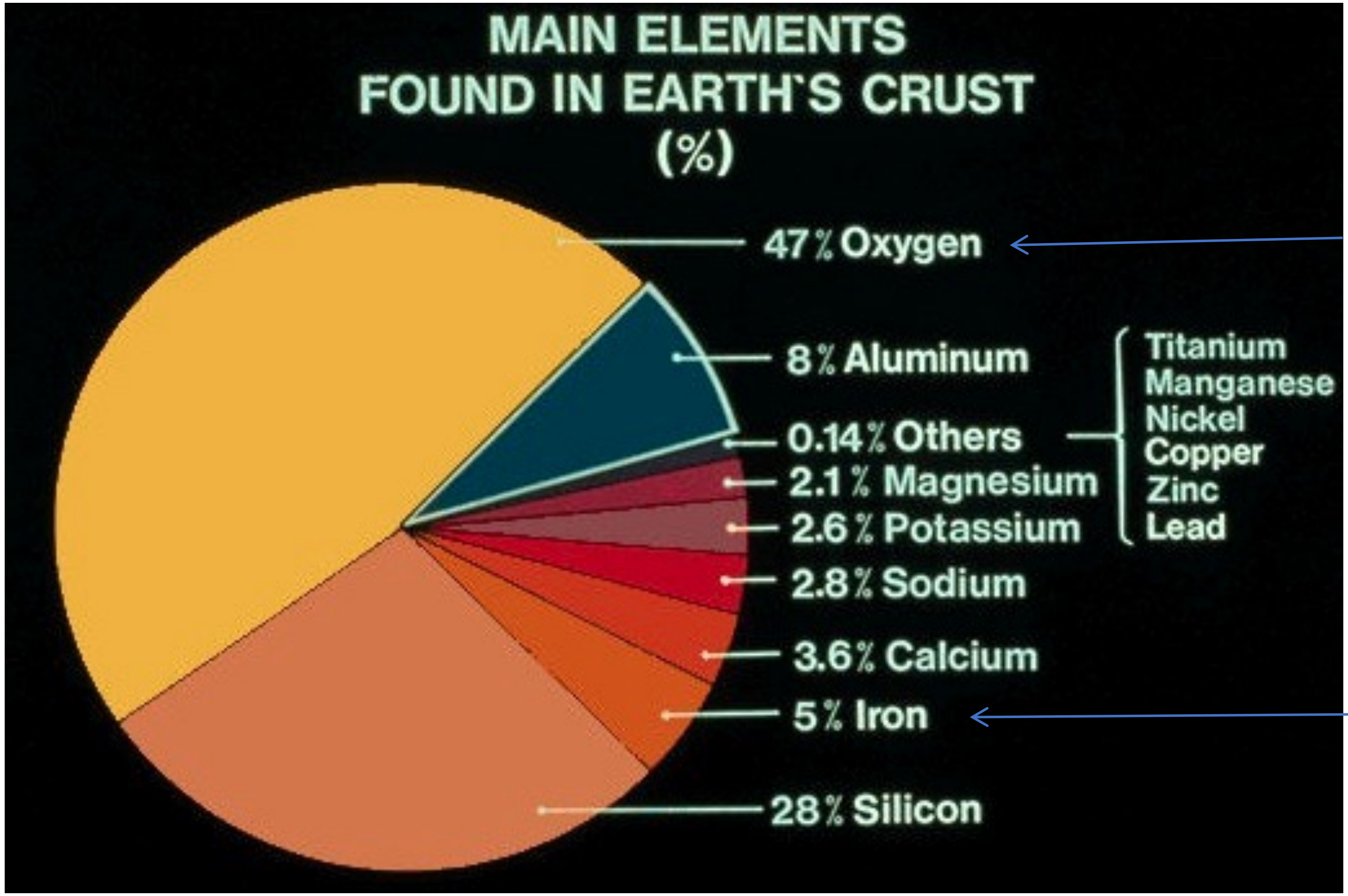
Functional annotation lesson

Targeted HMM-based annotation:

Iron cycling introduction

Iron-cycling



Redox-active

Redox-active

Iron cycling in the presence of life

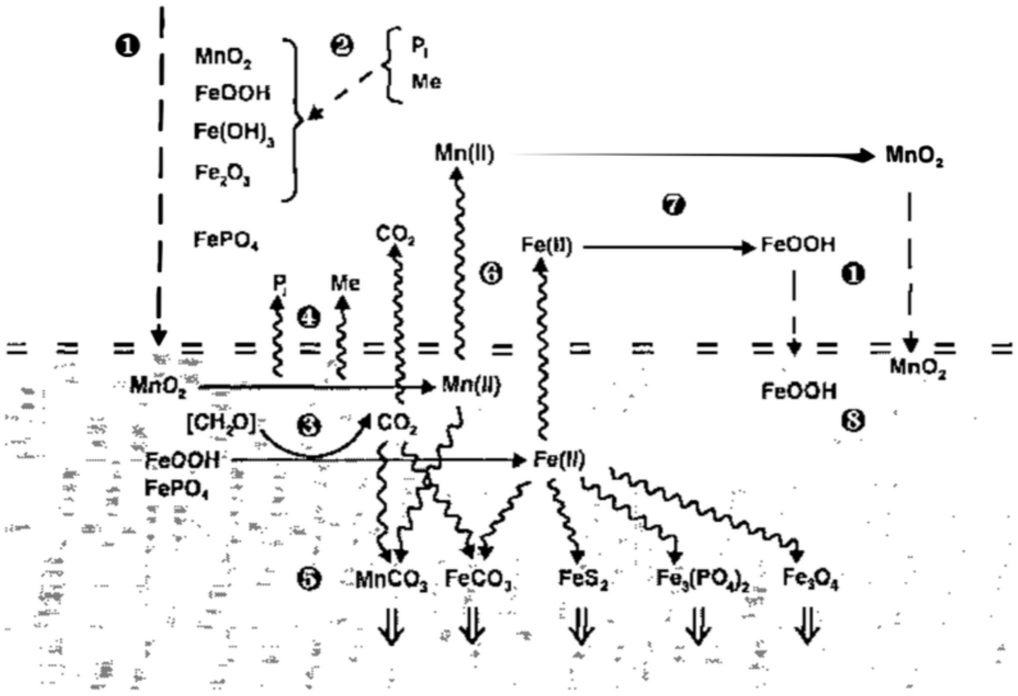


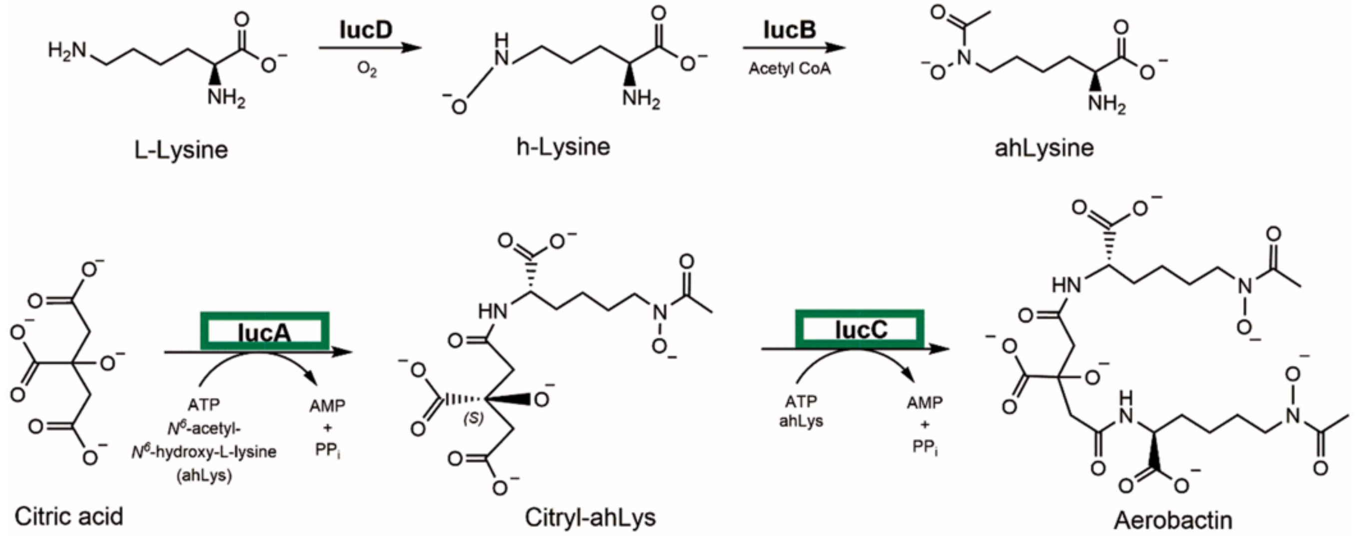
Figure 2 Iron and manganese reactions in natural environments. The various reactions that affect iron and manganese distribution in nature are depicted as 8 separate steps: (*Step 1*) Solid-phase iron and manganese oxides are removed to the suboxic zone (*shaded area*) via settling. (*Step 2*) Phosphate (P_i) is removed via precipitation as ferric phosphate, and metals (Cu, Cd, Co, Pb, As, etc) are removed via complexation with iron or manganese oxides. (*Step 3*) Organic carbon oxidation occurs at the expense of manganese or iron oxides as electron acceptors, thus releasing CO_2, Mn(II), and Fe(II). (*Step 4*) During iron reduction, inorganic phosphate and metals are released from their bound state. During manganese reduction, bound metals are released. (*Step 5*) Reduced metals form insoluble precipitates in the suboxic zone. These include rhodochrosite ($MnCO_3$), siderite ($FeCO_3$), pyrite (FeS_2), vivianite [$Fe_3(PO_4)_2$], and magnetite (Fe_3O_4). (*Step 6*) Mn(II) and Fe(II) diffuse out of the anoxic zone into the overlying oxic waters. (*Step 7*) Reoxidation of Mn and Fe takes place to form insoluble colloids or solids. (*Step 8*) If settling (step 1) occurs without an input of organic matter, the metals accumulate in the sediment with Mn oxides overlaying iron oxides.

Nealson and Saffarini, 1994

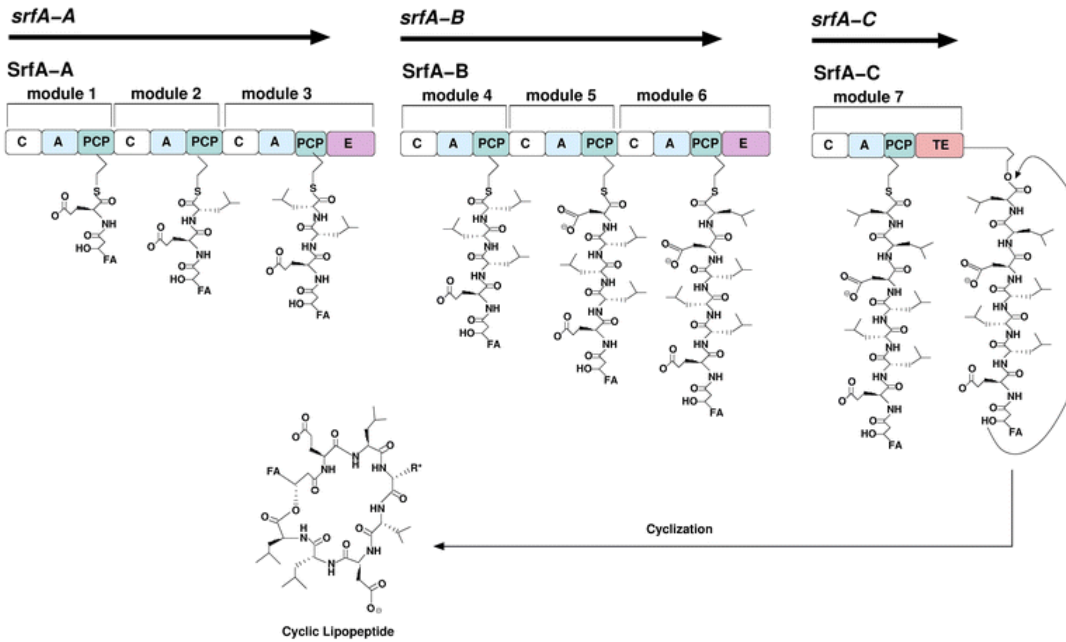
Siderophores - synthesis

What are siderophores?
Molecules that are secreted by bacteria and archaea
Bind iron, and the iron(III)-chelated siderophores are then taken up by the cell (sometimes not the same cell that secreted the siderophore!)

NRPS siderophore production

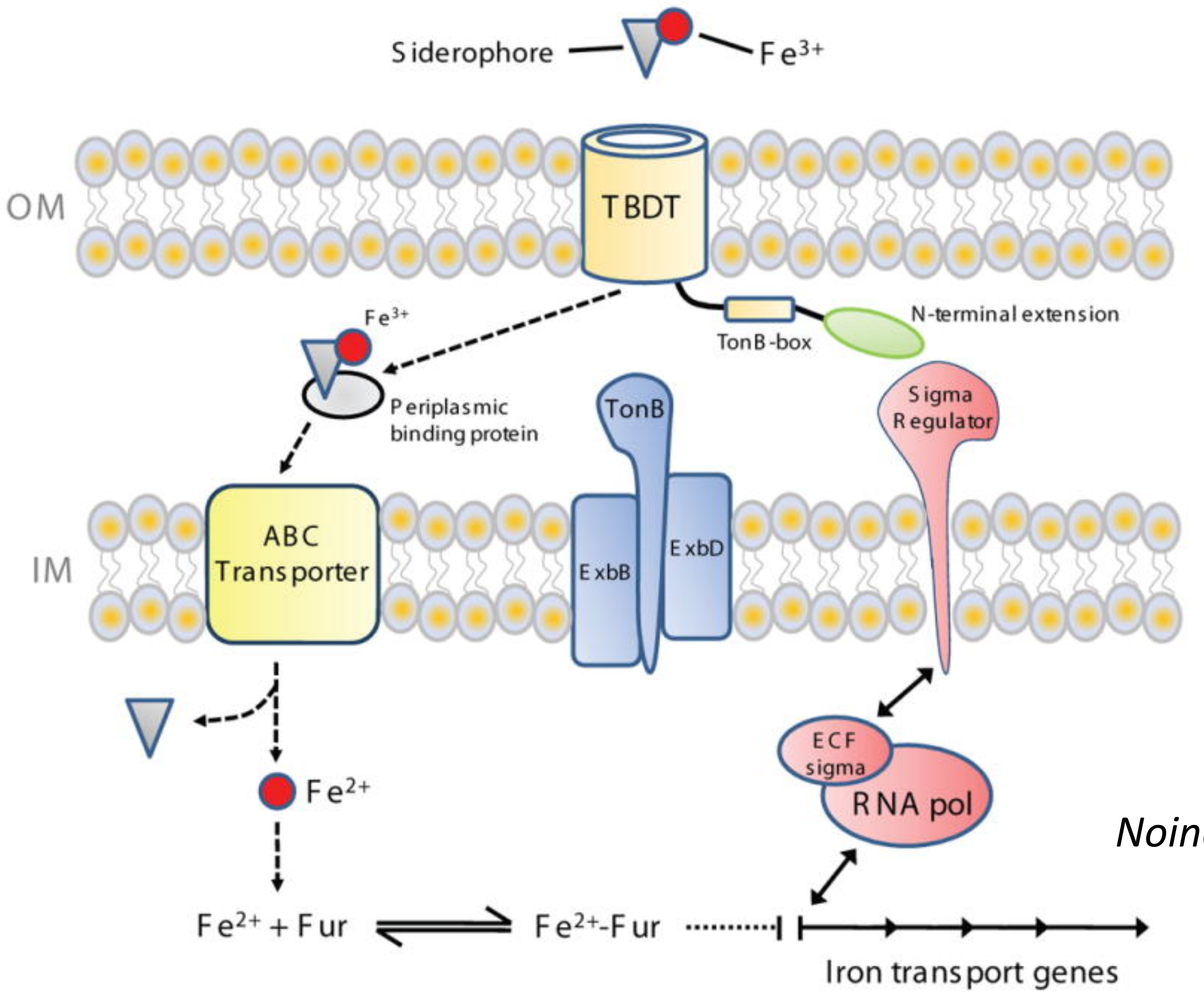


NRPS-independent siderophore production



Martinez-Nunez and Lopez, 2016

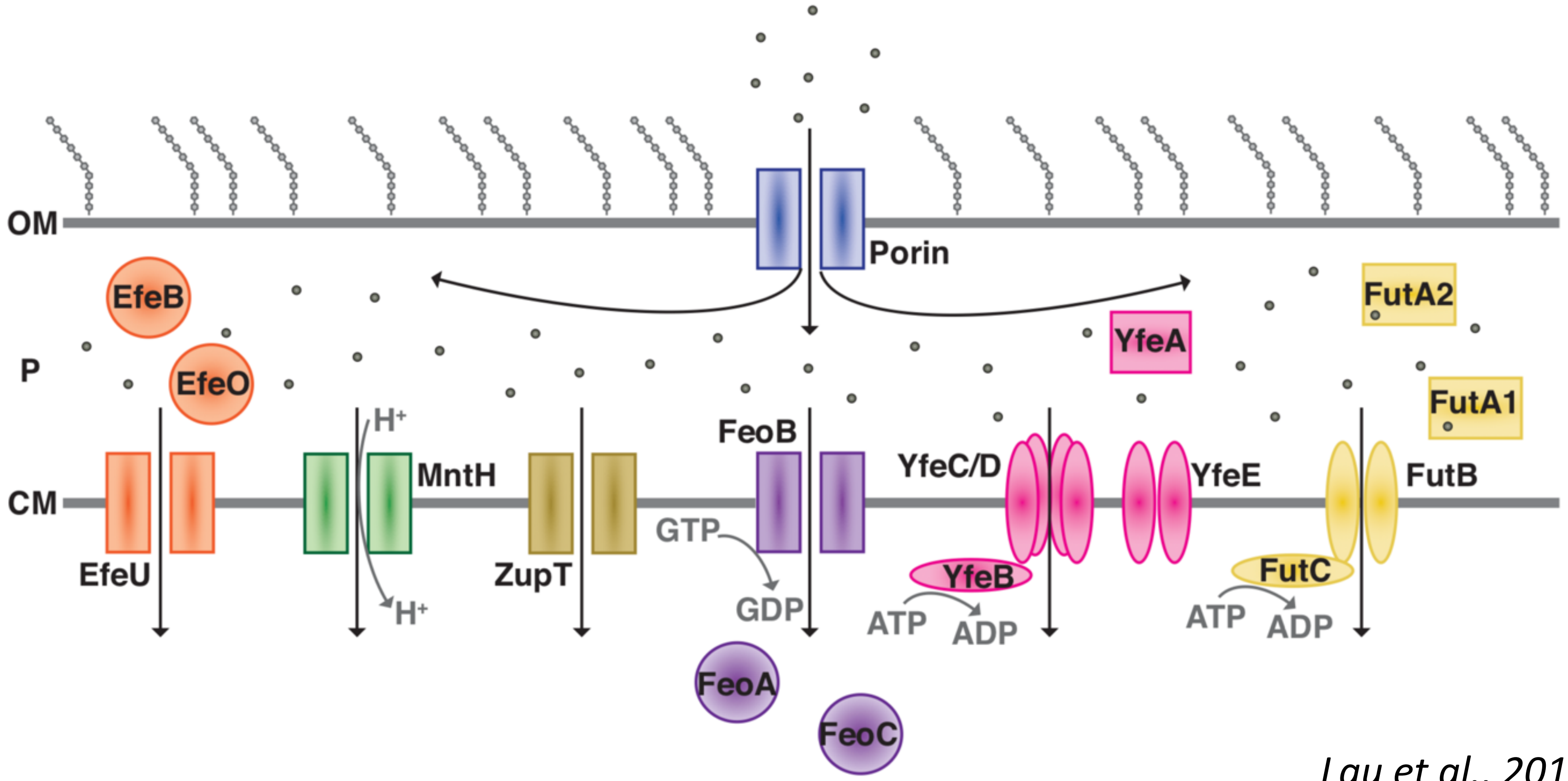
Transport of siderophores, hemes, and other iron(III)-chelates



Noinaj et al., 2010

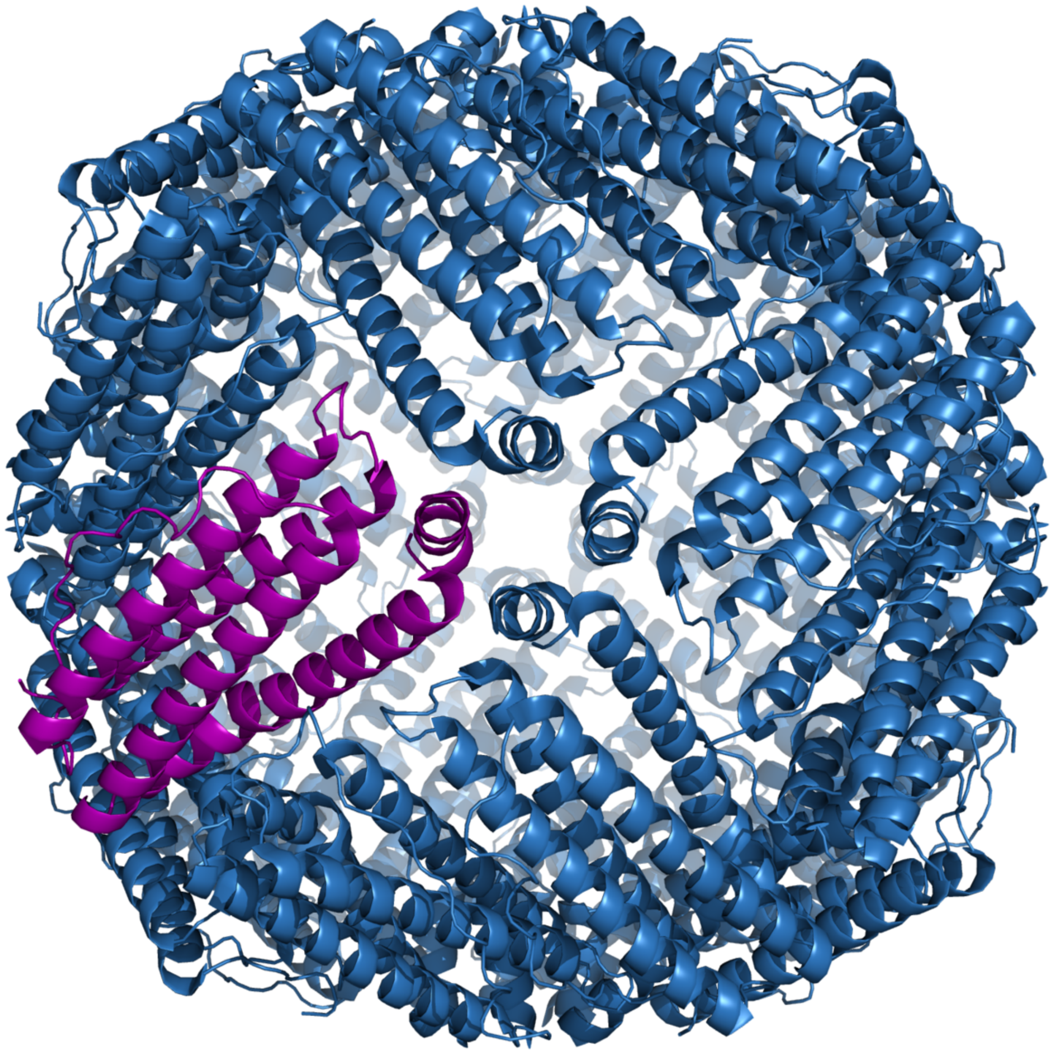
TonB-dependent receptors are not specific to sierophores and hemes

Iron ion transport – usually involves a non-selective porin and ATP or PMF-dependent transmembrane proteins

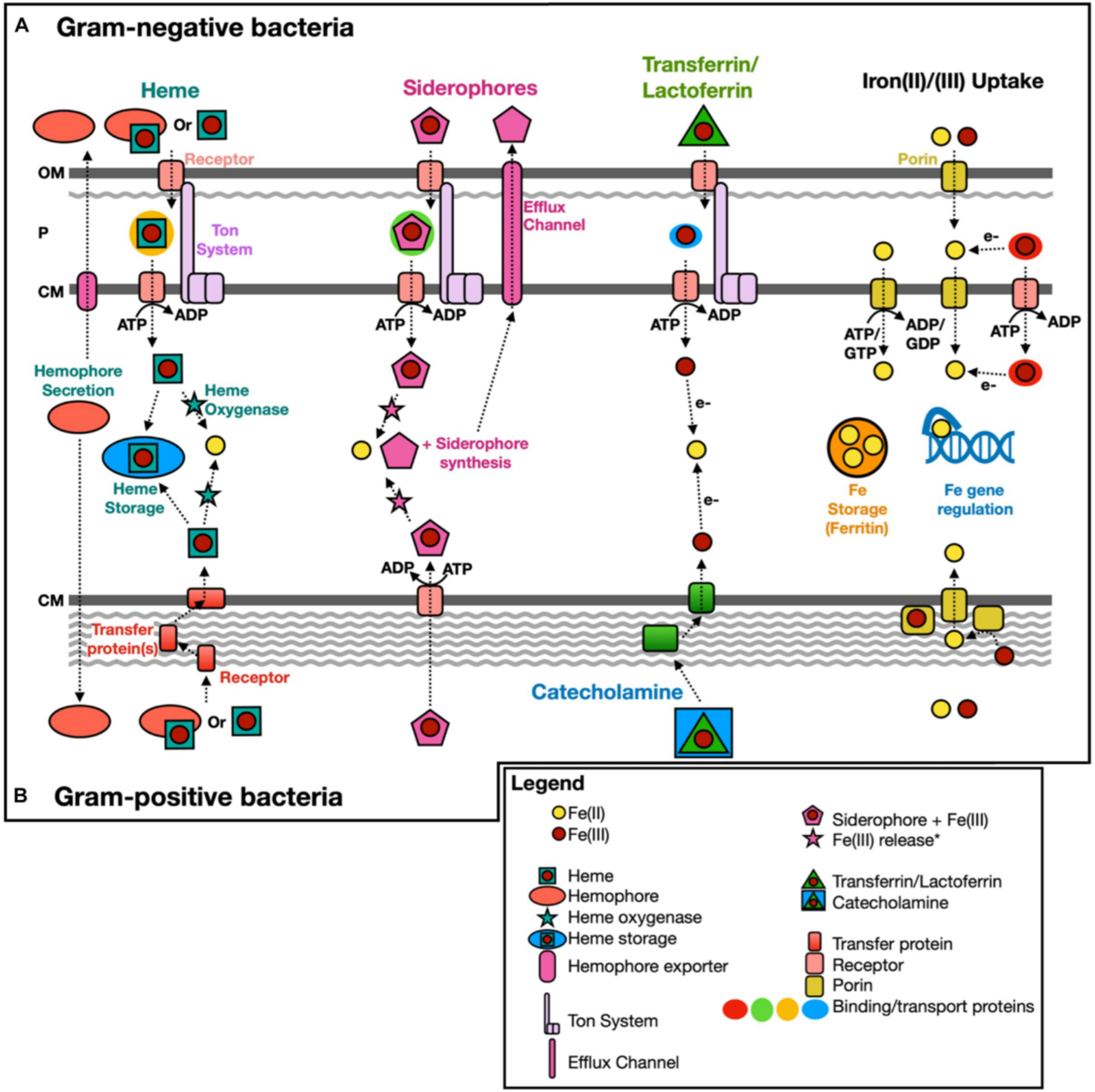


Lau et al., 2015

Iron storage - Ferritin

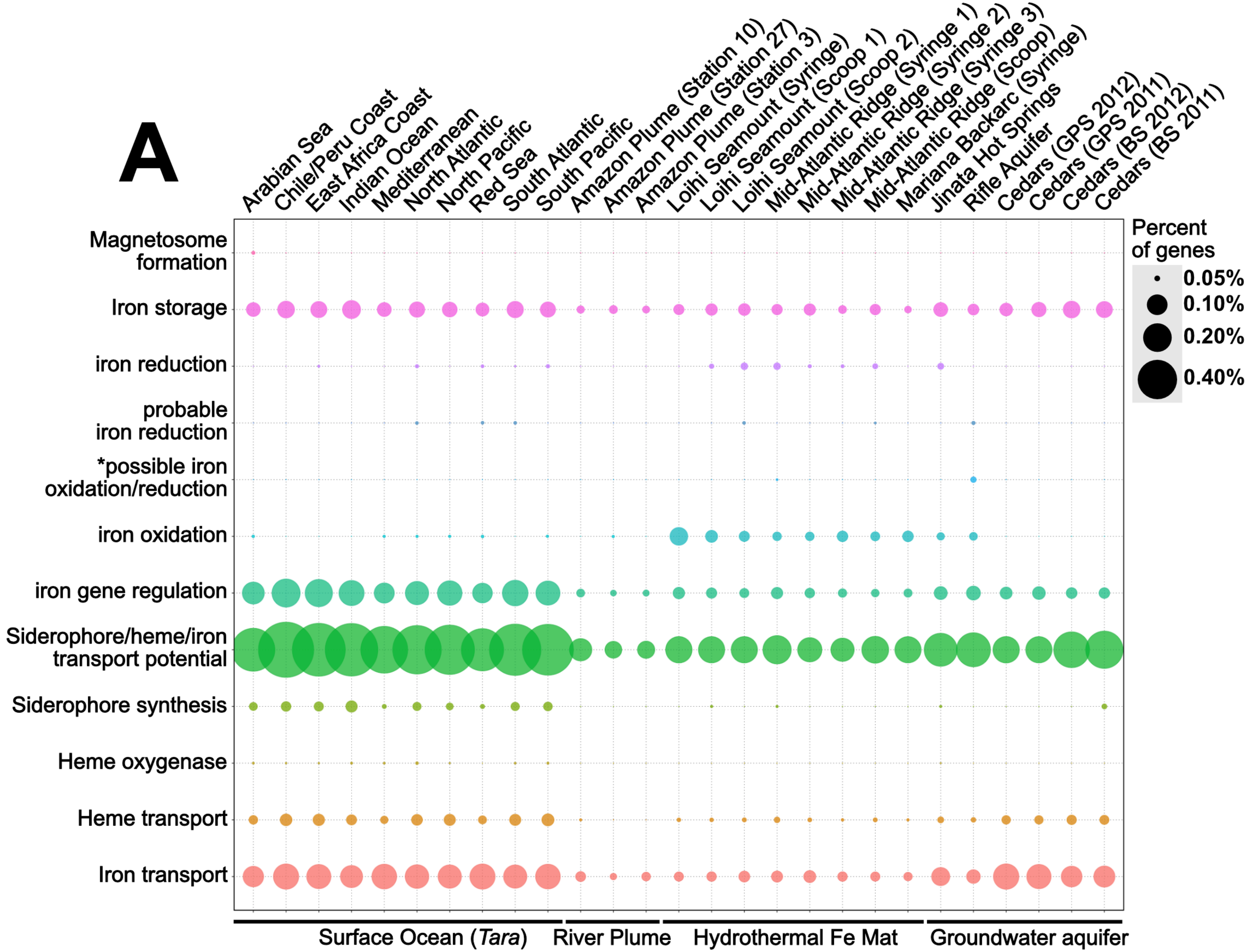


PDB: 1lb3; Granier et al., 2003, Journal of Biological Inorganic Chemistry

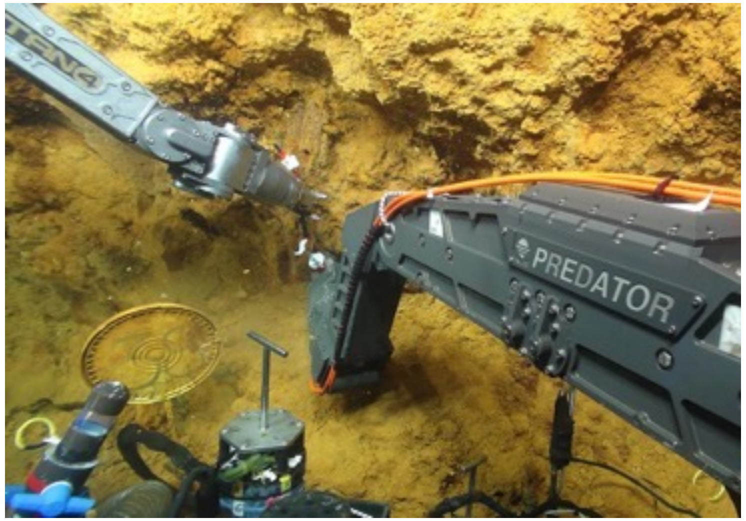


Summary of iron acquisition, efflux, and storage strategies in bacteria

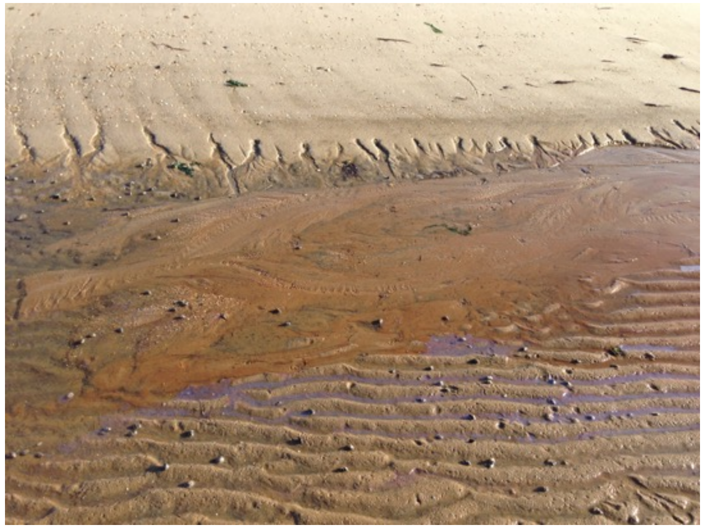
Iron acquisition/scavanging strategies very improtant in iron-limiting enviornments like the open ocean


A
Arabian Sea
Chile/Peru Coast
East Africa Coast
Indian Ocean
Mediterranean
North Atlantic
North Pacific
Red Sea
South Atlantic
South Pacific
Amazon Plume (Station 10)
Amazon Plume (Station 27)
Amazon Plume (Station 3)
Loihi Seamount (Syringe)
Loihi Seamount (Scoop 1)
Loihi Seamount (Scoop 2)
Mid-Atlantic Ridge (Syringe 1)
Mid-Atlantic Ridge (Syringe 2)
Mid-Atlantic Ridge (Syringe 3)
Mariana Backarc (Scoop)
Jinata Hot Springs
Rifle Aquifer
Cedars (GPS 2012)
Cedars (GPS 2011)
Cedars (BS 2012)
Cedars (BS 2011)
Magnetosome formation
Iron storage
iron reduction
probable iron reduction
*possible iron oxidation/reduction
iron oxidation
iron gene regulation
Siderophore/heme/iron transport potential
Siderophore synthesis
Heme oxygenase
Heme transport
Iron transport
Percent of genes
0.05%
0.10%
0.20%
0.40%
Surface Ocean (Tara)
River Plume
Hydrothermal Fe Mat
Groundwater aquifer

What do iron-oxidizers in to the environment?



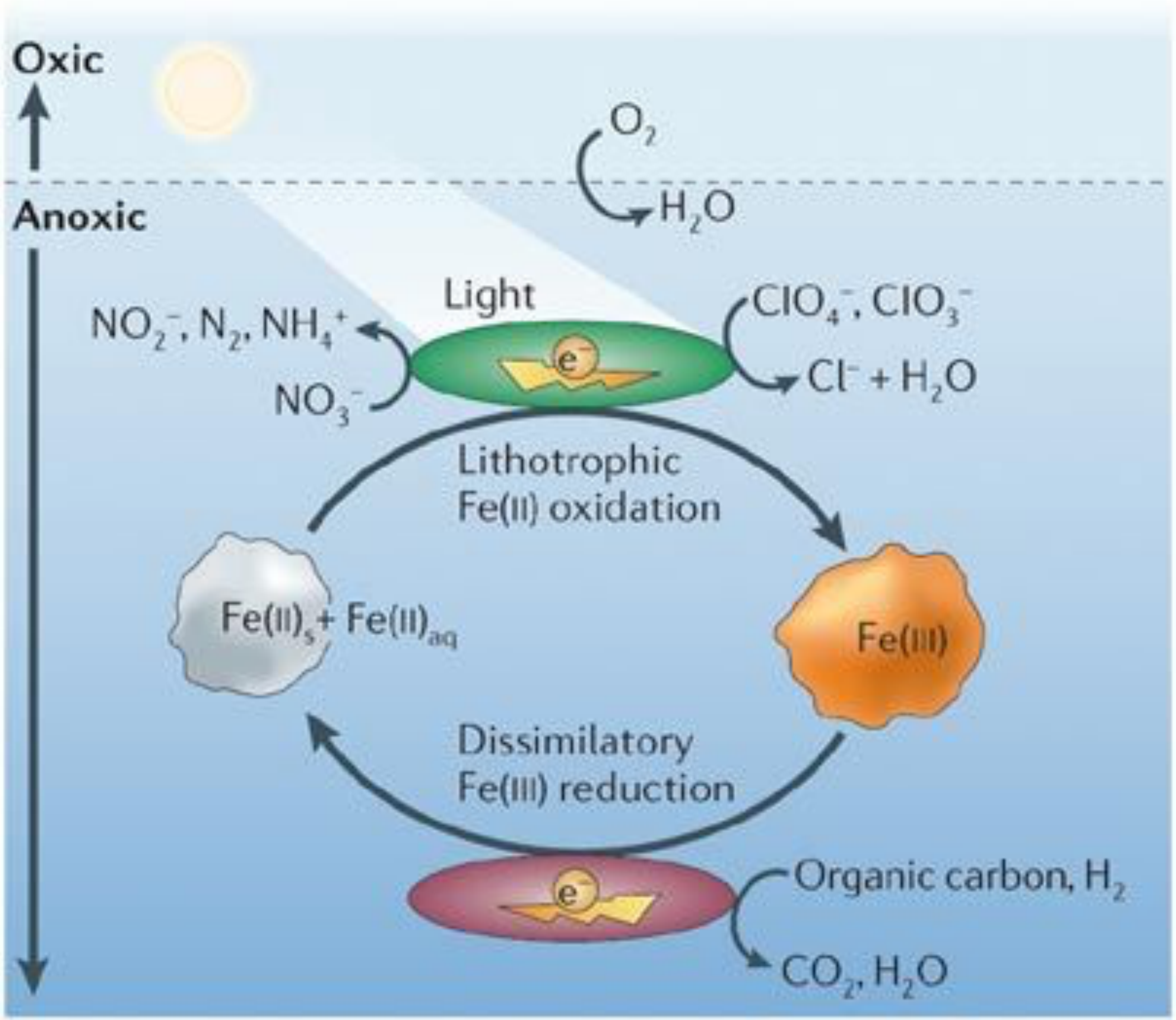
Loihi seamount (Hawaii) Fe mat (photo: Jason crew)


Coastal groundwater discharge


Acid mine drainage, phot Rana Xavier/Flickr

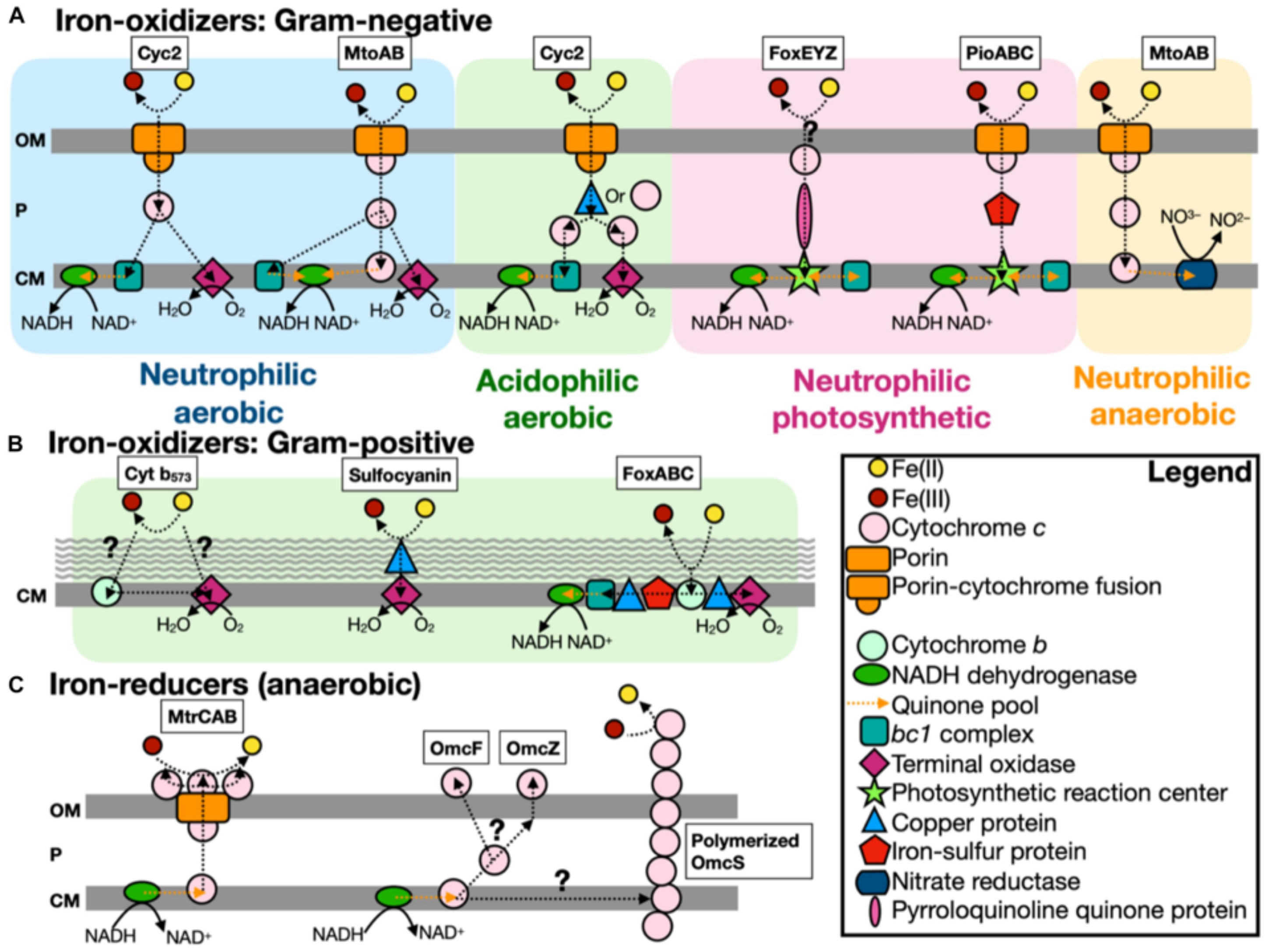

James F. Hall trail freshwater stream


Worm burrows, photo: Beverly Chiu



Nature Reviews | Microbiology

Iron oxidation and reduction – porin-cytochrome modules are key players in iron-related redox reactions in gram-negative bacteria



S-layer and cytoplasmic membrane associated proteins are used by gram-positive bacteria and Archaea