Adam Wespiser

Blog Assignment

Title: Arsenic Based Life? Not so fast say Princeton researchers

Few can recall an event with greater implications on our collective notion of life than the announcement that GFAJ-1 bacteria living in Mono Lake California can incorporate arsenic into the backbone of their DNA. The discovery published by Felisa Wolfe-Simon (FWS) in Science magazine in December 2010, received coverage from many major news organizations. Although much of the media regaled her discovery as a paradigm shift in the definition of life, vocal researchers posted blog articles with serious concerns about her methods and conclusion. Despite the uncertainty, FWS's claims could not be confirmed or refuted without data from independent experiments. Eventually, a handful of papers would call into question FWS’s most basic conclusion: that GFAJ-1 is capable of incorporating Arsenic into the backbone of its DNA. This blog entry will discuss the context of FWS’s initial discovery, and describe the methods employed by Marshal to refute her major conclusions.

FWS released her findings via press conference before the paper was made available by Science magazine. Instead of forming opinions from the technical findings, media outlets used only a handful of statements to create their stories. This lead to many articles with exaggerated the claims, and may have contributed the backlash from scientists uncomfortable with the unjustified and bold claims of the paper. As a result of the initial and continued criticism, FWS was removed from her laboratory [0] and has sought positions at other universities. This is an extremely disappointing consequence. Although it is easy to blame FWS for what happened to her, her story reveals the shortcomings of the peer-review process and scientific publishing, the desire of the science media to exaggerate major results, and an unprecedented outcry from the scientific community that, at times, seemed unfit for professional scholars.

To understand how FWS was let down, we must recognize that a key tenet of academic publishing is that every scientific paper must undergo unbiased peer-review by a panel of recognized scientists and experts. Facilitated by the publishing journal, this criticism serves two purposes: to further strengthen good research for publication, and to prevent the publication of bad work. FWS's submission spanned multiple fields: microbiology, molecular biology and physical chemistry, and received positive comments from the reviewers not indicative of the widespread criticism to come.[1] This failure to provide FWS with adequate critics, on the part of Science magazine, robbed FWS of a chance to respond to the criticism before the paper was published.

The technical evaluation of FWS's work has taken months to complete, and with it comes the validation for many of FWS's harshest critics, and possibly the dismissal of her findings. The work by Marshal and co-workers undertaken at Yale University and also published in Science magazine, follows up on FWS's original claims that the extremophile bacteria, GFAJ-1, incorporates arsenic into its biomolecules instead of phosphorus, and growth of GFAJ-1 in conditions of no phosphate and high arsenic is evidence that biomolecules are able to use arsenic over phosphorous.

Marshal and co-workers demonstrate that FWS's experiment, GFAJ-1 grown on arsenic rich and phosphorous poor conditions, is not valid. In the original experiment, FWS detected low levels of phosphorous, possibly from contamination or impure chemicals. For most organisms, this level of phosphorous is too low to support life and the addition of arsenic would be valid to test if arsenic can be used in place of phosphorous. However, the environment of Mono Lake is extreme enough to host life forms capable of thriving in adverse conditions. Marshal and co-workers demonstrated that GFAJ-1 can grow at these low levels of phosphorous, which contradicts FWS's claim that this was only possible by the incorporation of arsenic into the DNA backbone instead of phosphorous. Further, Marshal and co-workers never observed a scenario where the addition of arsenic to low phosphate conditions resulted in growth of GFAJ-1. This evidence contradicts the initial experiments and the justification used by FWS to claim that arsenic is essential for growth in this organism. However, the non-essential incorporation of arsenic into other biomolecules cannot yet be ruled out.

If GFAJ-1 incorporates arsenic into the backbone of its DNA, then it should degrade much quicker than regular DNA, which has a more stable phosphorous backbone. Marshal and co-workers grew GFAJ-1 under the same conditions as FWS, then waited two months to see if DNA extracted from GFAJ-1 grown in arsenic conditions degraded. It did not. Despite the simplicity of the experiment, it is perhaps the most straightforward way of testing whether DNA has an arsenic backbone, and the results of this experiment should be weighed heavily.

To test the incorporation of arsenic into to other biomolecules besides DNA, Marshal and co-workers separated out small molecules from GFAJ-1 bacteria grown in arsenic conditions and looked for the presence of arsenic bound to biomolecules. They did find arsenic incorporated, although at a rate fifty times lower than what was reported by FWS. This suggests that arsenic may be incorporated at low levels, but that incorporation does not negatively affect the bacteria. When they repeated the same experiment and separated out DNA, they did not find any arsenic incorporated into DNA’s backbone. This is consistent with their early work, and directly conflicts with FWS's claim that arsenic incorporates into DNA. Yet, the finding of bound arsenic suggests some mechanism interacting with arsenic, possibly related to the mechanism that allows GFAJ-1 to grow in very high arsenic conditions.

There are many valuable lessons to be learned from this research and it’s subsequent publication. The first is that research findings should be published along with their data in scientific periodicals, rather than through a press conference designed to produce hype and media attention. I cannot help but be reminded of the quote “extraordinary claims require extraordinary evidence”, popularized by Carl Sagan. FWS had a fundamental result that would change how we view life on earth and elsewhere in the universe. She profoundly failed to provide evidence beyond any reasonable doubt, and instead gave the media what they wanted to hear, a great news story with significant findings. Unfortunately, her career may be over before the surely interesting science of GFAJ-1 and arsenic is figured out.

References

[0] <http://www.popsci.com/science/article/2011-09/scientist-strange-land>

[1] <http://www.documentcloud.org/documents/564124-foia2012-nasa-01-dvergano.html>

Marshal L R, “Absence of detectable arsenate in DNA from arsenate-grown GFAJ-1 cells”. 2012. Science. Volume 337. Issue 609. <http://arxiv.org/pdf/1201.6643v2.pdf>