questions in their field 65% of the time. The same scholars, when attempting to answer questions outside their field, scored only 34%, despite having access to the Internet during the test (randomly selecting answers would yield a score of 25%). As of last year, AI systems scored about 30–40%. This year, Rein says, Claude 3 — the latest chatbot released by AI company Anthropic, based in San Francisco, California — scored about 60%. "The rate of progress is pretty shocking to a lot of people, me included," Rein adds. "It's quite difficult to make a benchmark that survives for more than a few years."

Cost of business

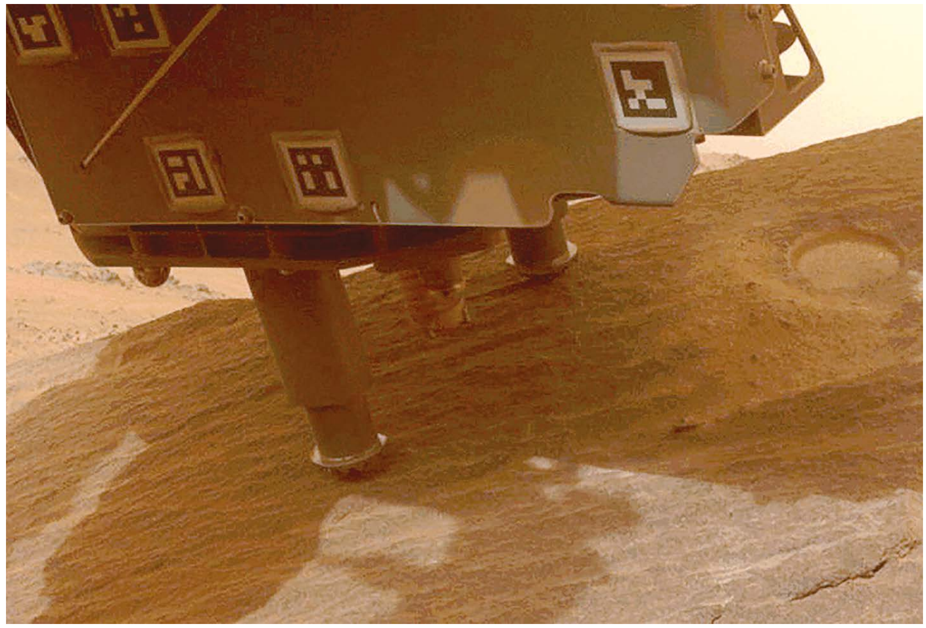
As performance is skyrocketing, so are costs. GPT-4 — the LLM that powers ChatGPT and that was released in March 2023 by San Francisco-based firm OpenAI — reportedly cost US$78 million to train. Google's chatbot Gemini Ultra, launched in December, cost $191 million. Many people are concerned about the energy use of these systems, as well as the amount of water needed to cool the data centres that help to run them (P. Li *et al*. Preprint at arXiv https://doi.org/mr2m; 2023). "These systems are impressive, but they're also very inefficient," Maslej says.

AI models' costs and energy use are high in large part because one of the main ways to make systems better is to make them bigger. This means training them on ever-larger stocks of text and images. The AI Index notes that some researchers now worry about running out of training data. Last year, according to the report, the non-profit research institute Epoch projected that supplies of high-quality language data could be exhausted as soon as this year. (However, the institute's most recent analysis suggests that 2028 is a better estimate.)

Ethical concerns about AI are also mounting. "People are way more nervous about AI than ever before, both in the United States and across the globe," says Maslej, who sees signs of a growing international divide. "There are now some countries very excited about AI, and others that are very pessimistic."

In the United States, the report notes a steep rise in regulatory interest. In 2016, there was just one US regulation that mentioned AI; last year, there were 25. "After 2022, there's a massive spike in the number of AI-related bills that have been proposed" by policymakers, Maslej says.

Regulatory action is increasingly focused on promoting responsible AI use. Although benchmarks are emerging that can score metrics such as an AI tool's truthfulness, bias and even likeability, not everyone is using the same models, Maslej says, which makes cross-comparisons hard. "This is a really important topic," he says. "We need to bring the community together on this."



NASA/JPL-CALTECH

NASA's Perseverance rover uses its robotic arm to drill into a Martian rock.

NASA SEEKS FRESH IDEAS FOR BRINGING MARS ROCKS TO EARTH

The agency's head says the current schedule for delivering samples to Earth is 'unacceptable'.

By Sumeet Kulkarni

NASA announced on 15 April that it is abandoning its long-standing plan for ferrying rock and soil samples from Mars to Earth. Instead, the agency will seek proposals for quicker and cheaper ways to deliver the samples to Earth.

An independent review board concluded last year that NASA's Mars sample return mission could cost as much as US$11 billion, more than the cost of launching the James Webb Space Telescope. In a report released on 15 April, a separate NASA review team concluded that even if the agency spent that much money, the samples would not reach Earth until 2040. NASA had originally sought to drop the samples on Earth in the early 2030s.

The $11-billion price tag is "too expensive", said NASA administrator Bill Nelson at a briefing, and "not returning the samples until 2040 is unacceptable". Nelson said the agency would bring "more than 30" of the 43 planned samples to Earth.

Scaling back

NASA's Perseverance rover has already collected more than 20 rock samples from Jezero Crater, where the rover landed in 2021. Scientists think that the crater was once filled with a lake of water, and samples from the crater and its surroundings could provide a window into the planet's history and, perhaps, evidence of past life on the red planet.

In the agency's original vision, a NASA spacecraft would have flown to Mars carrying a two-part retrieval system: a 2.3-tonne lander — which would have been the heaviest vehicle ever to land there — and a rocket to fly the lander and samples into Martian orbit. There, they were to meet a spacecraft launched by the European Space Agency that would fly the samples to Earth.

Now, NASA plans to solicit proposals from companies as well as NASA centres for a streamlined system, perhaps using a lighter lander, said Nicky Fox, associate administrator for NASA's Science Mission Directorate, at the briefing. The revised mission will be chosen later this year. Fox did not respond directly to questions about when the samples will reach Earth under the new scheme.

NASA recommends spending $200 million of its planetary-science budget for 2025 on assessing alternative architectures for Mars sample return, Fox said. Dedicating any more money to the mission threatened to "cannibalize" other planetary-science missions, Nelson said.

Vicky Hamilton, a planetary scientist at the Southwest Research Institute in Boulder, Colorado, expressed disappointment that almost eight months after the independent review board released its report, the agency still lacks a solid plan for "a very valuable science goal".

Returning these samples would also demonstrate capability for a two-way trip to Mars before astronauts make the journey, says Bethany Ehlmann, a planetary scientist at the California Institute of Technology in Pasadena, California. "The sample-return technology is here, it exists," she says. "It's a matter of putting the pieces together."

Perseverance persists

But scientists were relieved about one announcement: Fox said the revised timeline for sample return will not affect the science goals for Perseverance, including plans for it to explore terrain beyond Jezero Crater.

Among samples collected outside the crater will be "some of the ancient crust of Mars, representing rocks older than we have seen yet in Jezero Crater, some of which may have been altered by near-surface water", says Meenakshi Wadhwa, a planetary scientist at Arizona State University in Tempe and principal scientist for the Mars sample return programme.

So far, the only Mars samples that scientists have been able to study on Earth are bits and pieces ejected from the red planet that made it to Earth as meteorites. All known Martian meteorites are igneous rocks, meaning that they solidified from lava, and all are very old. They provide valuable timestamps for parts of Mars's geological evolution, but carry little information about how the planet's surface was shaped by the water that once flowed across it.

> "The sample-return technology is here, it exists. It's a matter of putting the pieces together."

To achieve the mission's main goal of searching for signs of past life, the real treasures are layered sedimentary rocks formed by minerals and organic matter deposited over the eons by water. Perseverance's instruments have already detected organic molecules in Martian samples, but whether those molecules are a marker of past life can be determined only by closer scrutiny in laboratories on Earth.

SCIENTISTS DISCOVER FIRST ALGAE THAT CAN FIX NITROGEN

Organelle that converts nitrogen gas into a useful form could pave the way for low-fertilizer plants.

By Carissa Wong

Researchers have discovered a type of organelle, a fundamental cellular structure, that can turn nitrogen gas into a form that is useful for cell growth. The discovery of the structure, called a nitroplast, in an algal species could bolster efforts to genetically engineer plants to convert, or 'fix', their own nitrogen, which could boost crop yields and reduce the need for fertilizers. The work was published in *Science* on 11 April[1].

"The textbooks say nitrogen fixation only occurs in bacteria and archaea," says ocean ecologist Jonathan Zehr at the University of California, Santa Cruz, a co-author of the study. This species of algae is the "first nitrogen-fixing eukaryote", he adds, referring to the group of organisms that includes plants and animals.

In 2012, Zehr and his colleagues reported that the marine alga *Braarudosphaera bigelowii* interacted closely with a bacterium called UCYN-A that seemed to live in, or on, the algal cells[2]. The researchers hypothesized that UCYN-A converts nitrogen gas into compounds that the algae use to grow, such as ammonia. In return, the bacteria were thought to gain a carbon-based energy source from the algae.

But in the latest study, Zehr and his colleagues conclude that UCYN-A should be classed as an organelle inside the alga, rather than as a separate organism. According to genetic analysis from a previous study[3], ancestors of the algae and bacteria entered a symbiotic relationship around 100 million years ago, says Zehr. Eventually, this gave rise to the nitroplast organelle, now seen in *B. bigelowii*.

Researchers use two key criteria to decide whether a bacterial cell has become an organelle in a host cell. First, the cell structure in question must be passed down through generations of the host cell. Second, the structure must be reliant on proteins provided by the host cell.

By imaging dozens of algal cells at various stages of cell division, the team found that the nitroplast splits in two just before the whole algal cell divides. In this way, one nitroplast is passed down from the parent cell to its offspring, as happens with other cell structures.

Next, the researchers found that the nitroplast gets the proteins it needs to grow from the wider algal cell. The nitroplast itself – which makes up more than 8% of the volume of each host cell – lacks key proteins required for photosynthesis and making genetic material, says Zehr. "A lot of these proteins [from the alga] are just filling those gaps in metabolism," he says.

The discovery was made possible thanks to work by study author Kyoko Hagino at Kochi University in Japan, who spent around a decade fine-tuning a way to grow the alga in the laboratory – which allowed it to be studied in more detail, says Zehr.

"It's quite remarkable," says Siv Andersson, who studies how organelles evolve at Uppsala University in Sweden. "They really see all these hallmarks that we think are characteristic of organelles."

Upgraded plants

Understanding how the nitroplast interacts with its host cell could support efforts to engineer crops that can fix their own nitrogen, says Zehr. This would reduce the need for nitrogen-based fertilizers and avoid some of the environmental damage they cause. "The tricks that are involved in making this system work could be used in engineering land plants," he says.

"Crop yields are majorly limited by availability of nitrogen," says Eva Nowack, who studies symbiotic bacteria at the Heinrich Heine University Düsseldorf in Germany. "Having a nitrogen-fixing organelle in a crop plant would be, of course, fantastic." But introducing this ability into plants will be no easy feat, she warns. Plant cells containing the genetic code for the nitroplast would need to be engineered in such a way that the genes are transferred stably from generation to generation, for example. "That would be the most difficult thing to do," she says.

"It's both a pleasure and very impressive to see this work build up to what is certainly a major stepping stone in understanding," says Jeffrey Elhai, a cell biologist at Virginia Commonwealth University in Richmond.

1. T. H. Coale *et al. Science* **384**, 217–222 (2024).
2. A. W. Thompson *et al. Science* **337**, 1546–1550 (2012).
3. Cornejo-Castillo, F. *et al. Nature Commun.* **7**, 11071 (2016).