PhotoSynLab - BioSmart

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PhotoSynLab

Evolution of Bioenergetic Systems
- Bioenergetics
- Astrobiology

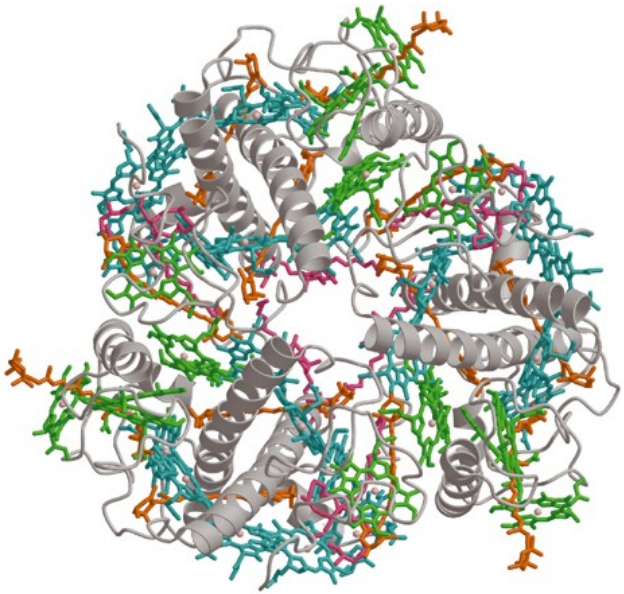
Bioenergy
- Biological Solar Cell
- Biofuels

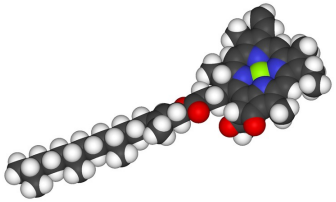
Sun energy output:

383×10^{24} W (yotta Watts)

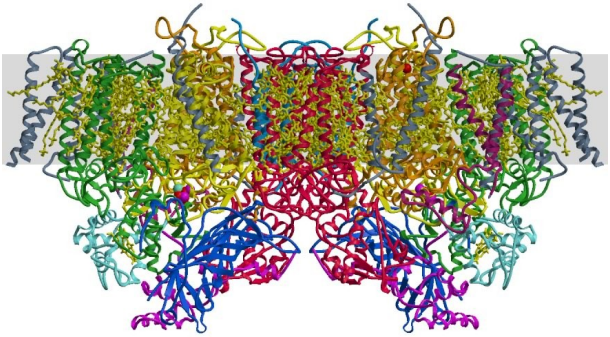
Steps in biological energy conversion

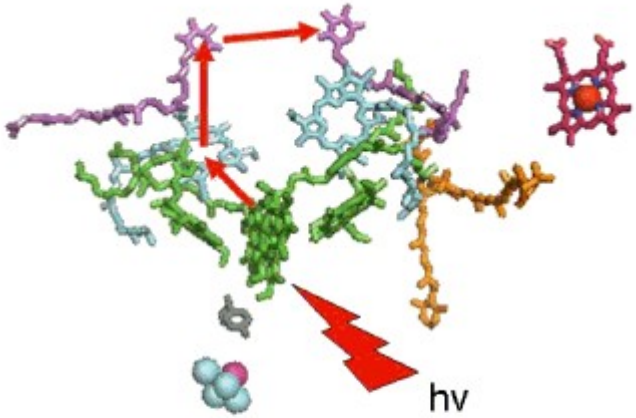
Excitation capture





Charge separation





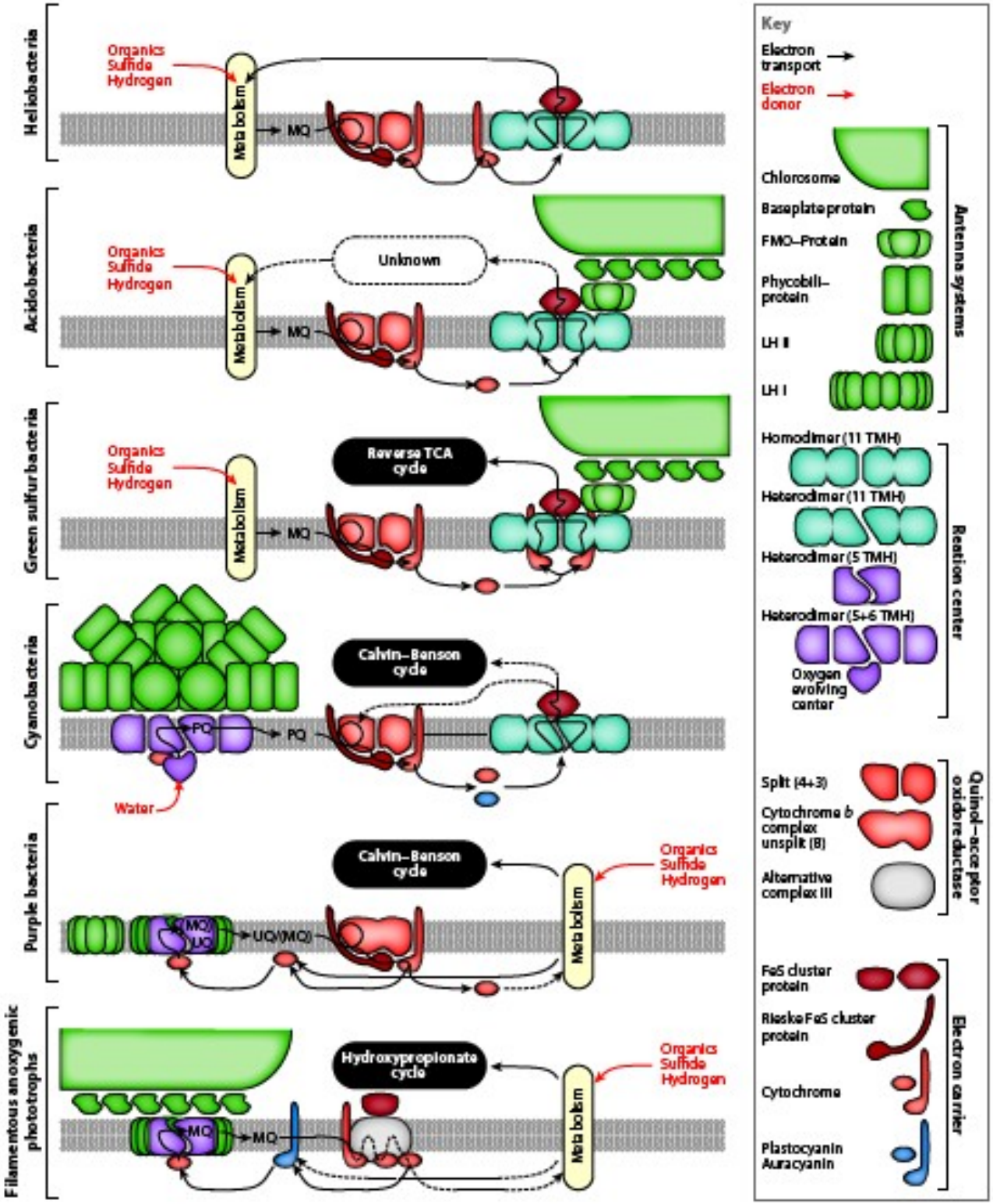
Charge stabilization

Ferreira K.N. et al. (2004) Science 303: 1831-1838 [PDB 1S5L]

Nelson, N. and Yocum, C.F. (2006) *Ann. Rev. Plant Biol* 57: 521-565

Van Pelt, R (2001) Forest Giants of North America, University of Washington Press

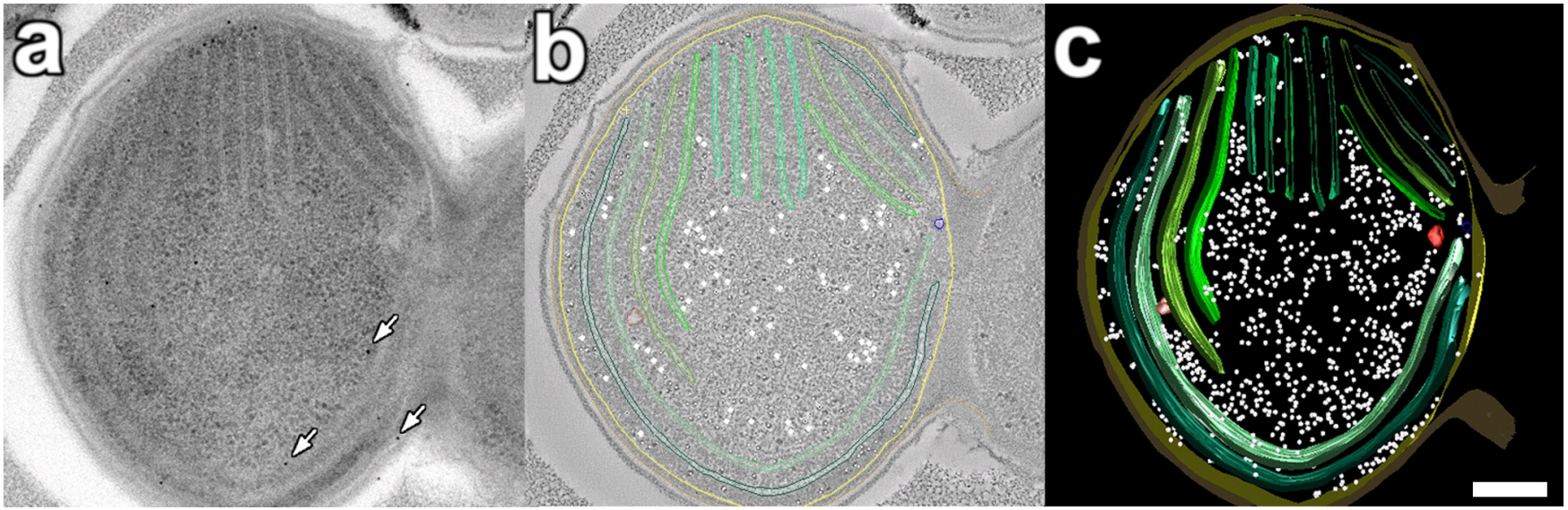
Photosynthetic Diversity



Hohmann-Marriott and Blankenship (2011)
Annu Rev Plant Biol

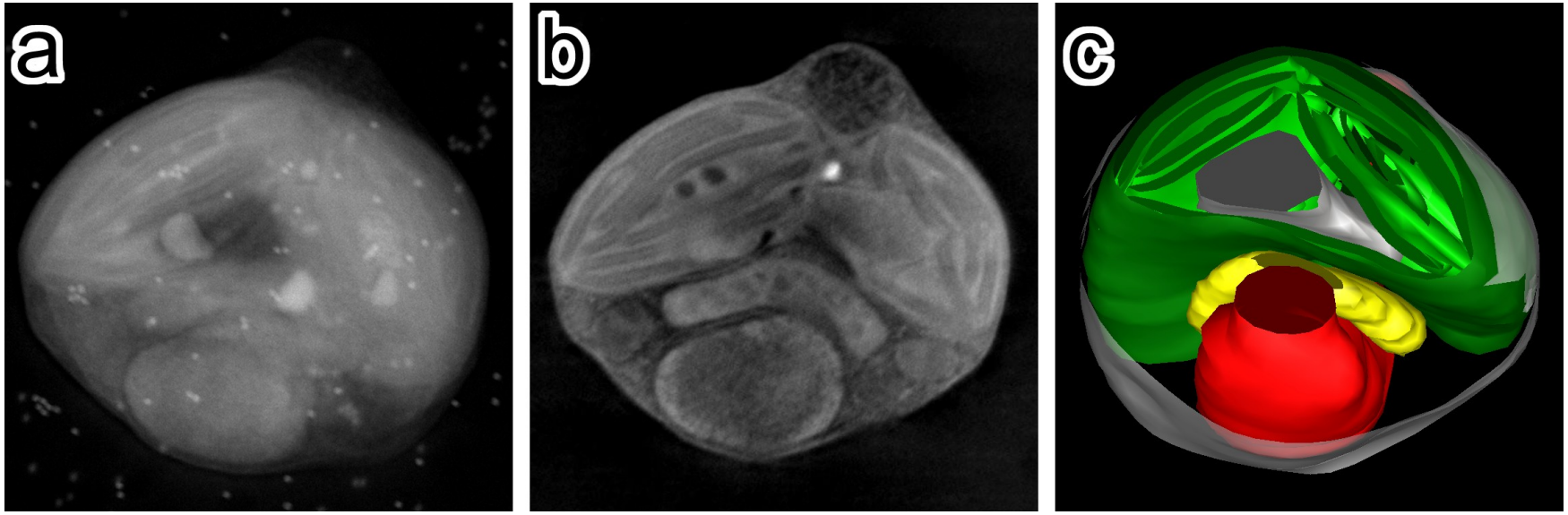
Oxygenic organisms

Cyanobacteria



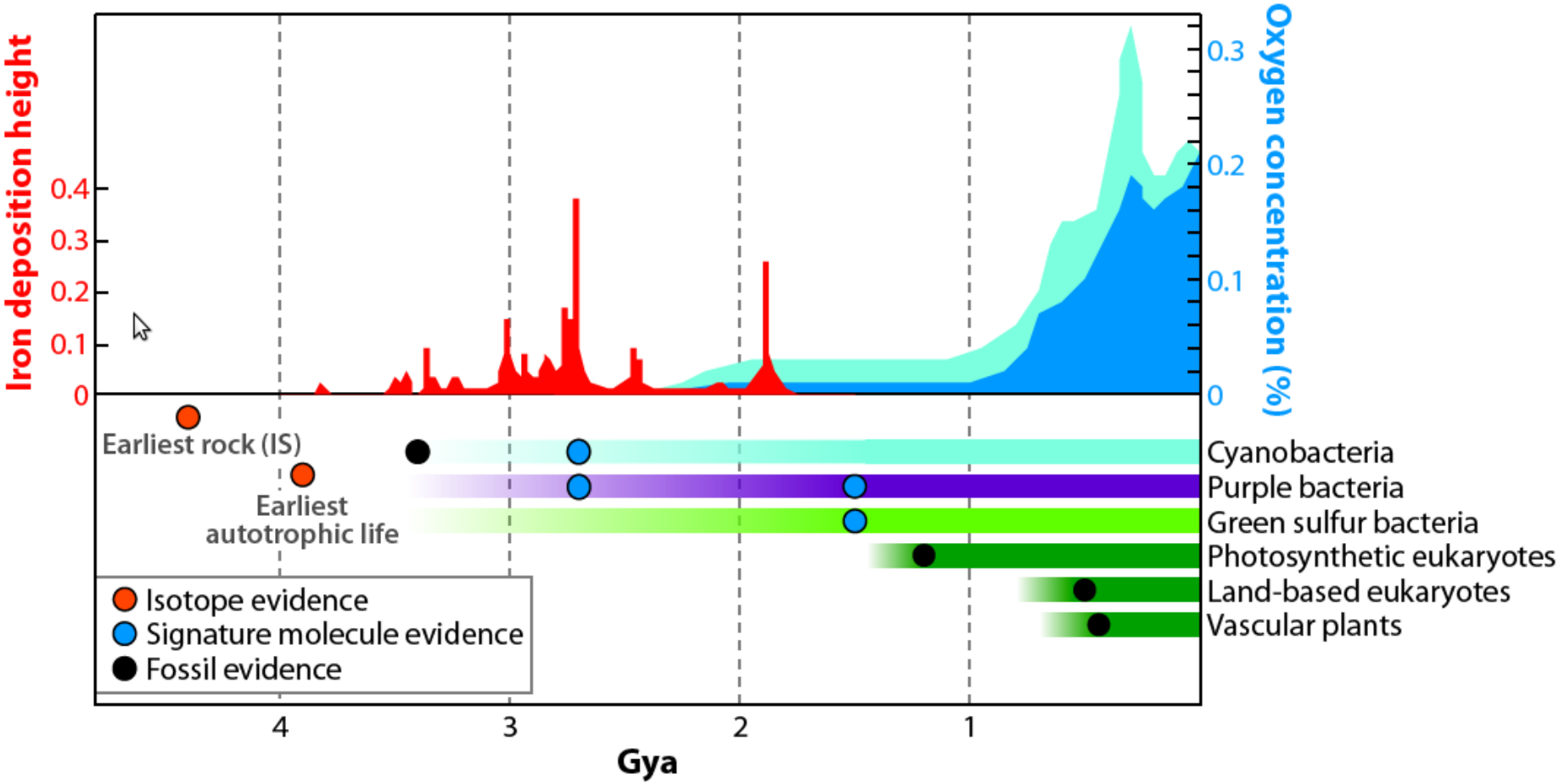
Hohmann-Marriott and Roberson (2009) Photosynth Res

Plants

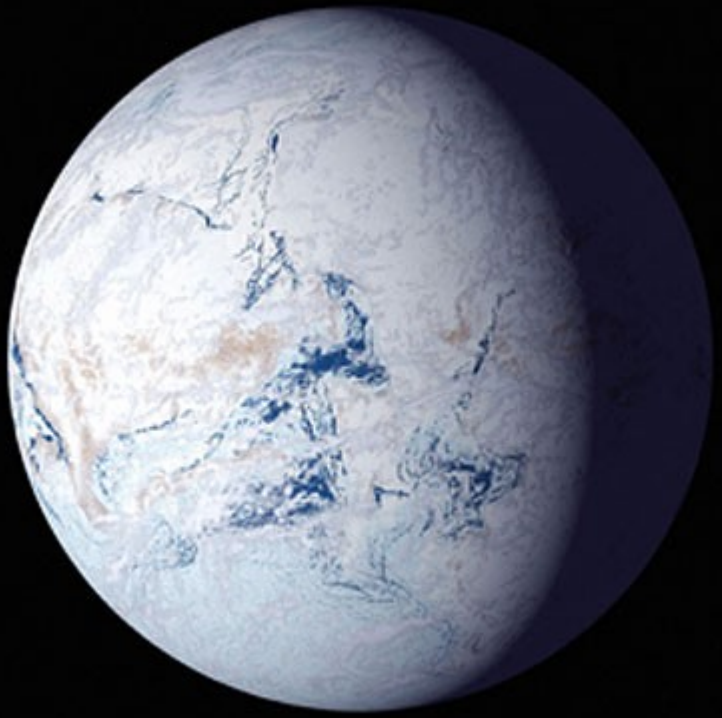


(Hohmann-Marriott & Sousa , unpublished)

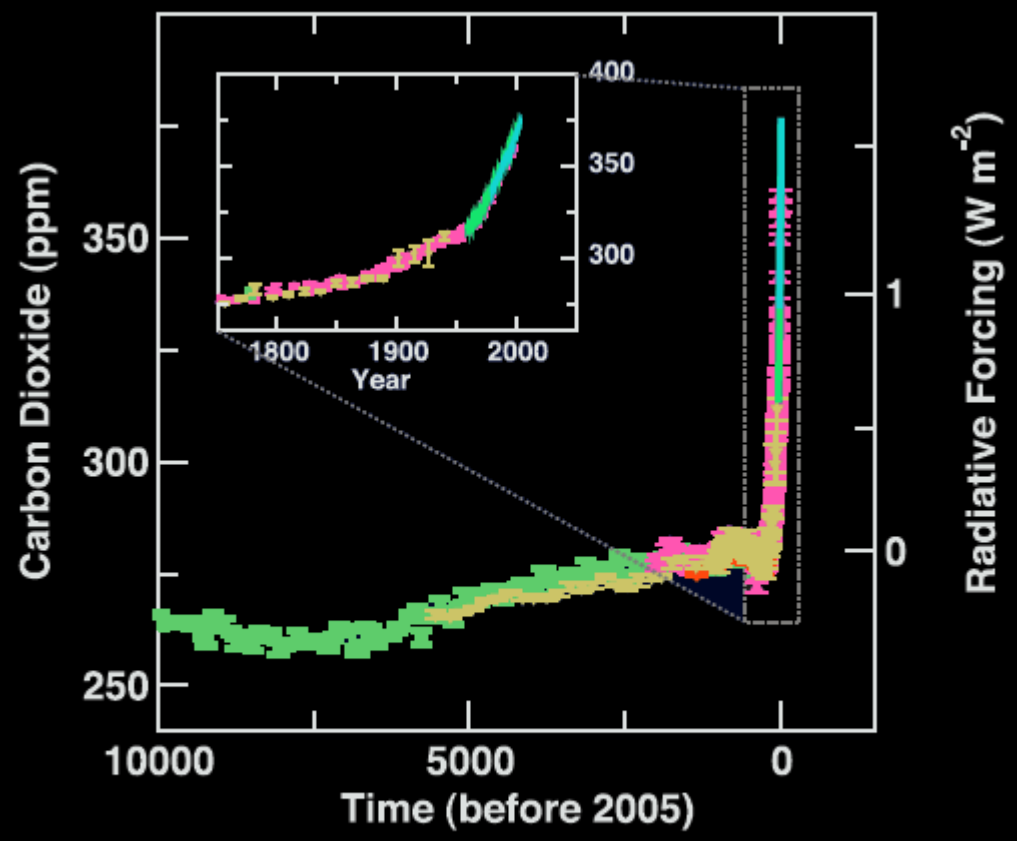
Transforming our atmosphere



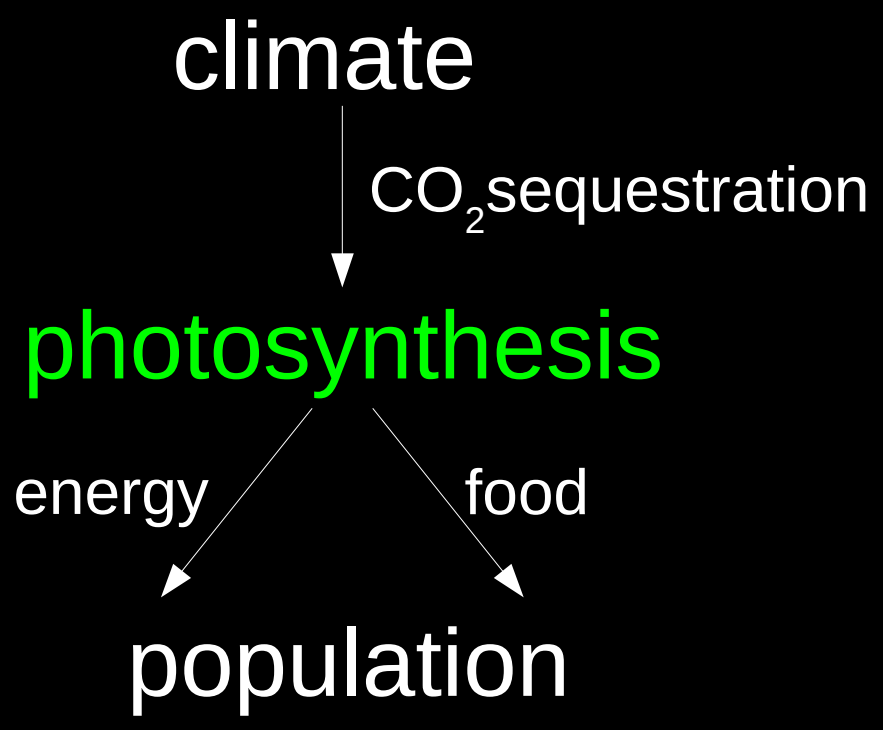
Hohmann-Marriott & Blankenship (2011) *Annu Rev Plant Biol*



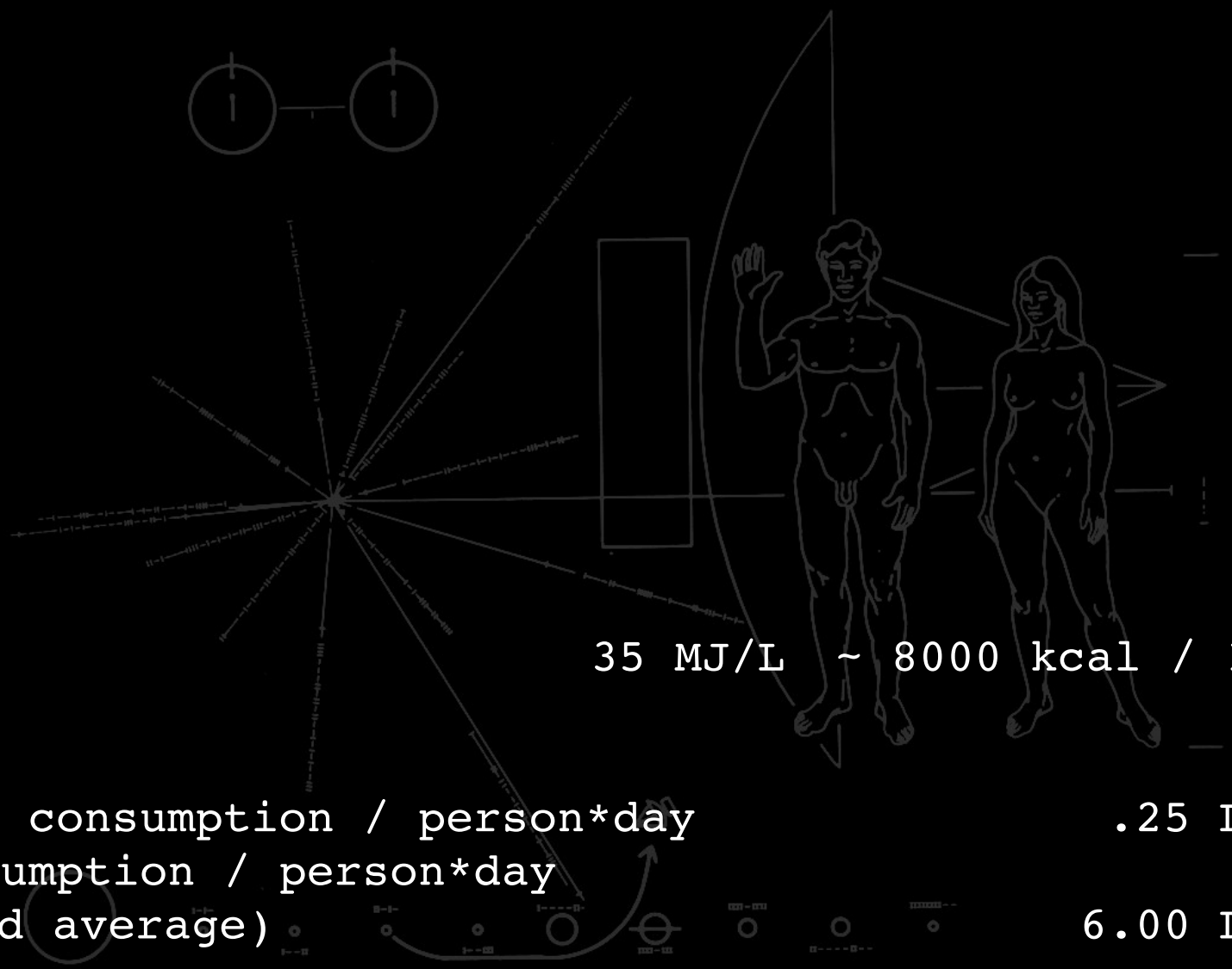
Atmospheric CO_2



Photosynthesis



Oil & Energy



oil	35 MJ/L ~ 8000 kcal / 1 L
food energy consumption / person*day	.25 L
energy consumption / person*day (world average)	6.00 L

Photosynthesis eficiency

Land area covered to produce rapeseed oil providing world energy demand [in black]

energy consumption / (person * year) (world average)	2000.00 L
energy per 100m x 100m of rapeseed / year	1000.00 L
total area needed for 7G people $2*100m*100m*7*10^9$	$140*10^{12}$ m^2
total land mass of earth	$148*10^{12}$ m^2

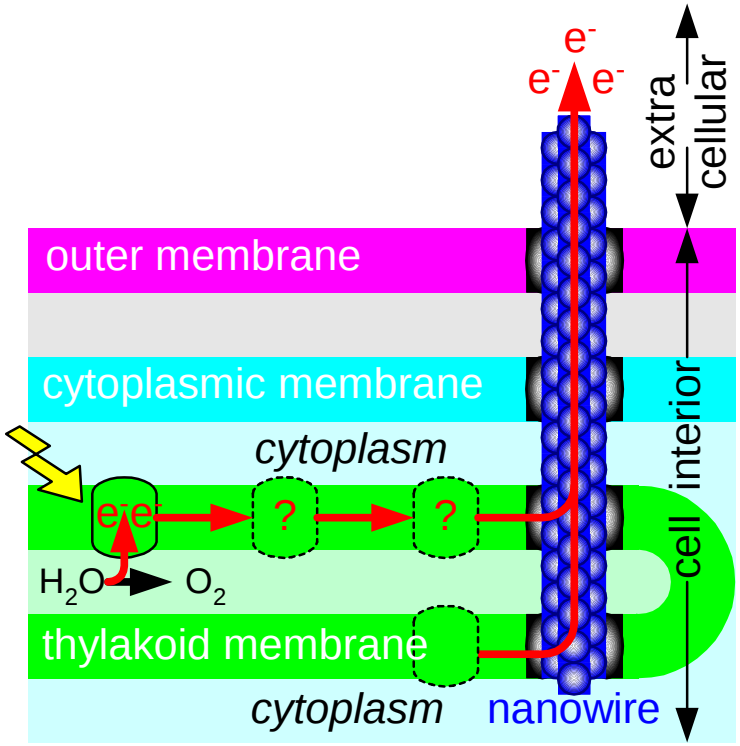
Efficiency pf photosynthesis

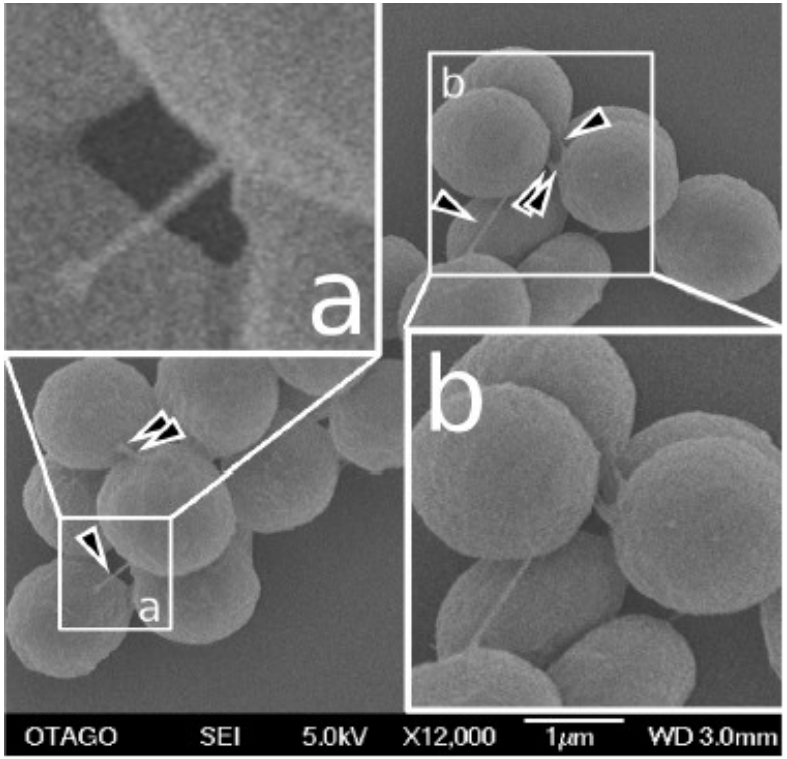
Efficiency of a leaf

100% sunlight
    non-bio-available-photons-waste-47%
53% in 400-700nm range
    30% of photons lost due to incomplete absorption
37% (absorbed photon energy)
    24% lost due to wavelength missmatch degradation to 700nm energy level
28.2% (sunlight energy collected by chlorophyl) → 95% charge separation
    32% efficient conversion of ATP and NADPH to glucose
9% (collected as sugar) –
    35-40% of sugar is recycled/consumed by the leaf in dark
5.4% net leaf efficiency

Overall eficieny (whole plant over year) 0.1-1%

Harvesting electrons directly





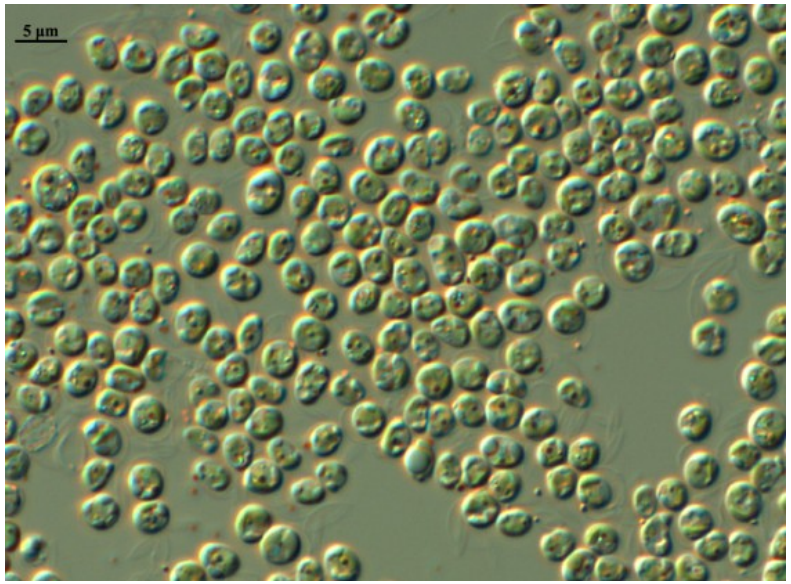
Synechocystis sp. PCC 6803

Hohmann-Marriott (unpublished data)

Biofuels - Lipids

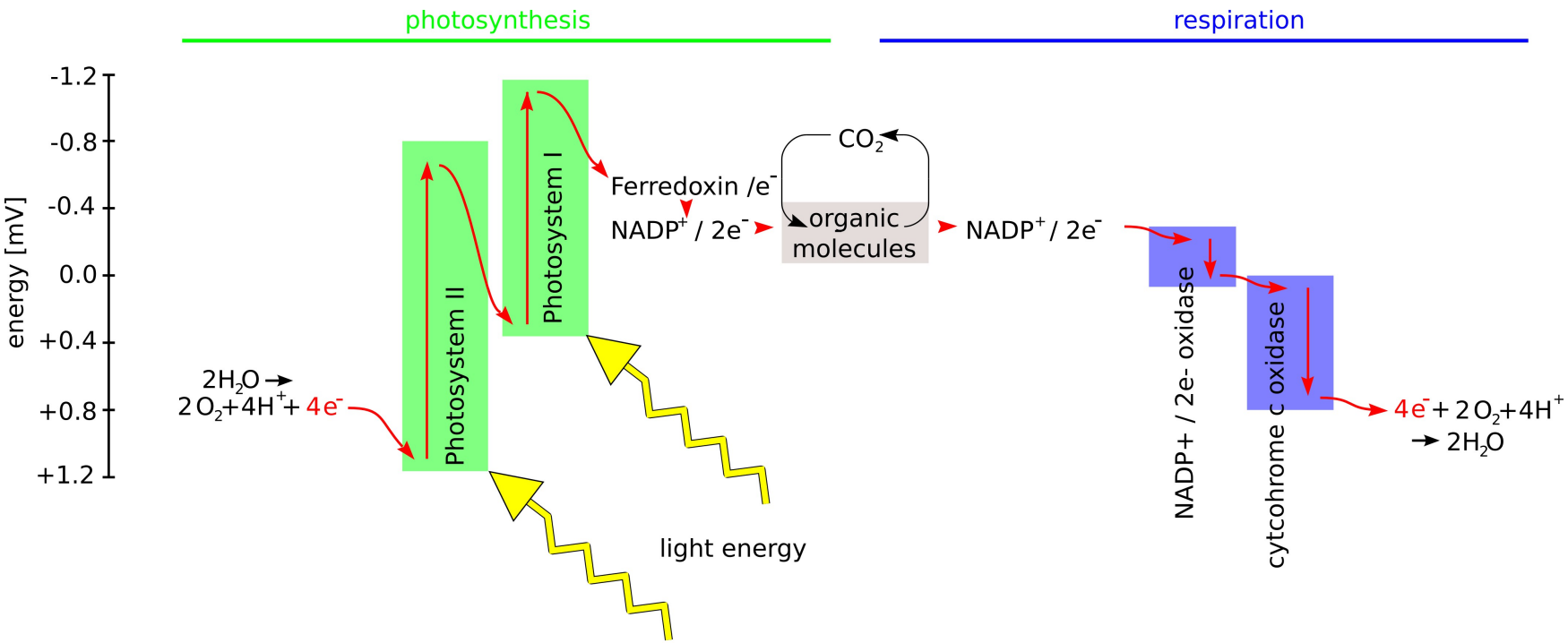
Nannochloropsis CCMP 1779 & CCMP 526

- marine algae
  (Heterokontophyta, Eustigmatophyceae)
  photosynthetic, free-living

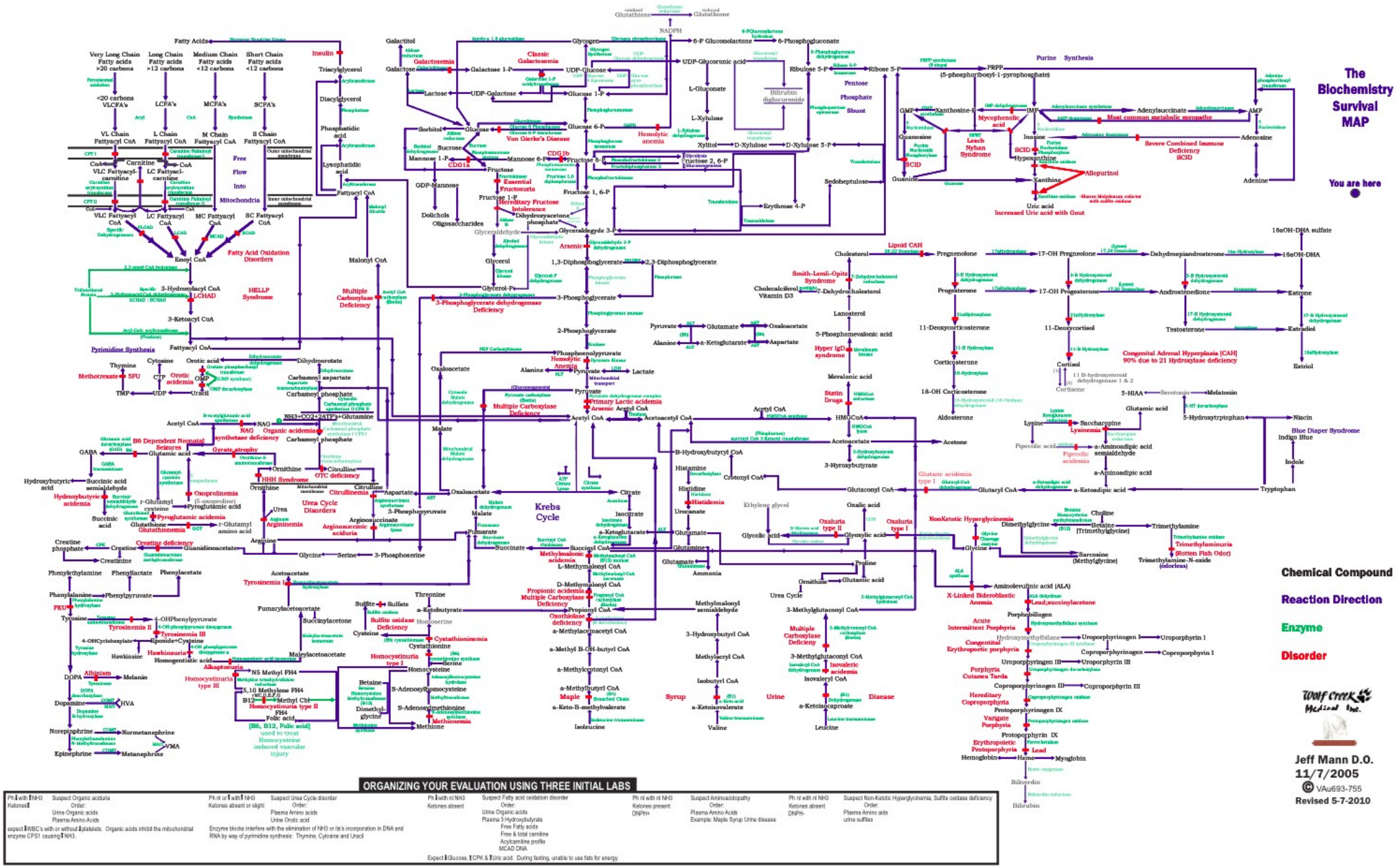


https://ncma.bigelow.org/node/1/strain/CCMP1179

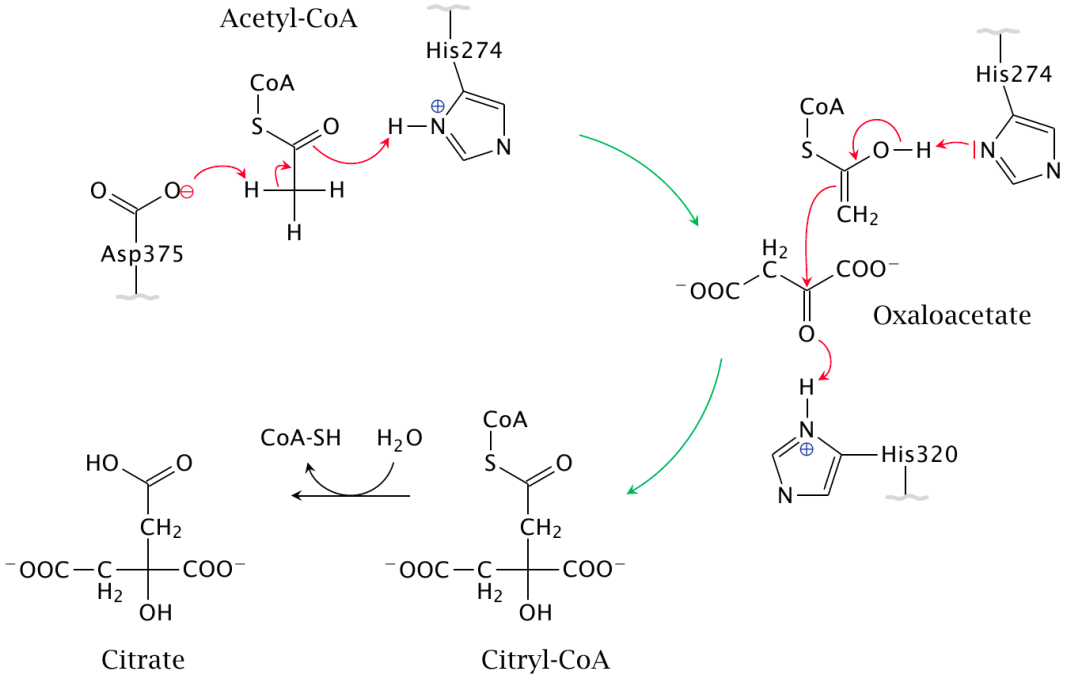
Energetics of the oxygen cycle



Biochemical networks



Solution: bond energies



Average Bond Dissociation Energies, *D* (kJ/mol)[a]									
H—H	436[a]	C—H	410	N—H	390	O—H	460	F—F	159[a]
H—C	410	C—C	350	N—C	300	O—C	350	Cl—Cl	243[a]
H—F	570[a]	C—F	450	N—F	270	O—F	180	Br—Br	193[a]
H—Cl	432[a]	C—Cl	330	N—Cl	200	O—Cl	200	I—I	151[a]
H—Br	366[a]	C—Br	270	N—Br	240	O—Br	210	S—F	310
H—I	298[a]	C—I	240	N—I	—	O—I	220	S—Cl	250
H—N	390	C—N	300	N—N	240	O—N	200	S—Br	210
H—O	460	C—O	350	N—O	200	O—O	180	S—S	225
H—S	340	C—S	260	N—S	—	O—S	—		
Multiple covalent bonds									
C=C	611	C≡C	835	C=O	732	O=O	498[a]	N≡N	945[a]

[a] Exact value

Nature vs. Petrochemicals

Nature

Naturechemicals

- Glucose
- Polyhydroxybuturate
- Ethanol
- ....

? substitutes

Petro-Industry

Petrochemicals

- Benzene
- Butadiene
- Ethylene
- p-Xylene
- Propylene

energetically viable ?

Bio-Industry

Naturechemicals

- Glucose ✗
- Polyhydroxybuturate ✓
- Ethanol ✗
- ....