Lomonosov Moscow State University
Faculty of Biology

LUXURY UPTAKE of PHOSPHORUS in MICROALGAE and CYANOBACTERIA

Alexei Solovchenko
solovchenko@mail.bio.msu.ru

Jülich 2018

What happens if phosphorus usage is NOT sustainable?

Apatite mines. Kola Peninsula, Russia, 2018

Consequences of a P mine water leakage.
Desert near Dead Sea, Israel, 2017

Luxury P uptake in microalgae

Why should we study it?

Microalgae have a formidable potential for P biosequestration because…

- They are naturally adapted to P shortage in the environment and stockpile P in their cells even if they are not P-hungry. Luxury P uptake
- Algae generate biomass suitable for diverse application e.g. biodiesel value-added compound extraction.
- And added benefit is photosynthetic CO_2 capture.

Burning questions

- What are the bottlenecks of luxury P uptake by microalgae?
- How is P uptake rate related with cell division rate, biomass accumulation, photosynthetic activity etc.?
- What are the molecular mechanisms of P_i uptake, its regulation and P storage?
- What is optimal for P biocapture from wastewater: P-starved OR exponentially growing cultures?

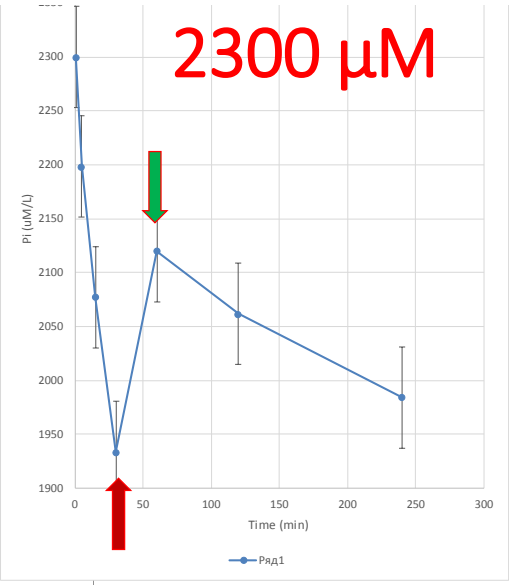
Biofertilizers!!!

Fast kinetics of P_i uptake in *Nostoc* sp. PCC 7118

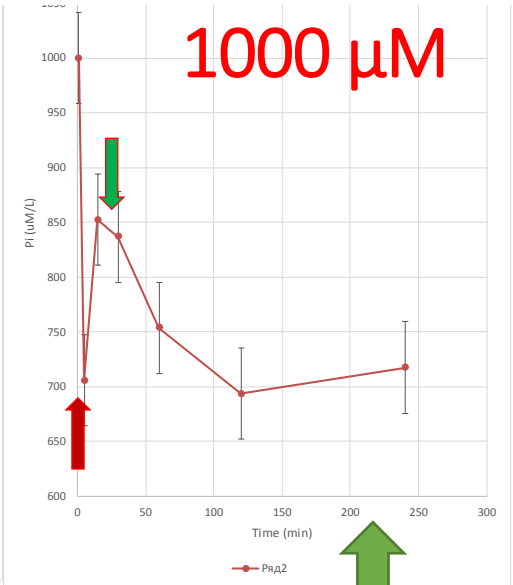
Re-feeding with different P*i* concentrations

Fast uptake and Outflow

2300 µM

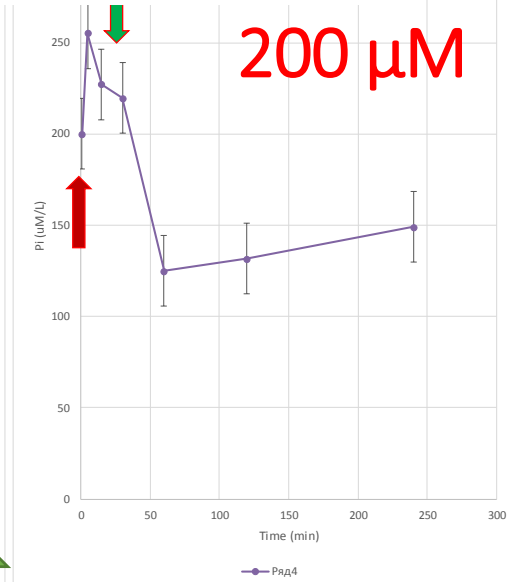


1000 µM

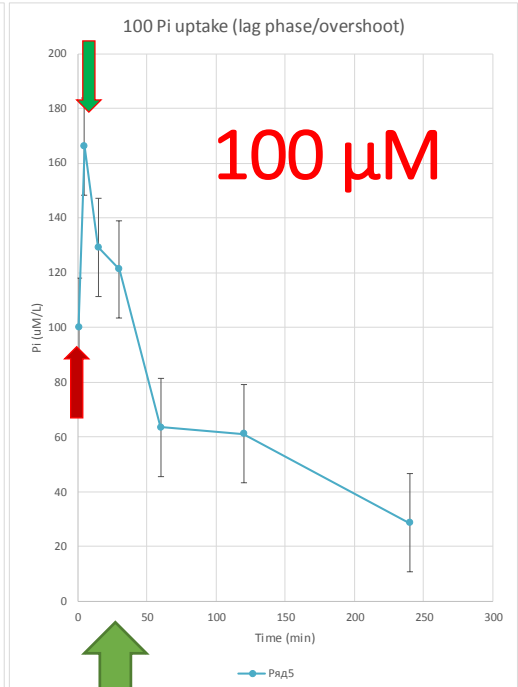


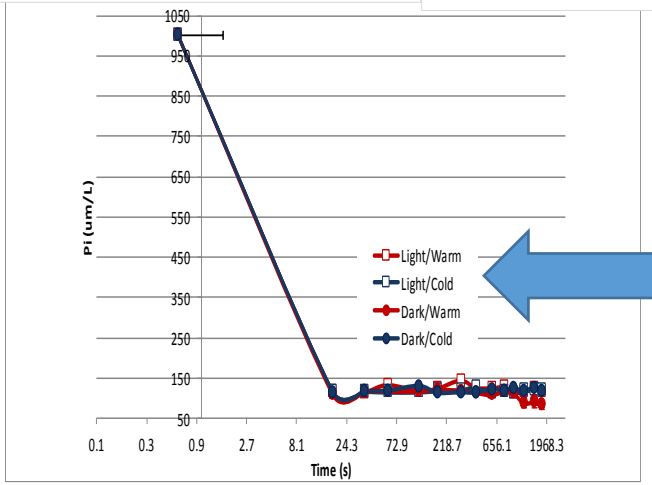
400 µM

200 µM



100 µM





The outflow depends on concentration of the P_i added

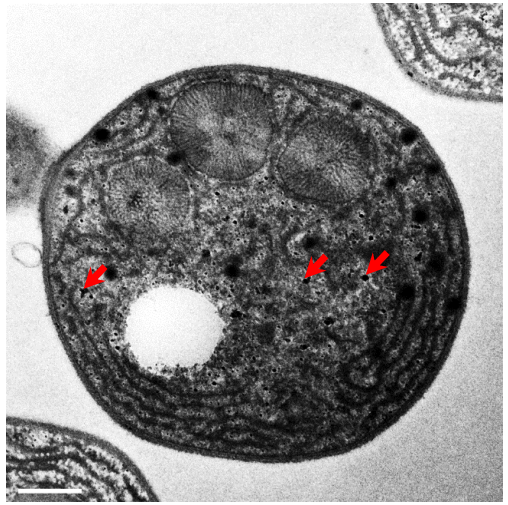
The fast uptake does NOT depend on light or temperature

Solovchenko et al., unpublished

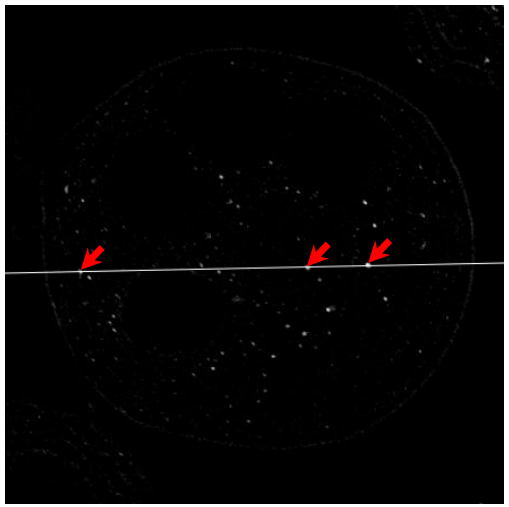
Visualization of PolyP in *Nostoc* sp. PCC 7118

1. Transient PolyP rise at lag-phase (4 h after P_i re-feeding)

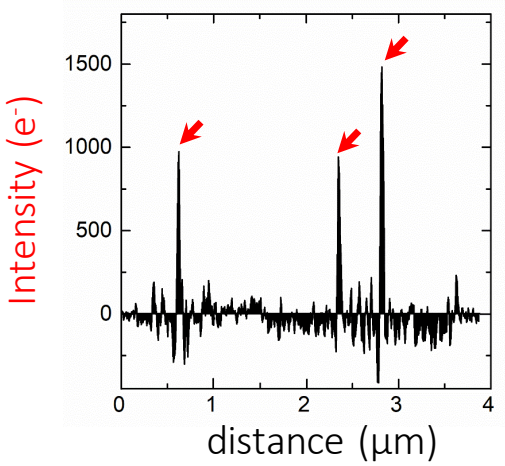
TEM image
(scale bar 0.5 µm)

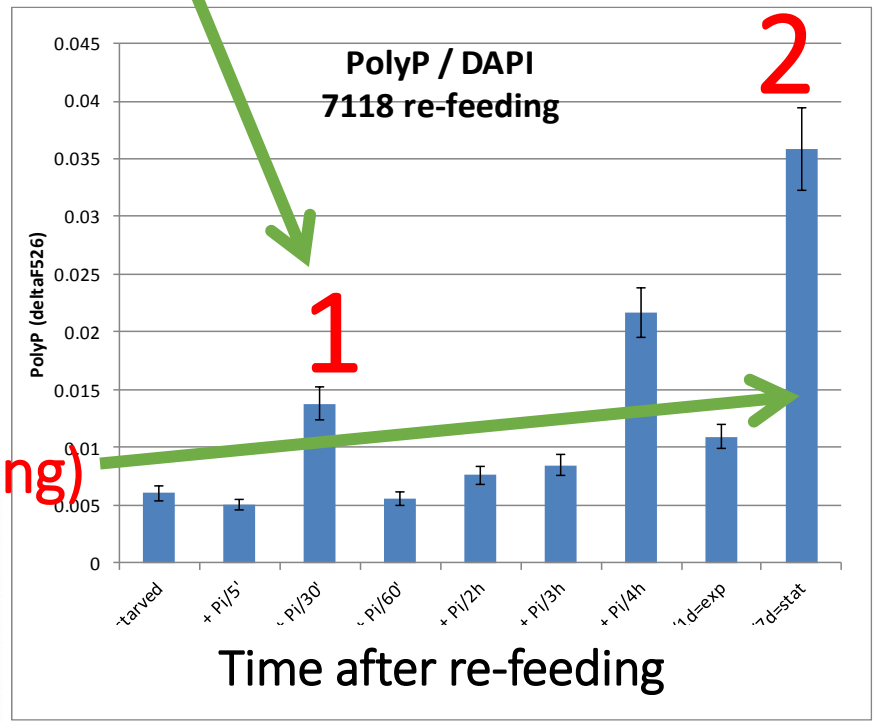


P distribution map
(EFTEM)

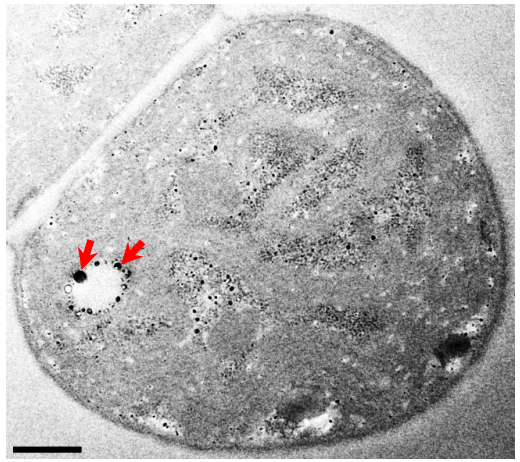


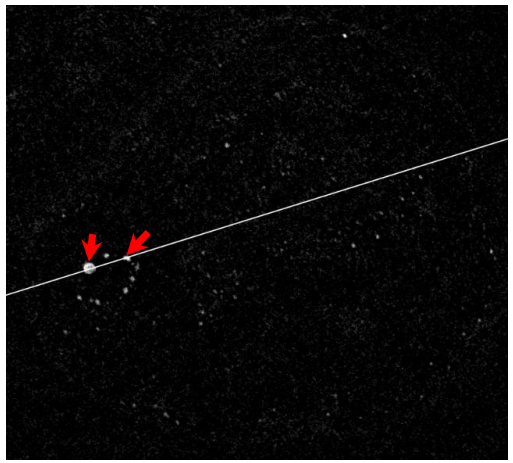
P signal intensity profile
along the white line

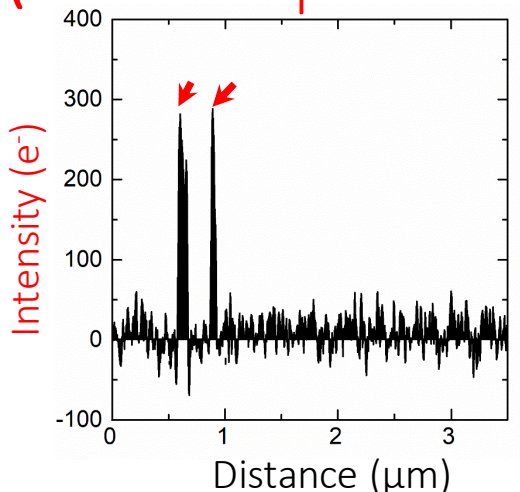




2. PolyP accumulation at stationary phase (7 d after P_i re-feeding)





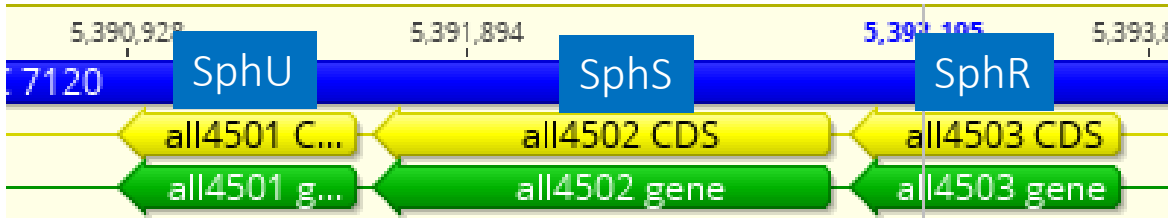


Ismagulova et al., unpublished

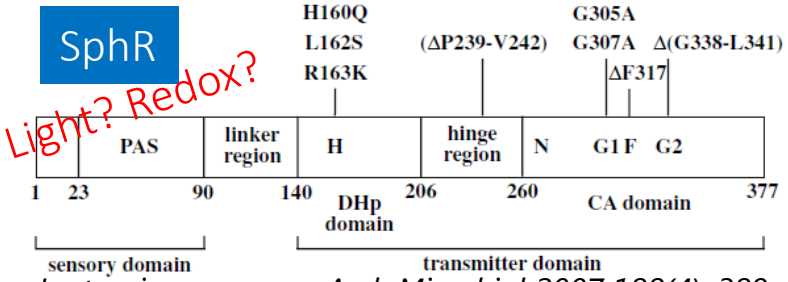
Factors affecting the P (PolyP) content of the cell

- [decline] Cell division rate: $P_{INT} \sim 1/\mu$
- [**increase**] External P_i concentration: $P_{INT} \sim P_i$
- [**increase**] Other nutrient starvation (S, N) on the background of ample P – increase in PolyP
- [**increase**] Energy availability (light/respiration)
- [**increase**] P pre-starvation

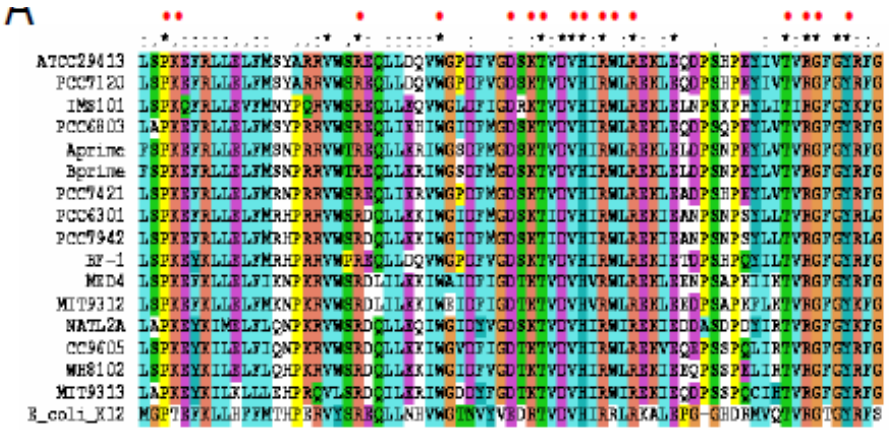
Sensing P_i availability: SphU|SphS/SphR



Our data/ *Nostoc* sp. PCC 7118



Juntarajumnong e.a. Arch Microbiol 2007 188(4), 389-402.



Su e.a. BMC Genomics 2007. 8, 156.

SphS is activated by autophosphorylation when P_i **outside** is low. SphU reduces autophosphorylation of SphS

SphU – repressor of Pho regulon is associated with SphS (a sensor His kinase).

In the presence of SphU, SphR (low P_i response regulator) is dephosphorylated and Pho regulon is repressed

Dephosphorylated SphR is unable to interact with σ^{70} (SigA) transcription factor; phosphorylated SphR binds Pho box in the promotor of **PhoA and other genes**.

Genome	Rank[1]	Tanscription unit	Names	Pho Boxes[2]	Positon[3]	Score[4]
PCC7120	6	*alr5291*	*phoA*	**ATTAATCTttaGTTAACCT**gaaTTTATATT		-223
	10	*all4575 all4574 all4573 all4572*	*pstS1 pstC1 pstA1 pstB1*	TTTTCTCTtga**TTTAACCTttcGTTAACCT**		-64
	38	*alr1094 alr1095*	*sphX gap3*	**CTTTACTAataCATCAACT**tttATTGATGA		-106
	51	*alr0276*	*nucH*	**TTTTACCTtctCCTATTAT**tctCTTAATCT		-178

Collaborative research proposal

- Specific mechanisms and genetic control of luxury P uptake and PolyP biosynthesis (incl. omics data mining).
- Search for and study of P-hyperaccumulator strains in the biofilms and communities of P mining sites (metagenomics & metatranscriptomics, functional screening).
- Interaction of photosynthesis and accumulation of phosphorus in the cell (relationships between photochemistry, P uptake).
- *You name it ;-)*

THANK YOU!

fb.me/msualgae

Follow us on ResearchGate & Facebook!

www.researchgate.net/profile/Alexei_Solovchenko

solovchenko@mail.bio.msu.ru

Photobiotechnology group

LOMONOSOV MOSCOW STATE UNIVERSITY

UNIVERSITAS MOSQUENSIS FACULTAS BIOLOGIAE

UNIVERSITÄT BONN

UNIVERSITAS CAROLINA PRAGENSIS

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

Alexei Solovchenko

Olga Baulina

Olga Gorelova

Elena Lobakova

Tatina Ismagulova

+ Irina Selyakh
+ Larisa Semenova
+ Olga Karpova
+ Pavel Scherbakov
+ Svetlana Vasilieva

Olga Chivkunova

Alexandr Lukyanov

BioSC
Bioeconomy Science Center

On the German side, this research was financially supported by the BioSC AlgalFertilizer project funded by the Ministry of Innovation, Science and Research of the German State of North Rhine-Westphalia.

On the Russian side, this research was financially supported by the Ministry of Science and Education of Russian Federation.