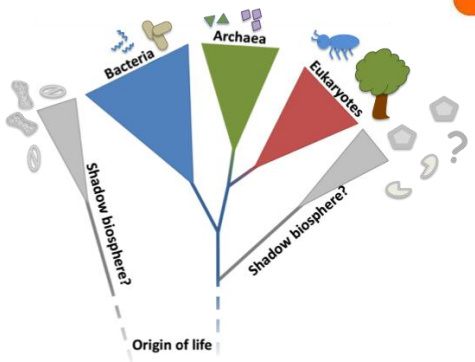
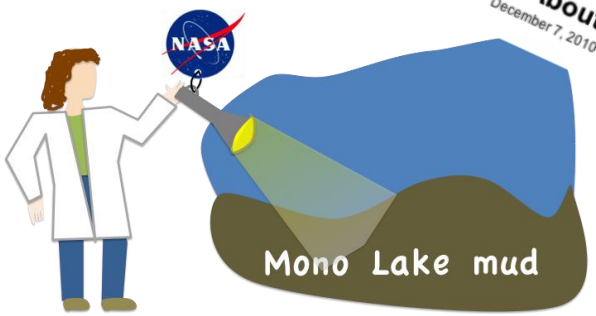
#aseniclife, social media and open science

Rosie Redfield

Dept. of Zoology, UBC

#evol2012
#aseniclife





NASA Sets News Conference on Astrobiology Discovery; Science Journal Has Embargoed Details Until 2 p.m. EST On Dec. 2

WASHINGTON -- NASA will hold a news conference at 2 p.m. EST on Thursday, Dec. 2, to discuss an astrobiology finding that will impact the search for evidence of extraterrestrial life.

The news conference will be held at the NASA Headquarters auditorium at 300 E St. SW, in Washington. It will be broadcast live on NASA Television and streamed on the agency's website at http://www.nasa.gov.

Participants are:

- Mary Voytek, director, Astrobiology Program, NASA Headquarters, Washington
- Felisa Wolfe-Simon, NASA astrobiology research fellow, U.S. Geological Survey, Menlo Park, Calif.
- Pamela Conrad, astrobiologist, NASA's Goddard Space Flight Center, Greenbelt, Md.
- Steven Benner, distinguished fellow, Foundation for Applied Molecular Evolution, Gainesville, Fla.
- James Elser, professor, Arizona State University, Tempe

Media representatives may attend the conference or ask questions by phone or from participating NASA locations. To obtain dial-in information, journalists must send their name, affiliation and telephone number to Steve Cole at stephen.e.cole@nasa.gov or call 202-358-0918 by noon Dec. 2.

Twitter response:

> [News] NASA Sets News Conference on Astrobiology Discovery: NASA will hold a news conference at 2 p.m. EST http://go.nasa.gov/gihgV4
>
> NASA 

> Close Encounters of the Media Kind—NASA press release leads to wild speculation about alien discovery: http://bit
>
> CJR 

> Greetings, Earthlings. Sorry to make you wait to talk NASA, but... http://bit.ly/gRLCLO
>
> ivanoransky 

> I'm sad to quell some of the @kottke-induced excitement about possible extraterrestrial life. I've seen the Science paper. It's not that.
>
> alexismadrigal 

> NASA's Hyped-Up Alien Life Press Conference Likely Just About Arsenic Biology http://bit.ly/gW6c8T
>
> astrobiology 

Sciencexpress Research Article

A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus

Felisa Wolfe-Simon,[1,2*] Jodi Switzer Blum,[2] Thomas R. Kulp,[2] Gwyneth W. Gordon,[3] Shelley E. Hoeft,[2] Jennifer Pett-Ridge,[4] John F. Stolz,[5] Samuel M. Webb,[6] Peter K. Weber,[4] Paul C. W. Davies,[1,7] Ariel D. Anbar,[1,3,8] Ronald S. Oremland[2]

[1]NASA Astrobiology Institute, USA. [2]U.S. Geological Survey, Menlo Park, CA, USA. [3]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA. [4]Lawrence Livermore National Laboratory, Livermore, CA, USA. [5]Department of Biological Sciences, Duquesne University, Pittsburgh, PA, USA. [6]Stanford Synchrotron Radiation Lightsource, Menlo Park, CA, USA. [7]BEYOND: Center for Fundamental Concepts in Science, Arizona State University, Tempe, AZ, USA. [8]Department o niversity, Tempe, AZ, USA.

Life is mostly composed of the elements carbon, hydrogen, nitrogen, oxygen, sulfur and phosphorus. Although these six elements make up nucleic acids, proteins and lipids and thus the bulk of living matter, it is theoretically possible that some other elements in the periodic table could serve the same functions. Here we describe a bacterium, strain GFAJ-1 of the Halomonadaceae, isolated from Mono Lake, CA, which substitutes arsenic for phosphorus to sustain its growth. Our data show evidence for arsenate in macromolecules that normally contain phosphate, most notably nucleic acids and proteins. Exchange of one of the major bio-elements may have profound evolutionary and geochemical significance.

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NASA Discovers New Life! Arsenic

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'Weird life': Clue to ali after scientists discov bacteria that can live

By FIONA MACRAE
Last updated at 8:33 AM on 3rd December 2010

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NASA has discovered alien life – but it is right here on Earth.

The announcement, at a press conference at the space agenc frenetic speculation that it was about to reveal the existence o

While the truth – an 'alien' bacterium lurking deep within a Cali markedly raises the odds of ET's existence.

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December 2, 2010 / Posted by: Aaron Gronstal

Geomicrobiologist Felisa Wolfe-Simon, collecting lake-bottom sediments in the shallow Mono Lake in California. Wolfe-Simon cultured the arsenic-utilizing organisms from this

THE Sun
Thursday, 23 December 2010

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NEWS

NASA Life Discovery: New Bacteria Makes DNA With A

EXCLUSIVE

It's life, but not as we know it

By PAUL SUTHERLAND, Sun Spaceman
Published: 01 Dec 2010

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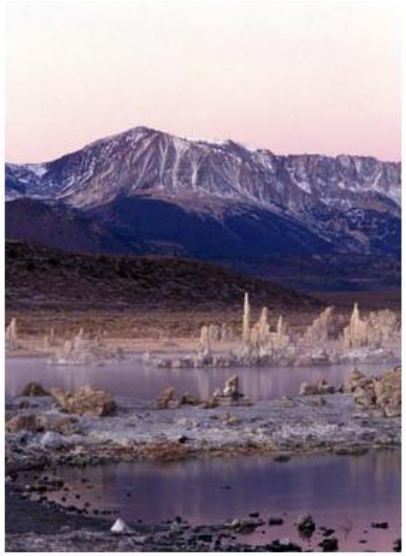
HOPE of finding ET-style life on other worlds has got a massive boost after scientists discovered microbes in a deadly poisonous ARSENIC lake.



Toxic ... but there's life in California lake

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2010 → Discovery of "Arsenic-bug" Expands ... finition of Life

Discovery of "Arsenic-bug" Expands Definition of Life

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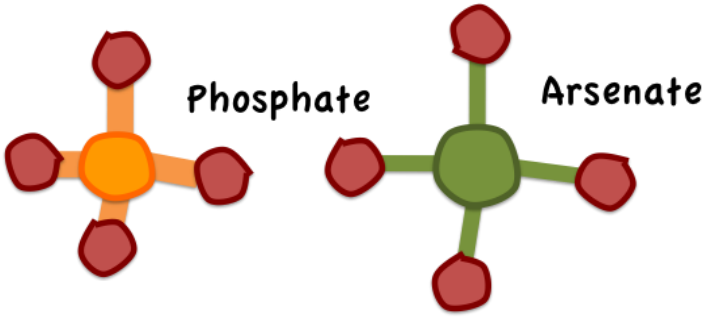
Dec. 2, 2010: NASA-supported researchers have discovered the first known microorganism on E and reproduce using the toxic chemical arsenic. The microorganism, which lives in California's Mo substitutes arsenic for phosphorus in the backbone of its DNA and other cellular components.

"The definition of life has just expanded," said Ed Weiler, NASA's associate administrator for the Science Mission Directorate at the agency's Headquarters in Washington. "As we pursue our efforts to seek signs of life in the solar system, we have to think more broadly, more diversely and consider life as we do not know it."

What were the researchers looking for?

A form of life that uses arsenic in place of phosphorus.



Why was NASA funding them?

Their Astrobiology Program wants to understand how life can originate and what
forms it can take.

International Journal of Astrobiology 8 (2): 69–74 (2009) Printed in the United Kingdom
doi:10.1017/S1473550408004394

Did nature also choose arsenic?

Felisa Wolfe-Simon[1]*, Paul C.W. Davies[2] and Ariel D. Anbar[1,3]

[1]*Metallomics Laboratory, Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ 85287, USA*
[2]*BEYOND: Center for Fundamental Concepts in Science, Arizona State University, Tempe, AZ 85287, USA*
[3]*School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA*
e-mail: wolfe@eps.harvard.edu

All known life requires phosphorus

Arsenic is chemically similar.

he form

phosphate-containing organic molecules. P_i serves as the backbone of the nucleic acids that constitute genetic material and as the major repository of chemical energy for metabolism in polyphosphate bonds. Arsenic (As) lies d

chemical properties, alth

We hypothesize that ancient biochemical systems...

could have used arsenate in the equivalent biochemical role.

sms attempt

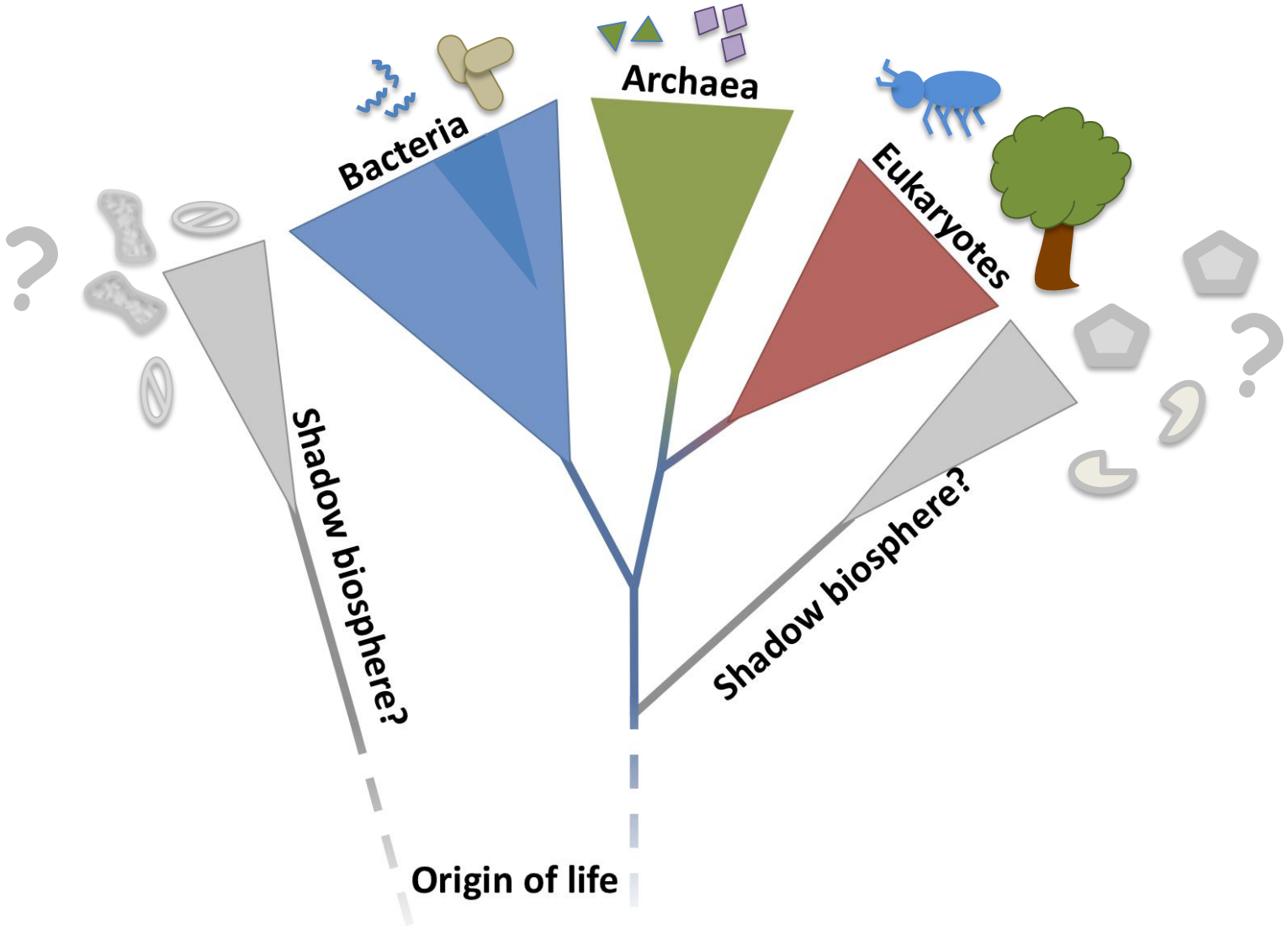
t from those known today, could have utilized arsenate in the equivalent biological role as phosphate. Organisms utilizing such 'weird life' biochemical pathways may have supported a 'shadow

Such organisms

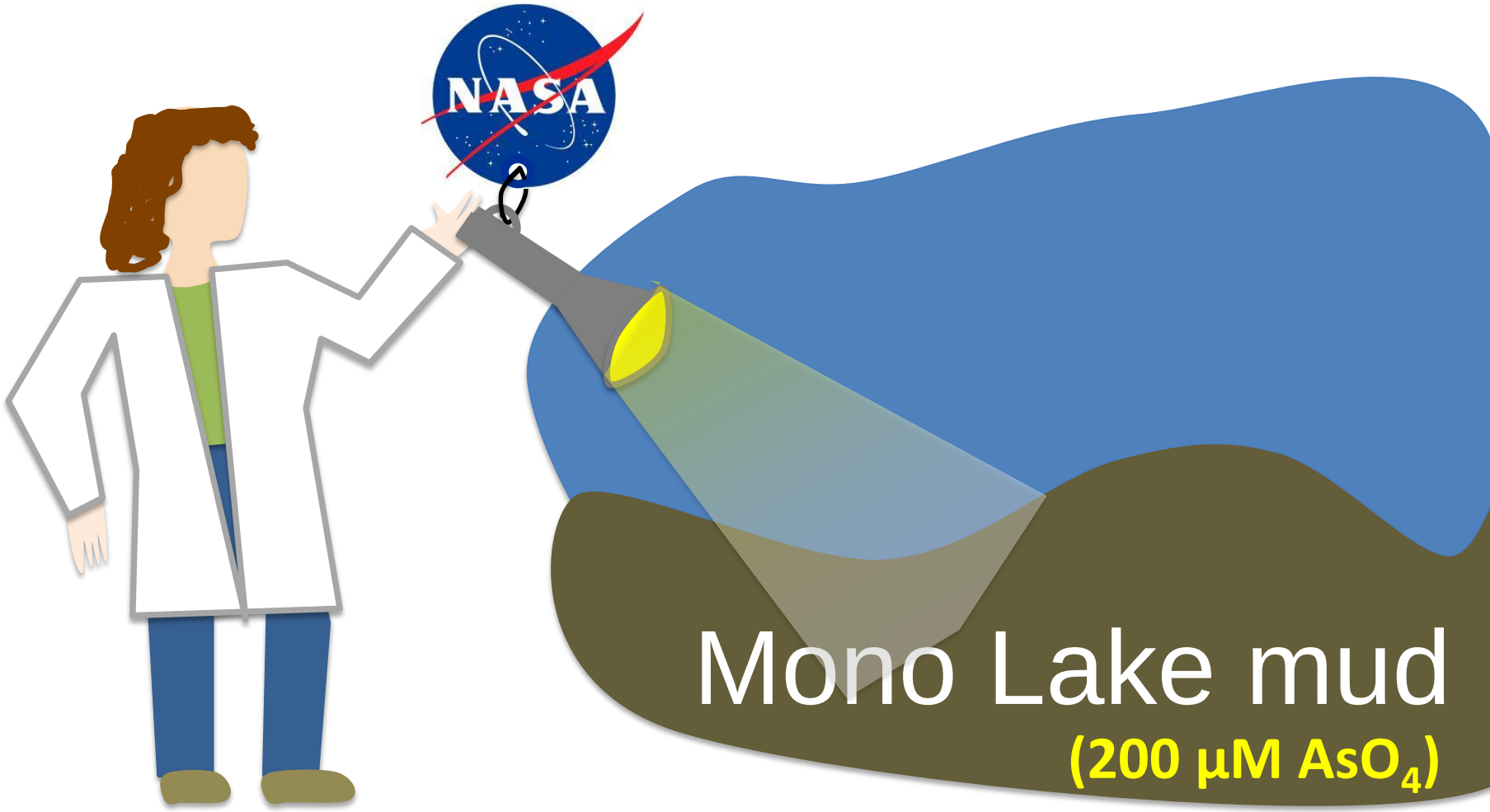
may even persist on Earth today, undetected, in unusual niches.

Received 16 July 2008, accepted 26 September 2008, first published online 30 January 2009

The Shadow Biosphere

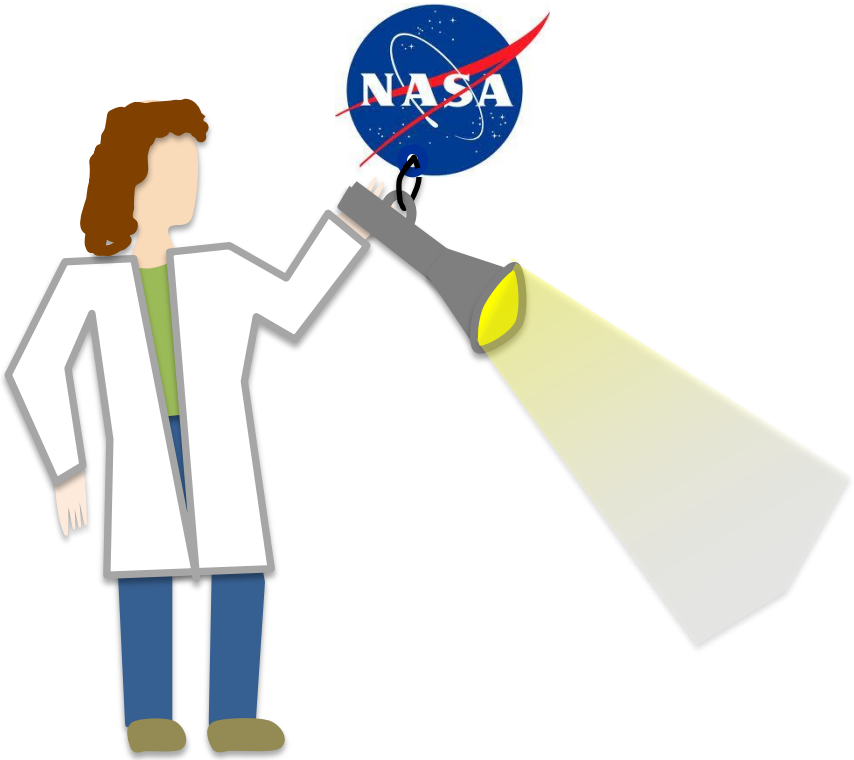


NASA gave Wolfe-Simon a fellowship to search for arsenic-using members of the Shadow Biosphere

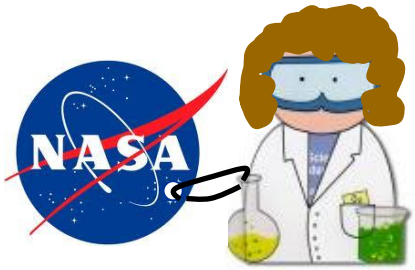


She added Mono Lake sediment to a culture medium containing AsO_4 rather than PO_4.

Cells eventually grew, even in 40 mM AsO_4.


NASA


NASA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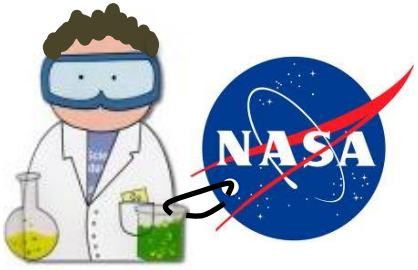
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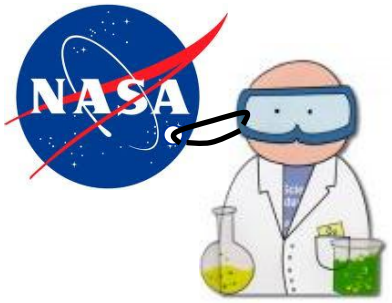
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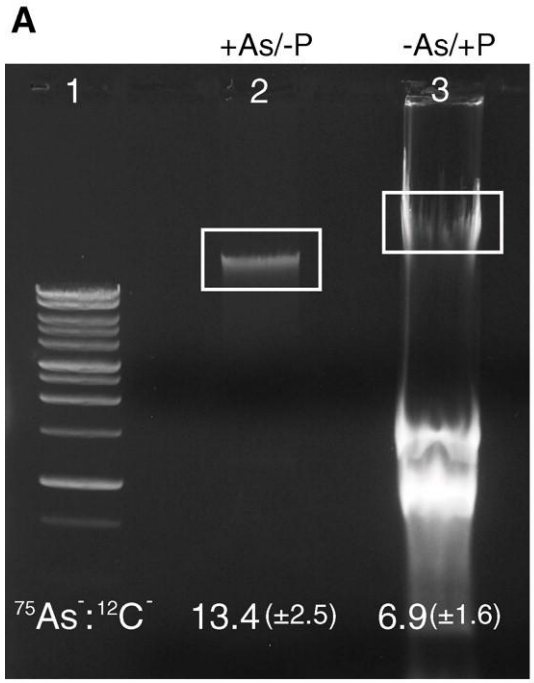


Fig. 3 X-ray analysis of GFAJ-1 +As/–P described similarity of As coordinated like P in DNA. (A) EXAFS comparisons of the Fourier transformed data for As in model environments and GFAJ-1 (washed and fixed, collected on whole cells).

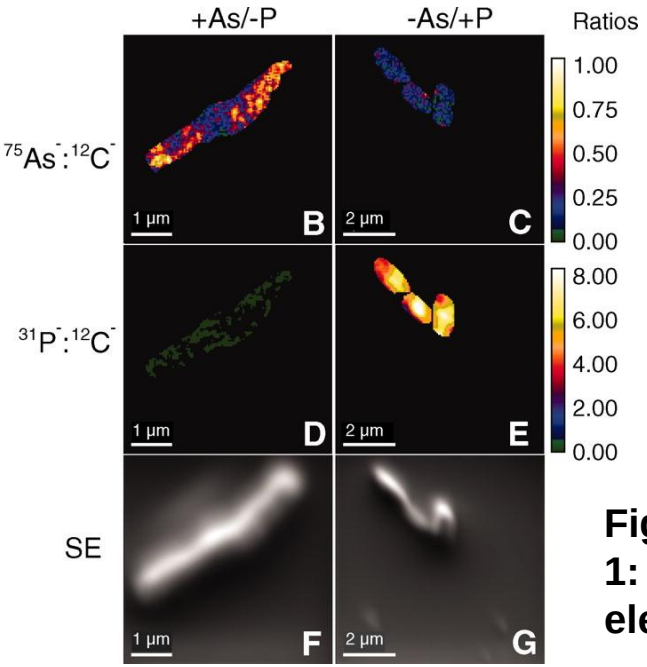
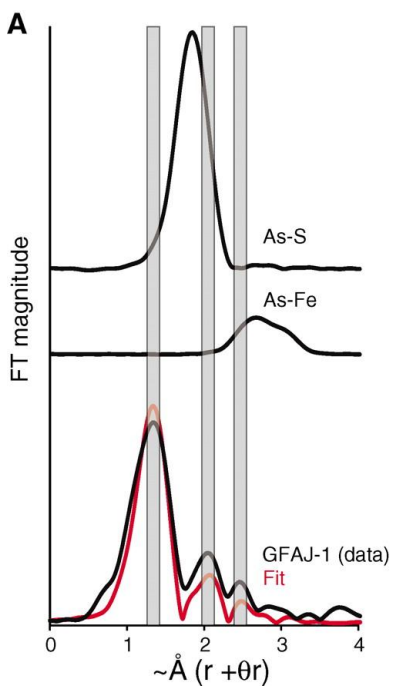
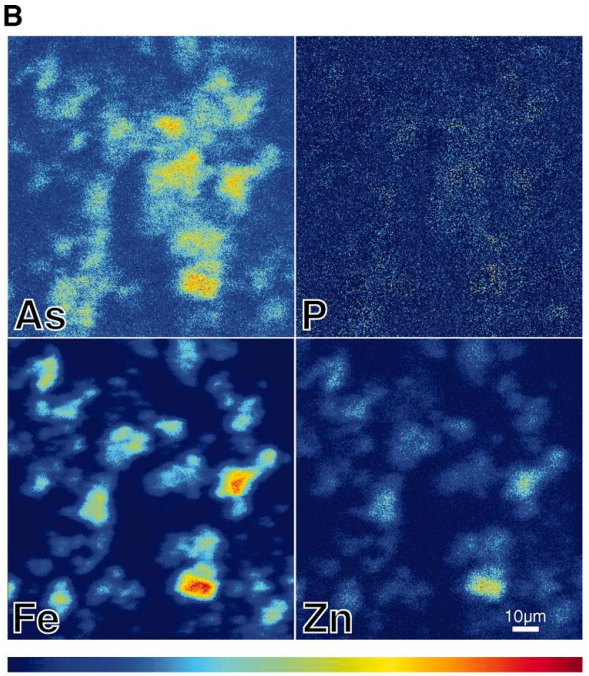


Fig. 2 NanoSIMS analyses of GFAJ-1: extracted DNA and whole-cells elemental ratio maps.

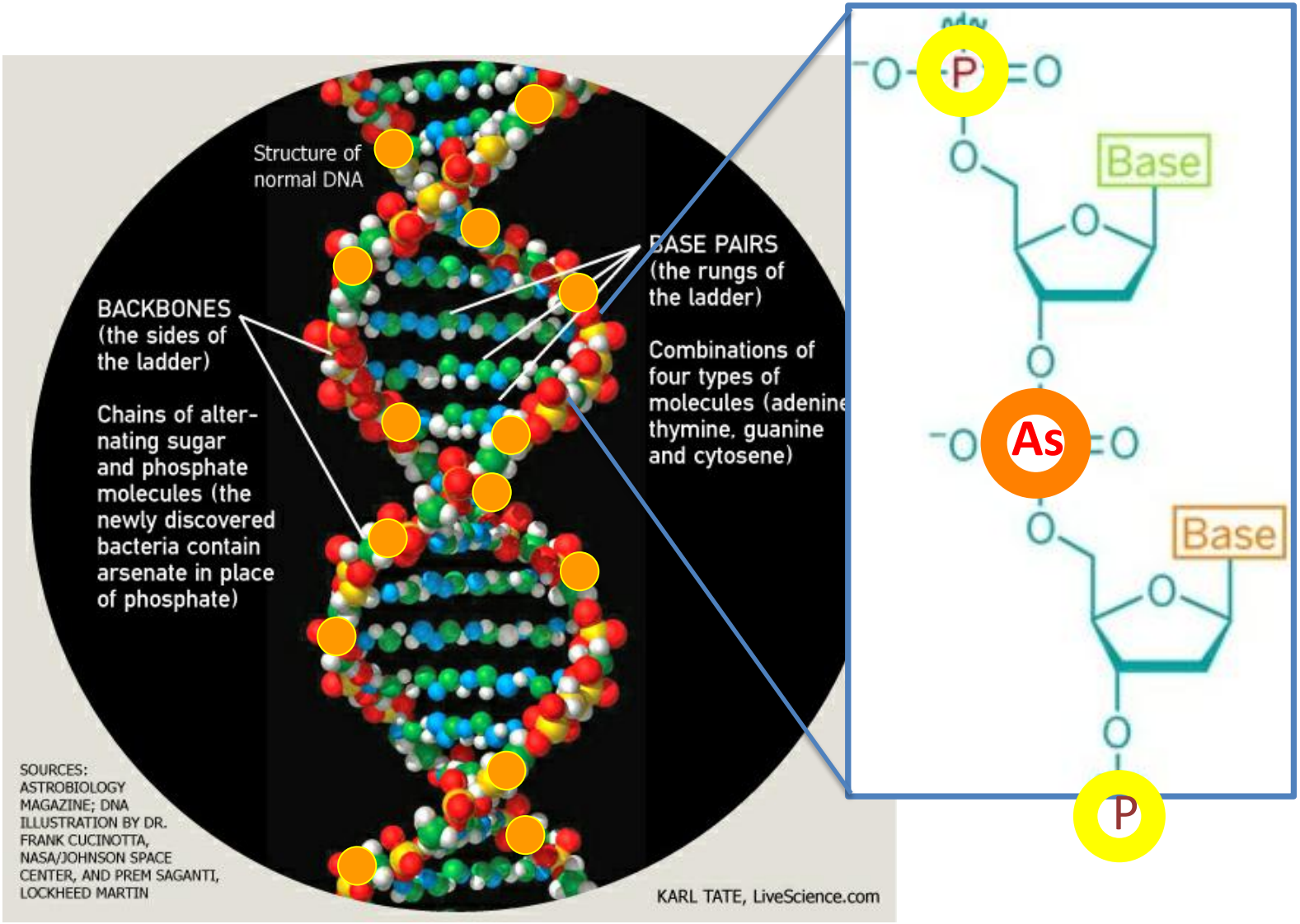




F Wolfe-Simon et al.
Science 2011 ;332:1163-1166

Science
AAAS

Chemical clarification:



RRResearch

Not your typical science blog, but an 'open science' research blog. Watch me fumbling my way towards understanding how and why bacteria take up DNA, and getting distracted by other cool questions.

Our lab home page

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what we've done

whose turn is it?

lab photos

Here's a detailed review of the new paper from NASA claiming to have isolated a bacterium that substitutes arsenic for phosphorus on its macromolecules and metabolites. (Wolfe-Simon *et al*. 2010, A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus.) NASA's shameful analysis of the alleged bacteria in the Mars meteorite made me very suspicious of their microbiology, an attitude that's only strengthened by my reading of this paper. Basically, it doesn't present ANY convincing evidence that arsenic has been incorporated into DNA (or any other biological molecule).

What did the authors actually do? They took sediment from Mono Lake in California, a very salty and alkaline lake containing 88 mg of phosphate and 17 mg of arsenic per liter. They put the sediment into a similarly alkaline and hypersaline defined medium containing 10 mM glucose as a carbon source, 0.8 mM NH_4SO_4 as a nitrogen and sulfur source, and a full assortment of

> I've posted a full analysis of NASA's arsenic-bacteria paper at http://rrresearch.blogspot.com. Bottom line: it's shamefully bad science.
>
> **RosieRedfield**
> December 4, 2010 at 17:07

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ENVIRONMENT

Poisoned Debate Encircles a Microbe Study's Result

By DENNIS OVERBYE
Published: December 13, 2010

The announcement that NASA experimenters had found a bacterium that seems to be able to subsist on arsenic in place of phosphorus — an element until now deemed essential for life — set off a cascading storm of criticism on the Internet, first about alleged errors and sloppiness in the paper published in Science by Felisa Wolfe-Simon and her colleagues, and then about their and NASA's refusal to address the criticisms.

The result has been a stormy brew of debate

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NASA's arsenic microbe science slammed

Last Updated: Monday, December 6, 2010 | 4:07 PM PT Comments 100 Recommend 73
CBC News

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Doubts Brew About NASA's New Arsenic Life

Slate

"This Paper Should Not Hav Published"

Scientists see fatal flaws in the NASA study of arsenic-based life.

By Carl Zimmer

Posted Tuesday, Dec. 7, 2010, at 10:53 AM ET

On Thursday, Dec. 2, Rosie Redfield sat down a new paper called "A Bacterium That Can Gr Using Arsenic Instead of Phosphorus." Despite innocuous title, the paper had great ambitions living thing that scientists have ever studied u

! Real peer review happens AFTER
n. Pre-publication review just quality
tp://bit.ly/dLjJOk http://bit.ly/gEF

Allochthonous
December 7, 2010 at 5:21

NASA #arseniclife story at
ogs.ucdavis.edu/egghead/

edyong209

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A Bacterium That Can Grow by Using Arsenic I

Felisa **Wolfe-Simon**, Jodi Switzer Blum, Thor ...on, Shelley E. Hoeft, Jennifer Pett-Ridge, John F. Stolz, Samu ...aul C. W. Davies, Ariel D. Anbar, and Ronald S. Orem

Science 3 June 2011: 1163–1 ...ember 2010
[DOI:10.1126/science.1

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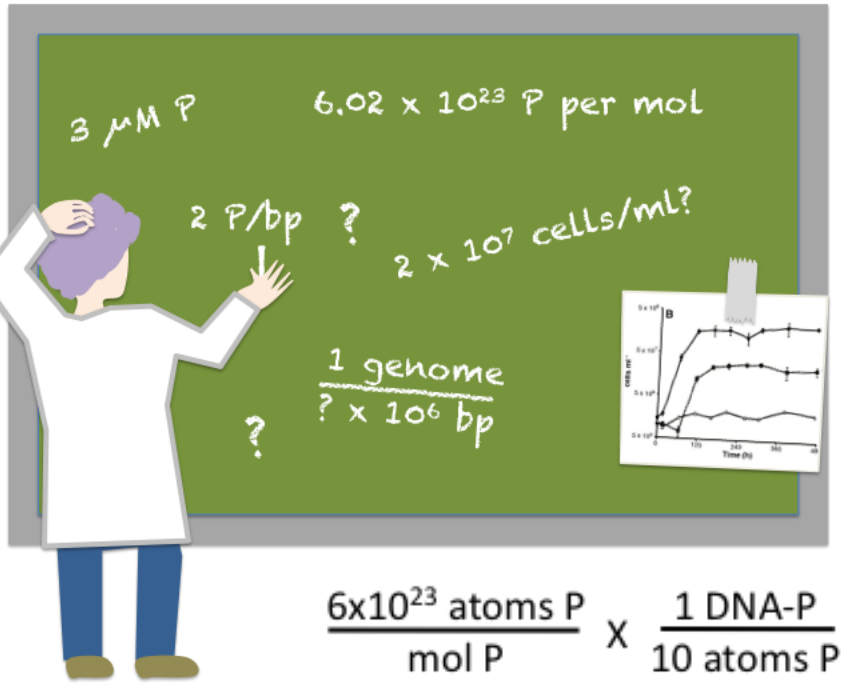
address so we car

The -P growth medium had contaminating PO_4, but nobody knew how much

MEDIA	PO_4 (µM)	Should be
-P/-As media (-vitamins, - arsenic, -phosphate, - glucose) 5 Apr 2010 batch	3.7	0
-P/-As media (-vitamins, - arsenate -phosphate, - glucose) 11 June 201 batch	<0.3	0
-P/+As media (+vitamins, +10 mM glucose, + arsenate) 29 July 2010 batch	2.9	0
-P/+As media (+ vitamins, +10 mM glucose, +arsenate) 5 Apr 2010 batch	2.7	0
+P/-As media (+ vitamins, +10 mM glucose, + phosphate) 5 Apr 2010 batch	2,003	1500
cell wash solution -P/-As media (-vitamins, - arsenic, -phosphate, - glucose, - trace metals), 3 July 2010 batch	*7.4*[a]	0

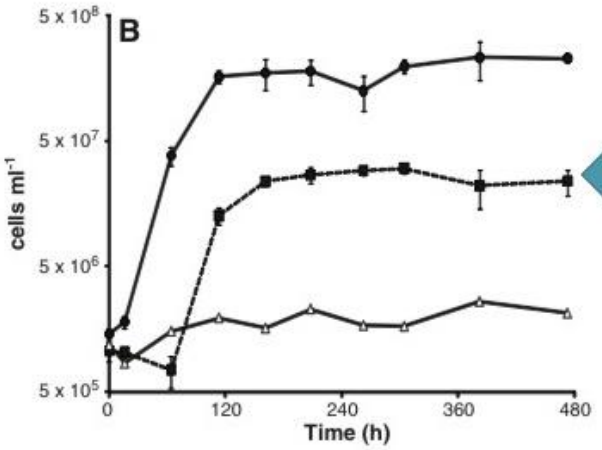
Most –P +As preps had enough PO_4 for the observed growth



The amount of phosphate in the 'no-phosphate' culture medium

$$\frac{6\times10^{23}\text{ atoms P}}{\text{mol P}} \times \frac{1\text{ DNA-P}}{10\text{ atoms P}} \times \frac{1\text{ bp}}{2\text{ DNA-p}} \times \frac{1\text{ genome}}{3.8\times10^{6}\text{ bp}} \times \frac{3.1\text{x}10\text{-}6\text{ mol P}}{10^{3}\text{ ml}}$$

$$= \frac{2.47 \times 10^{7}\text{ genomes}}{\text{ml}}$$

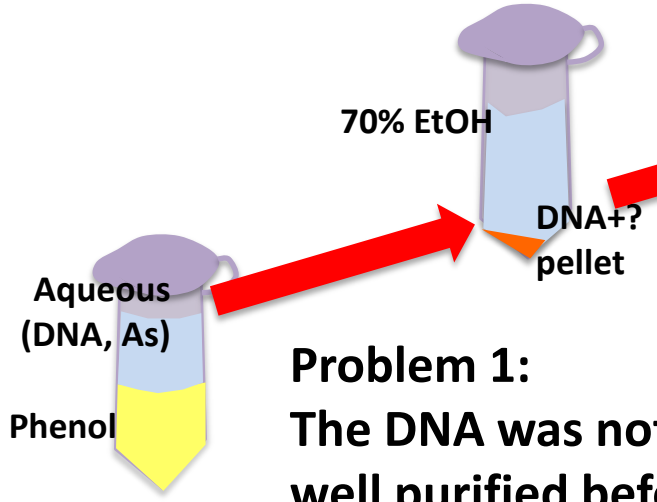


$$= \frac{2.47 \times 10^{7}\text{ cells}}{\text{ml}}$$

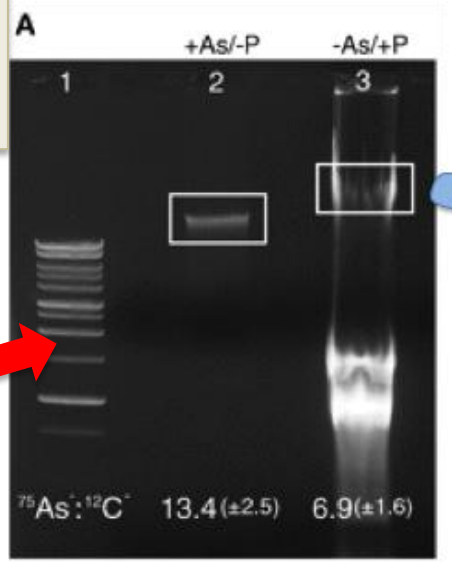
The number of cells that could be made using this phosphate

Maybe the arsenate was just carried along with the dirty DNA sample

"*NanoSIMS analyses.* Individual cells and **DNA in high purity agarose gel sections** were analyzed for As and P abundance by high-resolution secondary ion mass spectrometry."



Problem 1:
The DNA was not well purified before being loaded in the gel.



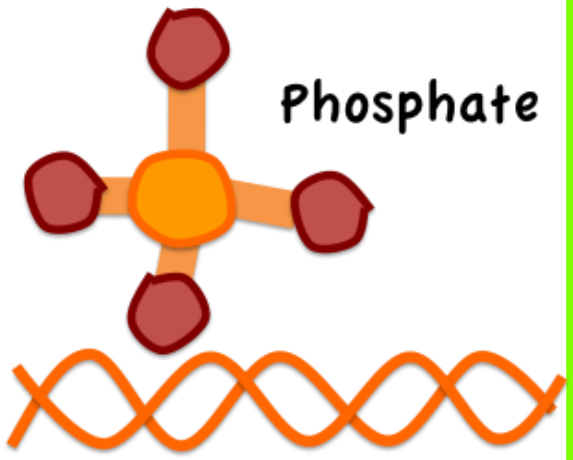
Gel

Arsenic in the gel, not in the DNA?

Problem 2:
The DNA was not purified from the gel before analysis.

The As in the gel slices may not have been part of the DNA.

Chemical consideration: As-DNA bonds are unstable

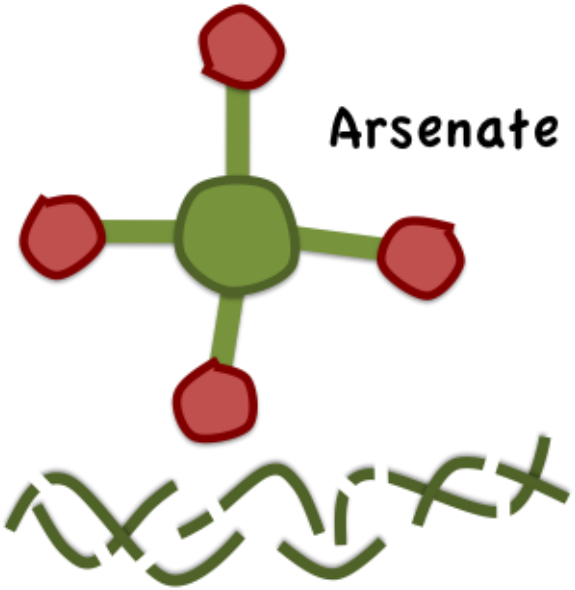


WE, BEASTIES

"Gentlemen, it is the microbes who will have the last word"
—LOUIS PASTEUR

with KEVIN BONHAM

[guest post: Alex Bradley, PhD] Arsenate-based DNA: a big idea with big holes



ACS chemical biology

PERSPECTIVE

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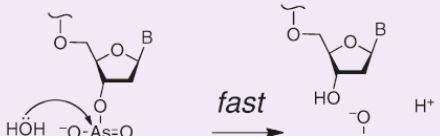
Kinetic Consequences of Replacing the Internucleotide Phosphorus Atoms in DNA with Arsenic

Mostafa I. Fekry,[†,§] Peter A. Tipton,[‡] and Kent S. Gates[†,‡,*]

[†]Department of Chemistry, 125 Chemistry Building, and [‡]Department of Biochemistry, 117 Schweitzer Hall, University of Missouri, Columbia, Missouri 65211, United States

[§]Pharmacognosy Department, Faculty of Pharmacy, Cairo University, Kasr El-Aini, Cairo, Egypt 11562

ABSTRACT: It was claimed in a recent publication that a strain of *Halomonadacea* bacteria (GFAJ-1) isolated from the arsenic-rich waters of Mono Lake, California is able to substitute arsenic for phosphorus in its macromolecules and small molecule metabolites. In this short Perspective, we consider chemical and biochemical



Some people changed their minds about social media...

Press Release by NASA (Nov. 29):

Dwayne Brown, NASA Headquarters,
Washington

WASHINGTON -- NASA will hold a news conference at 2 p.m. EST on Thursday, Dec. 2, to discuss an astrobiology finding that will impact the search for evidence of extraterrestrial life. Astrobiology is the study of the origin, evolution, distribution and future of life in the universe.

NASA spokesman Dwayne Brown (Dec. 6, quoted by CBC News):

Wolfe-Simon will not be responding to individual criticisms, as the agency doesn't feel it is appropriate to debate the science using the media and bloggers. Instead, it believes that should be done in scientific publications.

Felisa Wolfe-Simon (Dec. 7, quoted by Carl Zimmer):

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.

RRResearch

Not your typical science blog, but an 'open science' research blog. Watch me fumbling my way towards understanding how and why bacteria take up DNA, and getting distracted by other cool questions.

My Letter to Science

By Rosie Redfield on Wednesday, December 08, 2010

Below is

Wolfe-S

reager

made

sampl

The re

PO_4 c

the ce

7.5x1(

SteveF December 8, 2010 9:27 AM

There seems to be a lack of references to back up a number of your statements in this letter. Perhaps this concern reflects my considerable lack of expertise in the subject and the things you mention are so

Anonymous December 8, 2010 8:45 AM

I'd reword this opening paragraph. It's sort of confusing because you say they eliminated contamination in their materials but not in their assayed materials.

Should reword this sentence so it doesn't start with "And because". No correction can be made for the agarose contribution to the total carbon because the levels of DNA and agarose in the gel slice are unknown yaddaydaddayadda.

Science

AAAS

TECHNICAL COMMENT

Patricia L. Foster

Rosemary

Response to Comments on "A Bacterium That Can Grow Using Arsenic Instead of Phosphorus"

Felisa Wolfe-Simon,[1,2]*† Jodi Switzer Blum,[2] Thomas R. Kulp,[2] Gwyneth W. Gordon,[3] Shelley E. Hoeft,[2] Jennifer Pett-Ridge,[4] John F. Stolz,[5] Samuel M. Webb,[6] Peter K. Weber,[4] Paul C. W. Davies,[1,7] Ariel D. Anbar,[3,8] Ronald S. Oremland[2]

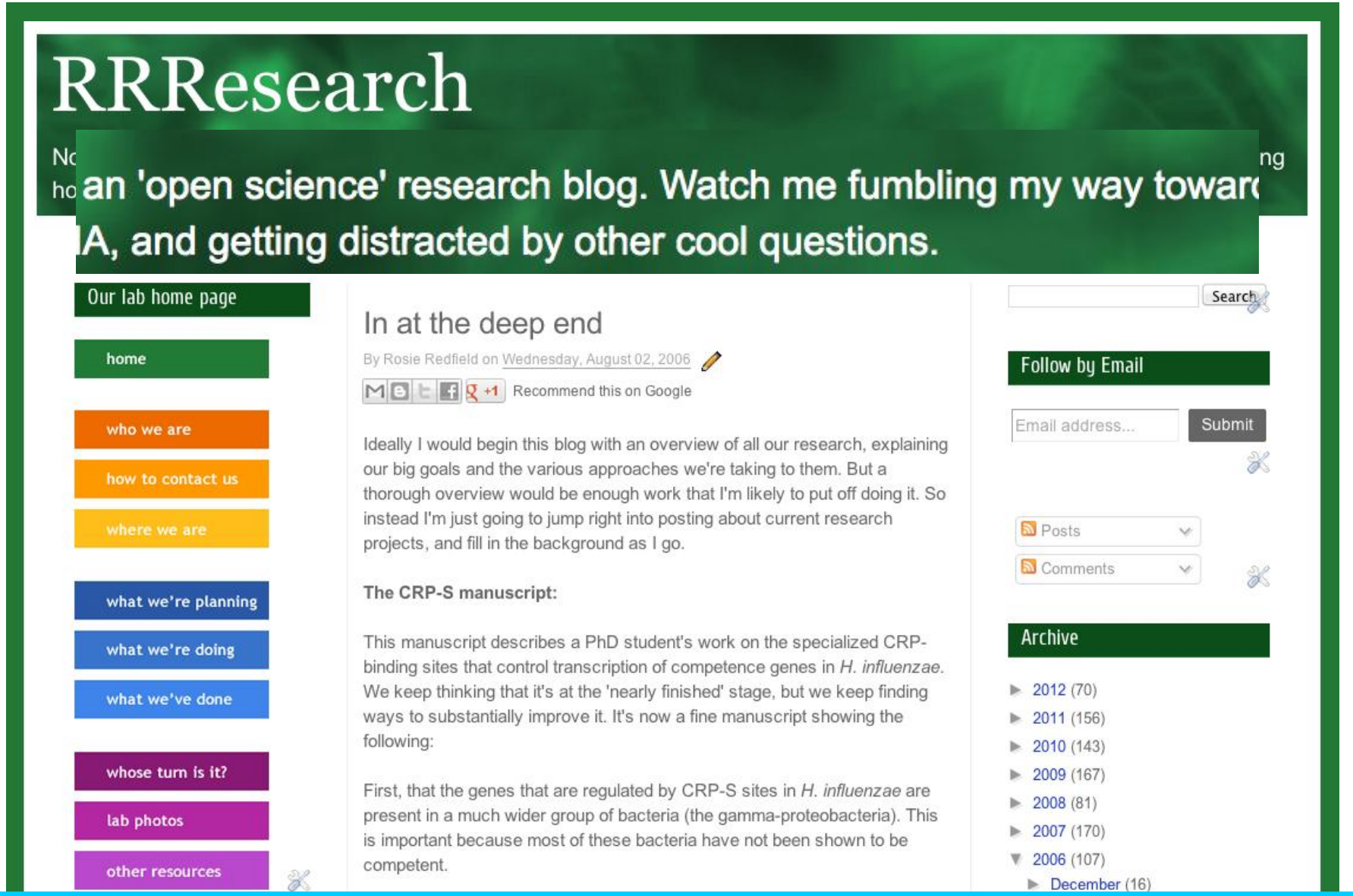
Concerns have been raised about our recent study suggesting that arsenic (As) substitutes for phosphorus in major biomolecules of a bacterium that tolerates extreme As concentrations. We welcome the opportunity to better explain our methods and results and to consider alternative interpretations. We maintain that our interpretation of As substitution, based on multiple congruent lines of evidence, is viable.

for phosphorus appears premature based on the data presented.

The flawed evidence for arsenic in DNA is overwhelmed by the 'prior-knowledge' obstacles.

Nevertheless, the blogosphere, the twitterverse, and the mainstream media all agreed: 'Someone should put the claims to an experimental test!'

Social media: Why I blog



The minimal experiments needed to test the #arseniclife claims:

RRResearch

1. Get GFAJ-1 cells from authors; check identity by 16S sequencing
2. Measure growth (# of cells/ml) in AML-60 medium $\pm PO_4$ and $\pm AsO_4$
3. Thoroughly purify DNA from cells grown $\pm AsO_4$; check stability
4. Assay DNA for arsenic (send DNA to collaborators with expertise)

Blog about every step...

Collaborators (at Princeton):

Joshua D. Rabinowitz

Professor

Chemistry and Integrative Genomics
241 Carl Icahn Laboratory
Washington Road
Princeton University
Princeton, NJ 08544
joshr@princeton.edu

Marshall Louis Reaves
mreaves at princeton.edu

Leonid Kruglyak
@leonidkruglyak FOLLOWS YOU

Professor of Genomics and Evolutionary Biology. Lapsed physicist. Math and statistics junkie. Occasional mountaineer
Princeton, NJ · http://www.princeton.edu/genomics/kruglyak/

RRResearch

Not your typical science blog, but an 'open science' research blog.
understanding how and why bacteria take up DNA, and getting dis

GFAJ-1 (no real progress to report)

By Rosie Redfield on Wednesday, July 06, 2011

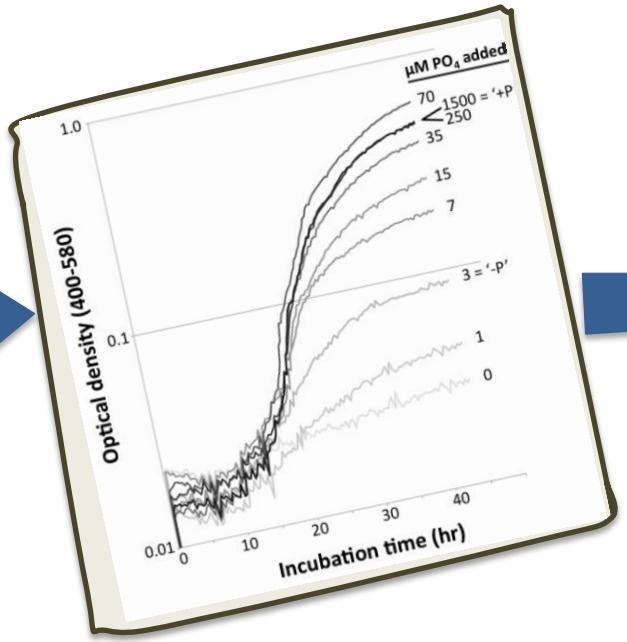
I'm now using the medium exactly as specified, but the cells still aren't growing consistently. They also form variable numbers and sizes of Tween 20-resistant clumps.

Yes, that last experiment was grasping at straws...

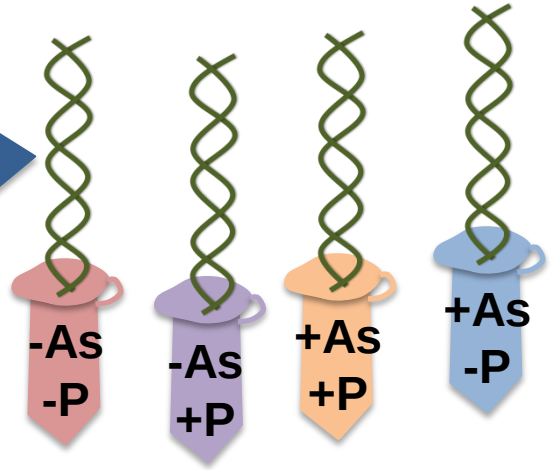
By Rosie Redfield on Tuesday, October 11, 2011

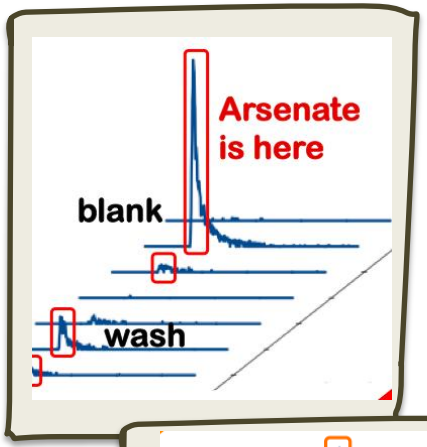
DNA! Lots and lots of lovely GFAJ-1 DNA!

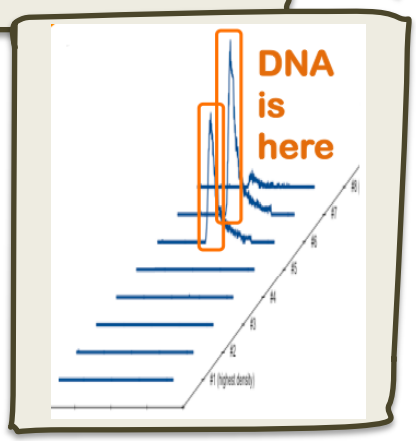
By Rosie Redfield on Friday, November 18, 2011



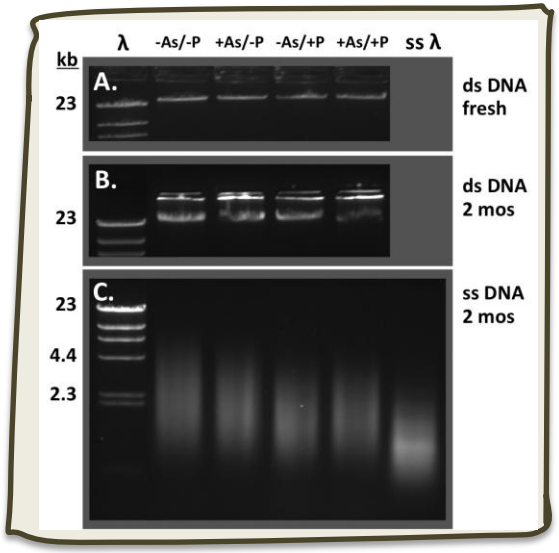
GFAJ-1 DNA







liquid chromatography-mass spectrometry



The manuscript is available on the arXiv server.

The paper is 'in press' at Science.

In early July I gave a big public outreach talk at the big joint Evolution meeting. Here's a slide I showed.

Science *had* embargoed it until July 26...

Some journals use ‘press embargos’ to control how research is publicized.

Journalists get advance copies of papers, on condition that they don’t publish anything until the paper appears in the journal.

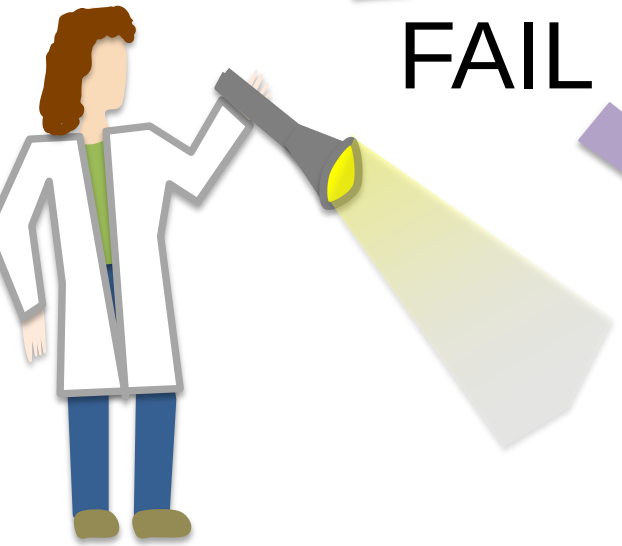
Authors are instructed not to speak to the press except under this condition.

Your cooperation protects you from problems that may jeopardize your paper’s publication.

Science
AAAS

FAIL

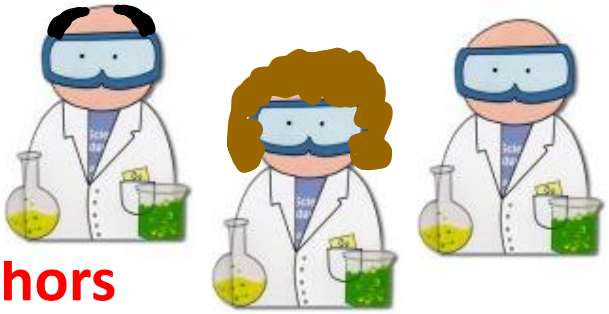
Lead author



FAIL

Senior author (her supervisor)

FAIL Other authors



FAIL Reviewers

?

Editors of Science FAIL

NASA *FAIL*

But science (the process) worked well.

Google

arsenic DNA

Google Search | I'm Feeling Lucky

'Arseniclife' bug lacks **arsenic** in **DNA** – USATODAY.com
usatoday30.usatoday.com/tech/...12.../**arsenic**life...**dna**/.../1

by Dan Vergano - in 112 Google+ circles - More by Dan Vergano
4 Dec 2011 – In the latest turn in the 'arseniclife' microbe saga, the bacteria lack **arsenic** genes and look downright ordinary, report researchers.

Absence of Detectable **Arsenate** in **DNA** from **Arsenate**-Grown GFA…
www.sciencemag.org › 27 July 2012
by ML Reaves - 2012 - Cited by 8 - Related articles
27 Jul 2012 – However, we have found that **arsenate** does not contribute to growth of GFAJ-1 when phosphate is limiting and that **DNA** purified from cells ...

Arsenic-Life Discovery Debunked—But "Alien" Organism Still Odd
news.nationalgeographic.com/.../120709-**arsenic**-space-nasa-science-...
9 Jul 2012 – The team concluded that GFAJ-1 must be incorporating **arsenic** into its **DNA** in place of phosphorous, which is essential for the **DNA** of all other ...

Finally, a real scientific controversy: **arsenic** in **DNA** | Ars Technica
arstechnica.com/.../is-there-**arsenic**-in-that-life-surprising-re...

by John Timmer - in 1,539 Google+ circles - More by John Timmer
31 May 2011 – The claim that bacteria had evolved to incorporate **arsenic** in their **DNA** set …

Can **arsenic** bind to bacterial **DNA**?
www.rsc.org/chemistryworld/News/2012/.../**arsenic**-in-**dna**.asp
by E Richards - Related articles
Can **arsenic** bind to bacterial **DNA**? 29 February 2012. In 2011, a paper published in Science claimed that bacteria from Mono Lake, California, US, had not only ...

Mono Lake bacteria build their **DNA** using **arsenic** (and no, this isn't ...
blogs.discovermagazine.com/.../mono-lake-bacteria-build-t...

by Ed Yong - in 479,600 Google+ circles - More by Ed Yong
2 Dec 2010 – Bacteria | **arsenic** | Note: Serious concerns have been raised about the conclusions of this study. I've written a summary of the backlash in a ...

Publication Rebuts 2010 **Arsenic-DNA** Finding - WSJ.com
online.wsj.com/.../SB10001424052702303684004577512870896 85...
8 Jul 2012 – The journal Science repudiated research it had published that said microbes could weave the poison **arsenic** into their **DNA**, a claim that, ...

Credits and Inspirations

- **Pedro Beltrao:** His blog post about open science started me blogging.

- **Sunita Sinha** (my lab RA): She did the 16S rDNA sequencing and helped write the paper.

- **Leonid Kruglyak**, **Josh Rabinowitz** and especially **Marshall Reaves**: They did the arsenate analysis and helped write the paper.

- **Canadian Institutes for Health Research:** They paid for the arsenate and Sunita's time.

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

- **Science** (the journal): They gave us an easy target and then a hospitable environment for rebutting it.

Science
AAAS