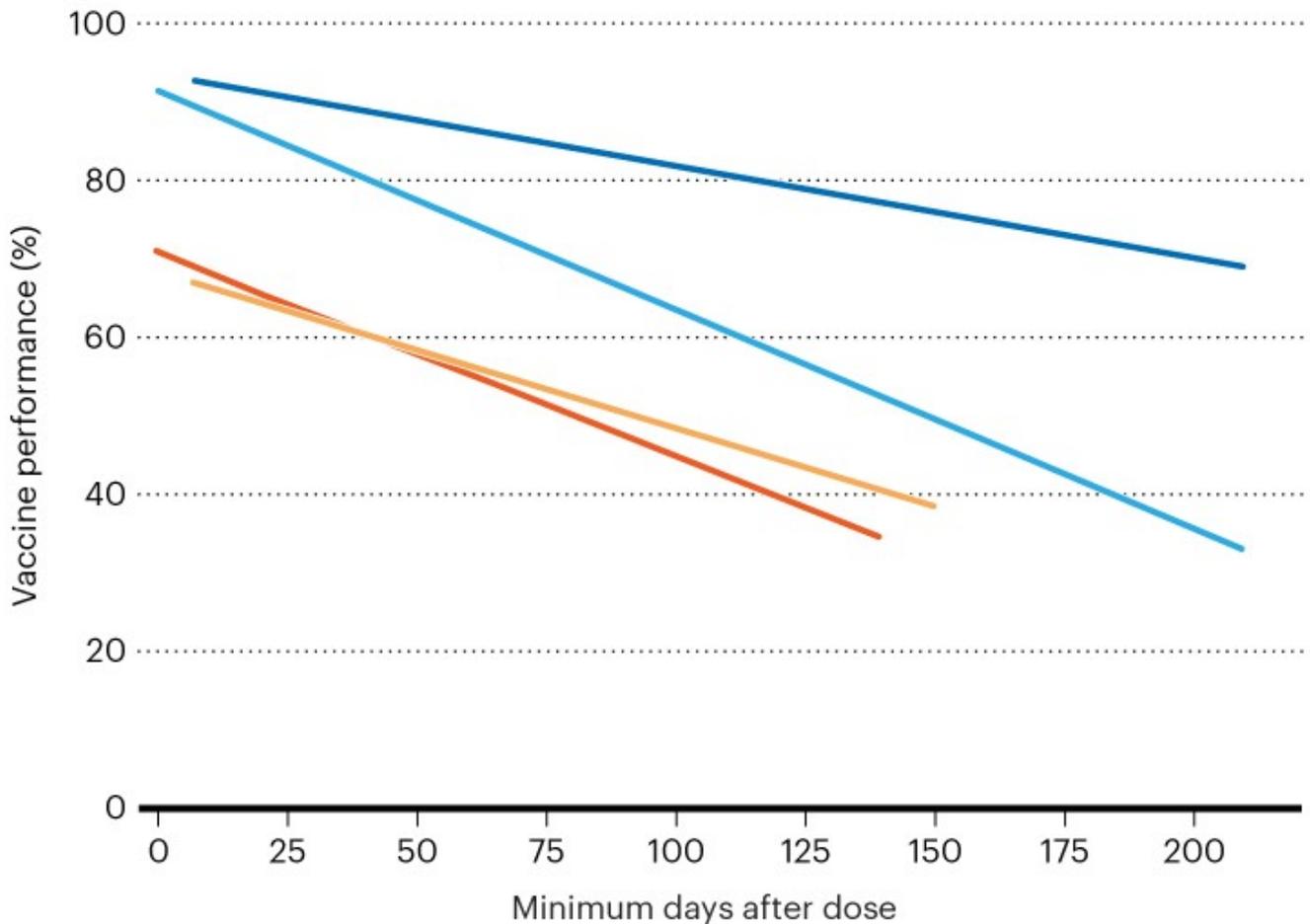
**Delta**, designated as a variant of concern in May, is currently responsible for most new infections globally and has further challenged vaccines. Countries such as Israel, the United States and the United Kingdom that began their campaigns early are now seeing signs that vaccines lose their potency over time (see ‘Waning immunity’).

Despite these challenges, the vaccines are still doing a good job at protecting against the most severe forms of COVID-19, says Laith Jamal Abu-Raddad, an infectious-disease epidemiologist at Weill Cornell Medicine–Qatar in Doha. “We now have lots of data and we see a very clear pattern that the vaccines are working very well against severity.”

## WANING IMMUNITY

The immunity conferred by COVID-19 vaccines, particularly to prevent infections, falls over time — as shown in these estimates of vaccine efficacy against Delta in the months following a second dose\*

— AstraZeneca — J&J — Moderna — Pfizer-BioNTech



©nature

\*Data as of 25 November. Estimates of vaccine effectiveness modelled by Airfinity, based on available data.

Source: Data from Airfinity

However, researchers are racing to determine how different vaccines **will hold up against the fast-spreading Omicron**, designated a variant of concern in late November. A preliminary study from the United Kingdom found that two vaccine doses offer little protection against becoming infected with Omicron (a third booster dose restored vaccine effectiveness to above 70%). Researchers expect that vaccines will continue to prevent severe disease caused by the variant — but to what extent is not yet clear.

## New vaccines on the horizon

While a little less than half the world's population still awaits a first dose of a COVID-19 vaccine, researchers are developing more than 300 fresh options. Of these, nearly 200 are still being tested in lab and animal studies rather than in people, but 40 are in large international clinical trials (see 'Under development').

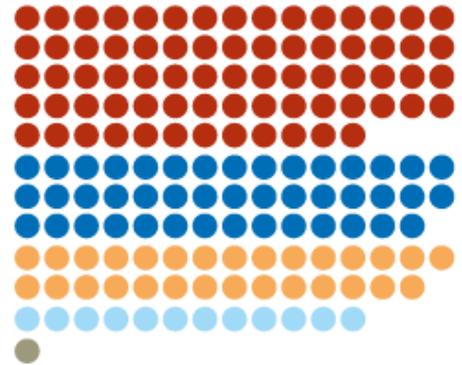
## UNDER DEVELOPMENT

Researchers are developing more than 300 COVID-19 vaccines in addition to the 23 already in use around the world; 84 are in early-stage clinical trials and 40 are at much later stages of development\*.

- Protein based
- Viral vector
- Nucleic acid
- Whole virus
- Bacterial antigen-spore expression vector

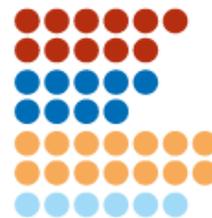
### Pre-clinical

194 vaccines



### Phase 1

40 vaccines



### Phase 2

44 vaccines



### Phase 3

40 vaccines



### In use

23 vaccines



### Phase 4

10 vaccines



\*Data as of 1 December 2021

©nature

Source: GAVI

Some of these next-generation vaccines could have key advantages over those currently available. For example, [protein vaccines](#) use SARS-CoV-2 proteins to rouse

the immune system against the virus, and promise to be easier to produce and transport than some existing vaccines.

In particular, two protein vaccines made by Novavax, in Gaithersburg, Maryland, and Clover Biopharmaceuticals in Chengdu, China, will be pivotal to hitting the COVID-19 Vaccines Global Access (COVAX) initiative's goal of distributing two billion doses to low-income nations next year, says Nicholas Jackson, head of programmes and innovative technology at the Coalition for Epidemic Preparedness Innovations (CEPI) in Oslo, which is a co-leader of COVAX.

Other upcoming COVID-19 vaccines are being formulated so that they can be administered by mouth or inhaled through the nose, such as nasally administered vaccines being developed by CanSino and AstraZeneca. Because these vaccines would be administered directly into the tissues that SARS-CoV-2 first infiltrates when it enters the body, it is hoped that oral or nasal vaccines could work well to prevent infection. They would also require fewer trained health-care personnel to administer injections.

Some COVID-19 vaccines are being developed to tackle [specific SARS-CoV-2 variants](#) – such as Omicron – or even a variety of coronaviruses. Three diseases caused by novel coronaviruses have already emerged in less than 20 years, says Jackson – severe acute respiratory syndrome (SARS) in 2002, Middle East respiratory syndrome (MERS) in 2012 and COVID-19 in late 2019. “A broadly protective coronavirus vaccine could revolutionize our response to future infectious-disease outbreaks,” he says.

## Vaccinating children

How the pandemic unfolds from now on might not only be driven by novel variants, but also by how quickly vaccines reach another large part of the global population that is yet to be vaccinated – children.

During 2021, the highly transmissible Delta variant caused a sharp rise in paediatric cases worldwide. Although only a relatively small proportion of kids develop severe

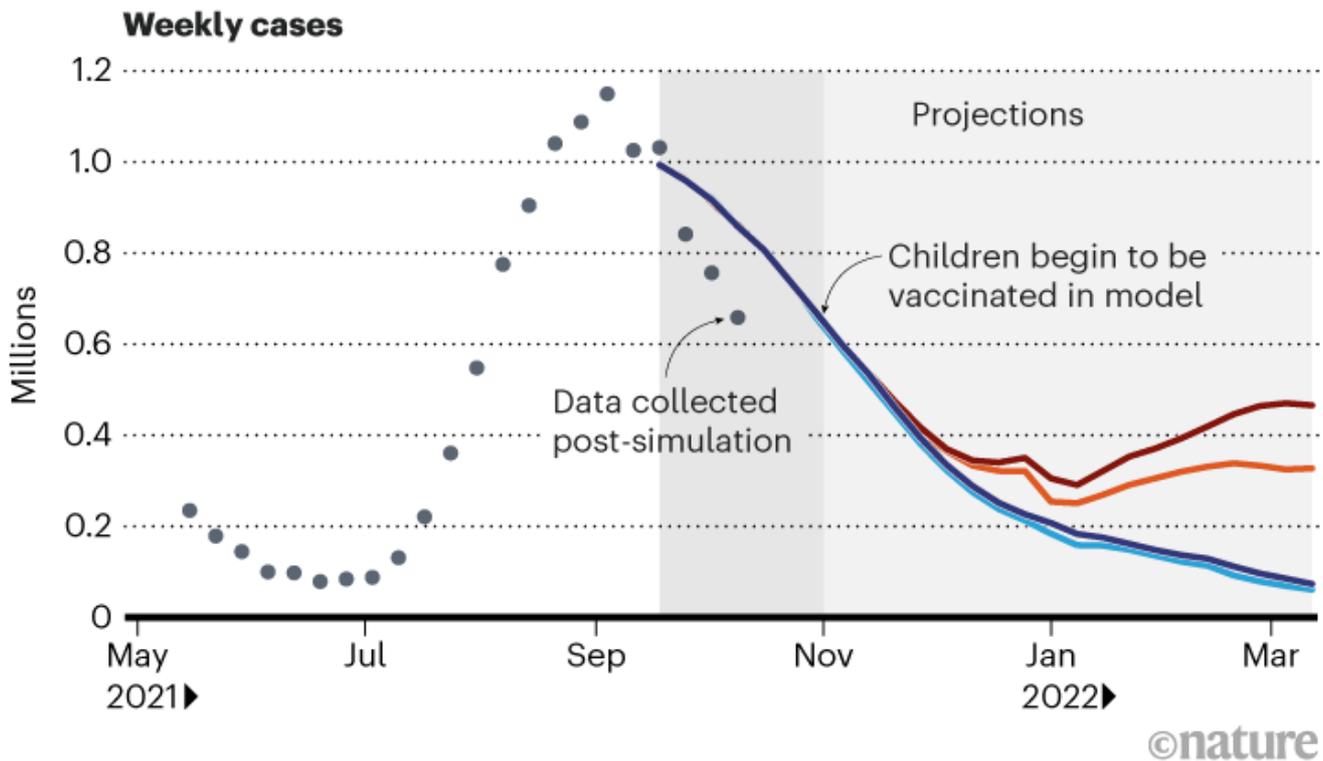
disease, that still translates to huge numbers of severe cases globally, says Andrew Pavia, a paediatric infectious-disease researcher at the University of Utah Health in Salt Lake City. Widespread vaccination of children will limit severe cases in that age group and help to control the spread of the virus, he says.

In the United States – where children have accounted for the largest numbers of COVID-19 cases of any age group since late October – the Food and Drug Administration (FDA) approved Pfizer–BioNTech’s vaccine **for the nation’s roughly 28 million kids** aged 5 to 11 in early November. Since then, more than five million children there have received a dose – and **modelling studies** in September that looked at the impact both in a scenario where there were no new variants and where there were, show that the benefits could be significant – particularly now, as we face the impacts of Omicron (see ‘The kid effect’). The same researchers are now starting to model the possible impacts of Omicron on case numbers in the United States.

## THE KID EFFECT

A simulation of the US pandemic, run in September and averaging multiple models, found that starting to vaccinate children aged 5 to 11 would not only lower COVID-19's toll, but would also have a large impact if a new, more transmissible coronavirus variant emerged.

- Observed data
- New variant**
  - Childhood vaccination
  - No childhood vaccination
- No new variant**
  - Childhood vaccination
  - No childhood vaccination



Source: [COVID-19 Scenario Modelling Hub](#)

Elsewhere, vaccinations for younger children have slowly been taking hold, too. Regulators in Canada, Israel and the European Medicines Agency, for example, all provisionally approved the Pfizer vaccine for children in late November, followed by Australia in early December. Colombia, Chile, Argentina and Venezuela are all now offering China's Sinopharm vaccine to children.

## Vaccine papers soar

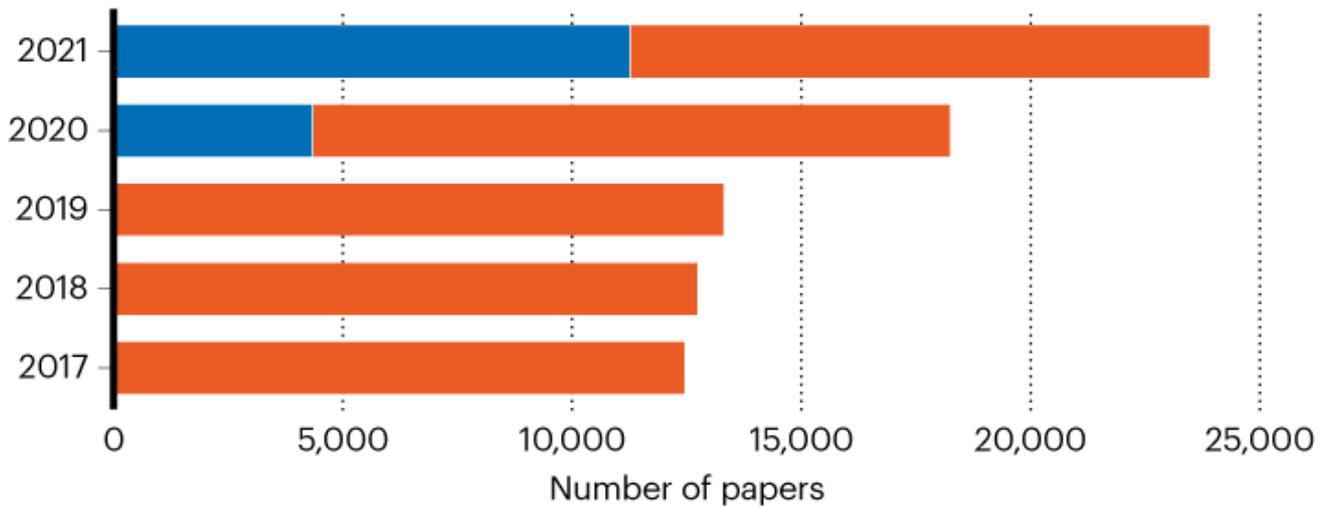
The development and deployment of COVID-19 vaccines has seen an extraordinary research effort over the past year. According to *Nature's* calculations, at least 15,000 papers on vaccines mentioning COVID-19 or SARS-CoV-2 have been published since early last year, with more than 11,000 of those during 2021 (see 'Explosion of

knowledge’). These made up more than 47% of all papers on vaccines published in 2021 – and made it a record-breaking year for vaccine-related publications.

## EXPLOSION OF KNOWLEDGE

More than 15,000 vaccine-related papers that mention COVID-19 or SARS-CoV-2 have been published since early last year; 11,000 were published in 2021 alone, making up an astonishing 47% of all vaccine-related publications this year\*.

■ Vaccine papers ■ COVID-19 vaccine papers



\*Journal articles, preprints, and clinical trial reports indexed on the PubMed database. Data as of 24 November 2021.

©nature

Source: Data from PubMed; *Nature* analysis

The benefits of that research extends beyond just COVID-19, to vaccines more generally, say researchers. “Humanity coming together to develop and deploy vaccines has opened up a lot of doors for vaccines and understanding what they are, how they work and why we might want to use them in the future,” says Azman.

Vaccines will continue to save lives and help some semblance of normal life to return and energize researchers. But the extent to which the world curtails the pandemic in 2022 and beyond will depend on how quickly it provides access in low-income nations, administers boosters in populations with waning immunity, and provides doses to children – as well as the nature and extent of new variants, such as Omicron.

doi: <https://doi.org/10.1038/d41586-021-03686-x>

## References

---

1. Meslé, M. M. I. *et al. Euro Surveill.* **26**, pii=2101021 (2021).
  2. Chen, Z. *et al.* Preprint at <https://www.medrxiv.org/content/10.1101/2021.10.25.21265504v1> (2021)
  3. Barry, V., *et al. Morbidity and Mortality Weekly Report (MMWR)* **70**, 818–824 (2021).
  4. Wrigley-Field, E. *et al.* Preprint at <https://www.medrxiv.org/content/10.1101/2021.11.19.21266612v1> (2021)
- 

### Latest on:

[Infection](#) Diseases Epidemiology

### Signature of long-lived memory CD8+ T cells in acute SARS-CoV-2 infection

ARTICLE | 07 DEC 21



### Omicron-variant border bans ignore the evidence, say scientists

NEWS | 02 DEC 21



### Victories against AIDS have lessons for COVID-19

WORLD VIEW | 29 NOV 21

---

Nature (*Nature*) | ISSN 1476-4687 (online) | ISSN 0028-0836 (print)

