

New research shows how bacterium in Mono Lake survive high arsenic concentrations

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(Phys.org)—A team of Israeli, French and Swiss biologists have discovered how a strain of the bacterium *Halomonas* known as GFAJ-1, manages to survive in California's Mono Lake despite arsenic levels that would kill most other living things. As explained in their article, published in the journal *Nature*, this phenomenon is due to the differences in the ion bonding angle between proteins in the bacteria and arsenate as compared to phosphate, which results in weaker bonding with the arsenate and a preference for phosphate.

This new research essentially puts an end to arguments, put forth by a paper published two years ago in the [journal Science](#), that the [bacterium](#) was somehow able to replace phosphorus in its DNA with arsenic, making it the only known form of life able survive without the six [basic elements](#): hydrogen, oxygen, nitrogen, phosphorus, sulfur and carbon.

To find out how GFAJ-1 is able to survive in such a [toxic environment](#), the research team studied four types of bacteria, including GFAJ-1, specifically focusing on the bacteria's phosphate-[binding proteins](#). Two of the bacteria types were resistant to arsenate (a combination of oxygen and arsenic), while the other two were sensitive to it. All four bacteria were placed in containers with identical amounts of phosphate, but differing amounts of arsenic, and allowed to sit for a full day. The researchers wanted to see how adept the bacteria were at differentiating between the two.

All five sample types were then examined to see how much of the

arsenic managed to bind to the proteins: the researchers found that all five showed a preference to binding with phosphate. One bacterium in particular, GFAJ-1, displayed a 4,500-fold preference.

To better understand why the proteins bound more easily to the phosphate, the team took an even closer look and found that it all came down to the slightly different shapes of the phosphate and arsenate ions, which created a difference in the bonding angles with the proteins. The phosphate angles are closer to the optimal 180 degrees than the arsenate, allowing them to bond more easily. Thus, GFAJ-1's tendency to let phosphate in, while keeping arsenic out, is explained.

More information: The molecular basis of phosphate discrimination in arsenate-rich environments, *Nature* (2012) [doi:10.1038/nature11517](https://doi.org/10.1038/nature11517)

Abstract

Arsenate and phosphate are abundant on Earth and have striking similarities: nearly identical pKa values^{1, 2}, similarly charged oxygen atoms, and thermochemical radii that differ by only 4% (ref. 3). Phosphate is indispensable and arsenate is toxic, but this extensive similarity raises the question whether arsenate may substitute for phosphate in certain niches^{4, 5}. However, whether it is used or excluded, discriminating phosphate from arsenate is a paramount challenge. Enzymes that utilize phosphate, for example, have the same binding mode and kinetic parameters as arsenate, and the latter's presence therefore decouples metabolism^{6, 7}. Can proteins discriminate between these two anions, and how would they do so? In particular, cellular phosphate uptake systems face a challenge in arsenate-rich environments. Here we describe a molecular mechanism for this process. We examined the periplasmic phosphate-binding proteins (PBPs) of the ABC-type transport system that mediates phosphate uptake into bacterial cells, including two PBPs from the arsenate-rich Mono Lake *Halomonas* strain GFAJ-1. All PBPs tested are capable of discriminating phosphate

over arsenate at least 500-fold. The exception is one of the PBPs of GFAJ-1 that shows roughly 4,500-fold discrimination and its gene is highly expressed under phosphate-limiting conditions. Sub-ångström-resolution structures of *Pseudomonas fluorescens* PBP with both arsenate and phosphate show a unique mode of binding that mediates discrimination. An extensive network of dipole–anion interactions^{8, 9}, and of repulsive interactions, results in the 4% larger arsenate distorting a unique low-barrier hydrogen bond. These features enable the phosphate transport system to bind phosphate selectively over arsenate (at least 103 excess) even in highly arsenate-rich environments.

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