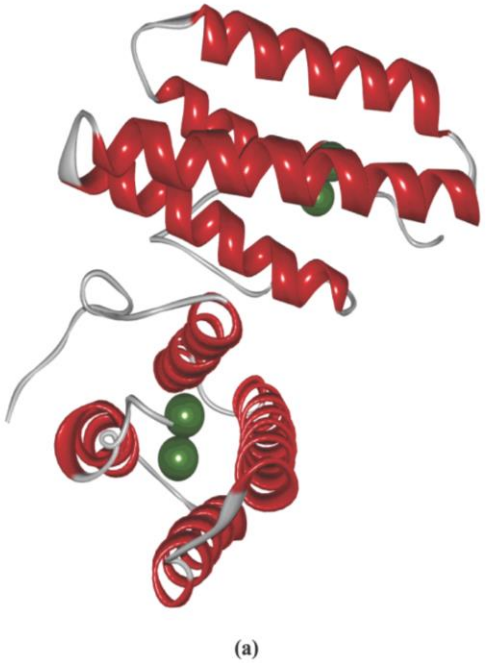
Proteins with non-heme Fe

1. Proteins where Fe is exclusively bound to aminoacids (and/or H_2O, OH^-, O^{2-})
2. Proteins that contain Fe–S centers

Hemerytrin

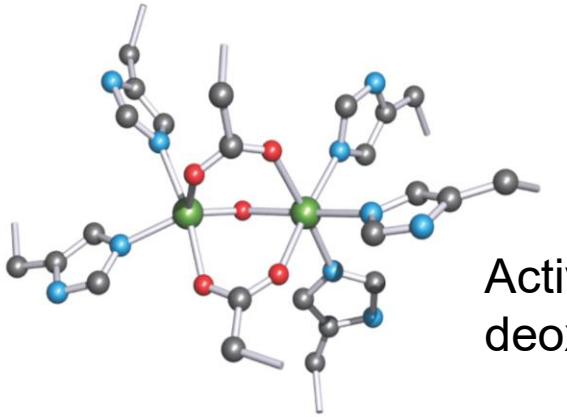
O_2 transport in some marine invertebrates

13,5 kDa
113 a.a.



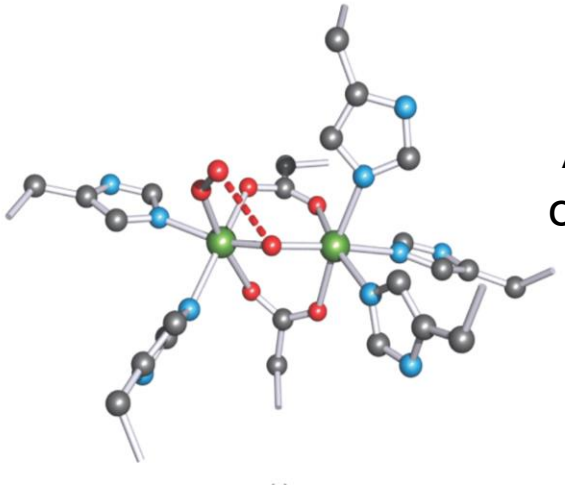
(a)

deoxyhemerytrin
(2 of 8 sub-units)



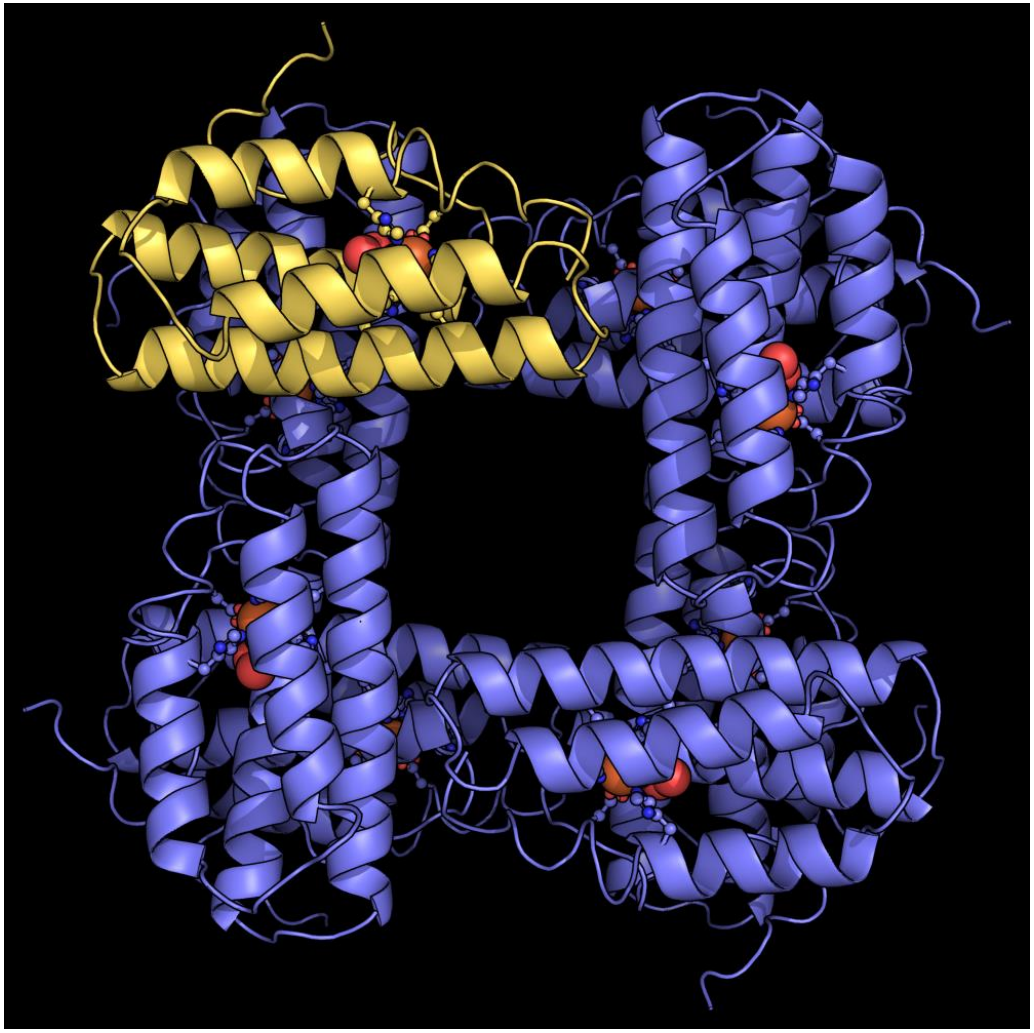
(b)

Active site of deoxyhemerytrin



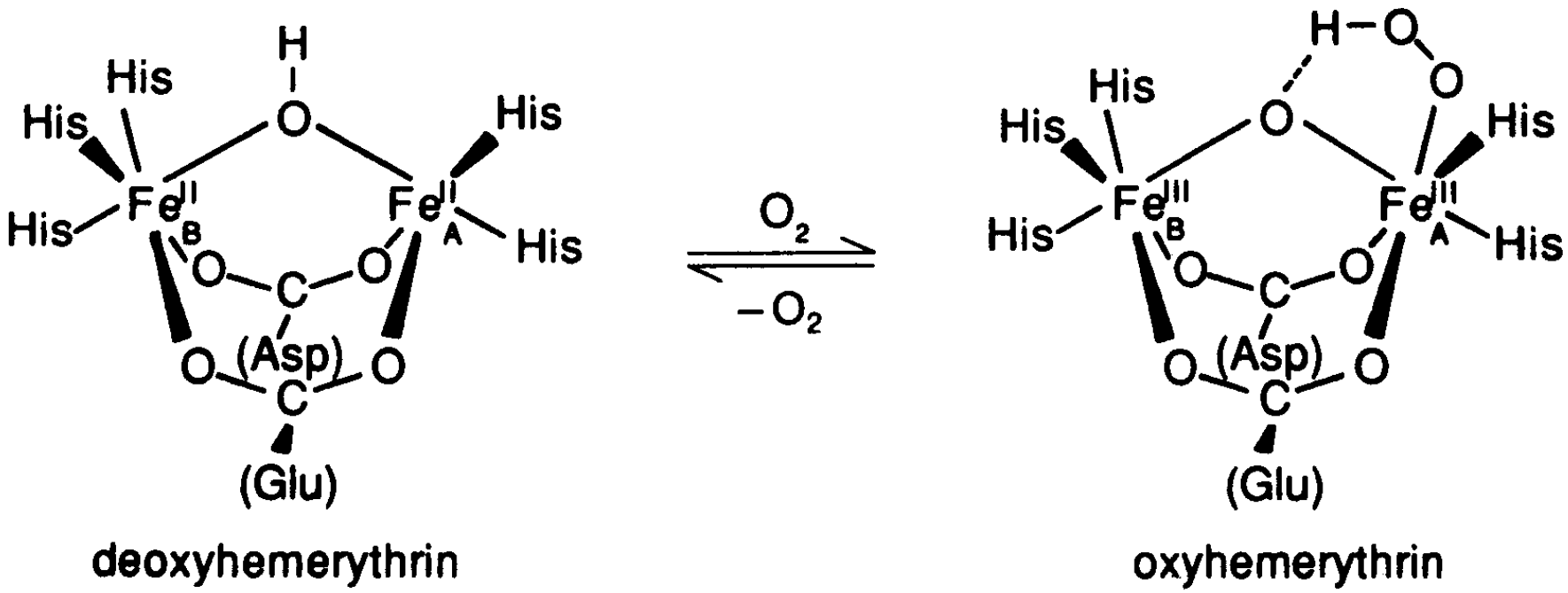
Active site of oxyhemerytrin

Hemerythrin homo-octamer with a single monomer highlighted in yellow. Each subunit has a four-α-helix fold binding a binuclear iron center.



Unlike hemoglobin, most hemerythrins lack cooperative binding to oxygen, making it roughly 1/4 as efficient as hemoglobin

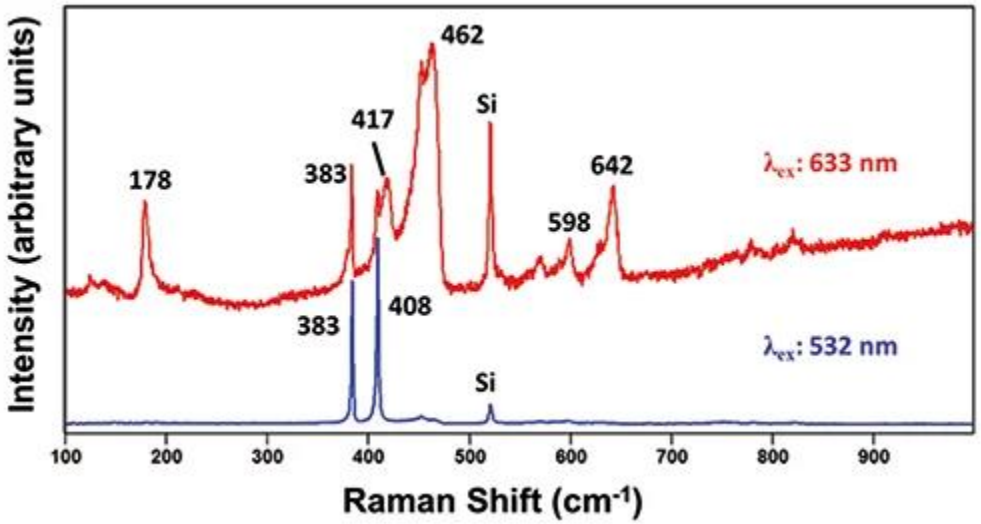
The di-iron active site of hemerythrin before and after oxygenation



Deoxyhemeritrin
Colorless
2 Fe(II) h.s. (*S* = 2, weak a.f. coupling)
Mossbauer: 2 indistinguishable Fe(II)

Oxyhemeritrin
Purple (LMCT, prob. from O_2^{2-} to Fe(III))
$1O_2$
2 Fe(III) l.s. (*S* = ½, strong a.f. coupling)
Resonant Raman: 848 cm^{-1}
Mossbauer: 2 different Fe(III)

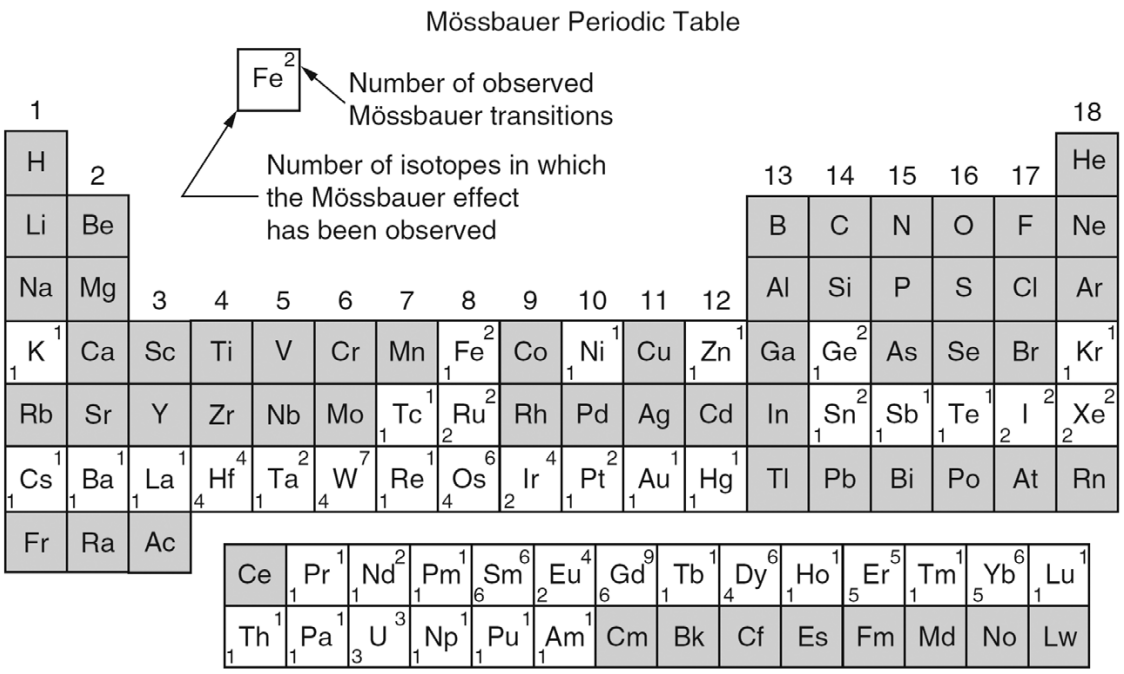
Resonance Raman

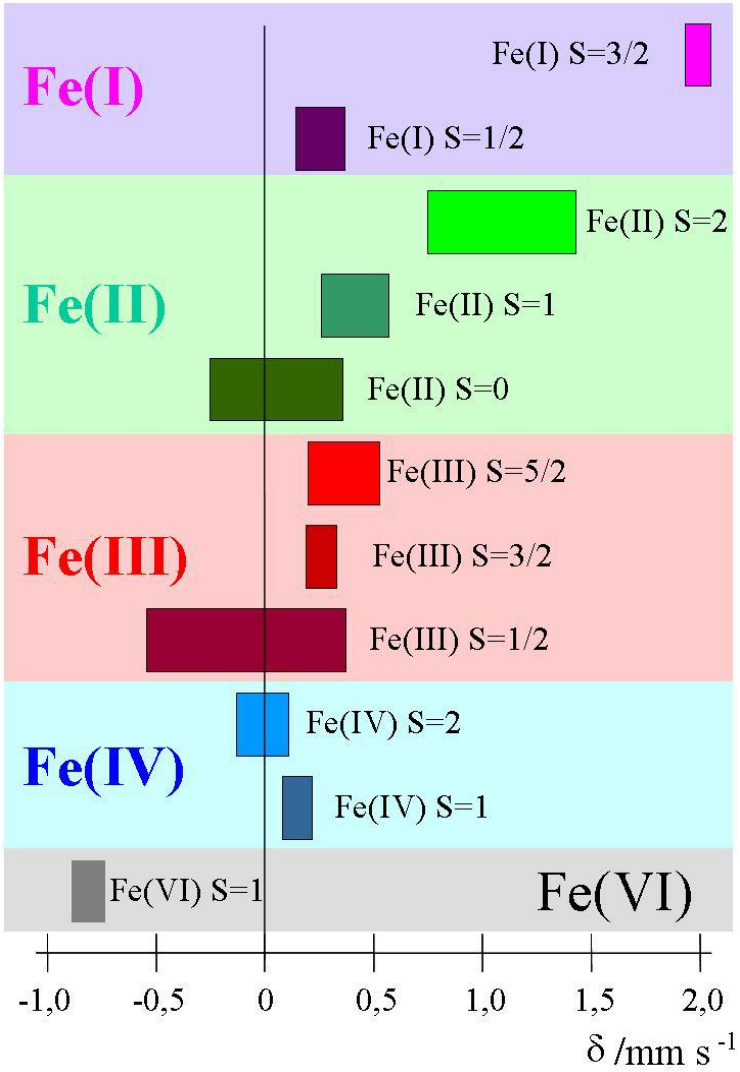


Resonance (top) and non-resonance (bottom) Raman spectra of MoS_2 on silicon. The excitation at 633 nm, near an electronic transition, causes appearance of bands that are too faint to be visible with excitation at 532 nm.

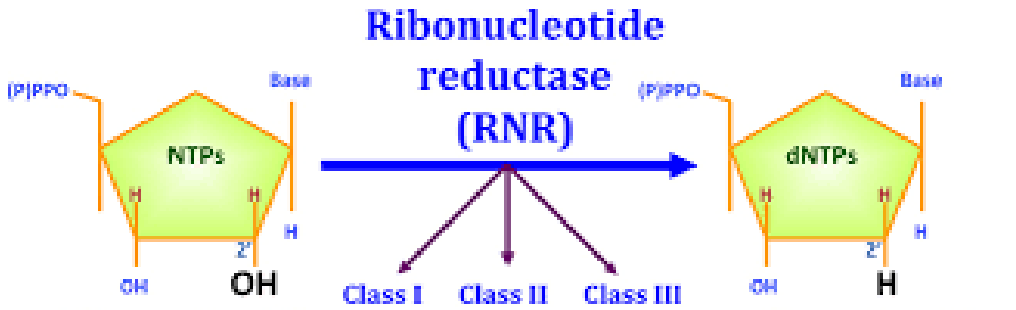
Mössbauer spectroscopy

(Rudolf Mössbauer, Nobel Prize for Physics in 1961)

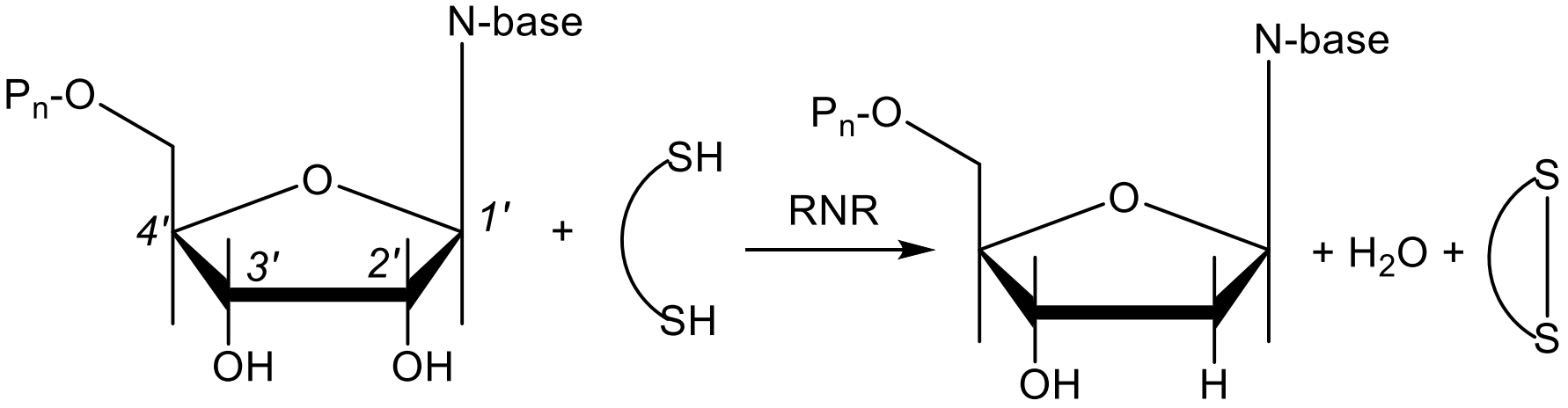




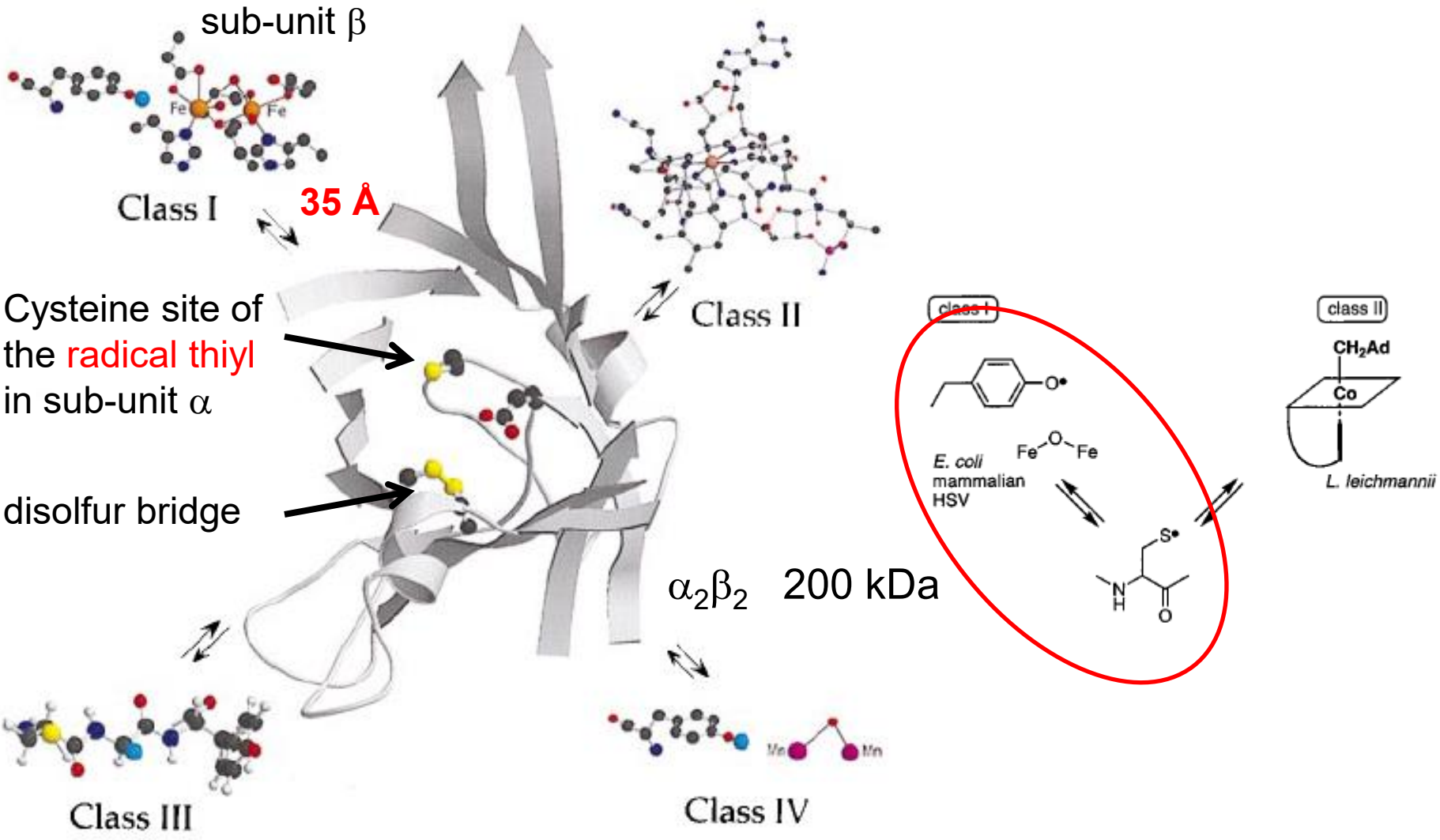
Ribonucleotide reductase (RNR)



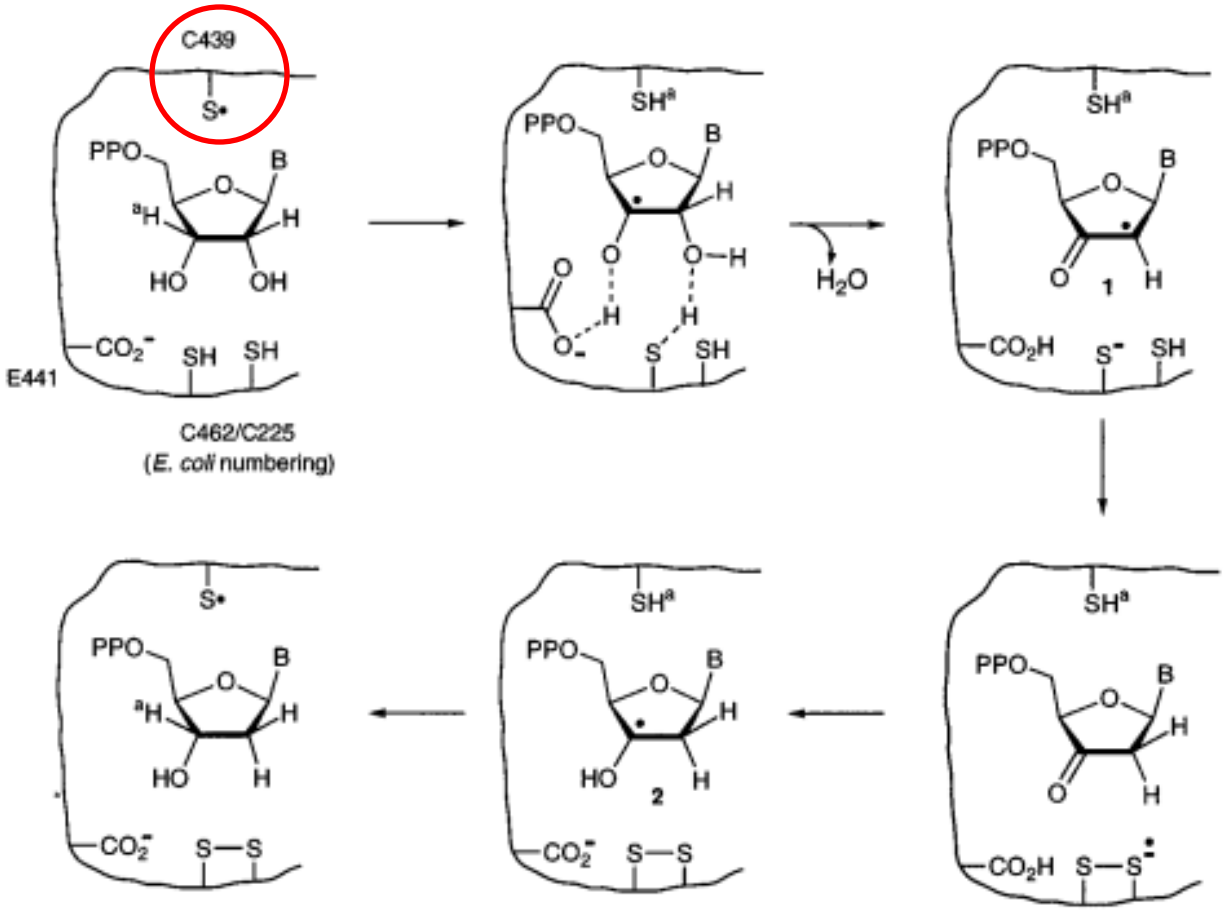
Different metal cofactor

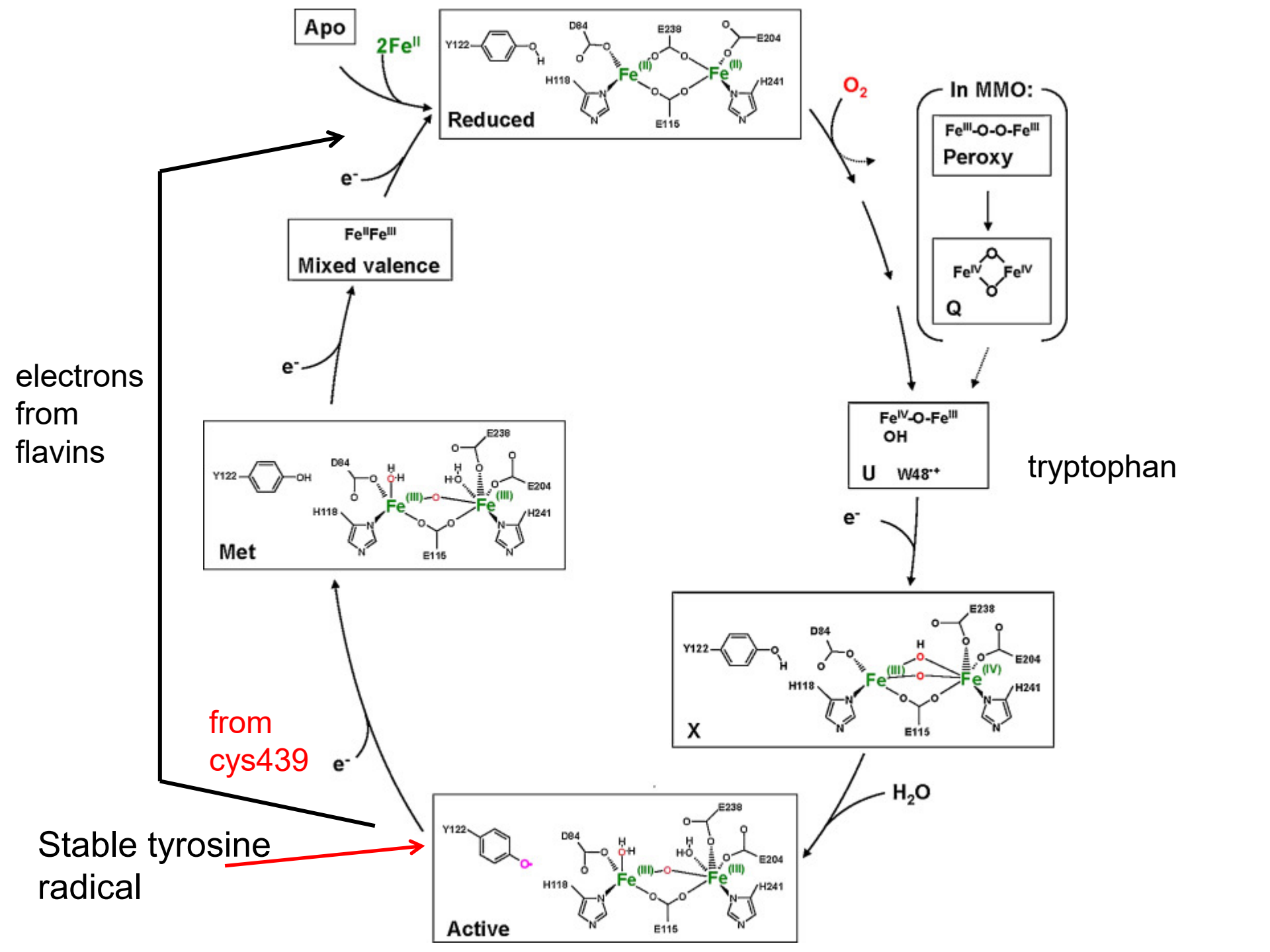


Active site and metal cofactors in different classes of Ribonucleotide reductases



Radical mechanism of RNR



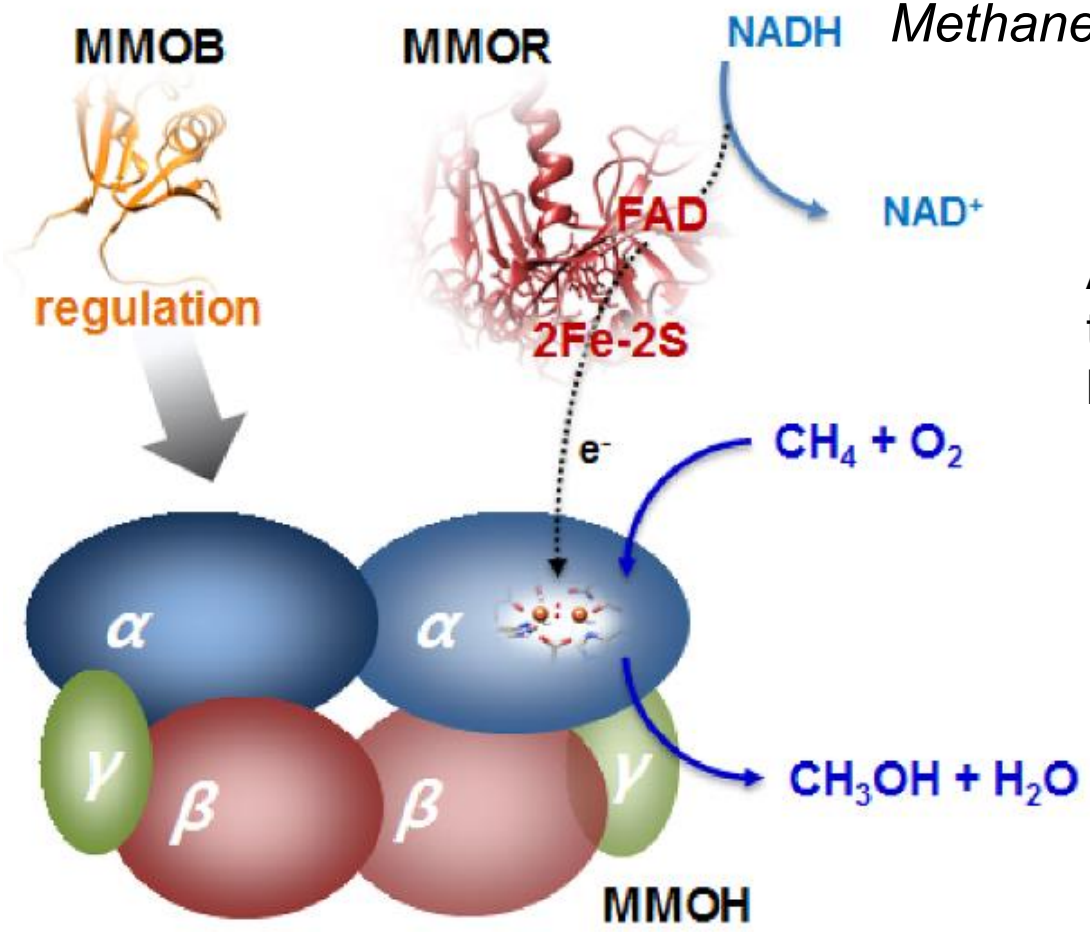

Apo
2Fe^II
Reduced
O2
In MMO:
Fe^III-O-O-Fe^III
Peroxy
Fe^IV Fe^IV
Q
e-
Fe^IIFe^III
Mixed valence
e-
electrons
from
flavins
Met
Fe^IV-O-Fe^III
OH
U W48•+
tryptophan
e-
X
from
cys439
e-
H2O
Stable tyrosine
radical
Active
Y122
D84
E238
E204
H118
H241
E115

Soluble methane monooxygenase (*s*MMO)

$$NADH + CH_4 + O_2 + H^+ \xrightarrow{MMO} NAD^+ + CH_3OH + H_2O$$

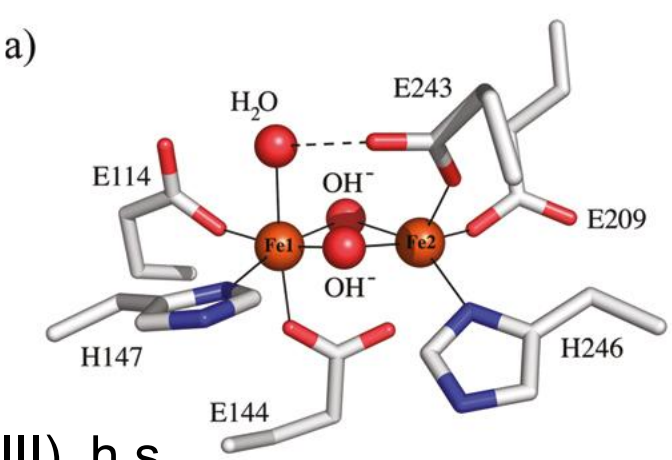
methanotrophic bacteria

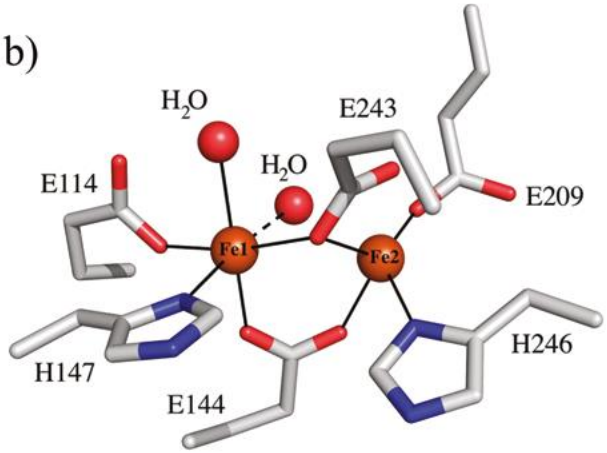
Methane as a source of C and energy



Among hydrocarbons, CH_4 is that with the strongest C−H bond, 104 kcal/mol

300 kDa





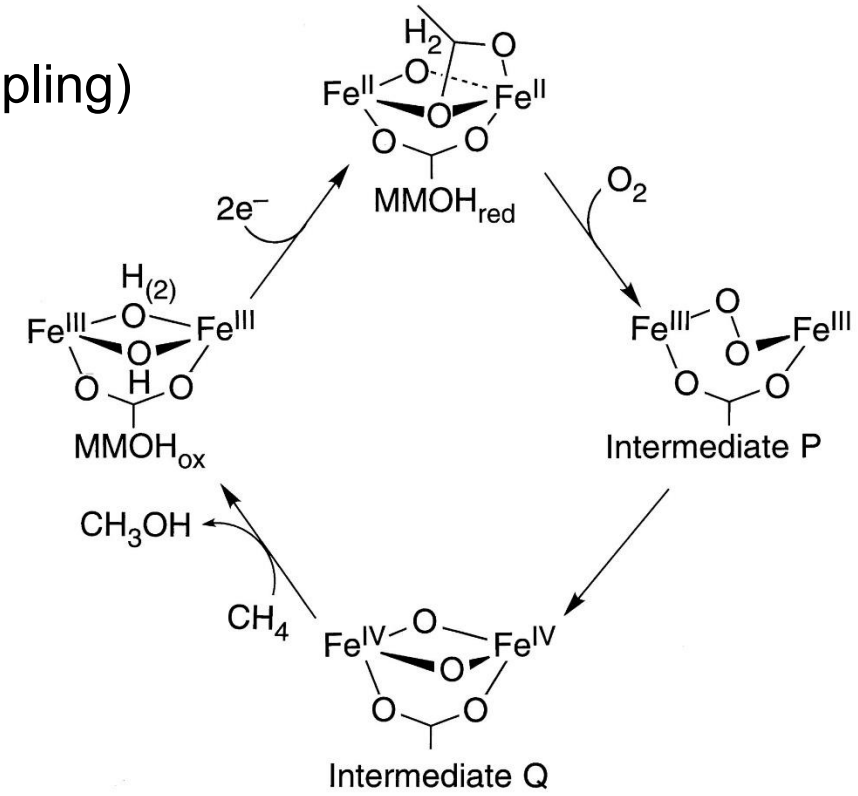
Fe(III), h.s.
colorless
diamagnetic
(strong a.f. coupling)

$MMOH_{ox}$

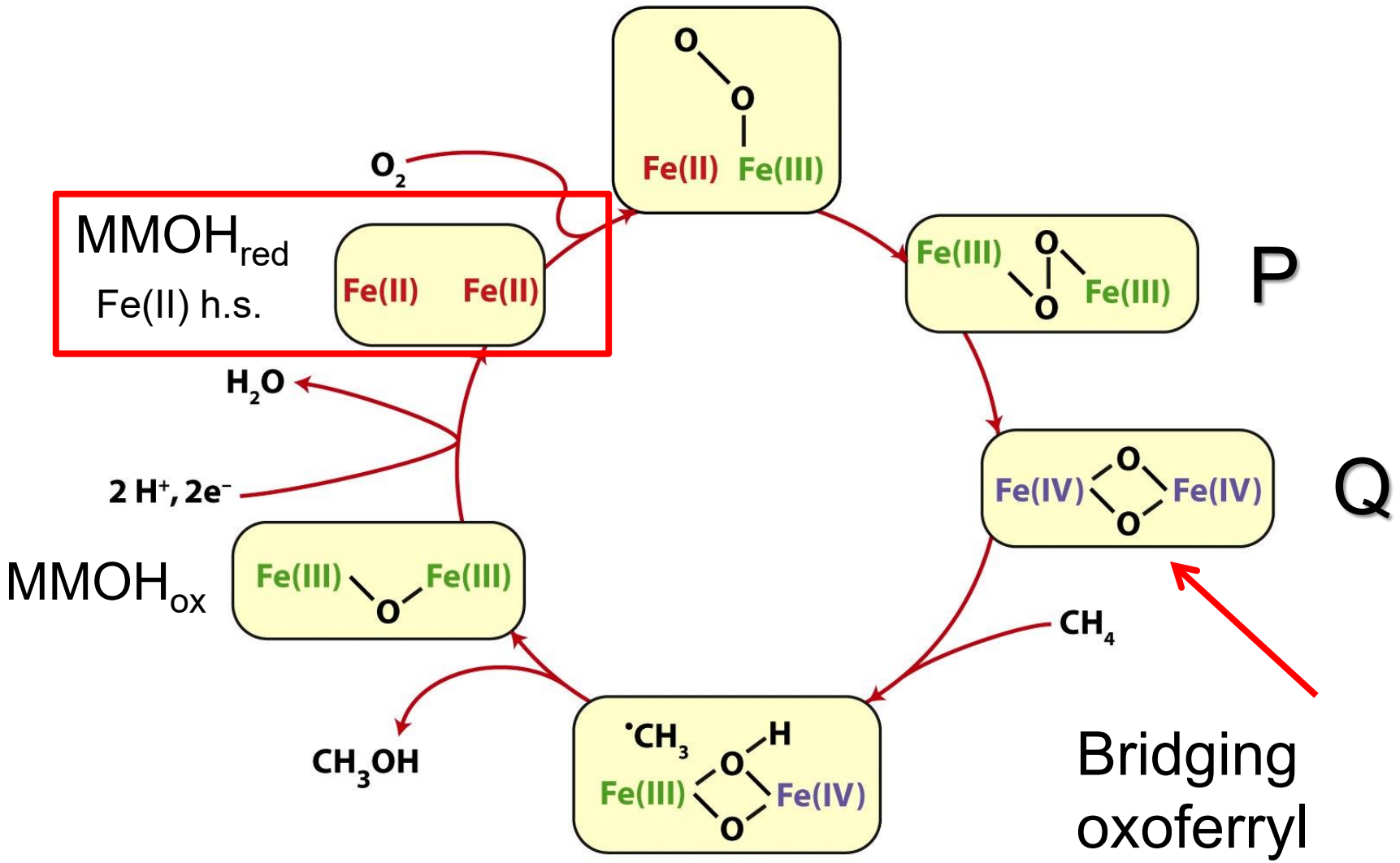
$MMOH_{red}$

Fe(II), h.s.
(weak a.f. coupling)

Resting state



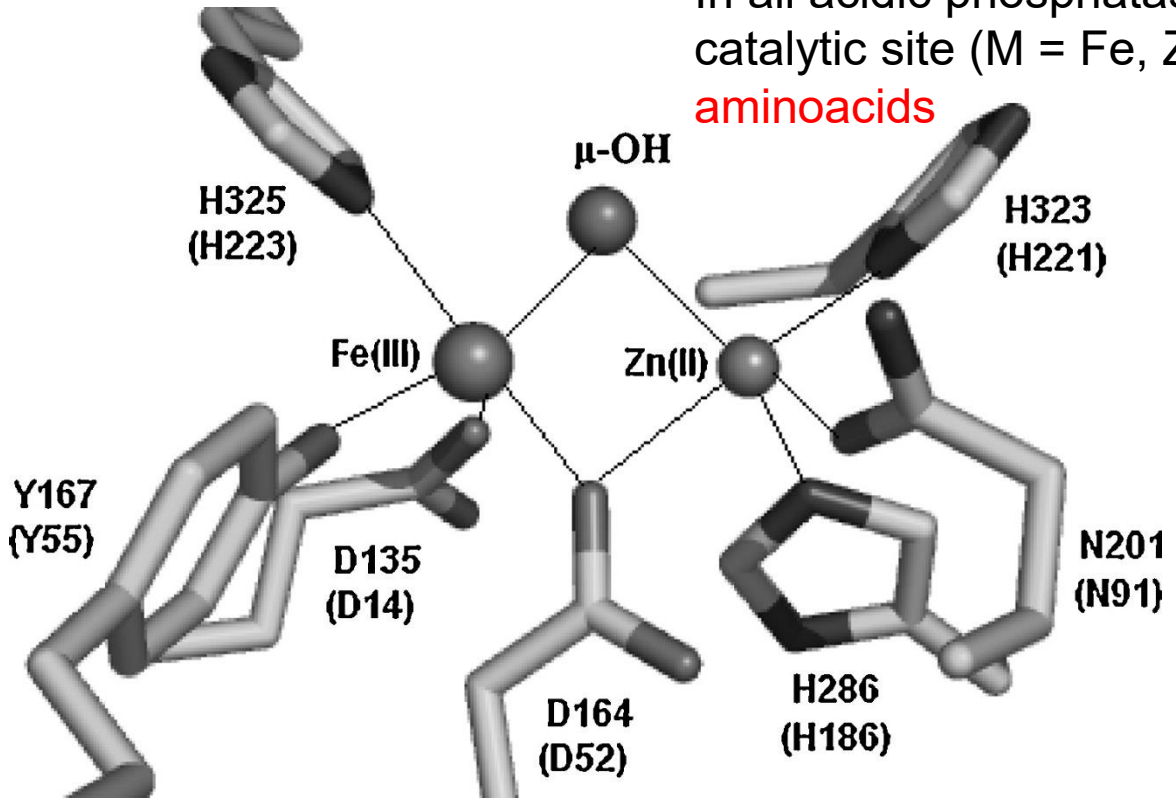
Hypothetical catalytic cycle of MMO



P and Q are spectroscopically characterized intermediates

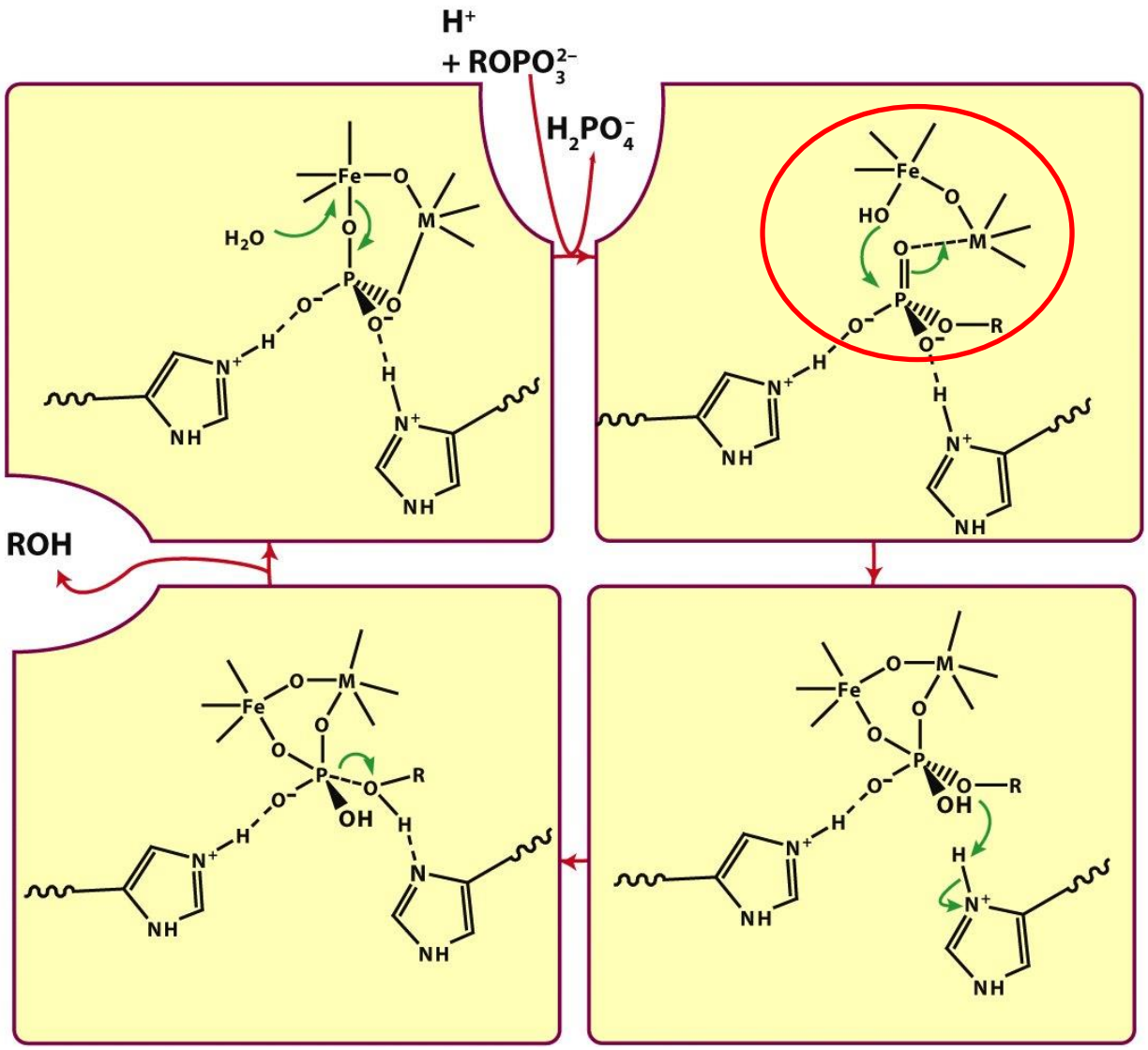
Active site of an acidic phosphatase
(catalyzes the hydrolysis of phosphate monoesters)

In all acidic phosphatases the Fe(III) – M(II) catalytic site (M = Fe, Zn, Mn) has 7 invariant aminoacids



Tyr (LMCT, λ_{max} fra 510 e 550 nm), responsible for the pink-to-purple color

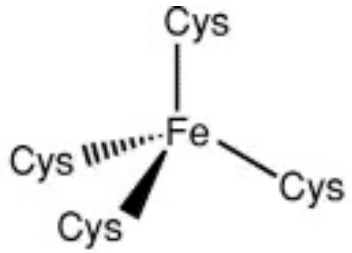
Catalytic cycle of an acidic phosphatase



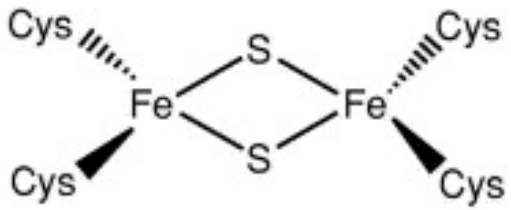
active site: Fe(III)-Fe(II)
Both high-spin

Fe–S proteins

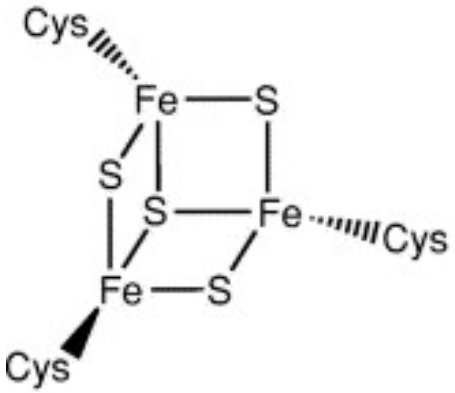
Electron transfer process at negative potentials



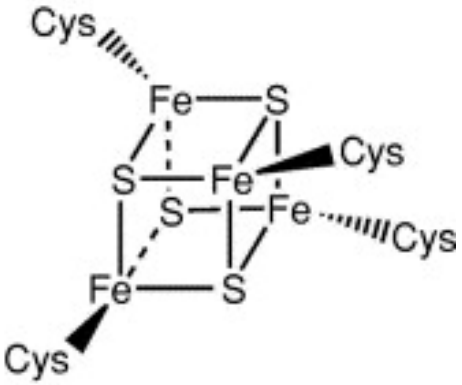
Rubredoxin type



2Fe–2S

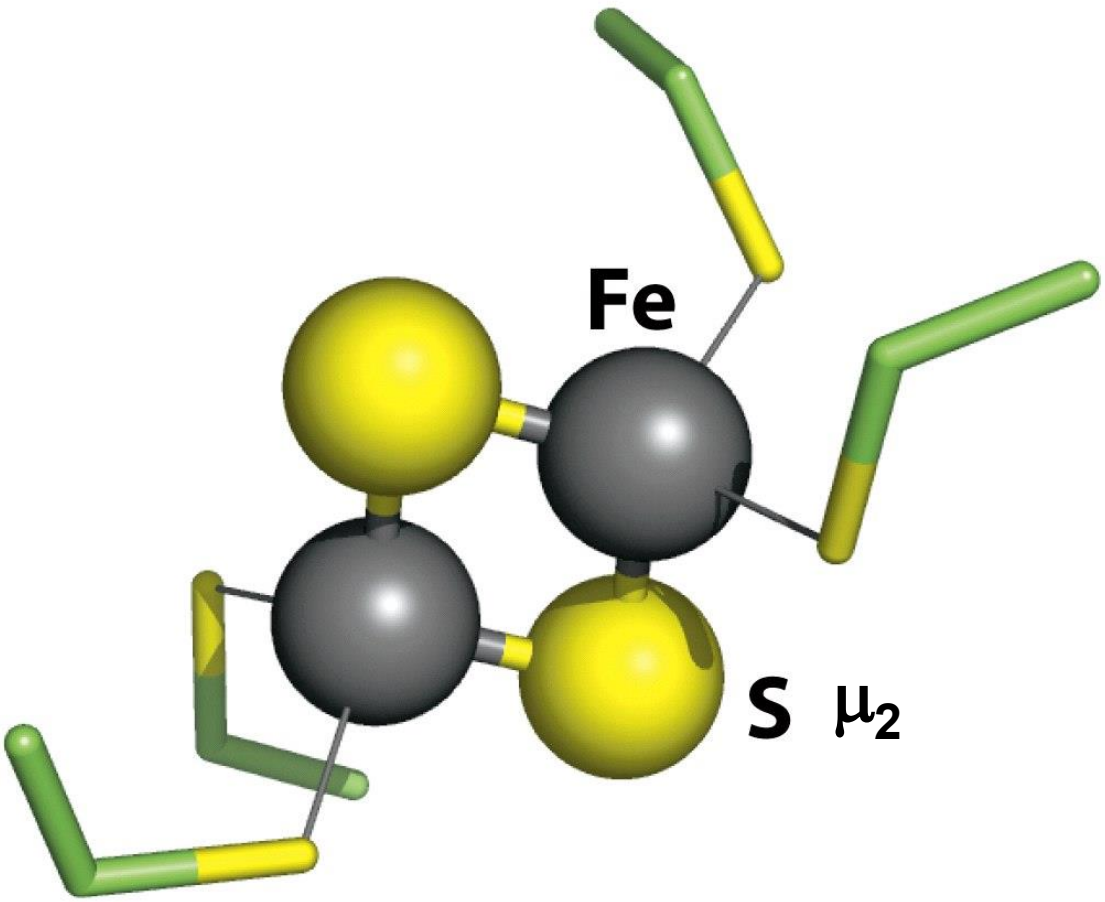


3Fe–4S

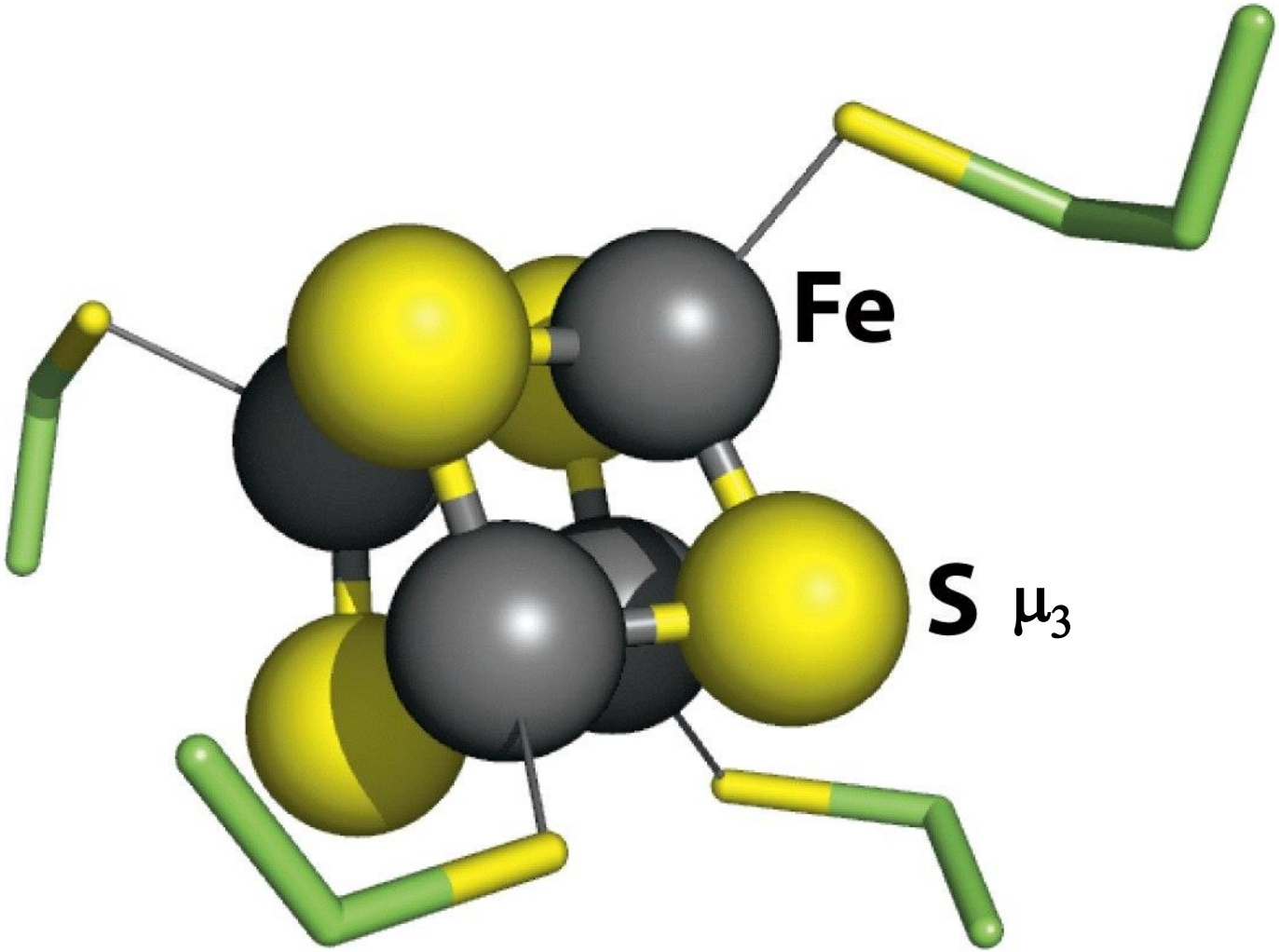


4Fe–4S

Cubanoid structure

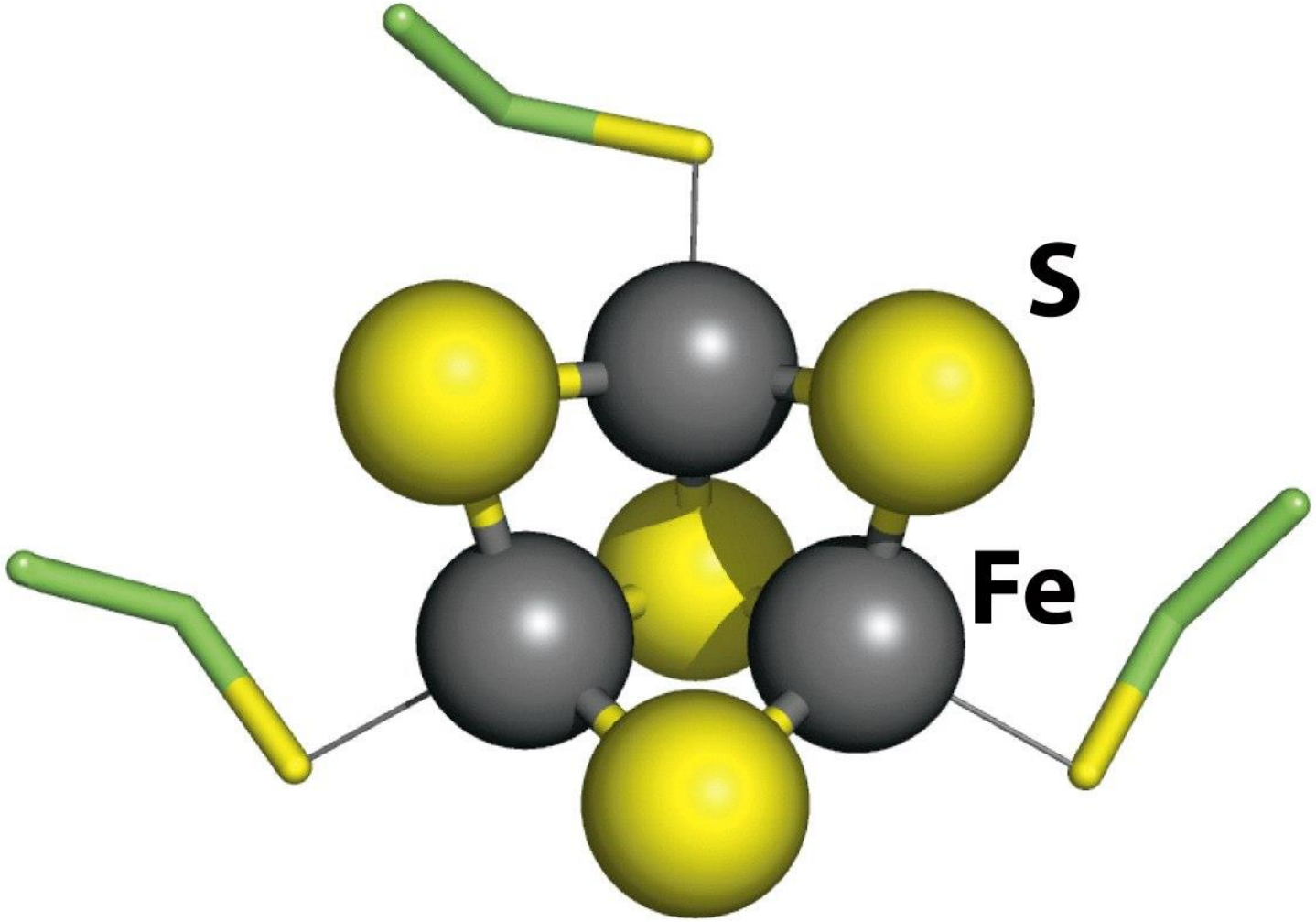


[2Fe–2S]



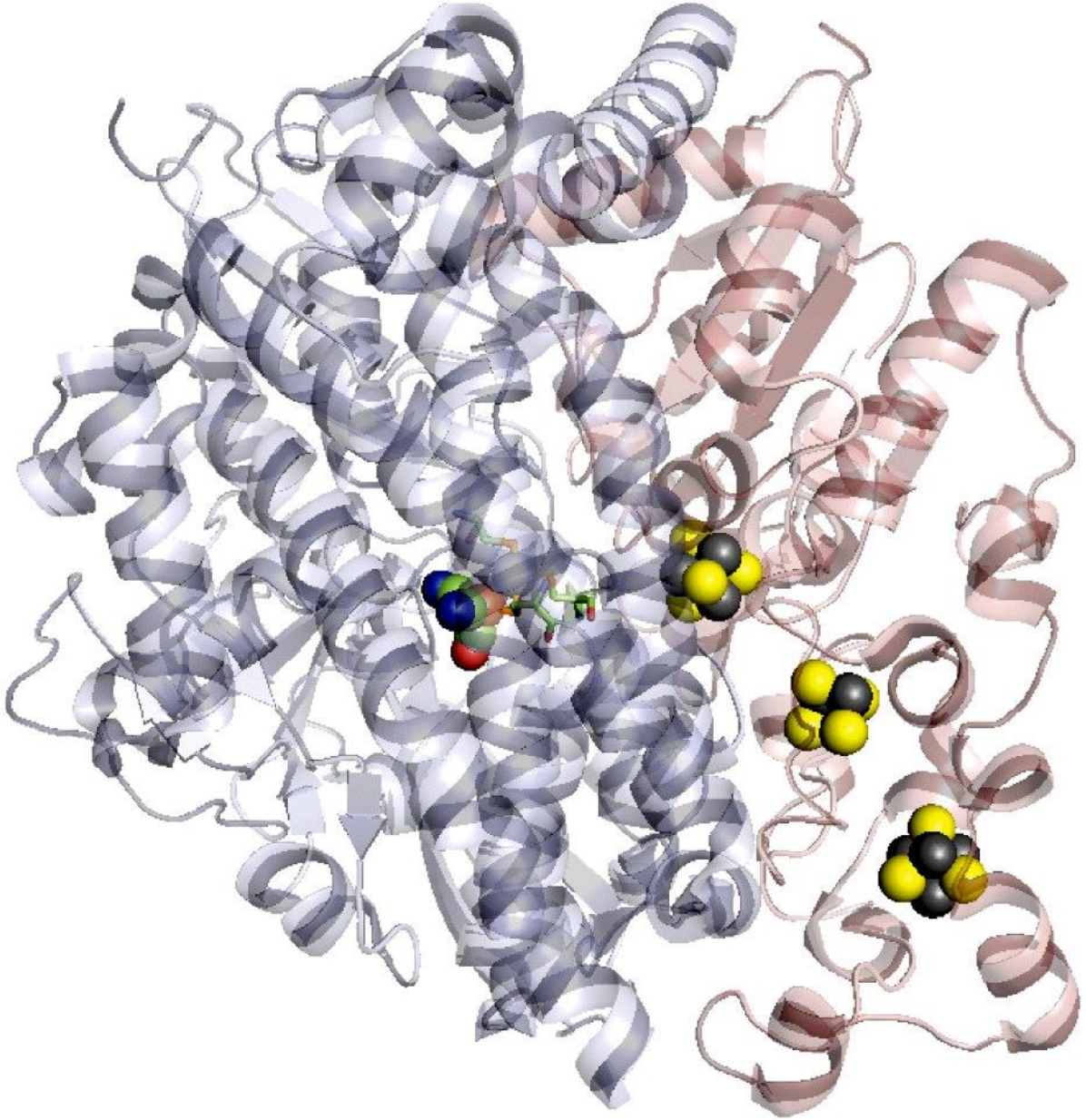
[4Fe–4S]

Cubanoid structure



[3Fe–4S]

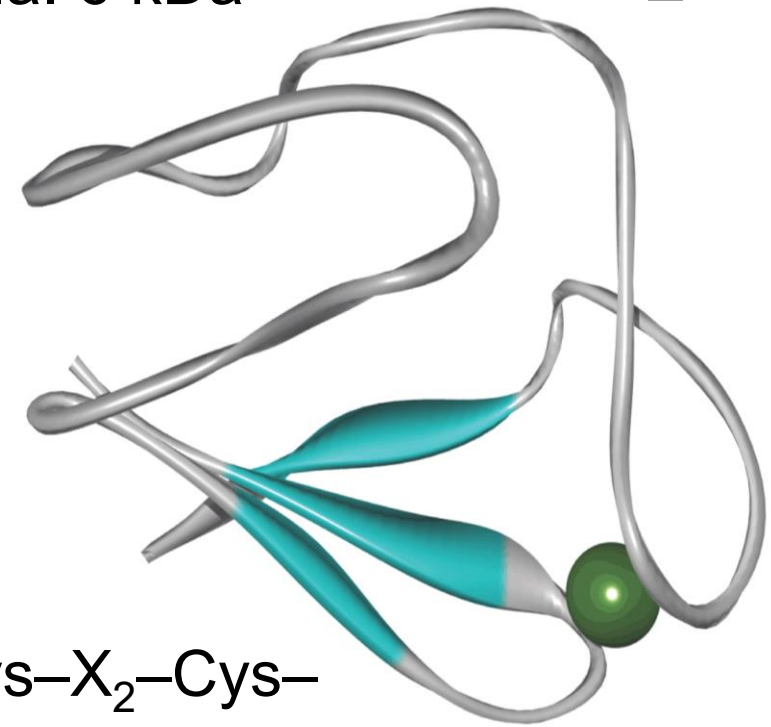
[Ni–Fe]-hydrogenase: redox path

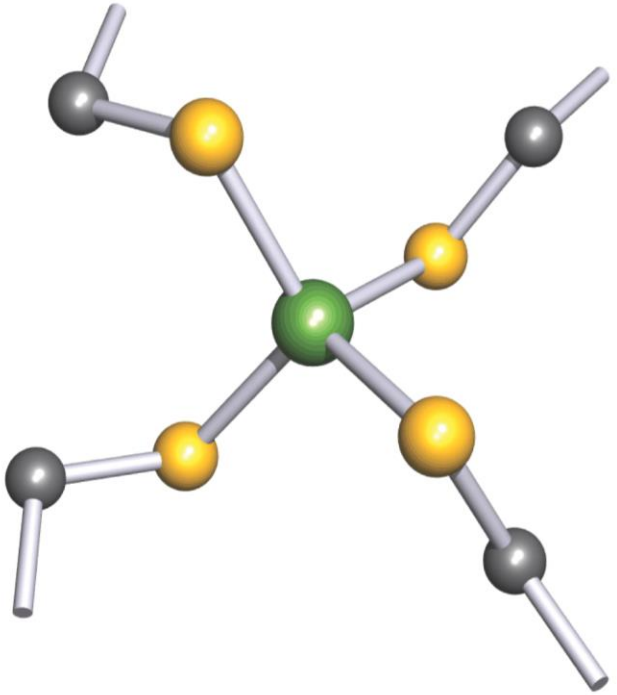


Rubredoxin from *clostridium pasteurianum*

c.a. 6 kDa

$E° \approx 0$ V



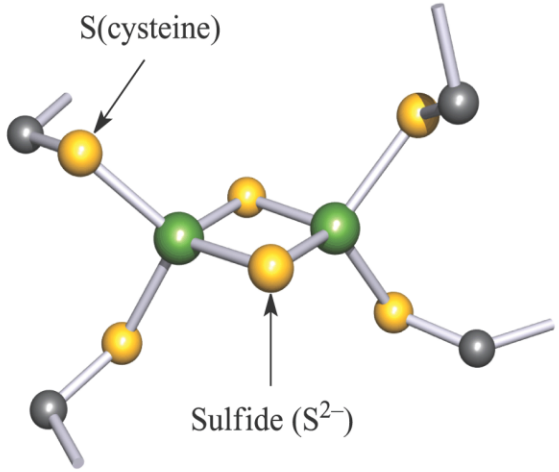


–Cys–X_2–Cys–

The Fe(III) status of the protein is red, due to LMCT transitions

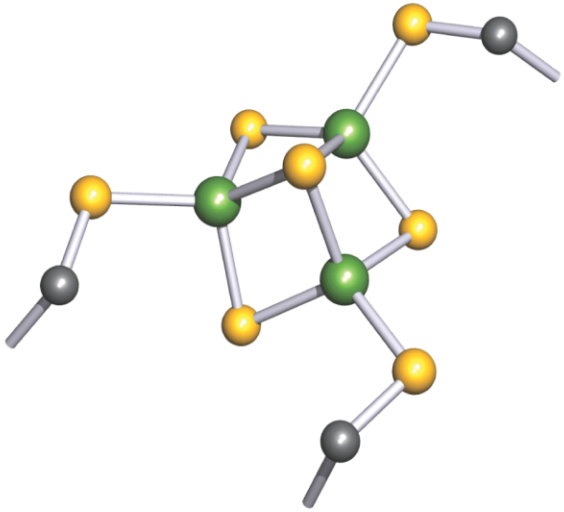
Iron-sulfur units in ferredoxins

E° between –250 and –450 mV

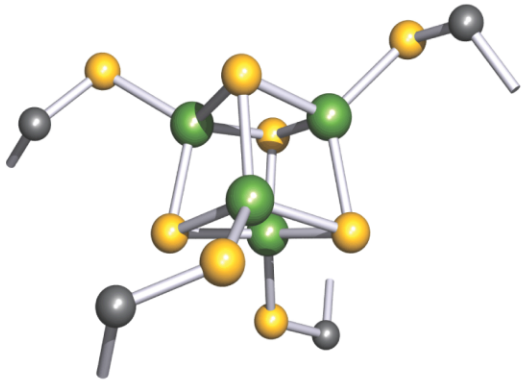


[2Fe–2S]
From spinach

E° = –420 mV
Fe(III)/Fe(III) – Fe(II)/Fe(III)

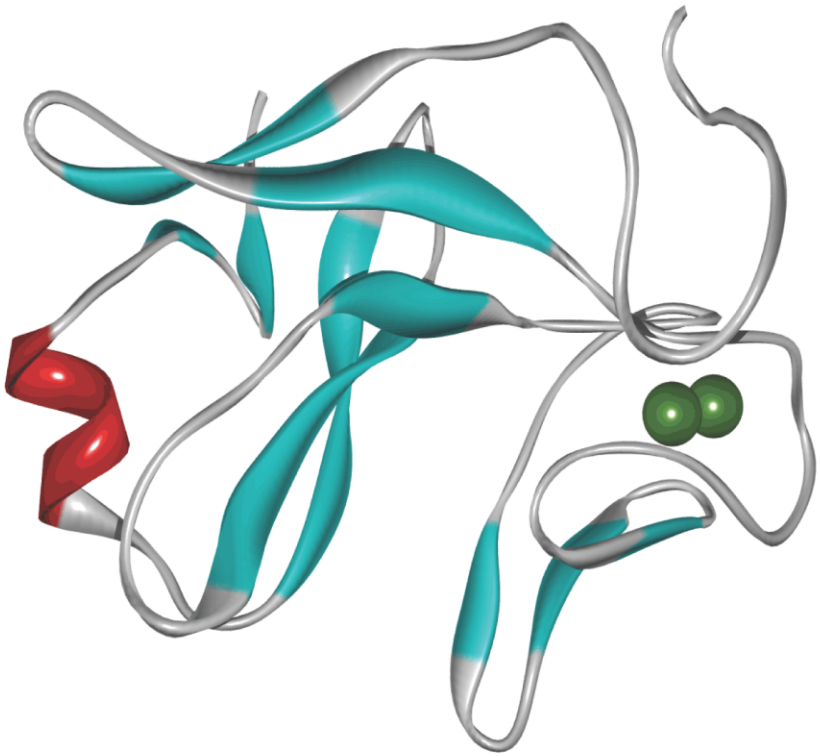


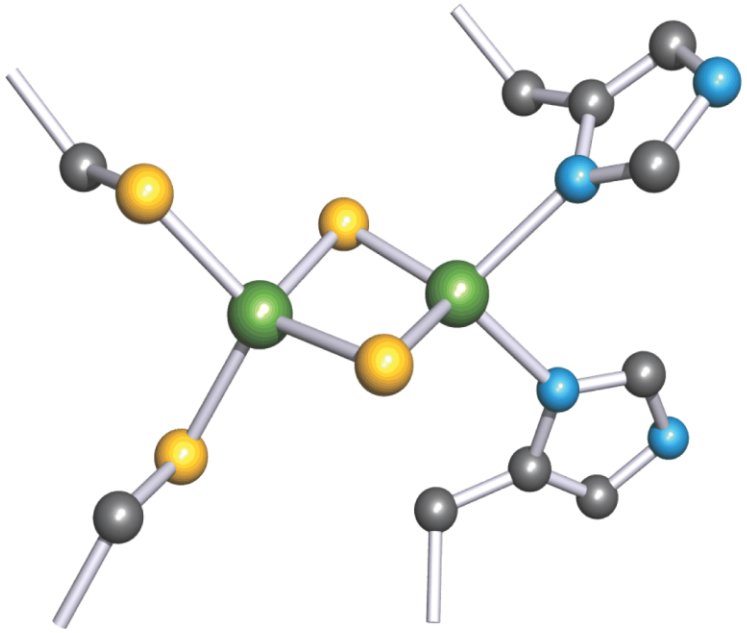
[3Fe–4S]
azotobacter vinelandii



[4Fe–4S]
chromatium vinosum

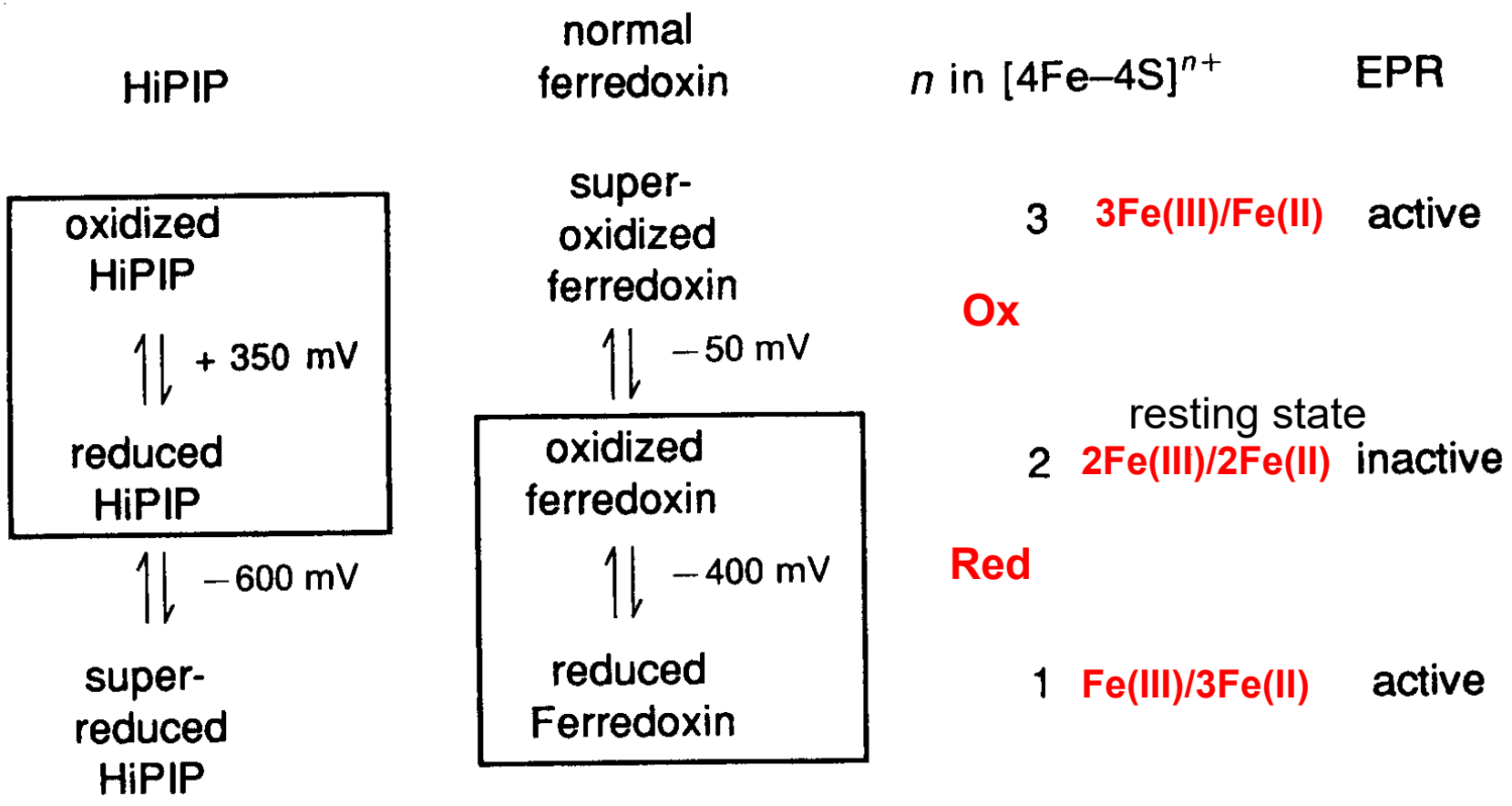
Rieske protein from spinach chloroplasts





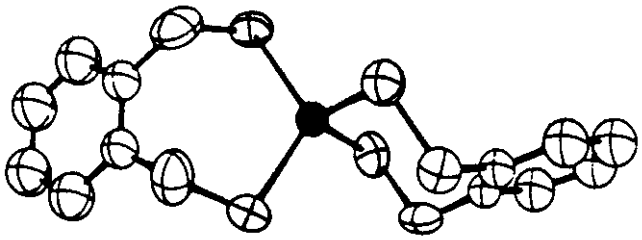
$E°$ = +290 mV

High Potential Iron-sulfur Proteins (HiPIP)

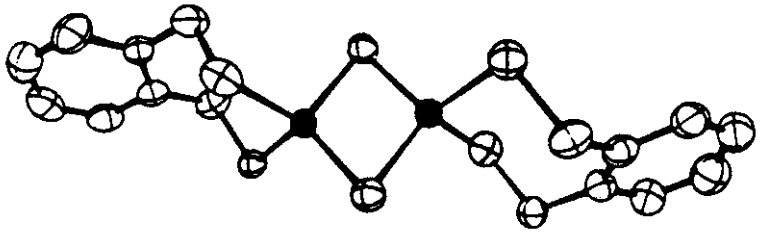


[Rd]:	–Cys–X_2–Cys–X_n–Cys–X_2–Cys–
[2Fe–2S]:	–Cys–X_4–Cys–X_2–Cys–X_{29}–Cys–
[4Fe–4S]:	–Cys–X_2–Cys–X_2–Cys–X_n–Cys–
HiPIP:	–Cys–X_2–Cys–X_{16}–Cys–X_{13}–Cys–
[3Fe–4S]:	–Cys–$X_{5,7}$–Cys–X_n–Cys–

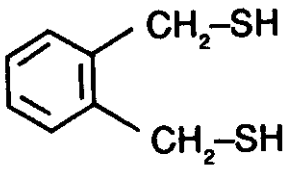
Model complexes



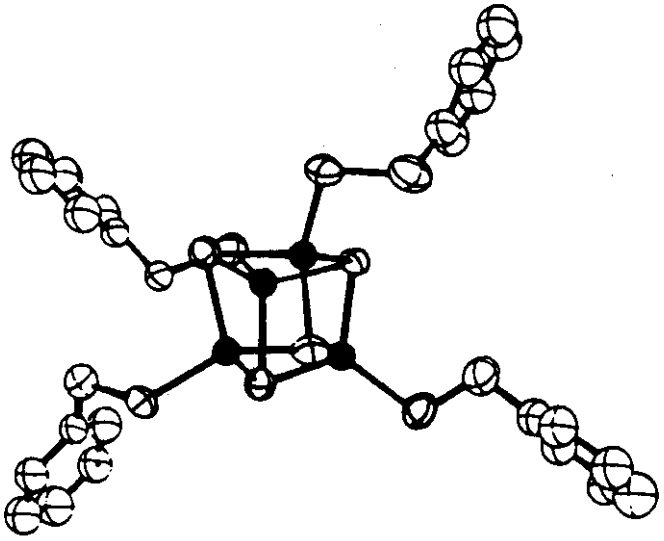
$Fe[(SCH_2)_2C_6H_4]_2^{-}$



$[FeS(SCH_2)_2C_6H_4]_2^{2-}$



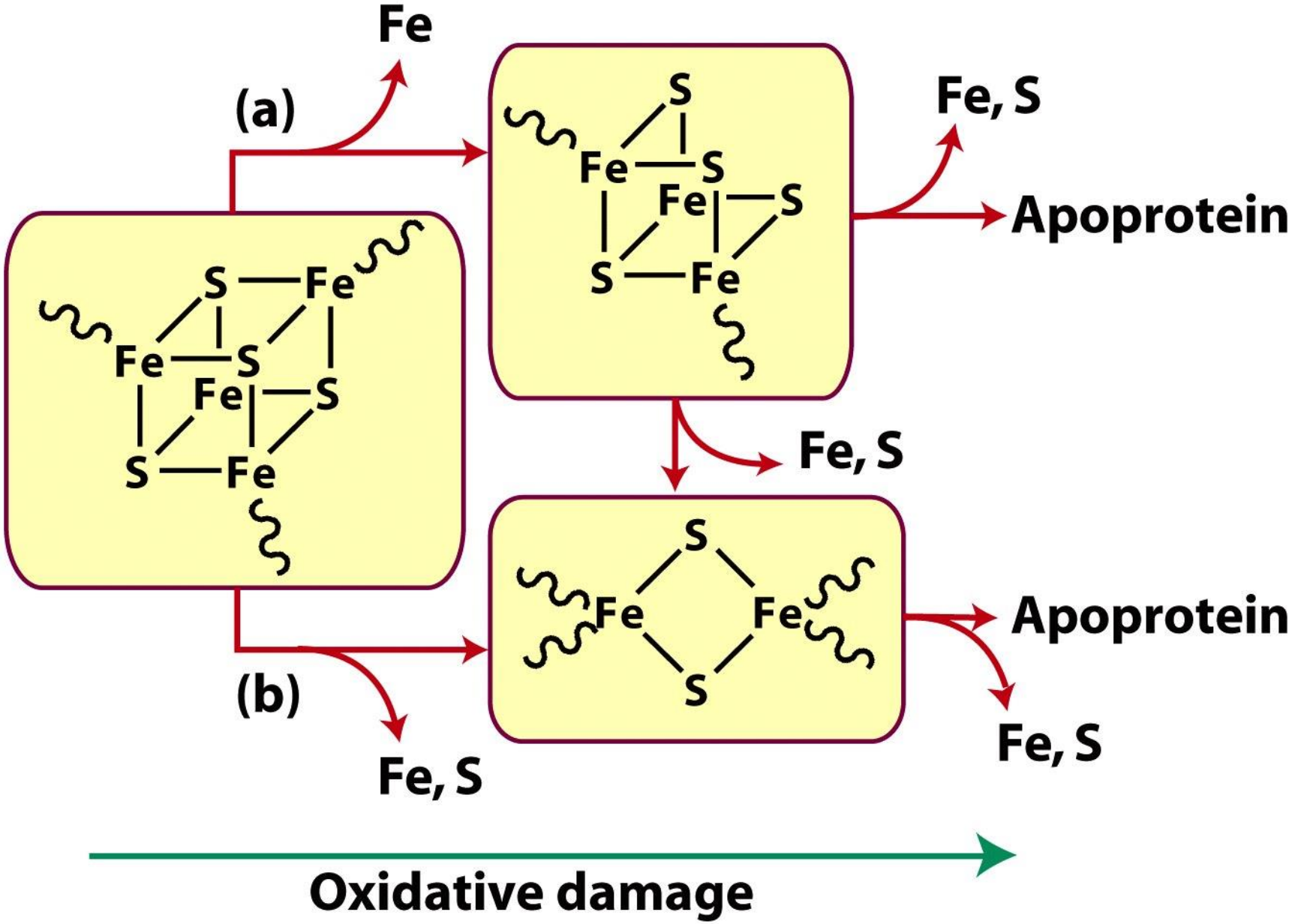
o-xylene-α,α′-dithiol, $(HSCH_2)_2C_6H_4$



$[Fe_4S_4(SCH_2C_6H_5)_4]^{2-}$

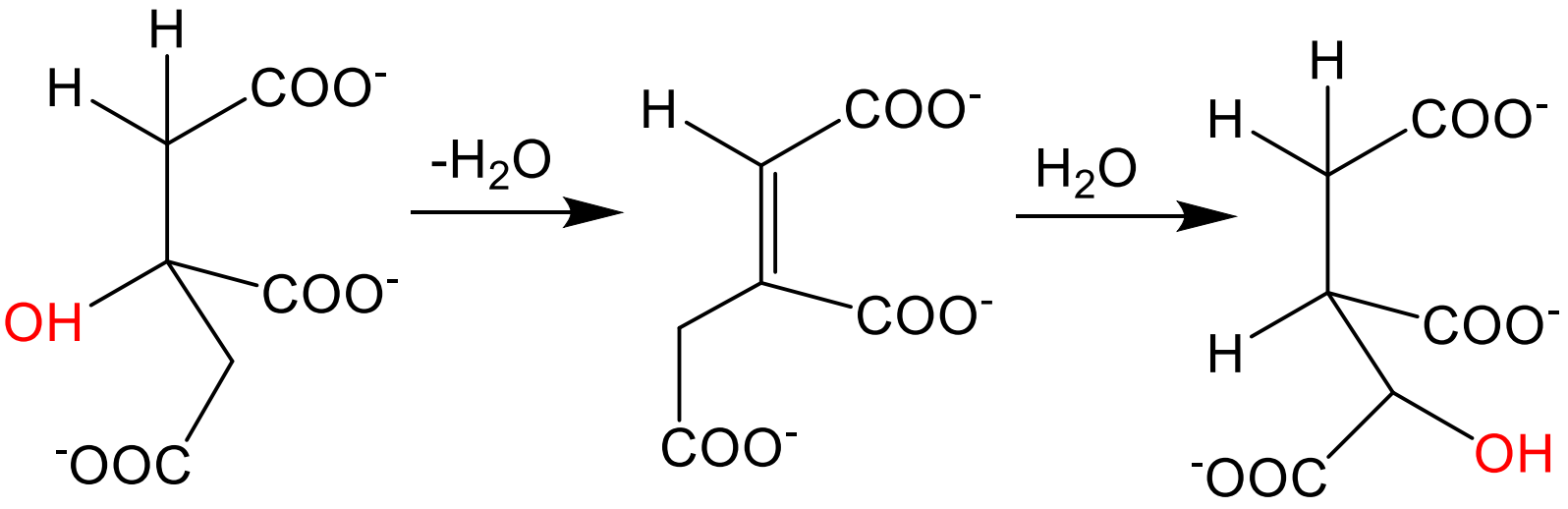
$6\ RSH + 4\ NaHS + 4\ FeCl_3 + 10\ NaOR \rightarrow Na_2[Fe_4S_4(RS)_4] + 10\ ROH + 12\ NaCl + RSSR$

Fe–S proteins as O_2 sensors



Aconitase enzyme

Catalyzes the interconversion of citrate to isocitrate



Citrato Aconitato Isocitrato

Catalytic site of aconitase