Microbial Diversity and Evolution

Part II: Microbial Respiration of Arsenate[As(V)]

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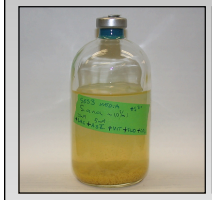
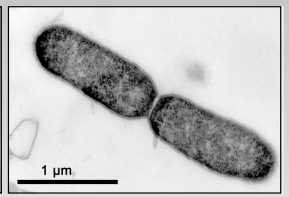
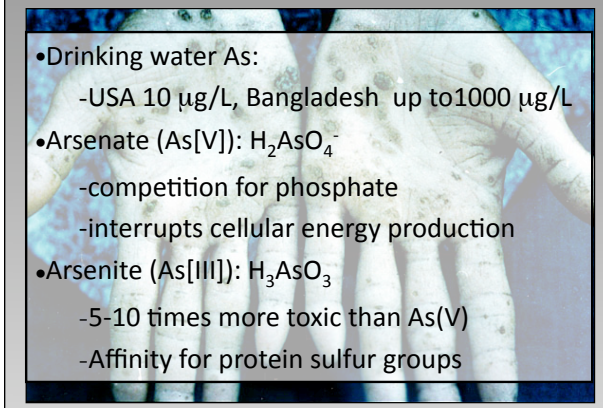




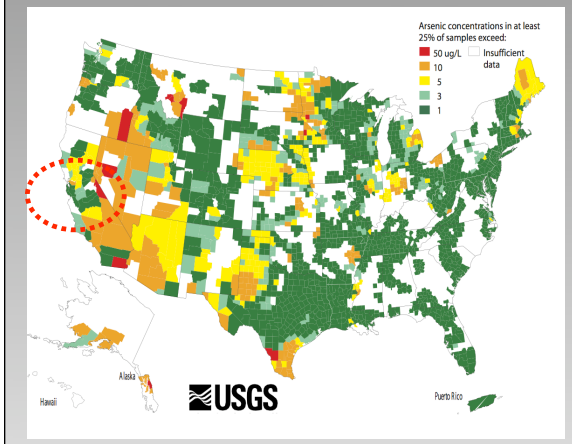
Arsenic is toxic!



http://phys4.harvard.edu/~wilson/inner_mongolia_paper1.html

Here is a picture of a person suffering from hyperkeratosis of the hands. The following pictures were taken from this website address.

Arsenic concentrations in groundwater

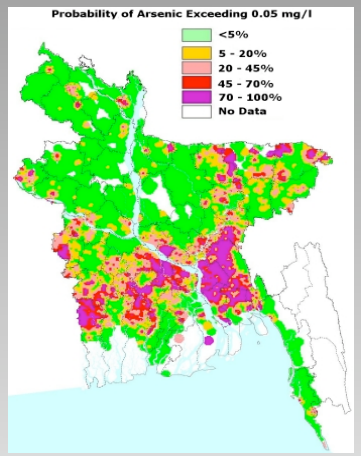


http://webserver.cr.usgs.gov/trace/pubs/geo_v46n11/fig2.html'

This graphic was taken from USGS's website. The graph shows the As concentrations of various groundwater samples taken across the United States. The red dots indicate that the As concentration is greater than the MCL (50 μg/L).

Much of these areas are located in CA, Idaho, AZ, and some in UT and Michigan.

Distribution of arsenic in Bangladesh



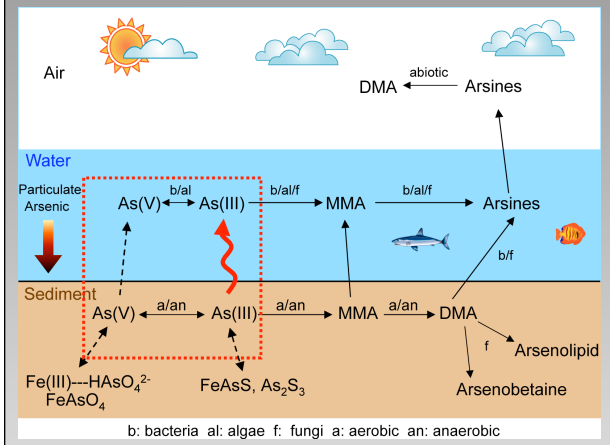
http://bicn.com/acic/

Bangladesh heavily affected by arsenicosis.

Groundwater is contaminated with As.

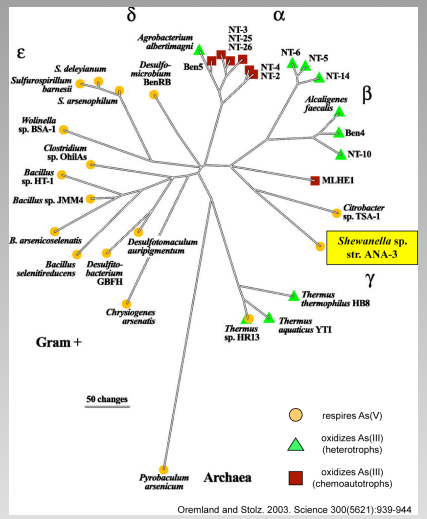
Geological origin.

Biogeochemical cycle of arsenic



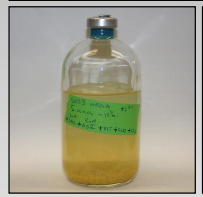
b: bacteria al: algae f: fungi a: aerobic an: anaerobic

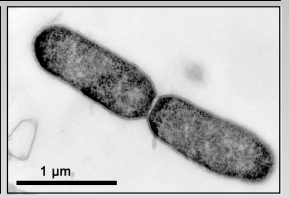
As(V)-respiring microorganisms are phylogenetically diverse



Oremland and Stolz. 2003. Science 300(5621):939-944

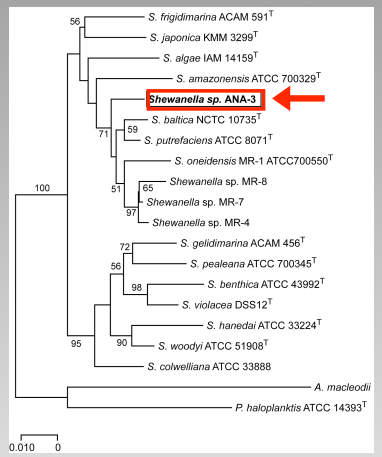
Shewanella sp. strain ANA-3





Shewanella sp. strain ANA-3

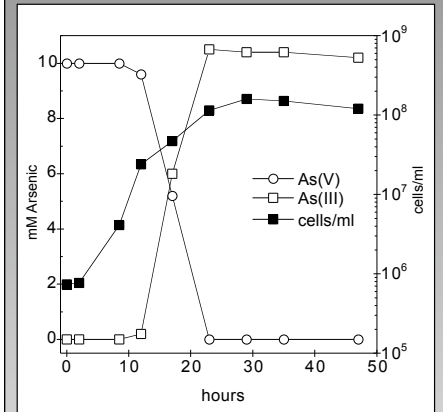
16S rDNA Phylogeny



ANA-3 is suitable for genetic studies

Saltikov *et al.* (2003) AEM

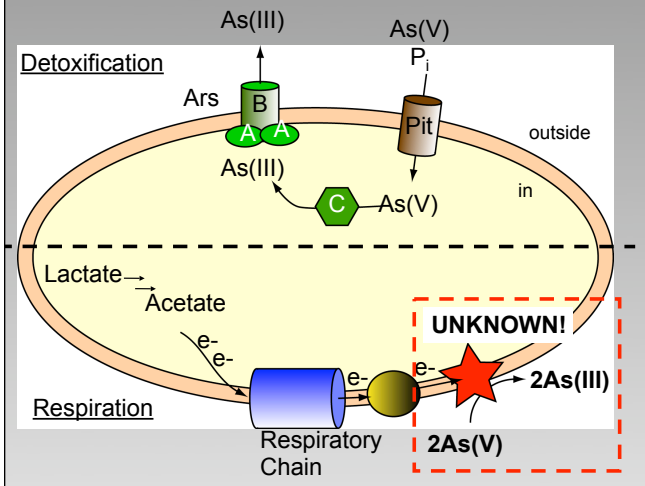
ANA-3 can respire As(V)



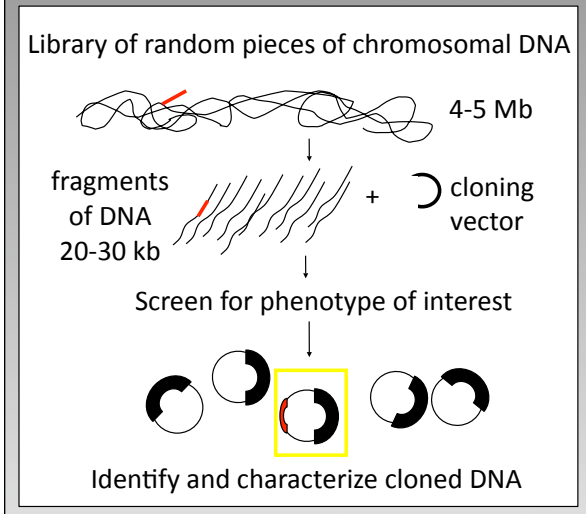
$lactate^- + 2HAsO_4^{2-} + 3H^+ \rightarrow$
$acetate^- + 2HAsO_2 + 2H_2O + HCO_3^-$

ΔG^o = -71.1 kJ/ mol electron

Two types of As(V) reduction by bacteria

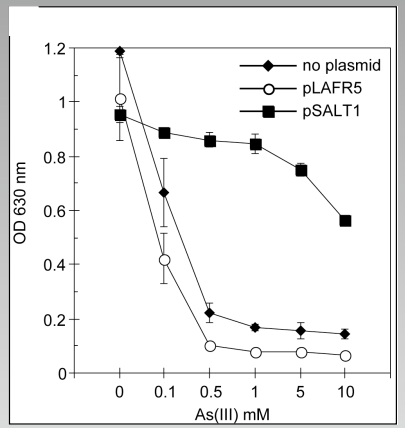


"Gain of function" approach



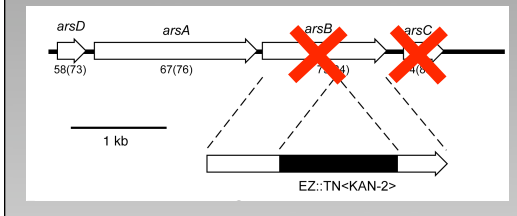
The ANA-3 *ars* system confers arsenic resistance to *E.coli*

E. coli AW3110

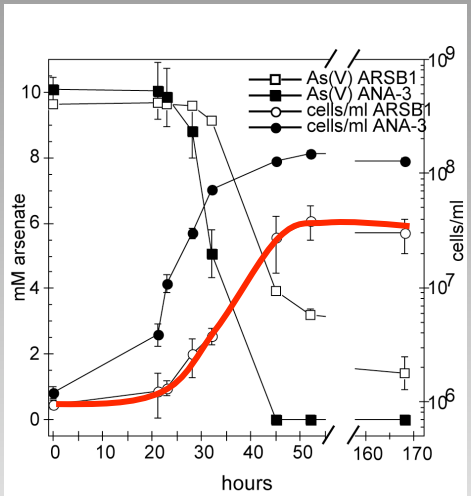


Saltikov *et al.* (2003) AEM

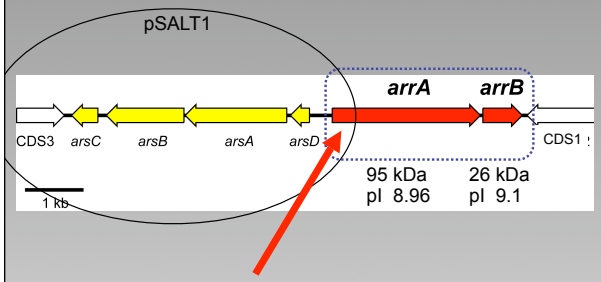
Is arsenite detoxification required for As(V) respiration?



No! *arsB/C* mutant still respires As(V)



What encodes the respiratory As(V) reductase?

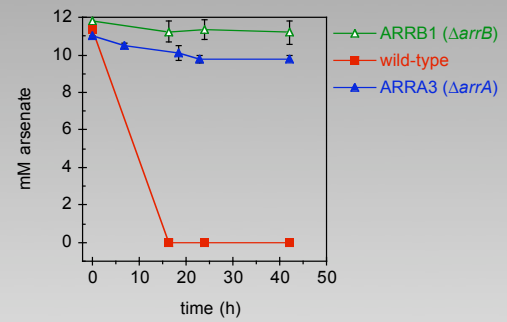


Hint: N-terminal homology to DMSO reductase protein family

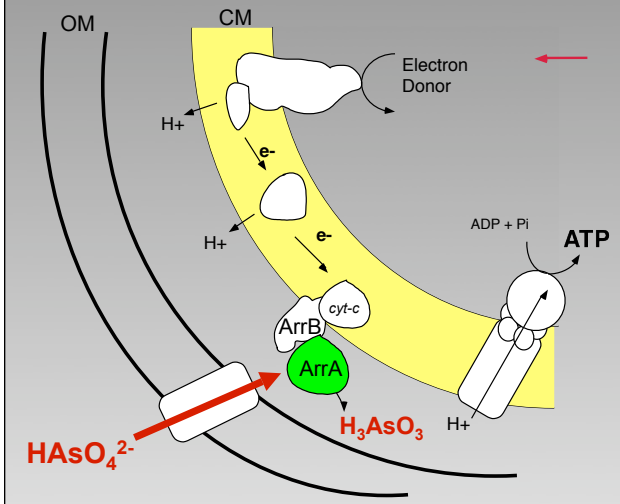
Saltikov and Newman (2004) PNAS

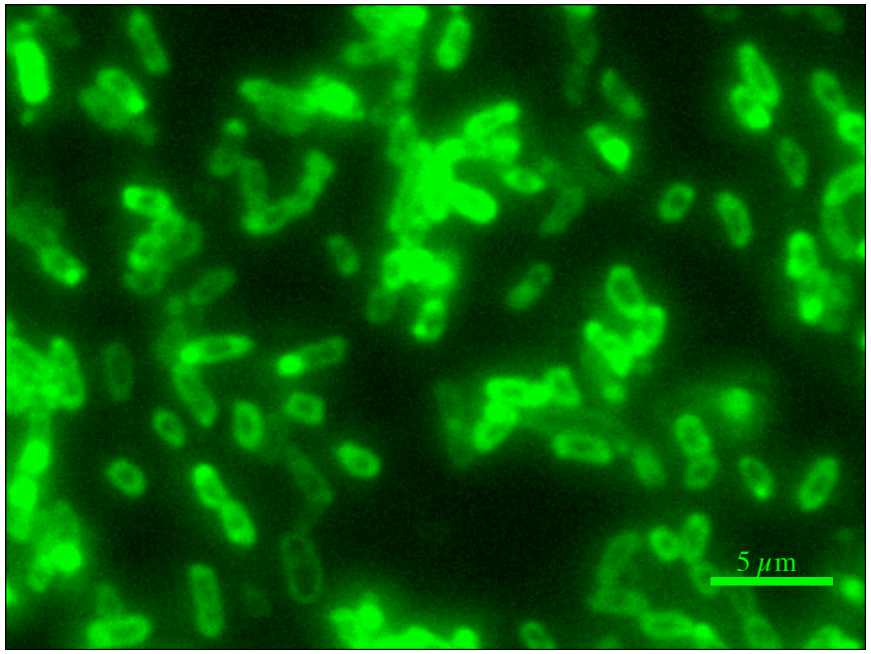
What encodes the respiratory As(V) reductase?

ArrA, ArrB



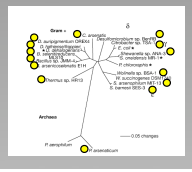
Location of ArrA/B

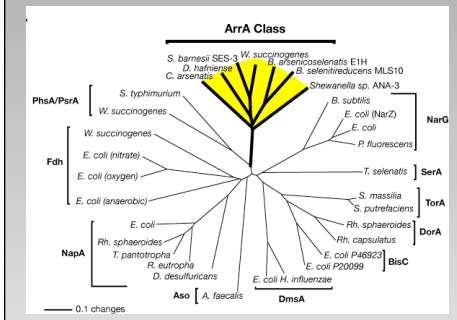



5 μm

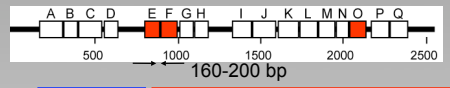

Environmental Relevance

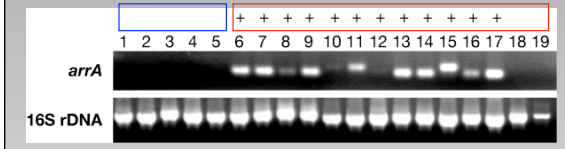
As(V)-respirers are diverse but *arrA* is highly conserved





arrA is a robust marker for As(V) respiration





Malasarn *et al.* (2005) Science

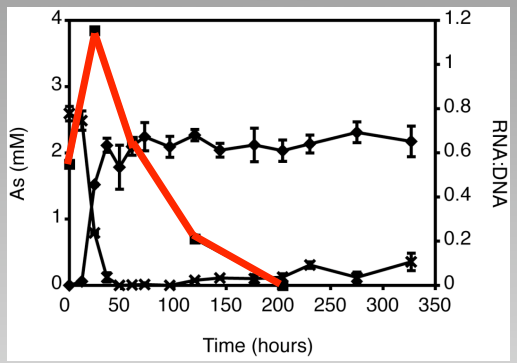
Is *arrA* important in the environment?

1. Is *arrA* required for As(V) transformations in iron-rich sediments?

   $Fe(OH)_3$=As(V)

2. Is *arrA* present and expressed in these sediments?

arrA controls As(V) reduction when bound to $Fe(OH)_{3(s)}$

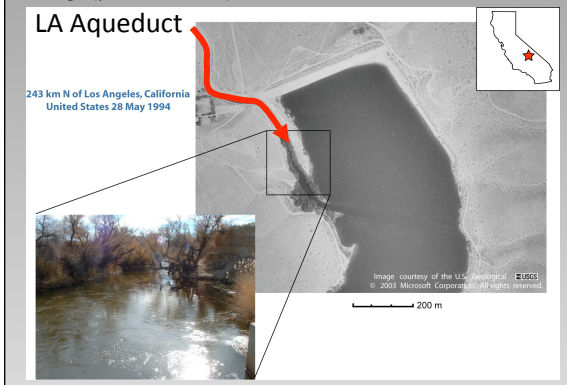


* No ArrA/B, no As(V) reduction!

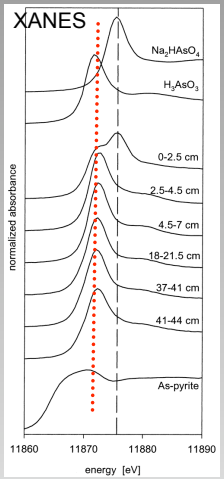
Malasarn *et al.* (2005) Science

Sampling at Haiwee Reservoir

25 mg/l (pre-Cottonwood)

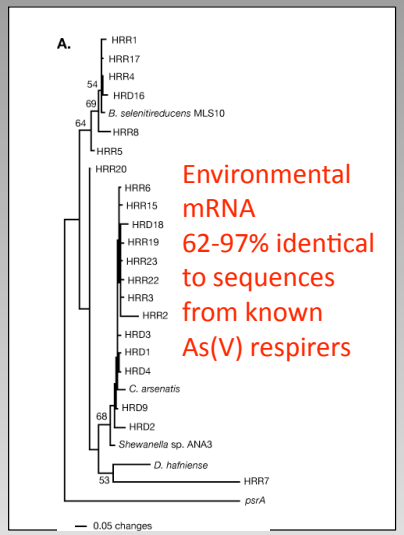


As(III) dominates Haiwee sediments below 2.5 cm



Kneebone *et al.* 2002, ES&T

mRNA *arrA* in Haiwee sediments



Environmental mRNA 62-97% identical to sequences from known As(V) respirers

SUMMARY

- Many microorganisms can respire As(V)
- *arrA* expression controls arsenic speciation in Fe-rich, low-temperature environments
- *arrA* is a reliable marker for respiratory As(V) reduction that can be used to track the activity of these microorganisms

Acknowledgements

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