Critics weigh in on arsenic life

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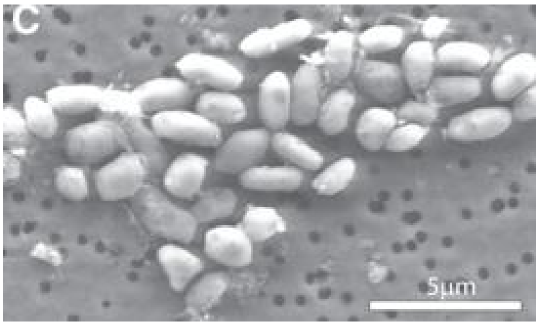
Field needs independent experiments to prove or disprove the work, researchers say.



Scanning electron micrograph of bacterium strain GFAJ-1.Science/AAAS

Nearly six months after its publication in Science[1], the controversial suggestion that a newly discovered bacterium survives by incorporating arsenic atoms into its DNA and other biomolecules is today facing a volley of terse critiques[2–9].

Many of the criticisms had previously been aired on blogs and in other publications. The arsenic paper's authors, led by Felisa Wolfe-Simon of the NASA Astrobiology Institute and the US Geological Survey in Menlo Park, California, defend their work in a technical response[10] issued alongside the critiques. The team says it will distribute samples of the bacterium, GFAJ-1, so that other researchers can attempt to replicate their work. The question now is whether independent researchers will take up that offer and put to the test the overwhelming sense that the study suffers from flaws that undermine its conclusions.

Some of the critics were frustrated that Wolfe-Simon and her colleagues did not release any new data in their response, noting that there had been ample time for them to bolster their case with new data.

"I'm tired of rehashing these preliminary data," says John Helmann of Cornell University in Ithaca, New York, who critiqued the work in January on the Faculty of 1000 website. "I look forward to the time when they or others in the field start doing the sort of rigorous experiments that need to be done to test this hypothesis."

The controversy first erupted in December, when NASA's press office issued a cryptic news release regarding an "astrobiology finding that will impact the search for evidence of extraterrestrial life". Once the Science paper was published, it quickly became apparent that, if true, the finding was astonishing. It implied that the bacterium had evolved to incorporate the usually toxic arsenic into its genetic backbone, possibly suggesting a broader range of molecular building blocks for life on Earth and beyond.

But the work was quickly attacked by researchers, both for not living up to NASA's billing about relevance to extraterrestrial life, and for being marred by technical shortcomings.

"I have not found anybody outside of [Wolfe-Simon's] laboratory who supports the work," says Barry Rosen of Florida International University in Miami, who published a critique of the work[11] in BioEssays in March.

A dearth of believers

Wolfe-Simon has previously defended her work both on her website, and in the pages of the women's magazine Glamour , where she dispensed her "four laws of getting people to believe in you".

"We maintain that our interpretation of As [arsenic] substitution, based on multiple congruent lines of evidence, is viable," she and her colleagues write today[10].

Felisa Wolfe-Simon collects a sample from 10 Mile Beach at Mono Lake, California.H. Bortman

In their original study[1], Wolfe-Simon and her team analysed bacteria taken from Mono Lake in southern California. The bacteria were grown in the lab on a medium that, the authors said, contained arsenic but no phosphorus — the core constituent of the DNA double helix. The team found that the bacteria reproduced and integrated arsenic into their DNA.

The critiques attack multiple parts of the work. Several allege that the growth medium contained trace amounts of phosphorus — enough to support a few rounds of bacterial growth[3–7]. Others say that the evidence purporting to show that arsenic integrated into the bacterium's DNA is flawed because the DNA was not properly purified[5].

One of the papers[2] asserts that Wolfe-Simon and her team used flawed methods to calculate the ratios of arsenic and phosphorus in their growth media. Many of the authors also say that there are alternative explanations for the fact that the bacteria could grow on a medium containing little or no phosphorus, such as the possibility that the medium selected for arsenic-tolerant bacteria that out-competed the non-tolerant microbes[5].

Some criticisms of the work come from within the same agencies that employ the authors; four of the authors of one critique are based at NASA's Jet Propulsion Laboratory, managed by the California Institute of Technology in Pasadena. "GFAJ-1 appears to do all it can to harvest P [phosphorus] atoms from the medium while drowning in As," they write[3]. "This suggests that GFAJ-1 is an extraordinary extremophile but does not support the more exceptional claim that As replaces the functions of P in this organism."

In search of follow-up

Steven Benner of the Foundation for Applied Molecular Evolution in Gainesville, Florida, suggests a series of follow-up experiments that could provide more solid evidence that arsenic has incorporated into the bacterium's DNA[4].

If GFAJ-1 is indeed utilizing arsenic as Wolfe-Simon and her co-authors suggest, Benner writes, the result would "set aside nearly a century of chemical data concerning arsenate and phosphate molecules". Benner cautions that inconsistent results should not be "discarded out of hand", although he criticizes the paper for not fully taking into account how much existing science would need to be rewritten to accommodate its extraordinary claim.

Rosemary Redfield of the University of British Columbia in Vancouver, Canada, who previously critiqued the arsenic paper on her blog and who wrote one of the commentaries published today[5], says that proving or disproving the work would be easy. She says it would be "relatively straightforward" to grow the bacteria in arsenic-containing media and to analyse them using mass spectrometry to test whether arsenic is covalently bonded into their DNA backbone.

"The important thing to do is what the authors didn't do, which is meticulously clean up the DNA first," Redfield says.

She adds that she will probably obtain samples of GFAJ-1 and is considering performing the follow-up tests she describes. She is also interested in getting a group of five of six laboratories to repeat the experiments independently and publish their results together.

However, most labs seem too busy to spend time replicating work that they feel is fundamentally flawed and is not likely to be published in high-impact journals. So principal investigators are reluctant to spend their resources, and their students' time, replicating the work.

"If you extended the results to show there is no detectable arsenic, where could you publish that?" asks Simon Silver of the University of Illinois at Chicago, who critiqued the work in FEMS Microbiology Letters[12] in January and on 24 May at the annual meeting of the American Society for Microbiology in New Orleans. "How could the young person who was asked to do that work ever get a job?"

Refuting another scientist's work also takes time that scientists could be spending on their own research. For instance, Helmann says he is installing a highly sensitive mass spectrometer that can measure trace amounts of elements. But, he says, "I've got my own science to do".

Helmann also points out that the bacterium is not yet available through cell repositories, and that researchers may be reluctant to sign the materials transfer agreement required to obtain it from the authors.

He and other researchers add that the response released by Wolfe-Simon and her team suggests that they are reluctant to accept that there may be alternative explanations for the phenomenon they observed.

"With so many mistakes pointed out, there should be at least some where the authors say, 'you're right, we should have done that but we didn't'," Redfield says. "This as an entirely a 'we were right' response, and that's a bad sign in science."

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