Uptake Rates as Fundamentals of Iron Availability to Phytoplankton

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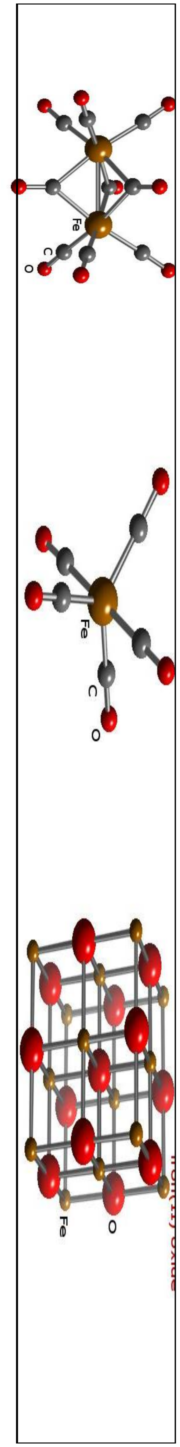


What determines the bioavailability of iron to phytoplankton ?

Fundamentals of Fe availability

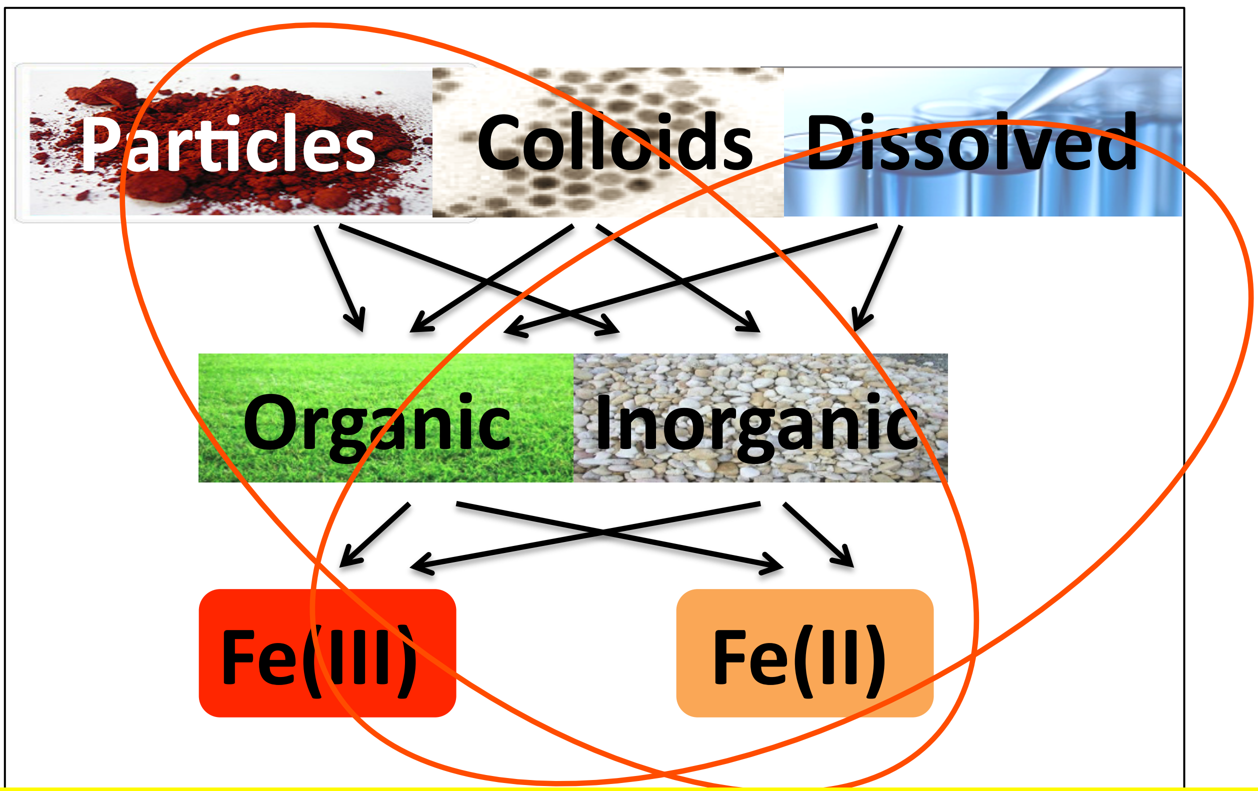
Interactions and ecosystem processes

Shaked and Lis, 2012

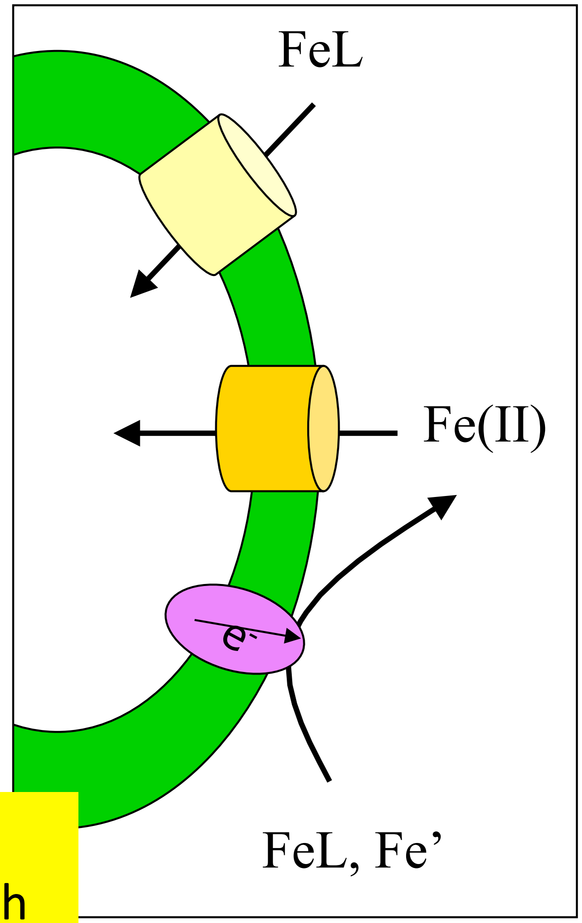
Fundamentals of Fe availability

Emphasis on **kinetics** - Using uptake rate constants (Kin) for comparisons & extrapolation to the environment

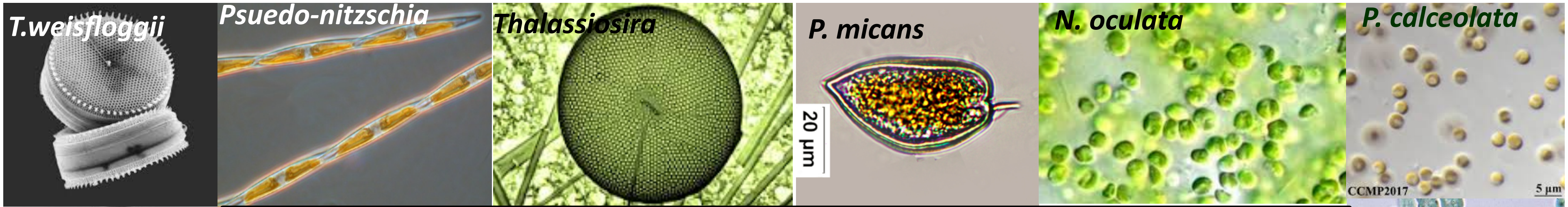
Chemical speciation and kinetics

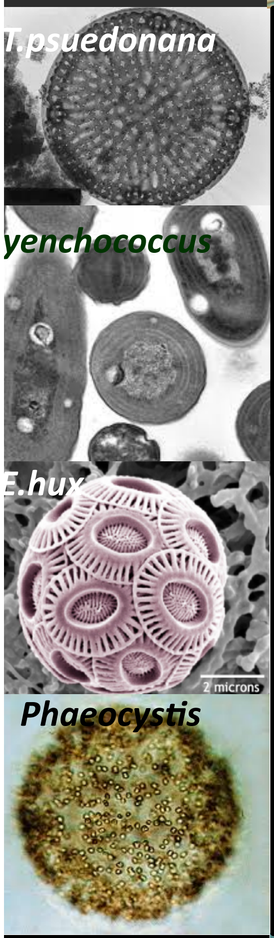


Uptake pathways & rates



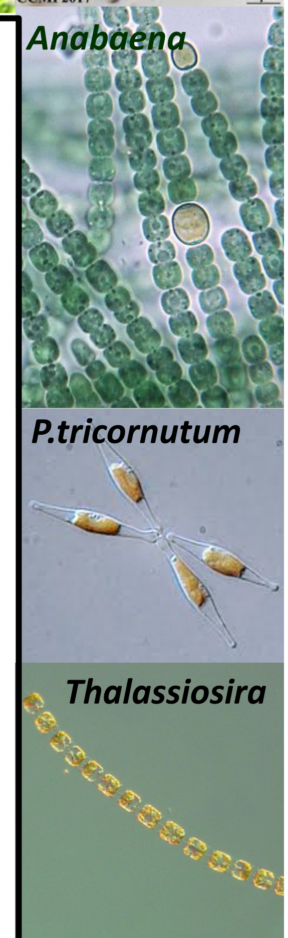
Lis, Shaked, Kranzler, Keren and Morel. 2015. ISME
Iron bioavailability to phytoplankton: an empirical approach

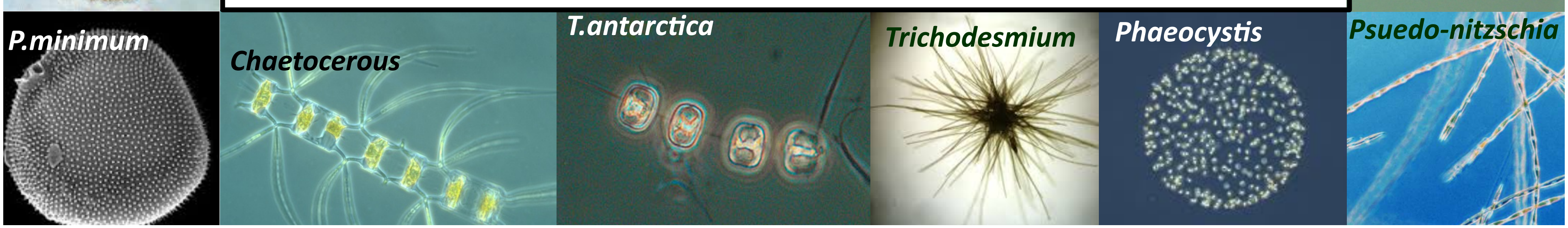


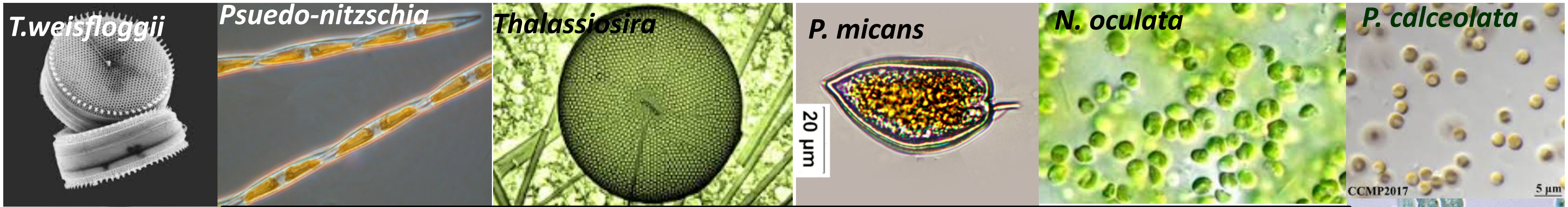


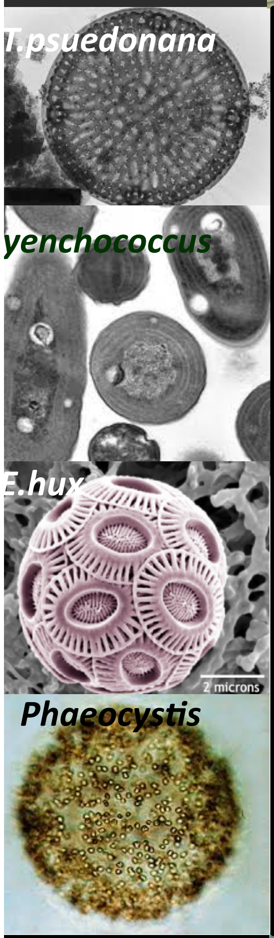
Compiling 5 decades of uptake studies:

- Do phytoplankton differ in their ability to acquire Fe?
- Are there lower/upper limits to uptake rates?
- Which Fe complexes are more/less available?
- Can lab studies help define Fe availability in natural environments?









Compiling 5 decades of uptake studies:

18 studies from **13** research groups

Short term and long term (growth) uptake

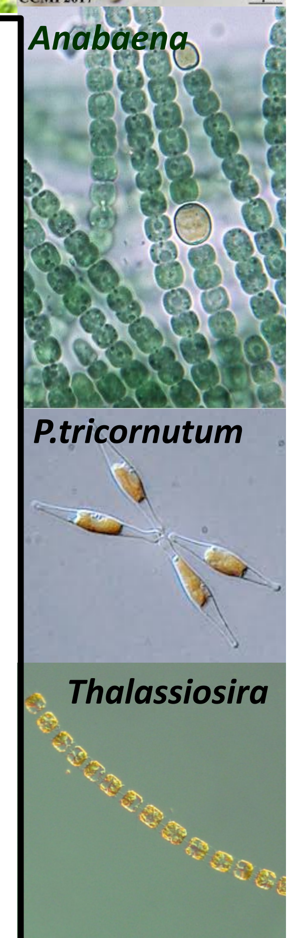
15 phytoplankton species and **28** strains

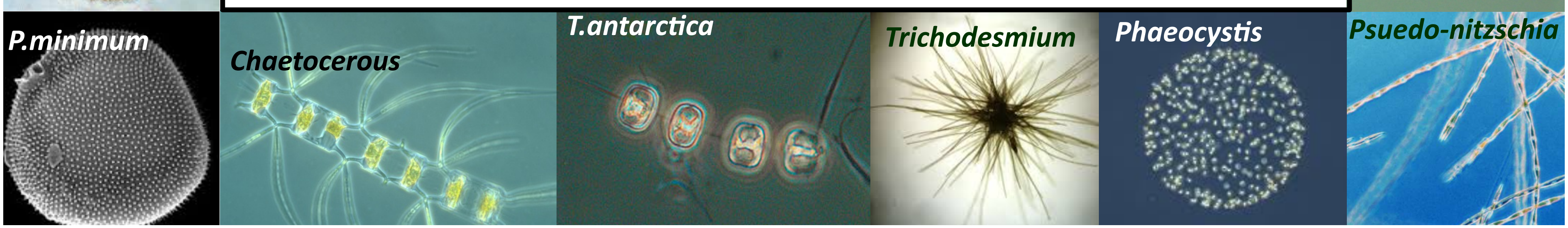
5 major divisions (Euks & Cyanos)

16 Fe-substrates

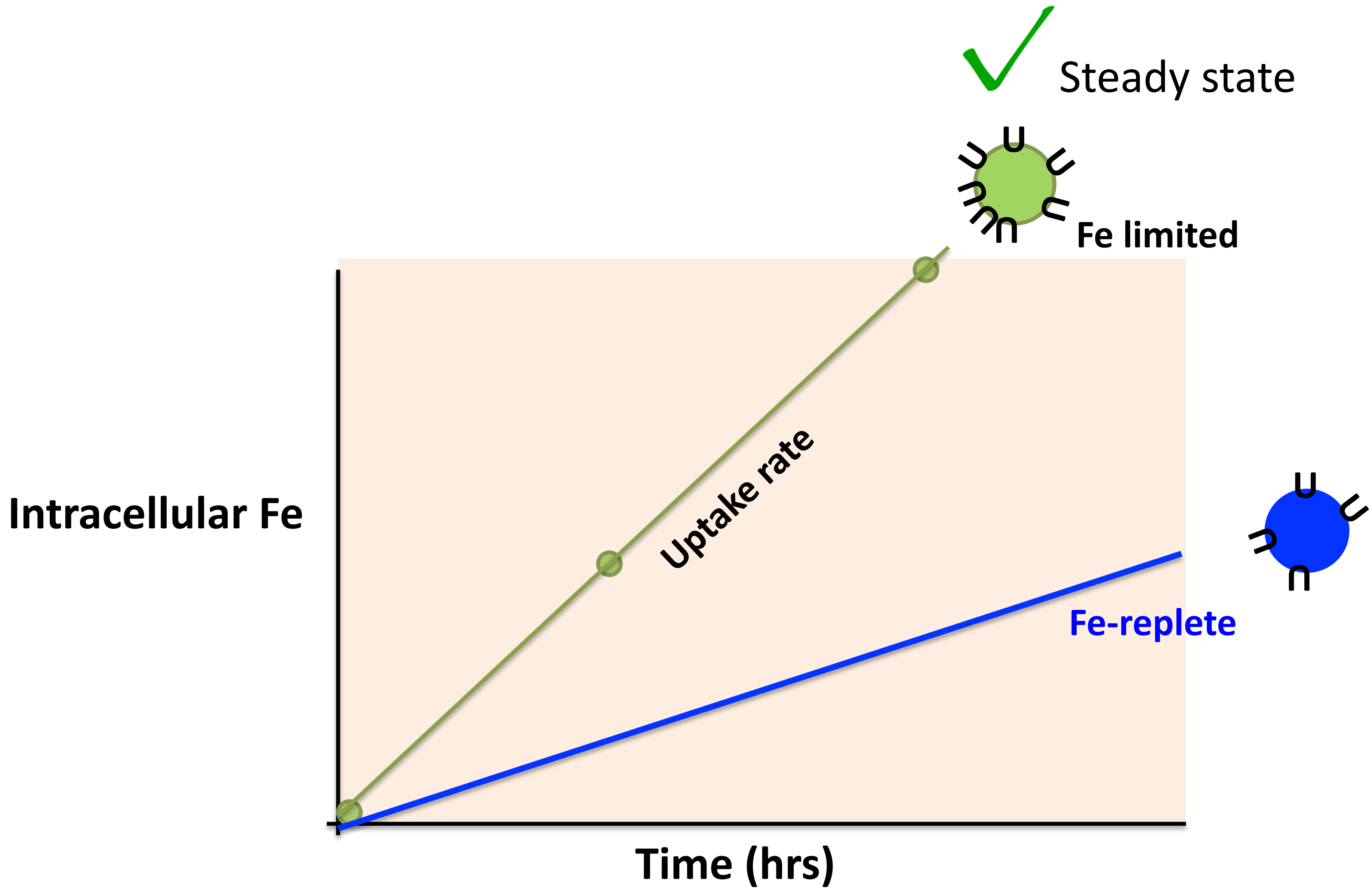
~ 25% our own data

Stringent data selection criteria
(Fe limited cells, log phase, [Fe] below that of V_{max}, etc..)

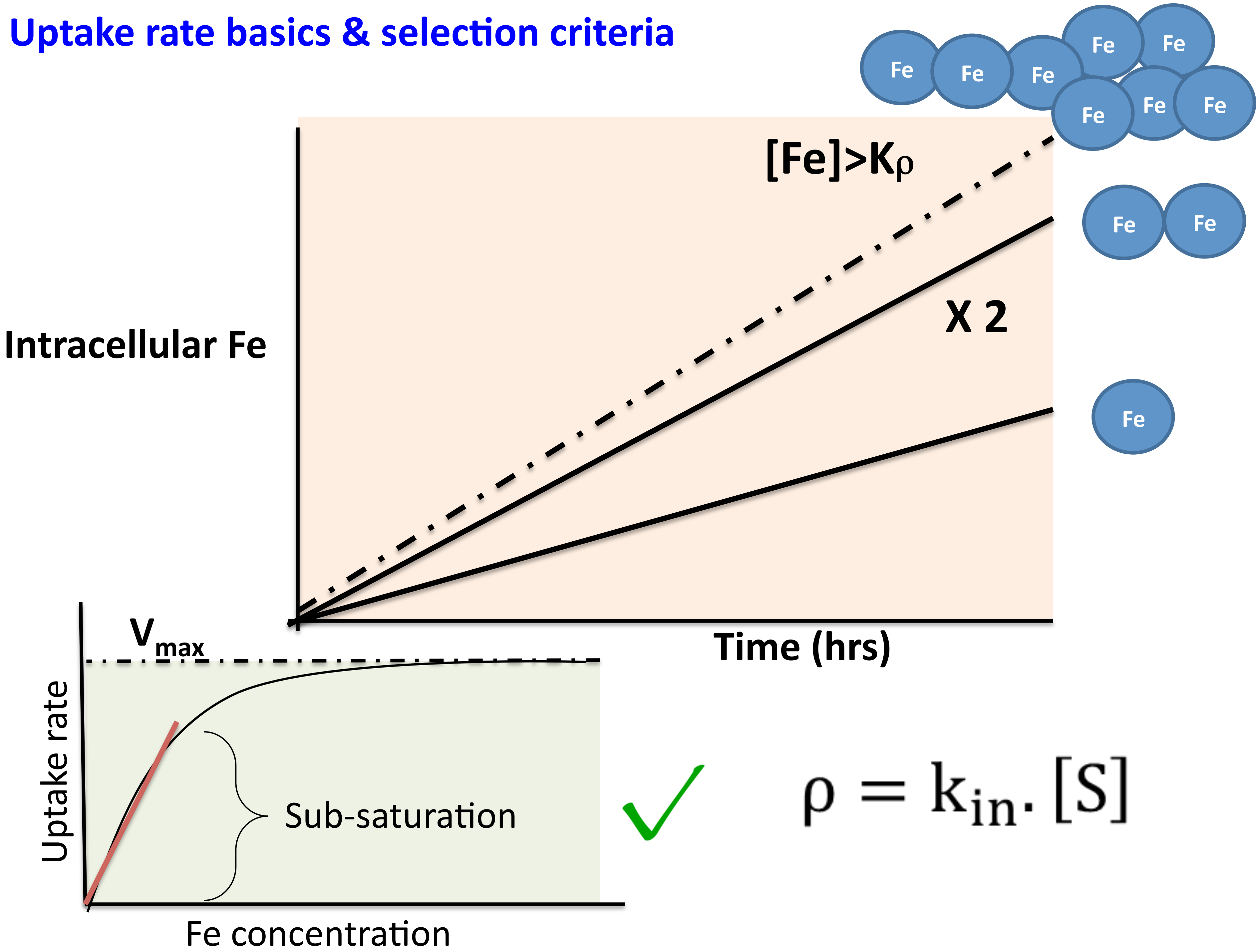




Uptake rate basics & selection criteria

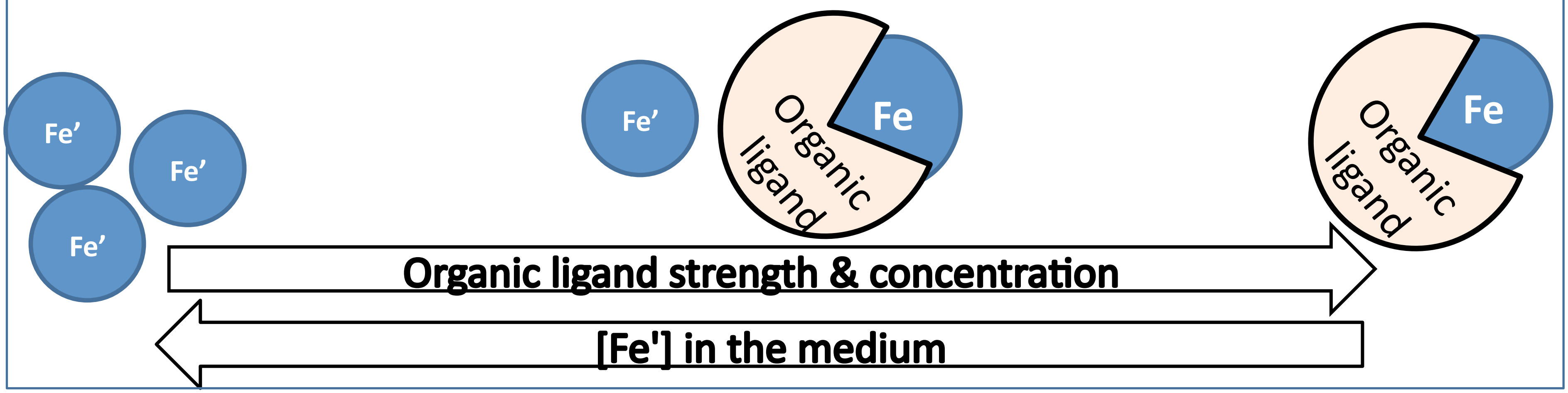


Uptake rate basics & selection criteria

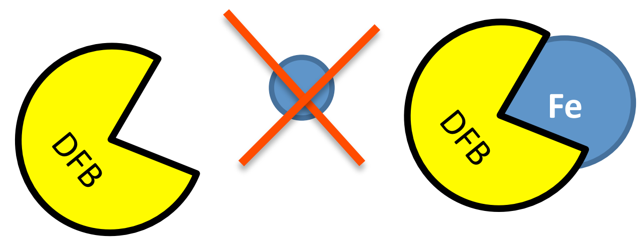


$$\rho = k_{in} . [S]$$

Uptake rate basics & selection criteria

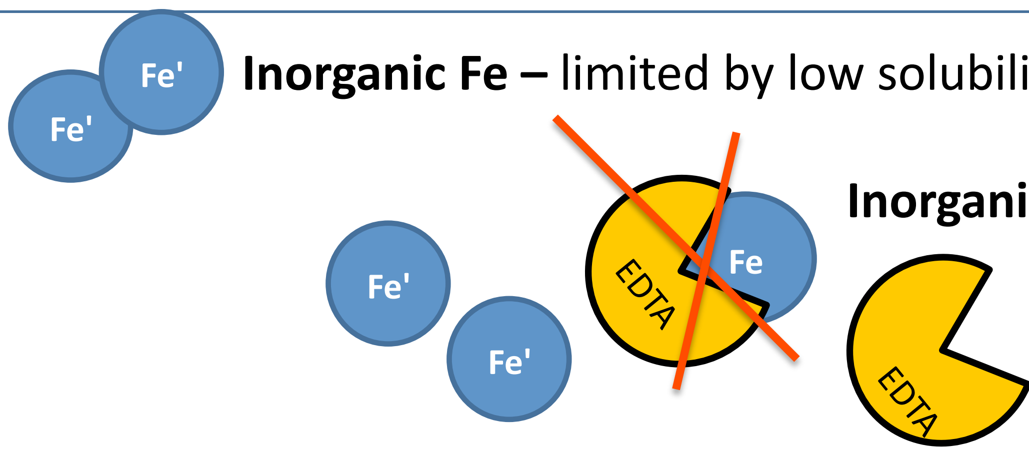


Strong Ligands – FeDFB



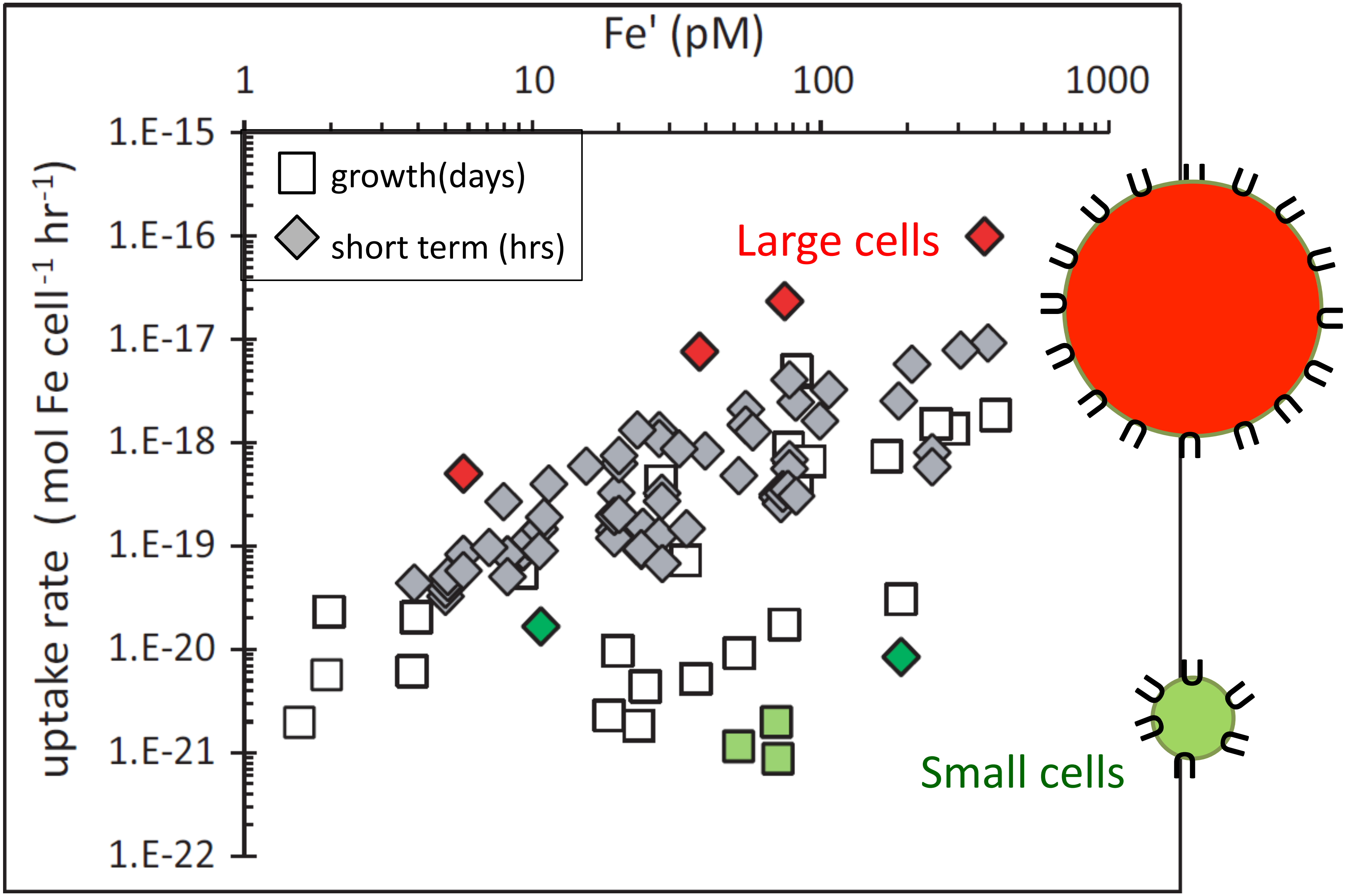
Inorganic Fe – limited by low solubility

Inorganic Fe – buffered by EDTA



$$\rho = k_{in} . [S]$$

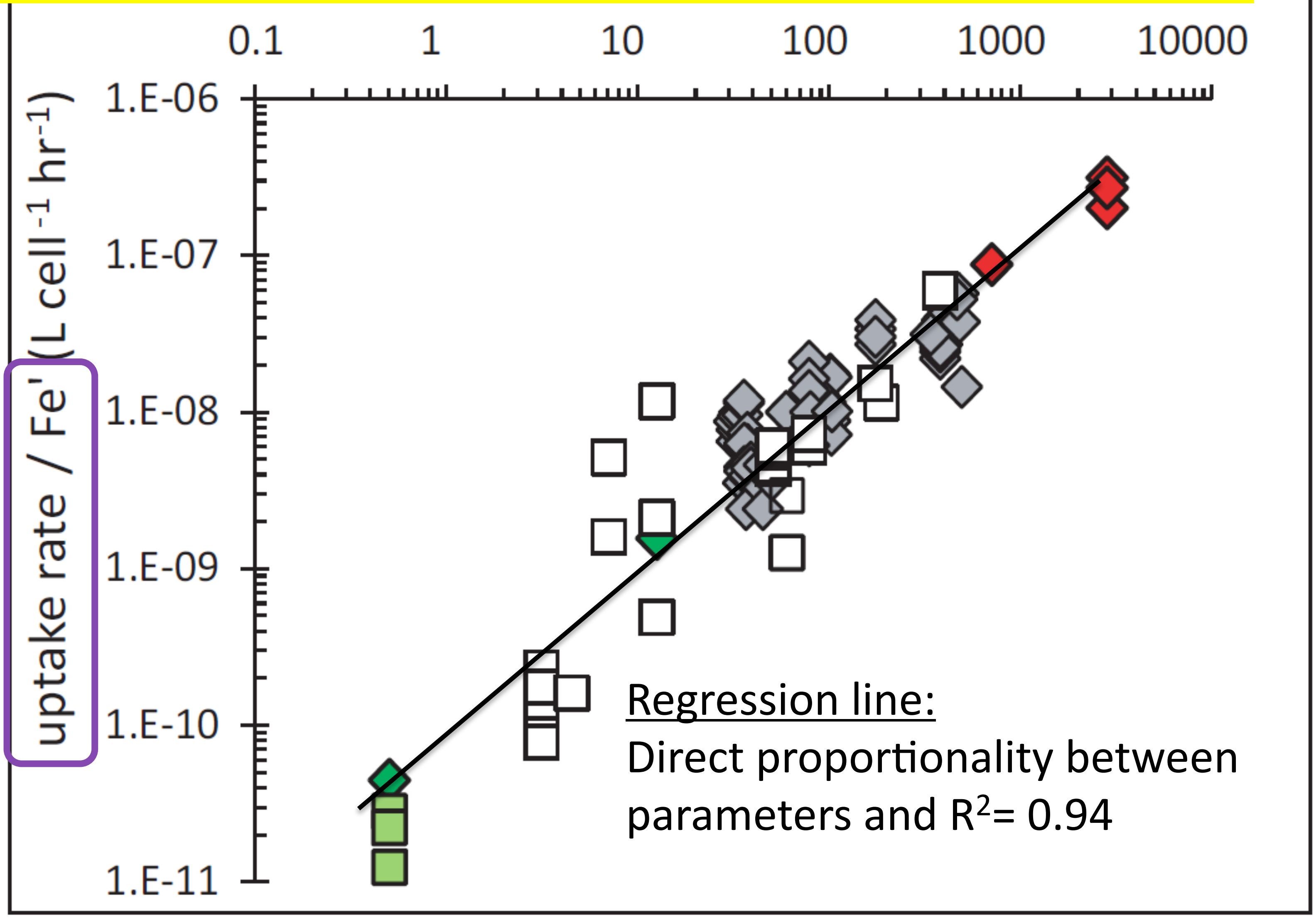
Uptake of inorganic Iron (Fe')



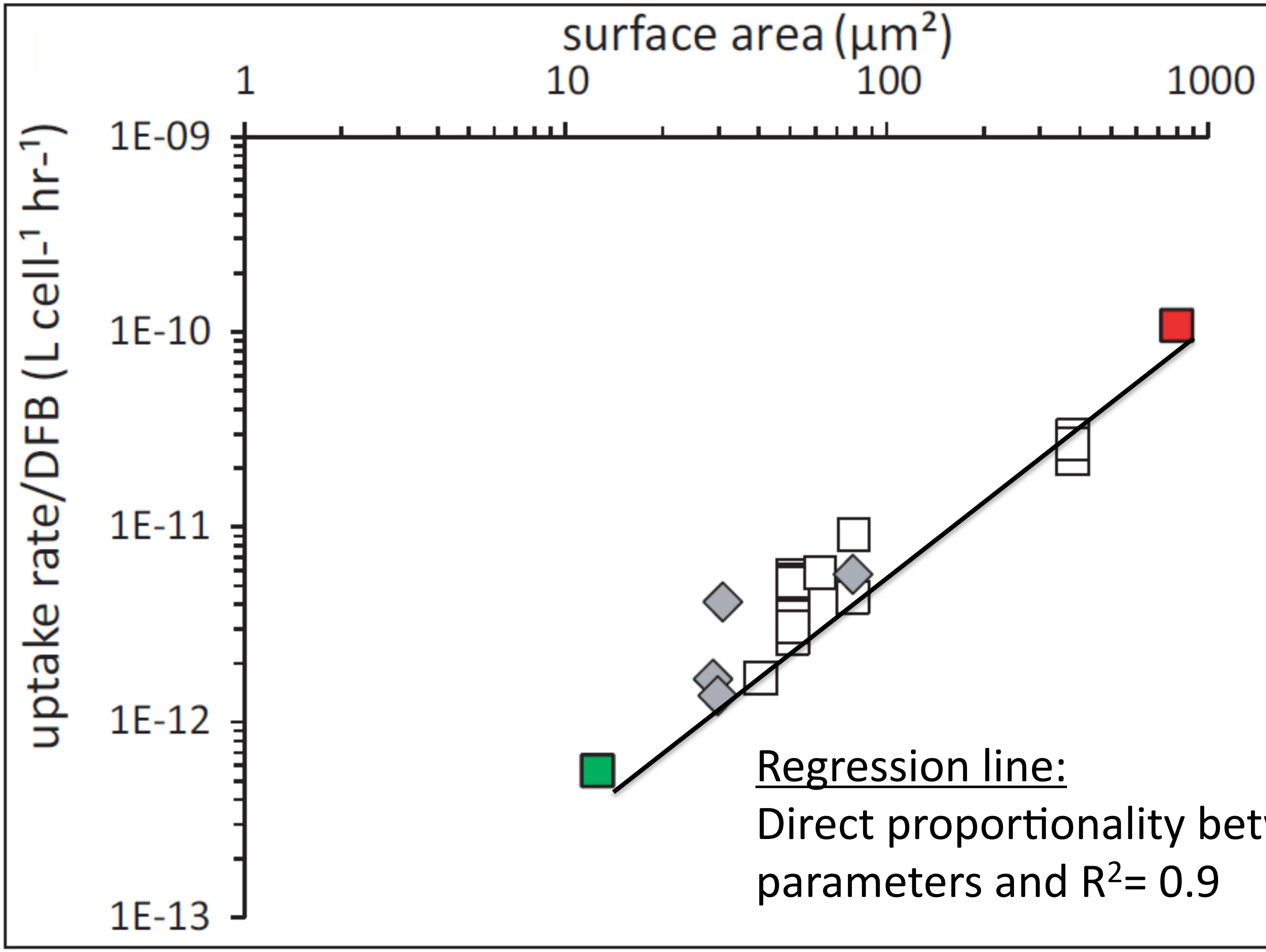
Surface area normalized uptake (k_{in}/S.A) is similar among all studied eukaryotes

$\rho = k_{in}.[S]$

$$k_{in} = \frac{\rho}{[S]}$$

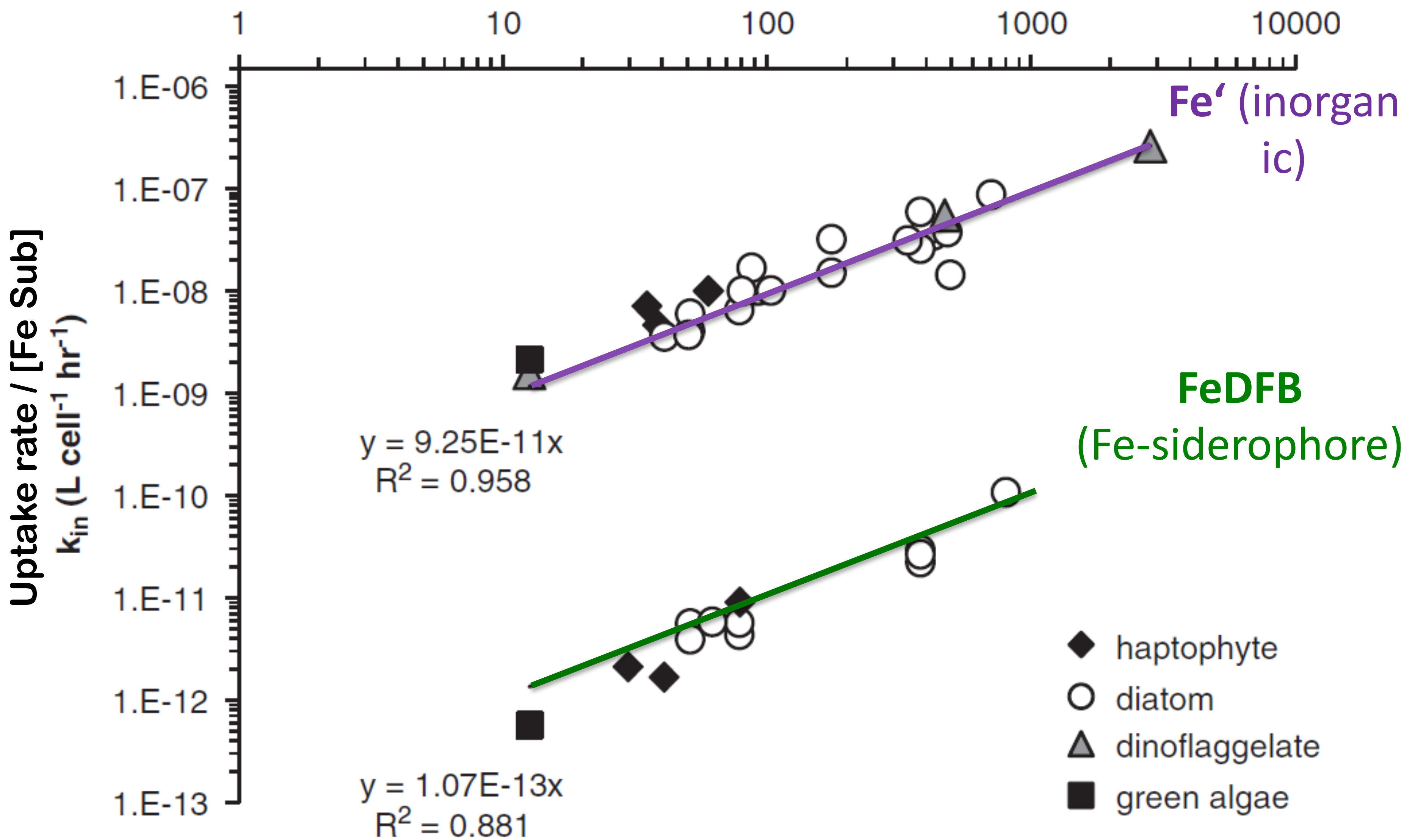


Uptake of siderophore bound Fe (FeDFB)



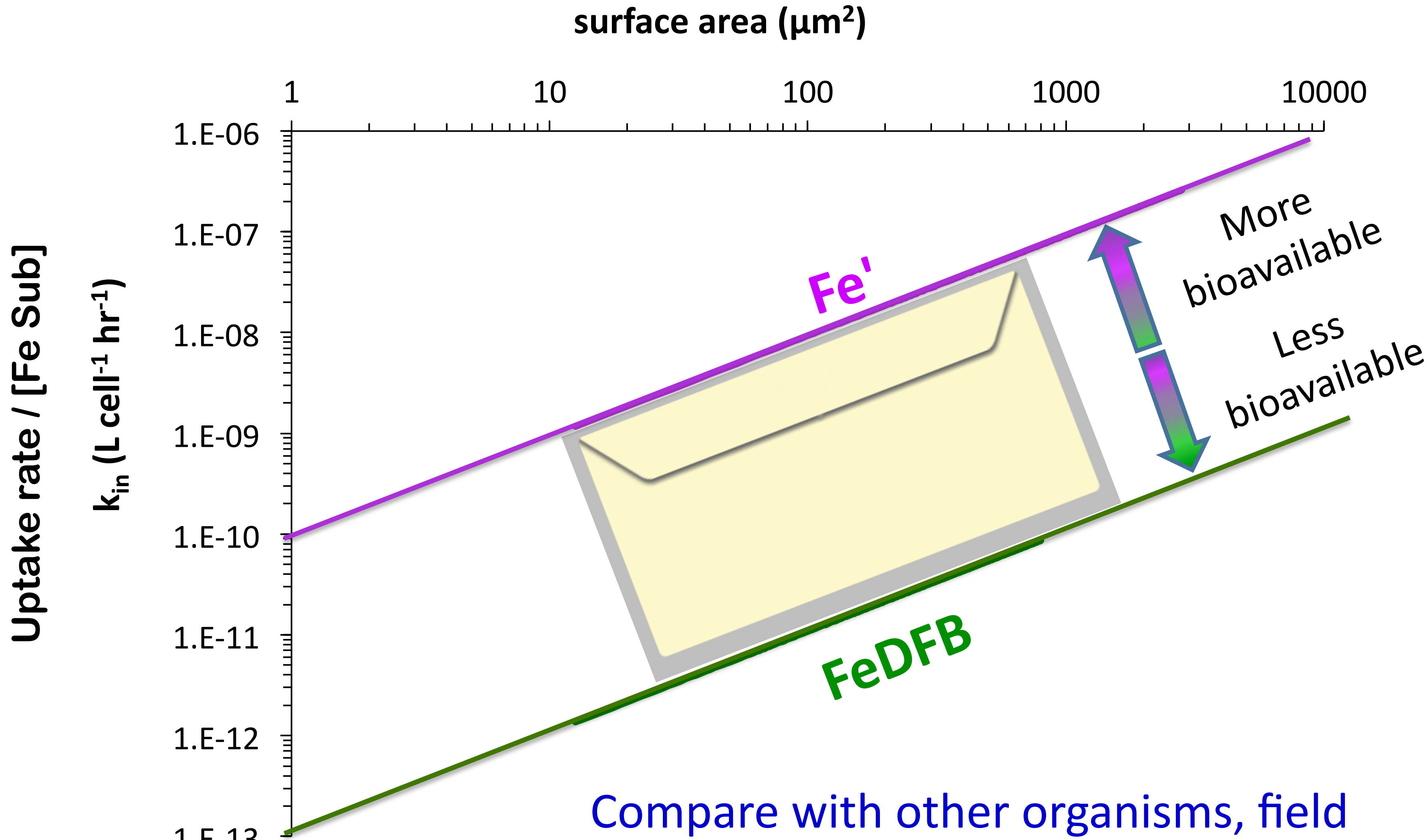
Regression line:
Direct proportionality between parameters and R^2= 0.9

Surface area normalized uptake (K_{in}/S.A) is similar among all Euks for Fe' and for FeDFB. But Fe' >> FeDFB (x1000)



The bioavailability envelope

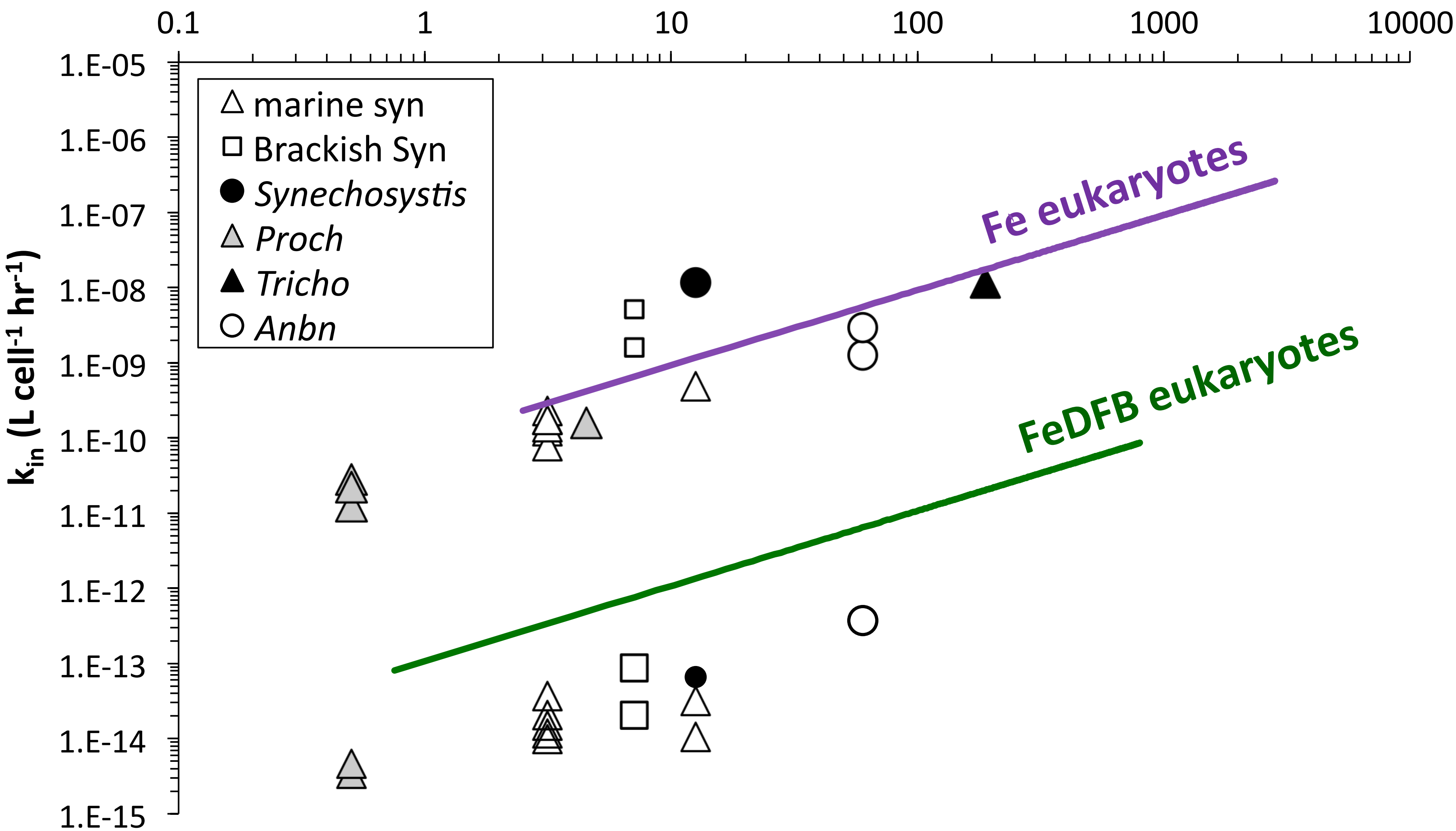
Empirical results of lab studies with euks



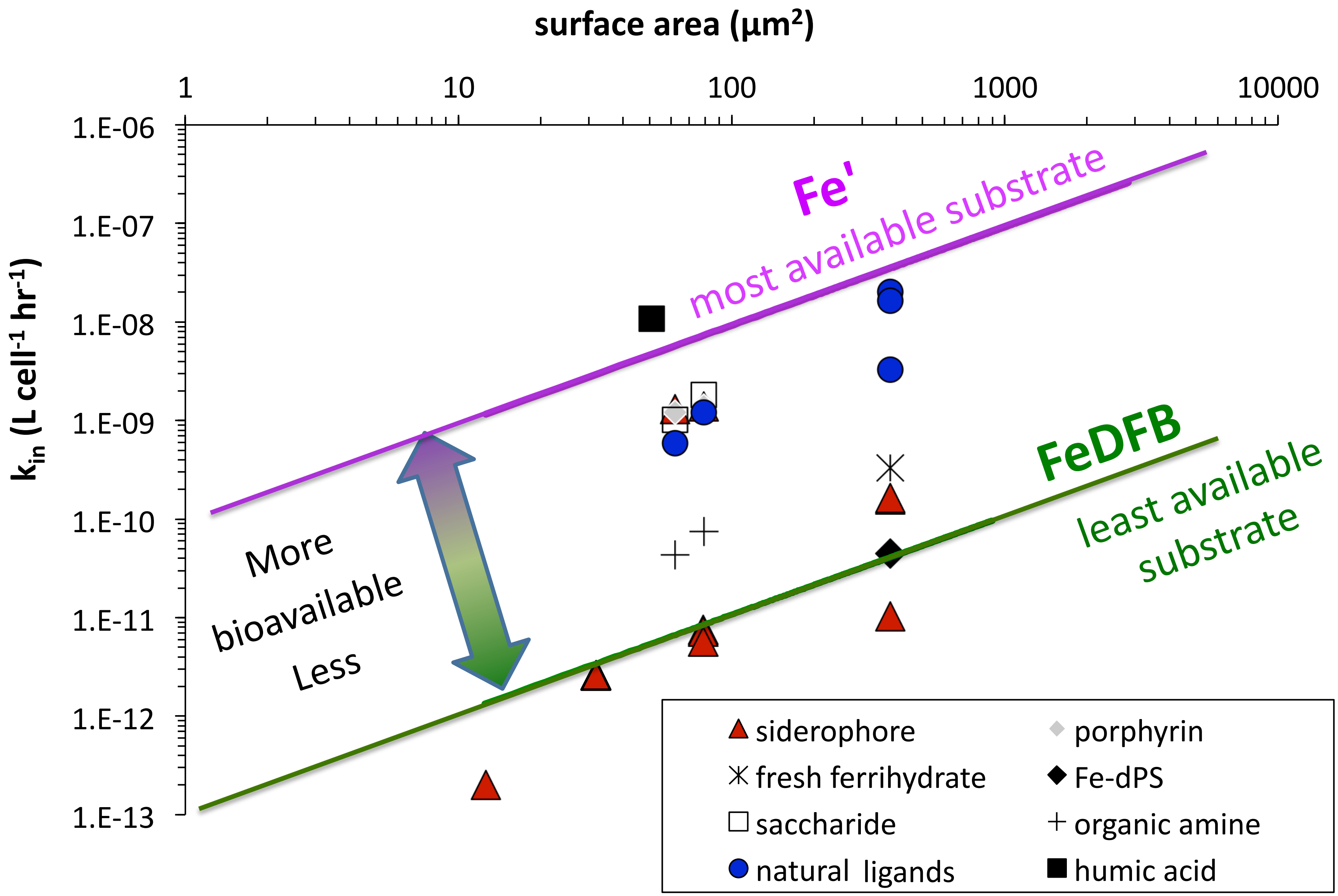
Compare with other organisms, field studies, different Fe substrates…

k_{in}/S.A is similar among all studied organisms for Fe’

FeDFB uptake of cyanos is slower than in euks



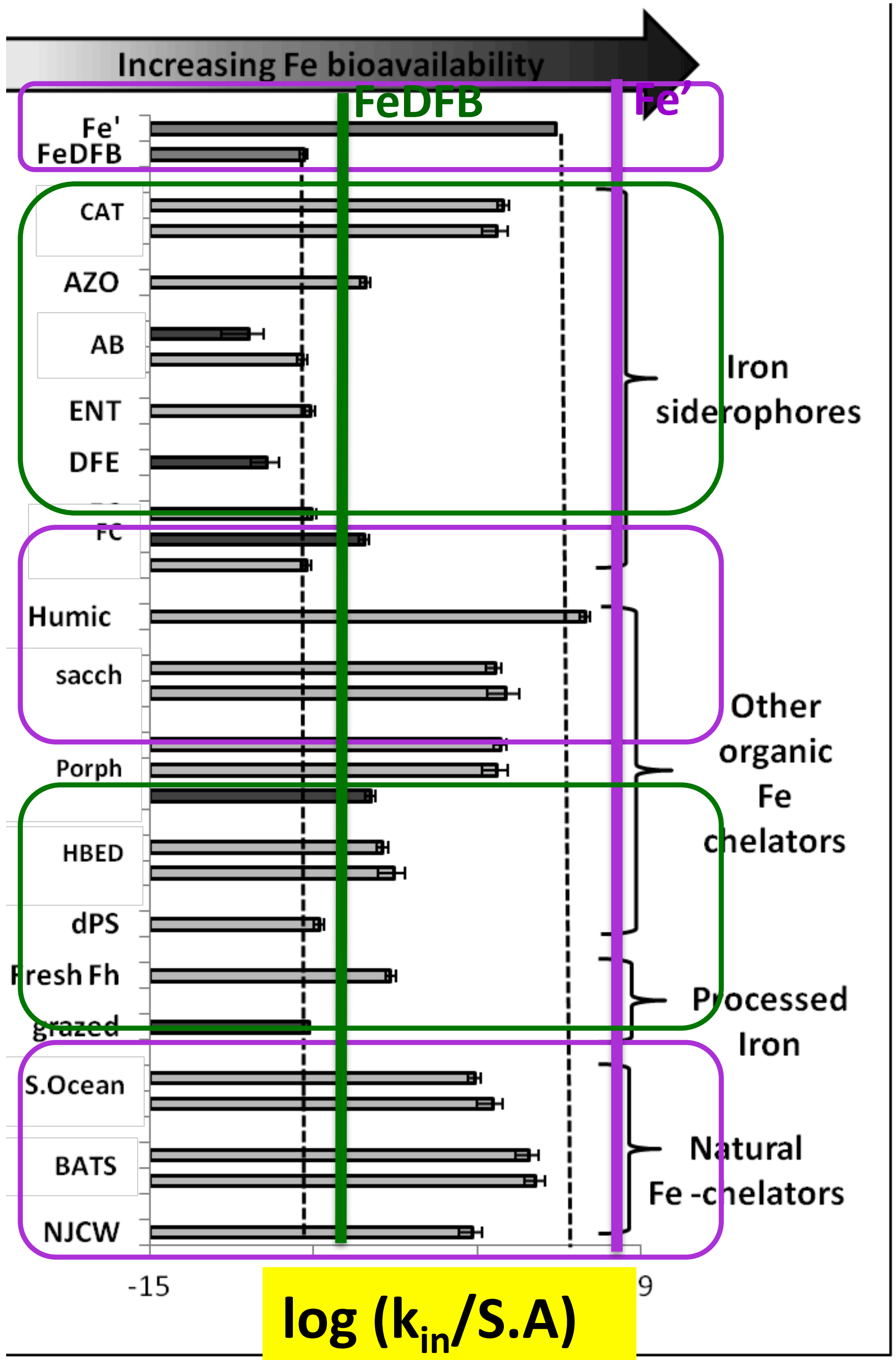
The bioavailability envelope: comparing Fe substrates



The bioavailability envelope:
comparing Fe substrates

More bioavailable Fe substrates

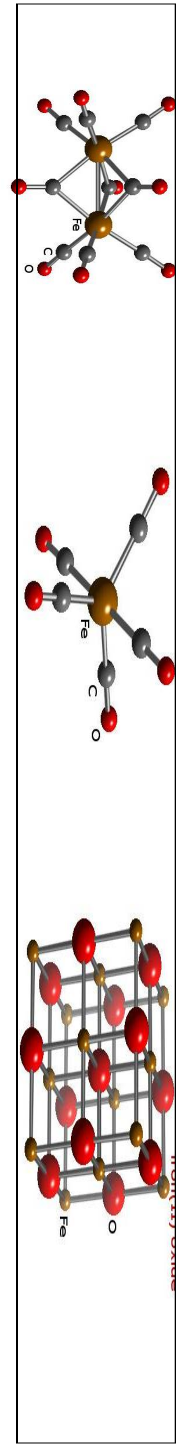
Less bioavailable Fe substrates



Conclusions and Implications

- Fe uptake rates of defined substrates can be predicted according to cell size.

- We present a convenient framework for addressing bioavailability by comparing across Fe-substrates and organisms.

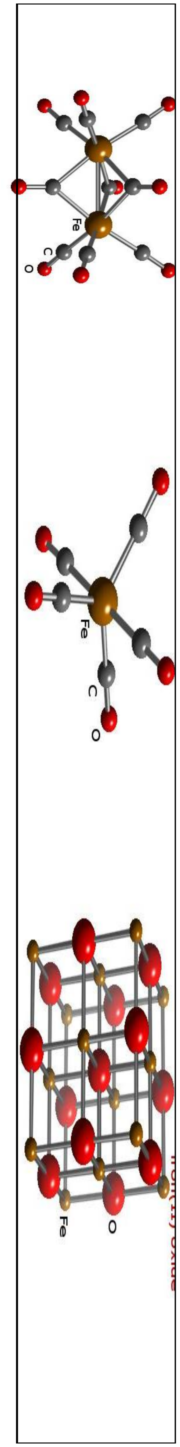


Conclusions and Implications

- All phytoplankton are limited by the same fundamental physical, chemical or biochemical factors. Uptake systems have evolved to operate at their maximal efficiency.

- Phytoplankton may employ a similar iron uptake mechanism : <u>reductive Fe uptake</u>
  Experimental data for ~10 cyanos and ~30 euks!!

- If phytoplankton cannot further increase uptake rates, a competitive advantage in Fe-limited waters must be gained through alternative means.
  Decrease cell size, decrease Fe demands, use alternative Fe sources



Availability of Solid Phase Fe to Phytoplankton:
Defining major factors at play

Which physico-chemical form can the cell access? → **Colloidal/ Particulate** (directly ingested) → **The whole pFe pool is available**

Dissolved
(generated from the particles)

How soluble is the mineral? (chemical reactivity, [ligand], light etc…) → **Availability extracted from solubility & dissolution rates**

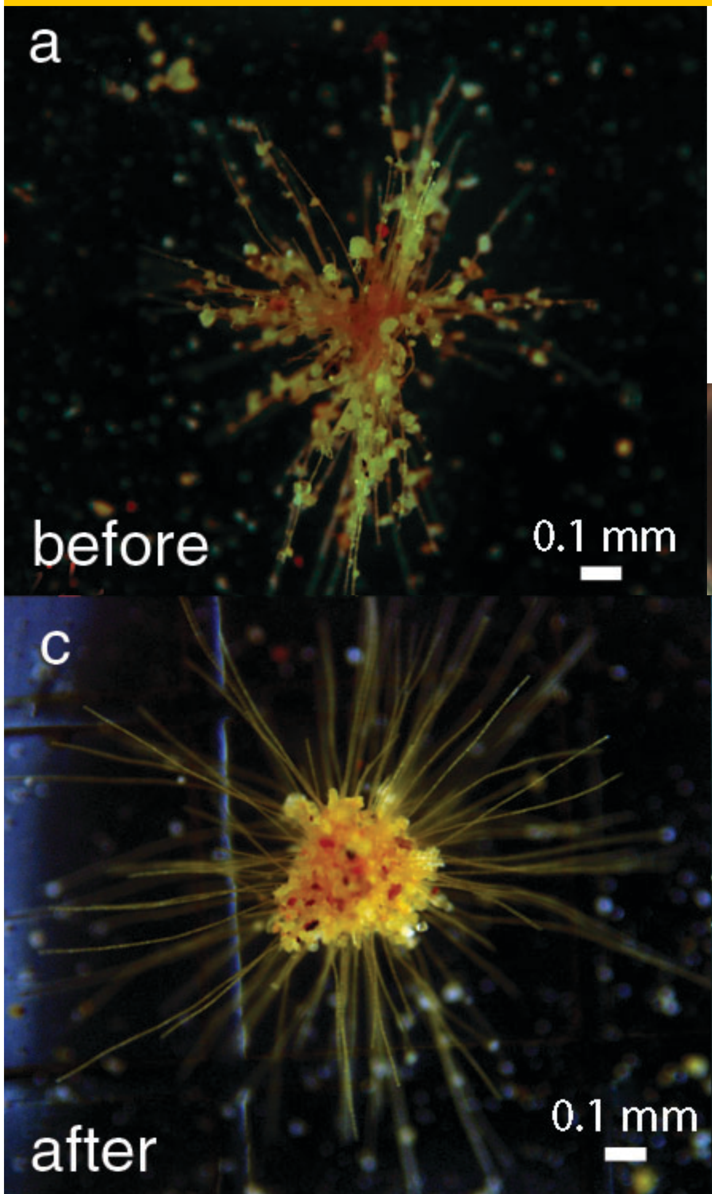
Can cells enhance mineral dissolution rate? → **Add bio-mediated dissolution**

- Removing Fe' (shifting equilibrium)
- Active dissolution by phytoplankton
- Team-up with bacteria (siderophores)

Mineral residence time in upper water → **Longer - availability** ↑

Can phytoplankton keep mineral Fe at the ocean surface?

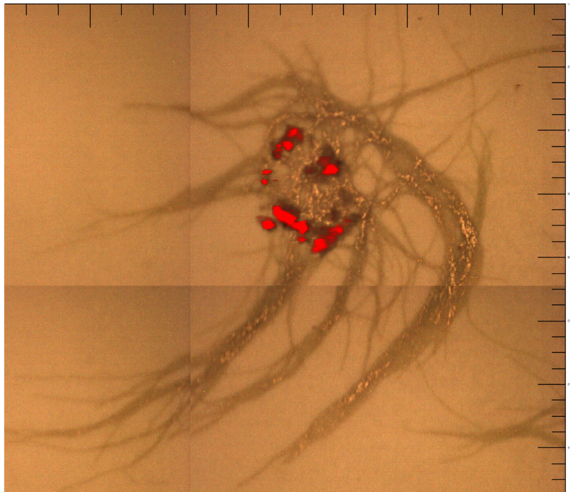
Dust-Fe capturing and modification by natural *Trichodesmium*

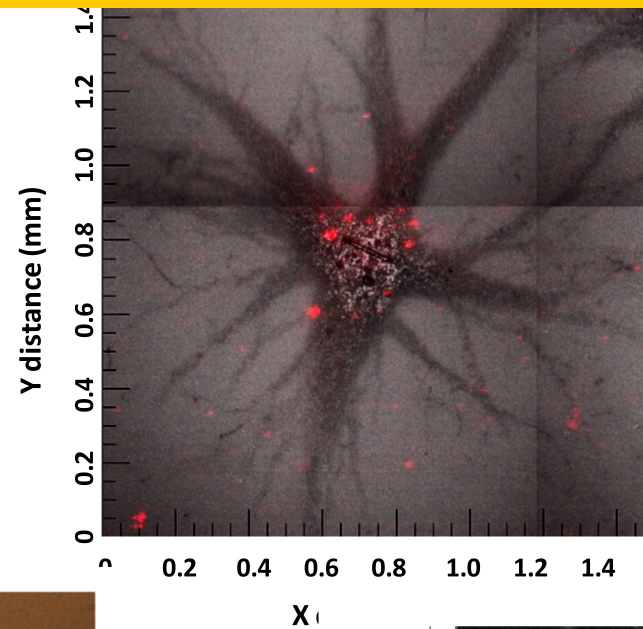


Rubin et al. 2011

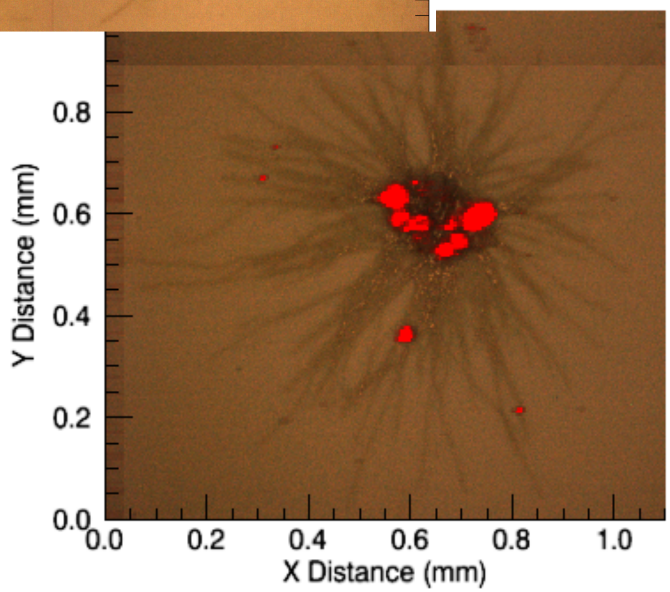
Dust-Fe capturing and modifications by natural *Trichodesmium*

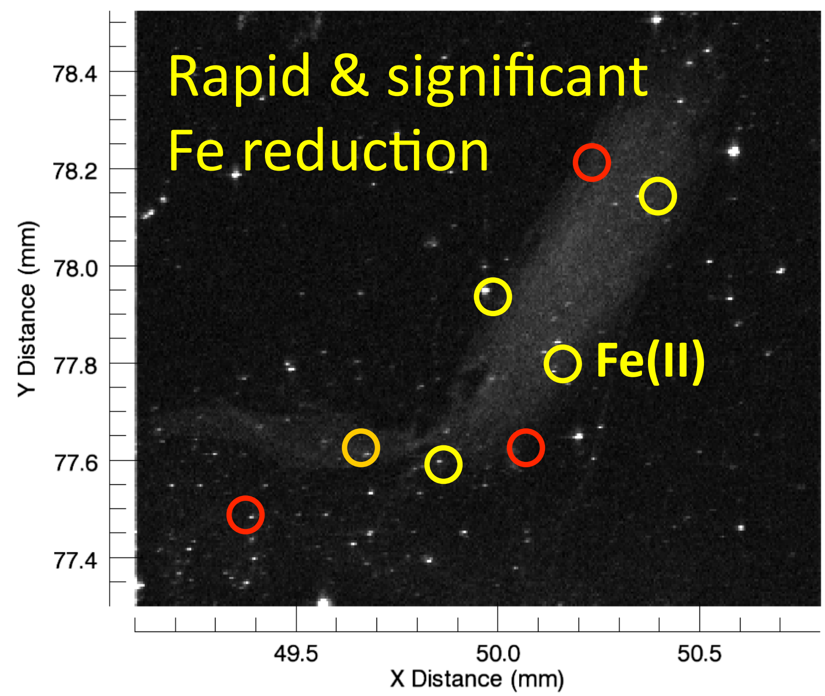
Centering of Fe-rich dust





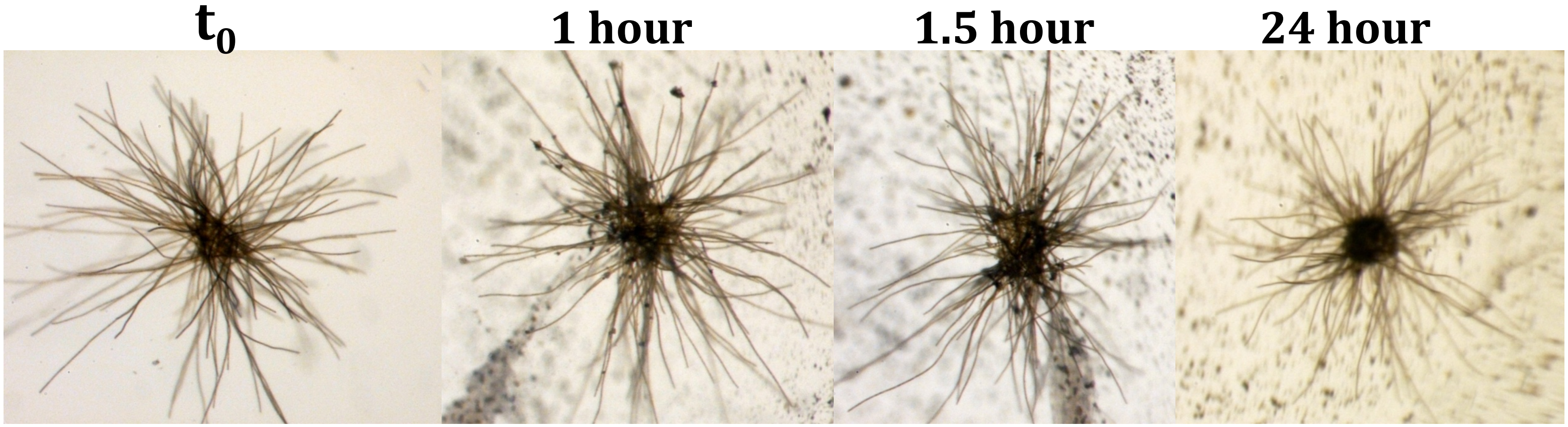
In situ association with Fe-rich particles

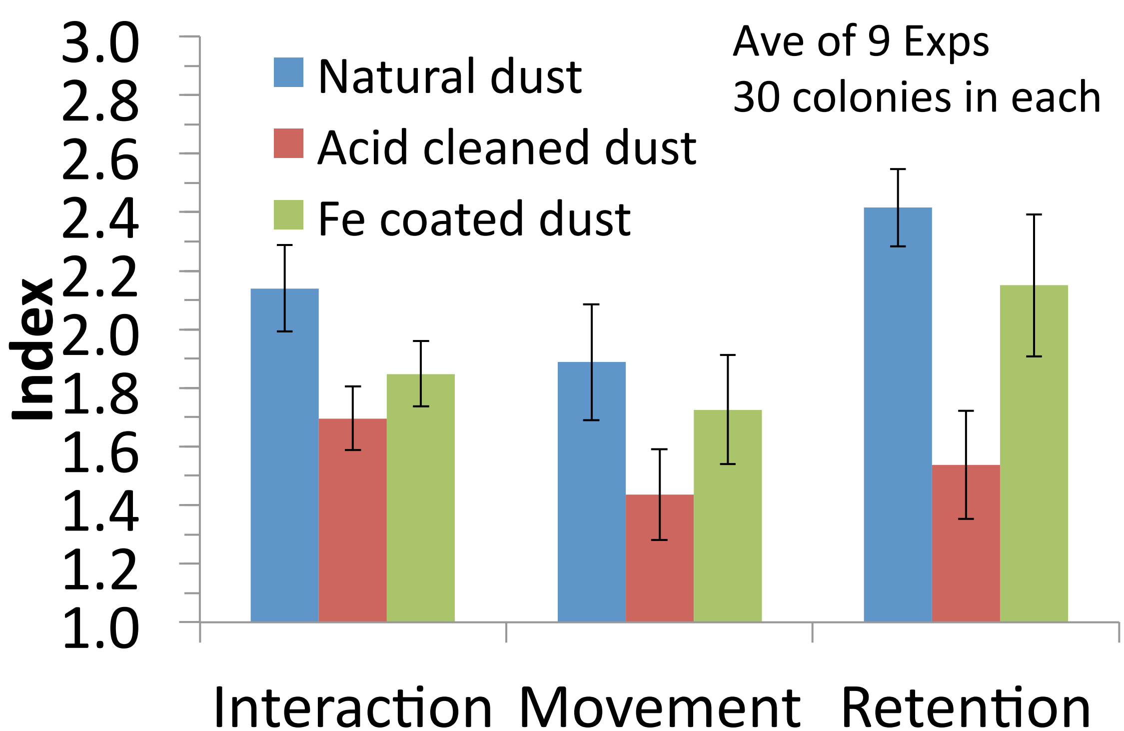




Synchrotron study with Satish Myneni

Sensing of Fe in particles by *Trichodesmium*





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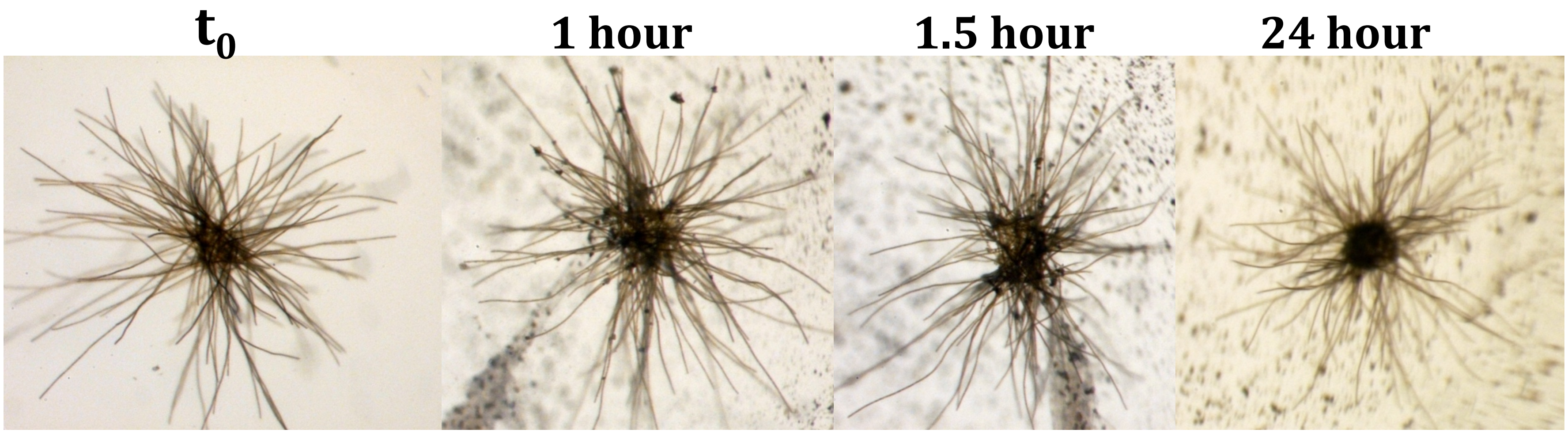
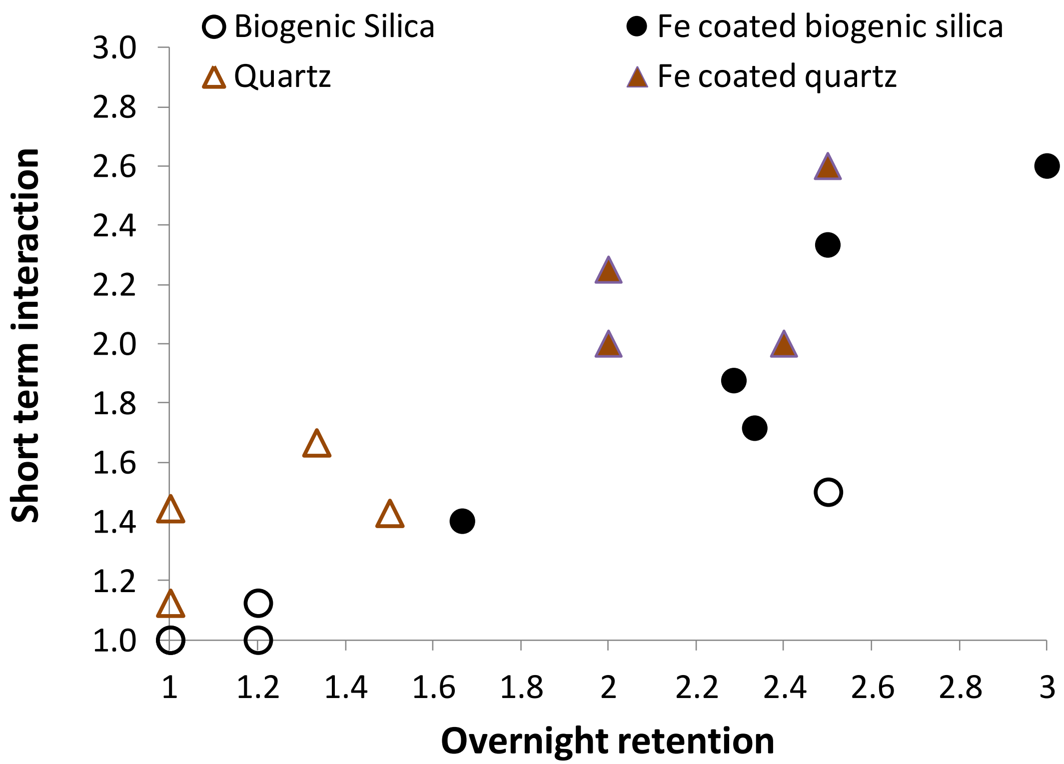


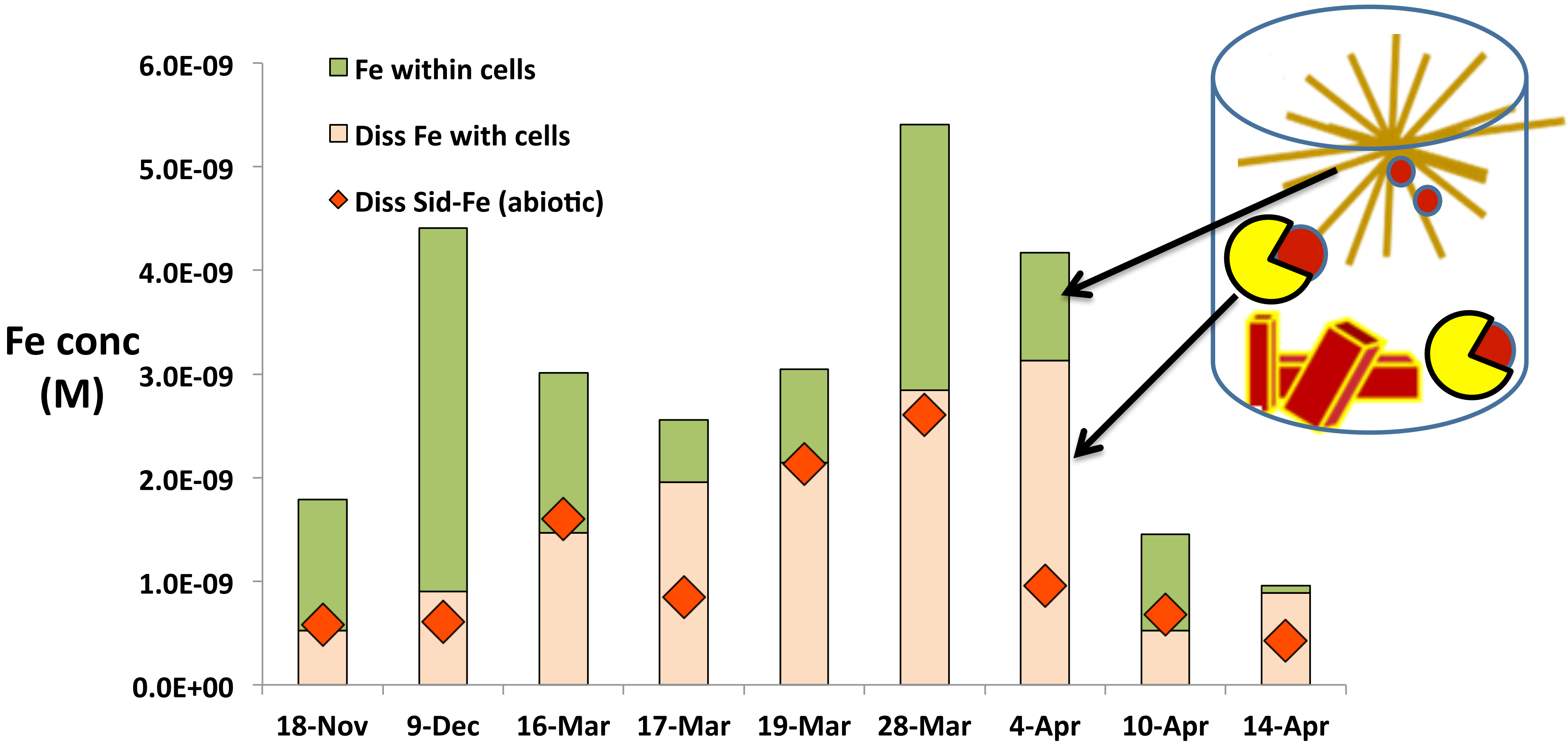


Dust-Fe capturing and modifications by natural *Trichodesmium*

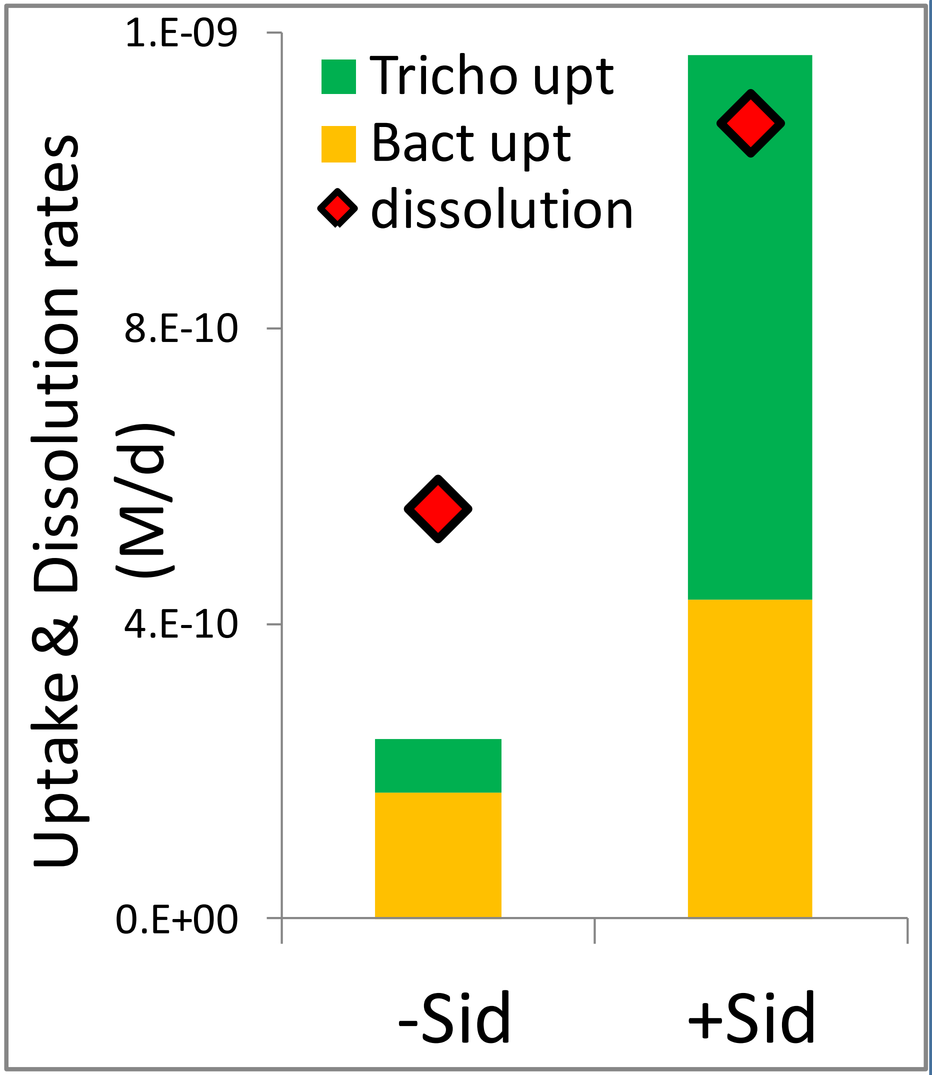
Low level assay for ^{55}Fe-ox dissolution with Sid

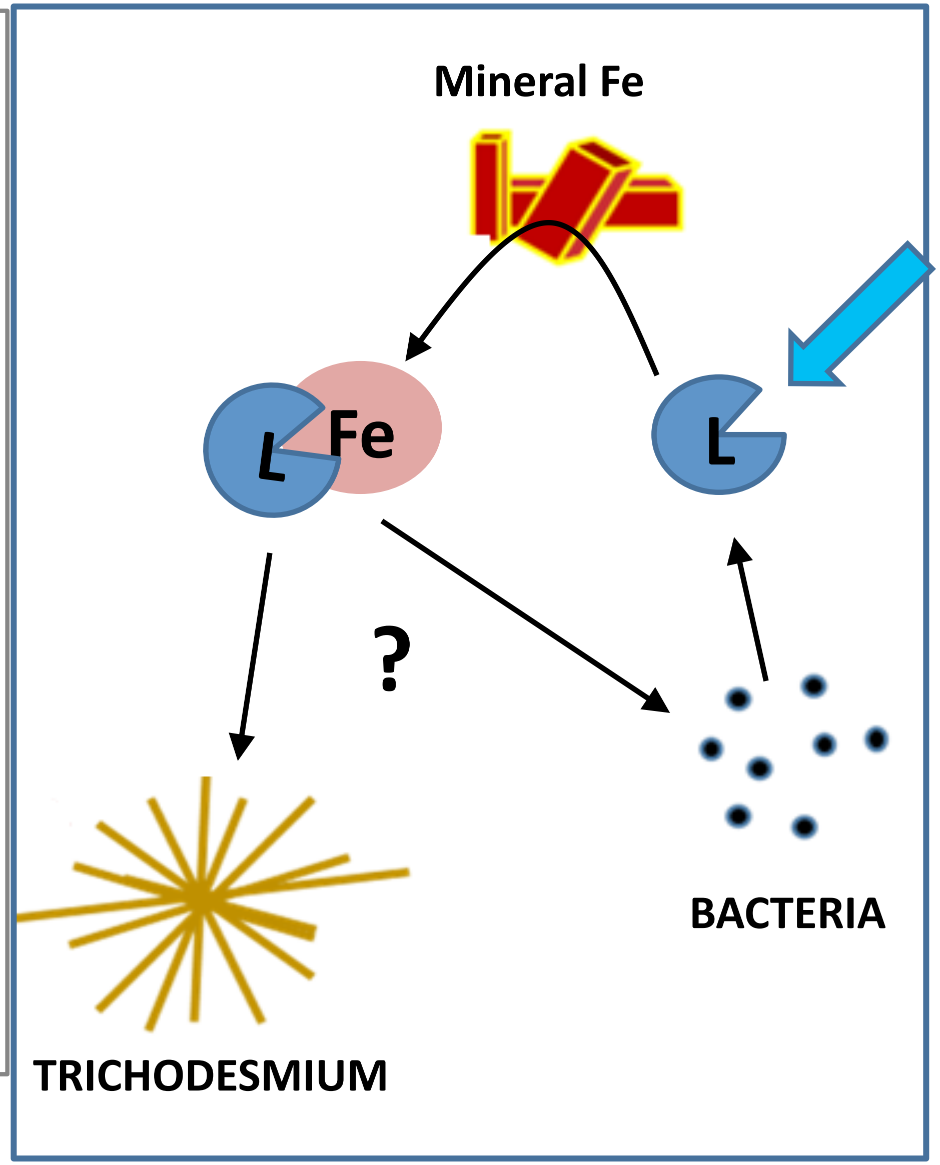
Dust-Fe capturing and modifications by natural *Trichodesmium*

Bio-mediated ^{55}Fe-ox dissolution



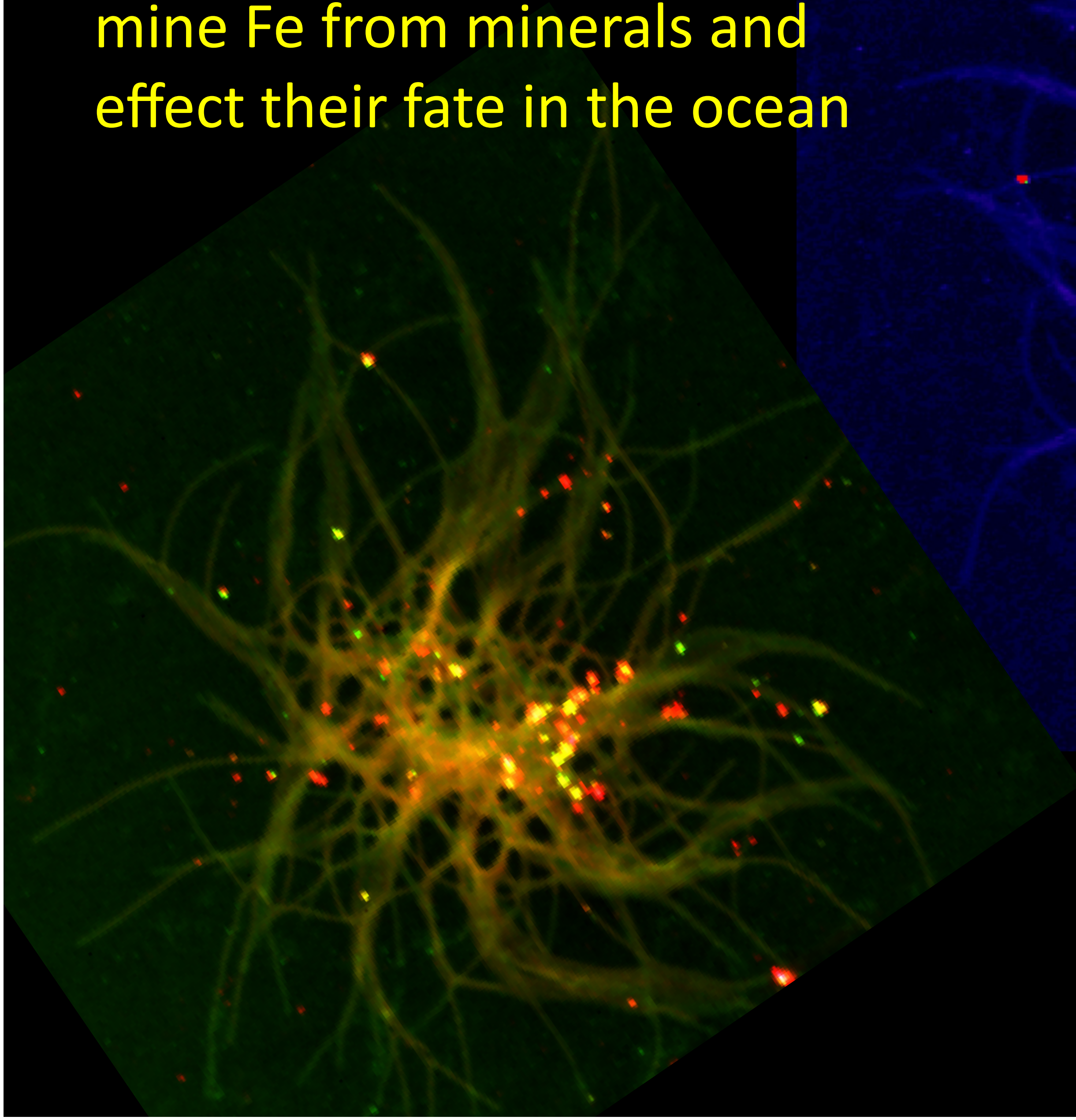
Dust-Fe uptake by natural *Trichodesmium*
Assisted by Bacteria

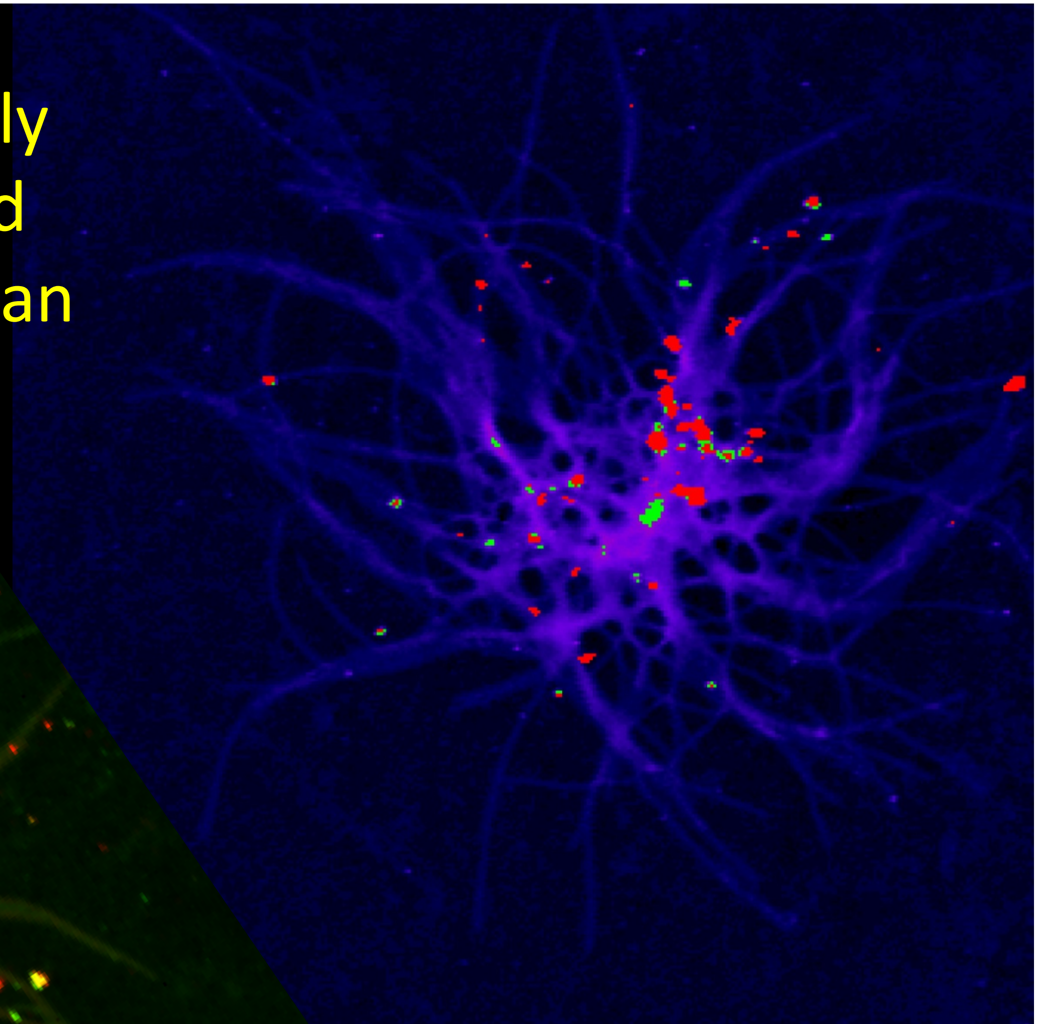




^{55}Fe-Ox, Natural colonies, Red Sea, Mar 2016

Phytoplankton may actively mine Fe from minerals and effect their fate in the ocean





Thank you