encourages and incentivizes real-time data sharing by parties who would otherwise be reluctant to share, by ensuring that they retain their rights in their data," says a spokesperson for the initiative.

"This issue is not only about science, but also about sovereignty and equity," says Marie-Paule Kieny, a vaccine researcher at INSERM, the French national health-research institute in Paris. "GISAID empowers the rapid flow of SARS-CoV-2 sequence data with maximal impact," she says, because scientists depositing sequences can trust that their rights will be respected by data users.

Senjuti Saha, a microbiologist who works on SARS-CoV-2 genomes at the Child Health Research Foundation in Dhaka, says that she appreciates the call for open data beyond what GISAID offers, but worries that it might further dissuade researchers in low- and middle-income countries (LMICs) from uploading data until they have analysed them. During the pandemic, she says, some LMICs have started doing more viral sequencing, although labs often lack computational infrastructure. She says that she's seen LMIC coronavirus data taken out of context by academics in wealthier countries who don't consult or credit the data providers. "We really want to share our data, but it is heart-breaking and demotivating when we know we worked so hard to generate data, but we don't get the credit for it," she says.

> **"We really want to share our data, but it is heart-breaking and demotivating when we don't get the credit."**

The letter, says Kieny, "seems to me like an initiative from European and high-income countries not fully informed on the critical need to ensure that low-resource countries accept to share sequences freely, so that the public-health impact of sequencing of pathogens such as SARS-CoV-2 is maximized".

ENA head Guy Cochrane says the EBI is aware of the global issues around data and benefit sharing, and is actively involved in finding benefit-sharing mechanisms that empower countries in the global south and keep data open. But even well-resourced European countries could do more to share their data openly, he says.

Some researchers told *Nature* that besides arguments about equity and openness, there is an issue with GISAID's differential control over how registered users can download its data. Some users must download files in small batches, for instance, but others can get an entire data set in bulk with GISAID approval. The GISAID spokesperson says that's because the initiative needs to know who is using its data and for what reason, so that nothing is erroneously redistributed.

AI MATHS WHIZ CREATES TOUGH NEW PROBLEMS FOR HUMANS TO SOLVE

Algorithm named after Srinivasa Ramanujan suggests formulae, some of which are difficult to prove.

By Davide Castelvecchi

Researchers have built an artificial intelligence (AI) that can generate new mathematical formulae — including some problems that continue to challenge mathematicians.

The Ramanujan Machine is designed to generate new ways of calculating the digits of important mathematical constants, such as π or e, many of which are irrational, meaning that they have an infinite number of non-repeating decimals.

The AI starts with well-known formulae to calculate the digits — the first few thousand digits of π, for example. From those, the algorithm tries to predict a new formula that does the same calculation just as well. The process produces a good guess called a conjecture — it is then up to human mathematicians to prove that the formula can correctly calculate the whole number.

The project team began to make the conjectures public on its website in 2019 (see go.nature.com/3td0ky3), and researchers have since proved several of them correct. But some remain open questions, including one on Apery's constant, which has important applications in physics. "The last result, the most exciting one, no one knows how to prove," says physicist Ido Kaminer, who leads the project at the Technion — Israel Institute of Technology in Haifa. The automated creation of conjectures could point mathematicians towards connections between branches of maths that people did not know existed, he adds.

The project — described in *Nature* on 3 February (G. Raayoni *et al. Nature* **590**, 67–73; 2021) — is named after Srinivasa Ramanujan, an Indian mathematician who was active in the early twentieth century. Ramanujan rarely wrote the types of proof that appear in conventional maths papers. Instead, he filled entire notebooks with formulae that he believed came from a goddess who appeared in his dreams. His work continues to inspire new research long after his death, aged 32, in 1920.

The Ramanujan Machine currently has limited applications: so far, the algorithms can generate only formulae of a particular type, called continued fractions. These express a number as an infinite sequence of fractions nested in each other's denominators.

HISTORIC COLLECTION/ALAMY

Mathematician Srinivasa Ramanujan.

Kaminer's team has experimented with a range of algorithms for finding continued fractions, and applied them to various conceptually important numbers. One of them is Catalan's constant, a number that originated from nineteenth-century Belgian mathematician Eugène Catalan's studies.

Catalan's constant is approximately 0.916, but it is so mysterious that no one has yet worked out whether it is rational — that is, whether it can be expressed as a fraction of two whole numbers. The best that mathematicians have been able to do is prove that its 'irrationality exponent' — a measure of how hard it is to approximate a number using rationals — is at least 0.554. Proving that Catalan's constant is irrational would be equivalent to proving that its irrationality exponent is greater than 1. Formulae generated by the Ramanujan Machine have enabled Kaminer's team to improve slightly on the best human result, bringing the exponent up to 0.567.

"The fact that they have improved the irrationality exponent ... reveals that they are able to make contributions to really hard problems," says George Andrews, a mathematician at Pennsylvania State University in University Park. But the contributions made so far are not of the calibre that using Ramanujan's name would suggest, he says. "Calling this the Ramanujan Machine is over the top."

Kaminer's team plans to broaden the AI's technique so that it can generate other kinds of mathematical formula.