Bacteria that consumes arsenic boosts search for “alien” life

By Chris Talbot
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A type of bacteria has been discovered in Mono Lake, California that transforms current understanding of how life can function [1]. All life on earth was thought to use six basic elements—carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus—together with trace quantities of other elements, mainly metals, that assist particular chemical processes in the cell.

The newly discovered bacteria, GFAJ-1, which belongs to a group of common bacteria called Gammaproteobacteria, has been shown to use arsenic instead of phosphorus in cell processes. Arsenic, though similar chemically to phosphorus, is usually extremely poisonous to all life.

The idea that a bacteria could be found that uses arsenic instead of phosphorus was put forward four years ago by Felisa Wolfe-Simon, then a post-doctoral researcher at Arizona State University. She persuaded the internationally known scientist Paul Davies to back her hypothesis and obtained a temporary post with the US Geological Survey in California. With backing from NASA, she worked with Ronald Oremland, an international expert in arsenic microbiology, sifting through the sediment of Mono Lake.

Davies told the BBC, “At the moment we have no idea if life is just a freak, bizarre accident which is confined to Earth or whether it is a natural part of a fundamentally biofriendly universe in which life pops up wherever there are Earth-like conditions.” According to Davies there is no evidence for the latter view, but he added, “If that is the case, then life should've started many times on Earth. So perhaps there's a 'shadow biosphere' all around us and we've overlooked it because it doesn't look terribly remarkable.”

This would mean finding life-forms that have evolved separately from our own DNA-based lineage. The bacteria that use arsenic do not come into that category as they are an adaptation of our usual form of biology. Nevertheless, the fact that such unusual chemistry can function in living matter does support the view that life could exist on other planets with radically different biochemistry to ours.

Davies is a coauthor of a research paper published in *Science*, along with a team that includes Wolfe-Simon, Oremland and Professor Ariel D. Anbar, an astrobiologist who is at Arizona State with Paul Davies.

“Life as we know it requires particular chemical elements and excludes others,” said Anbar. “But are those the only options? How different could life be?” He continued: “One of the guiding principles in the search for life on other planets, and of our astrobiology program, is that we should 'follow the elements.' Felisa's study teaches us that we ought to think harder about which elements to follow.”

The *Science* paper gives detailed experimental results showing that “Growth [of GFAAJ-1] was accompanied by arsenic uptake and assimilation into biochemical molecules, including nucleic acids, proteins and metabolites.”

In recent years the search for extraterrestrial life has received a boost from several directions. In biology there have been discoveries of a wide variety of “extremophiles,” microbes that can exist in apparently inhospitable places such deep in the ocean close to volcanic vents, and also in ice, boiling water, acid, and even the water core of nuclear reactors. They can thrive with no sunlight and instead of plants for food can, for example, use oxidation of hydrogen or hydrogen sulphide as an energy source. Then there is the possibility that life could exist or at least once existed on Mars—where water, believed to be essential for cellular life, is now known to exist—or on a moon of Jupiter, Europa, or perhaps on Saturn's moon Titan.

Many studies have revealed the existence of extrasolar planets, with the total of confirmed cases now over 500. Most are giants, similar to Jupiter, but an increasing number with a mass only several times that of the earth have now been found.

Even more persuasive evidence that life exists elsewhere is the recent discovery made with the Keck Observatory in Hawaii that the number of red dwarf stars is much higher than previously thought [3]. Estimates of the number of stars in the universe have tripled, and the large number of red dwarfs, in particular, supports the possibility of life-bearing planets. These stars, small and dim compared to our Sun, are difficult to detect with a telescope. They survive for billions

of years, giving enough time for life to evolve on planets circling them. A recently discovered earth-type exoplanet called Gliese 581 orbits a red dwarf star.

Discoveries such as these have now tilted the balance in favour of a conviction that “alien” life exists. It is true that microbes may appear dull compared to intelligent life, but evolution could then be expected to take over.

Research in this direction received a blow when public funding for SETI (Search for Extraterrestrial Intelligence) was ended. Seth Shostak, senior astronomer at the now privatised SETI Institute in California, said of the recent discoveries, “All of these have gone in the direction of encouraging life out there and they didn't have to.” He said that given the mounting evidence, to believe now that Earth is the only place harbouring life is essentially like believing in miracles, “And astronomers tend not to believe in miracles.”

It is certainly a move away from the “Rare Earth” hypothesis that was put forward a decade ago in a book by Peter Ward, a geologist and paleontologist, and Donald E. Brownlee, an astronomer and astrobiologist [4]. They attempted to refute any possibility of life outside the earth, citing the peculiarities of the earth's atmosphere and geology as support for life that would not be replicated elsewhere and opposing the position of SETI enthusiasts such as Carl Sagan and Frank Drake.

Research in astrobiology has since received a further battering by government spending cuts. Cuts made by the Bush government to NASA's funding led to a 50 percent cut in astrobiology over the two years from 2005 to 2007. An anonymous researcher at the time told *ScienceCareers* that astrobiology is “dead in the water” telling her students not to “go into anything related to NASA because its too difficult and unstable.” Needless to say the Bush cuts were not restored by the Obama administration.

In an article in the *Wall Street Journal* Paul Davies pays tribute to Felisa Wolfe-Simon for continuing her research with such determination and enthusiasm despite the adverse conditions. He points out that the title given to the arsenic-loving microbe GFAJ, actually stands for “Give Felisa a Job.” He adds that with the recent publicity surrounding her discovery, he has little doubt that someone will give her a job.

An attack has been mounted on the Mono Lake discovery in the somewhat unlikely pages of the online publication *Slate*. Science correspondent Carl Zimmer has pieced together an article entitled, “This paper should not have been published,” with critical comments from a number of other scientists in the field of microbiology. They assert that there are flaws in the methodology used by the NASA team. Oremland and Wolfe-Simon would not enter a debate or respond to criticisms when prompted by Zimmer.

Oremland declared, “If we are wrong, then other scientists should be motivated to reproduce our findings. If we are right (and I am strongly convinced that we are) our competitors will agree and help to advance our understanding of this phenomenon. I am eager for them to do so.” Wolfe-Simon wrote, “Any discourse will have to be peer-reviewed in the same manner as our paper was, and go through a vetting process so that all discussion is properly moderated.”

Why is *Slate* so concerned over the integrity of this research in astrobiology? It seems that Zimmer's real target is NASA. He asks why “NASA made such a big deal over a paper with so many flaws” and quotes a scientist claiming that NASA is “desperate for a positive story.” He points to the case in 1996 when NASA announced it had found fossils in a meteorite from Mars. Because only a small number of tests can be made on the few fossils found, the results were never conclusive and controversy surrounded the case.

Zimmer admits that this time there is plenty of evidence and that NASA has said it will be made available for other scientists to study. *Slate* is surely aware that, as in 1996, attacks on NASA's competence will be used to justify further cuts.

Notes:

[1] http://science.nasa.gov/science-news/science-at-nasa/2010/02dec_monolake/

[2] http://www.sciencemag.org/content/early/2010/12/01/science.1197258

[3] http://www.sciencedaily.com/releases/2010/12/101201134158.htm

[4] Rare Earth: Why Complex Life Is Uncommon in the Universe, by Peter Ward and Donald Brownlee, Springer, 2000.