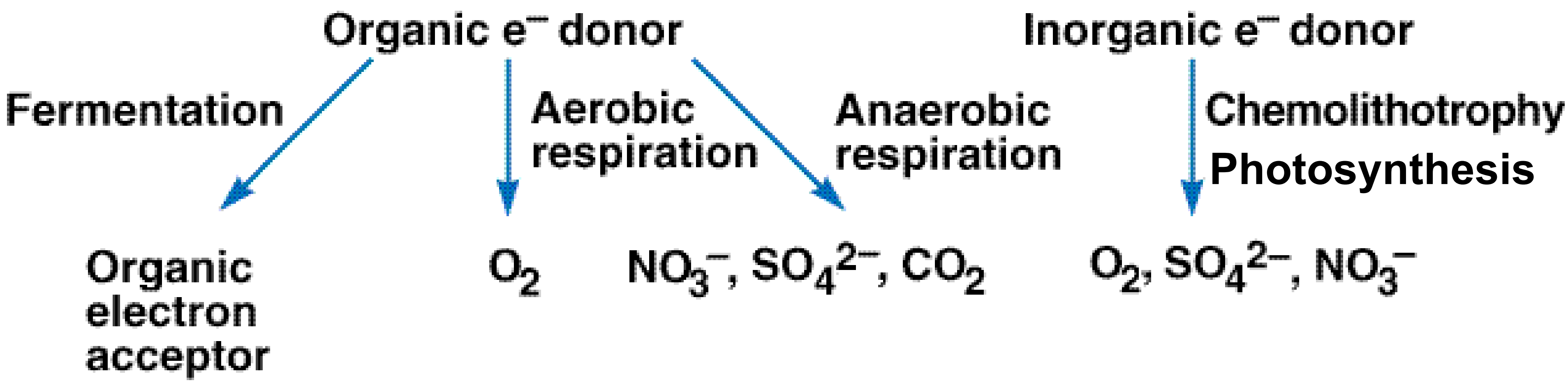
Patterns of Energy Production



Photosynthesis:

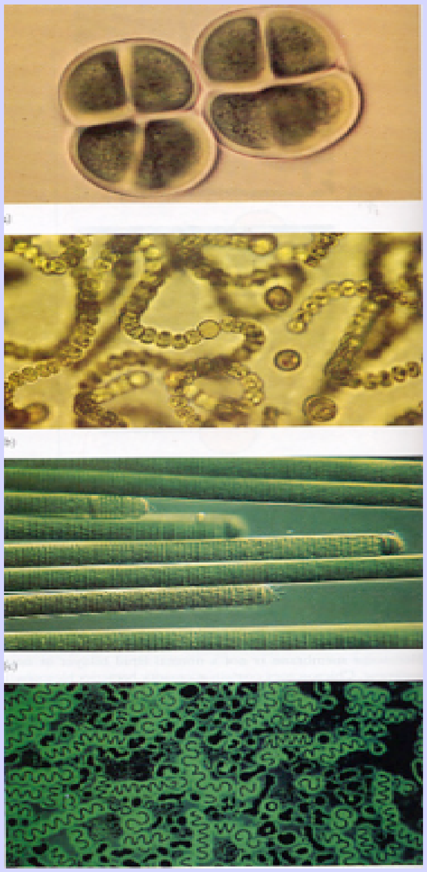
- the process by which light energy from the sun is captured and converted to chemical energy

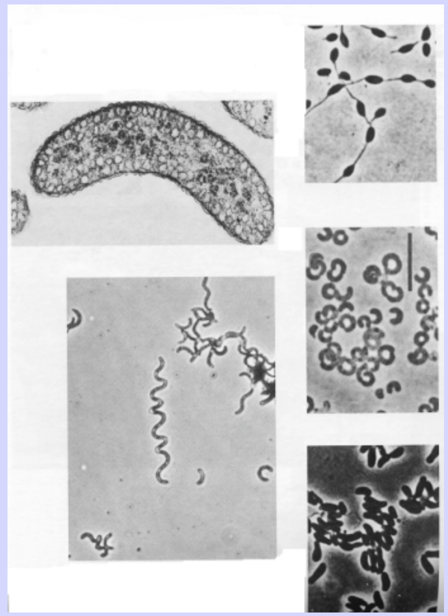
light

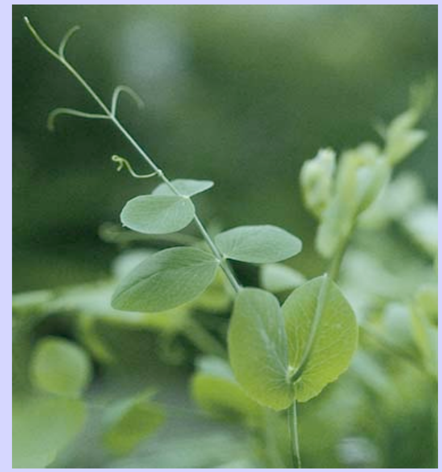
- $6\ CO_2 + 6H_2O \rightarrow 6O_2 + C_6H_{12}O_6$

  (H_2S, S^o, succinate)

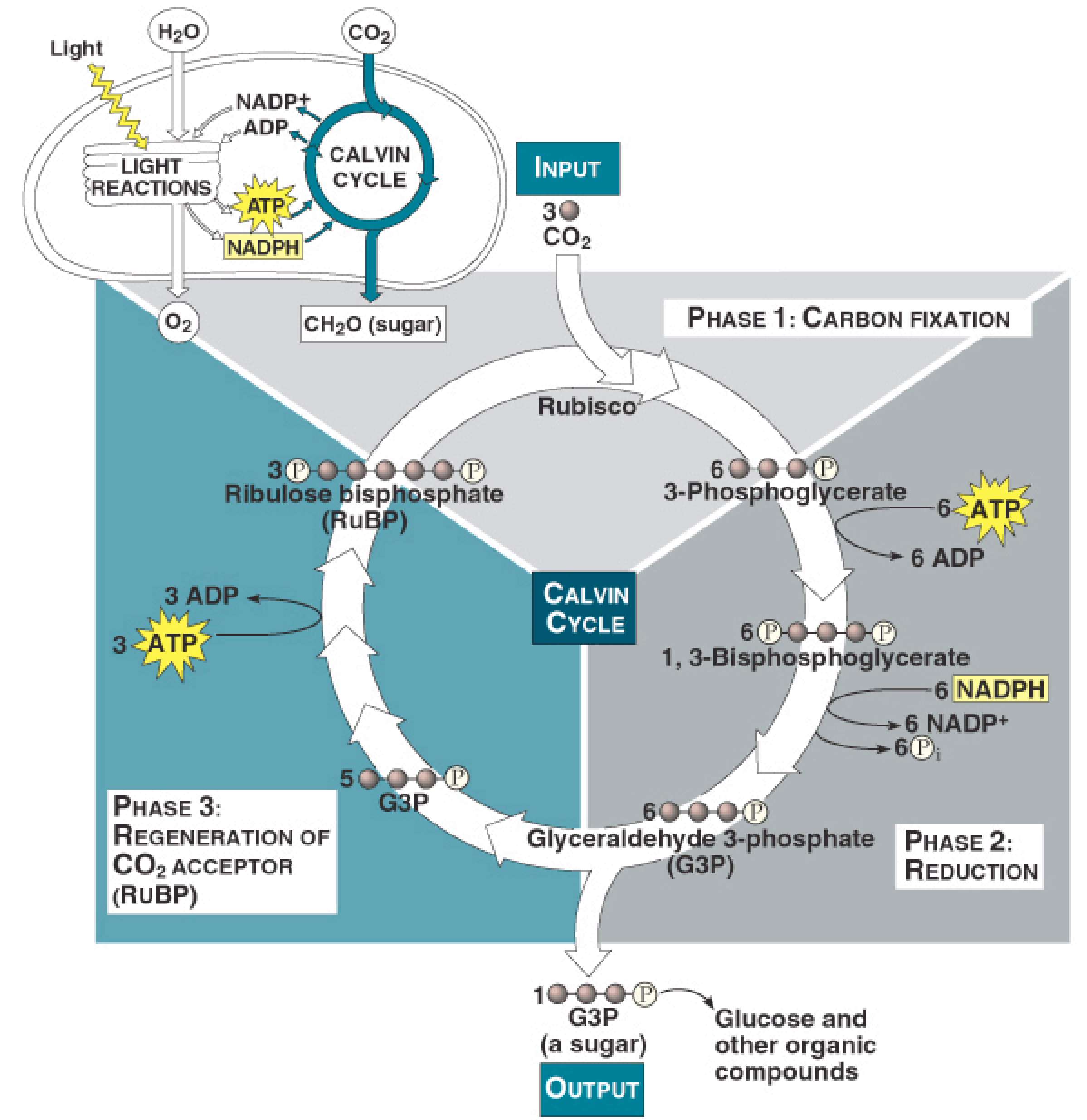
Photosynthetic Organisms







Cyanobacteria, plants , algae, purple or green sulfur bacteria, non-sulfur bacteria



Light
H2O
CO2
NADP+
ADP
CALVIN CYCLE
LIGHT REACTIONS
ATP
NADPH
O2
CH2O (sugar)
INPUT
3 CO2
PHASE 1: CARBON FIXATION
Rubisco
3 Ribulose bisphosphate (RuBP)
6 3-Phosphoglycerate
6 ATP
6 ADP
CALVIN CYCLE
3 ADP
3 ATP
6 1, 3-Bisphosphoglycerate
6 NADPH
6 NADP+
6 Pi
5 G3P
6 Glyceraldehyde 3-phosphate (G3P)
PHASE 3: REGENERATION OF CO2 ACCEPTOR (RUBP)
PHASE 2: REDUCTION
1 G3P (a sugar)
OUTPUT
Glucose and other organic compounds

Mechanism of Photosynthesis

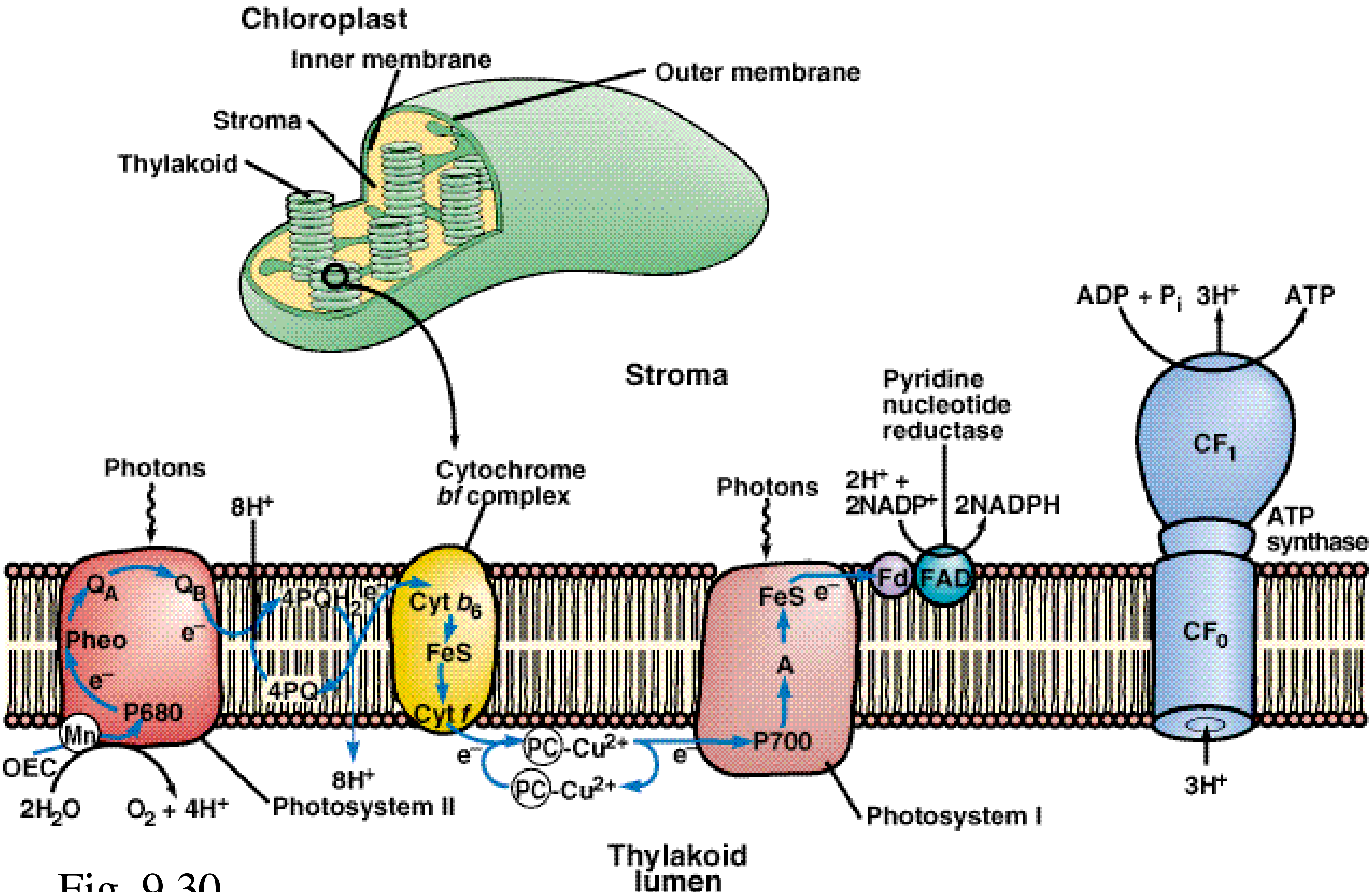
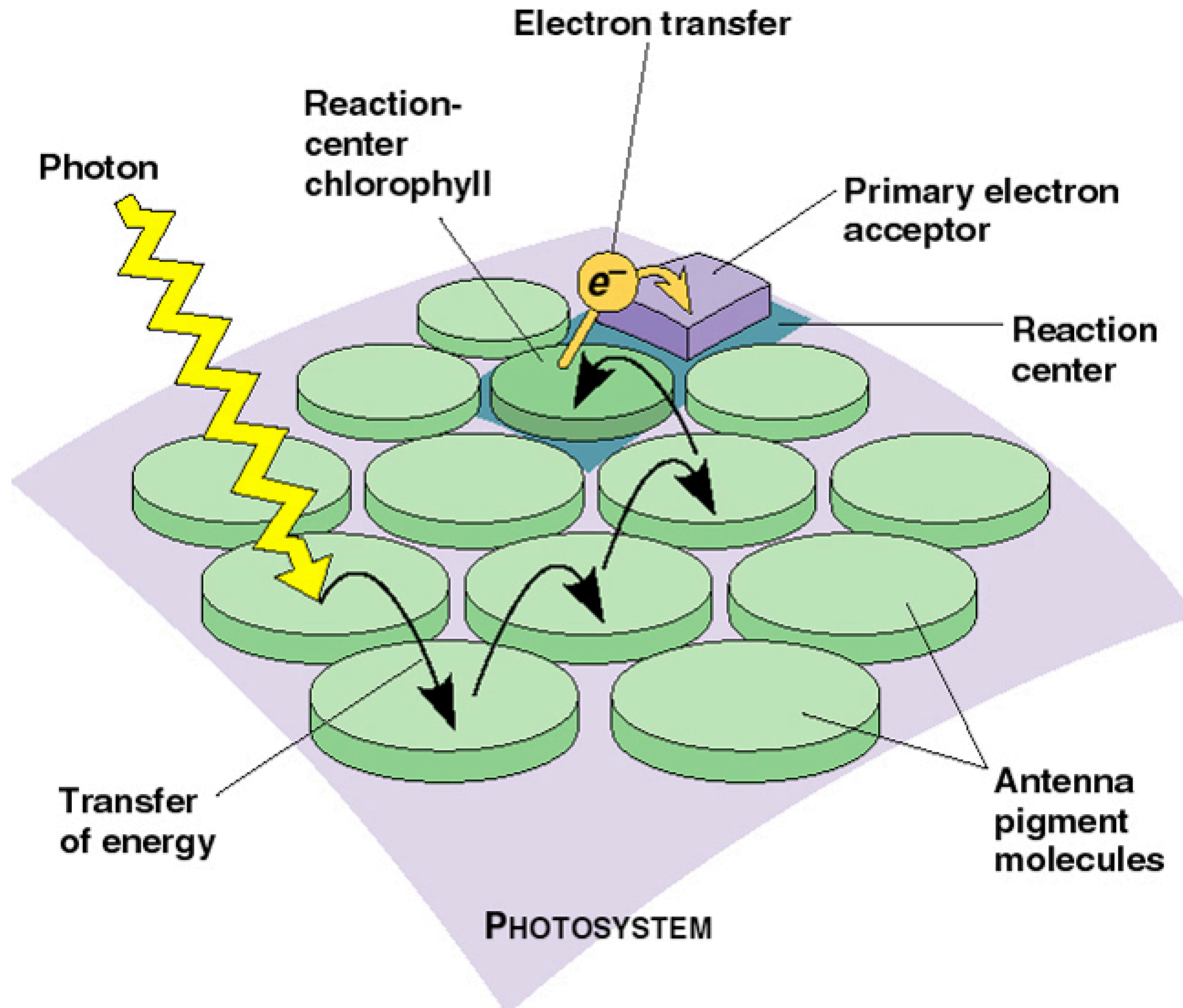


Fig. 9.30


Electron transfer
Reaction-
center
chlorophyll
Photon
Primary electron
acceptor
e⁻
Reaction
center
Transfer
of energy
Antenna
pigment
molecules
PHOTOSYSTEM

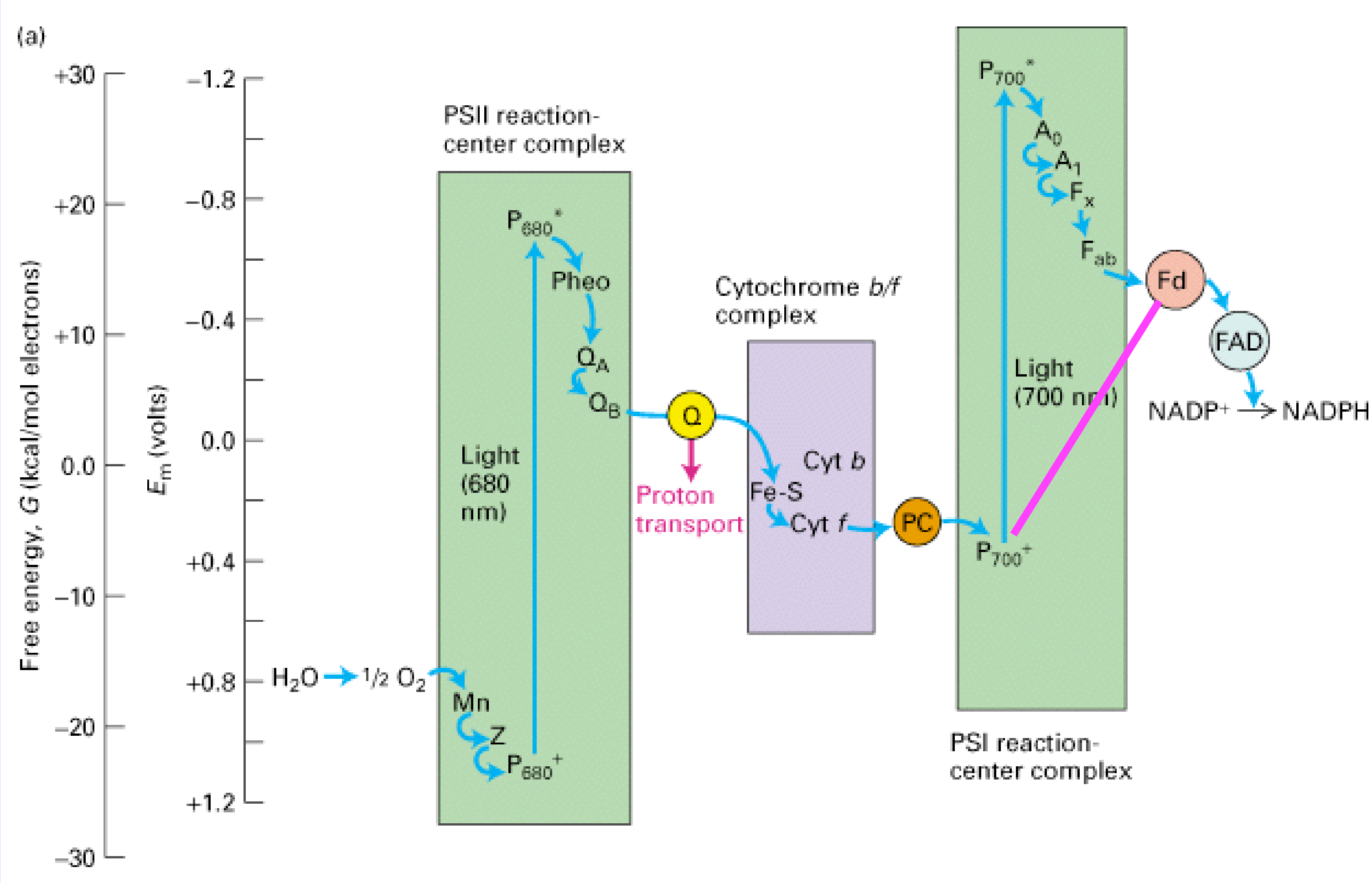

(a)
Free energy, G (kcal/mol electrons)
+30
+20
+10
0.0
−10
−20
−30
Em (volts)
−1.2
−0.8
−0.4
0.0
+0.4
+0.8
+1.2
PSII reaction-
center complex
P680*
Pheo
QA
QB
Light
(680
nm)
H2O
1/2 O2
Mn
Z
P680+
Q
Proton
transport
Cytochrome b/f
complex
Cyt b
Fe-S
Cyt f
PC
P700*
A0
A1
Fx
Fab
Light
(700 nm)
P700+
PSI reaction-
center complex
Fd
FAD
NADP+
NADPH

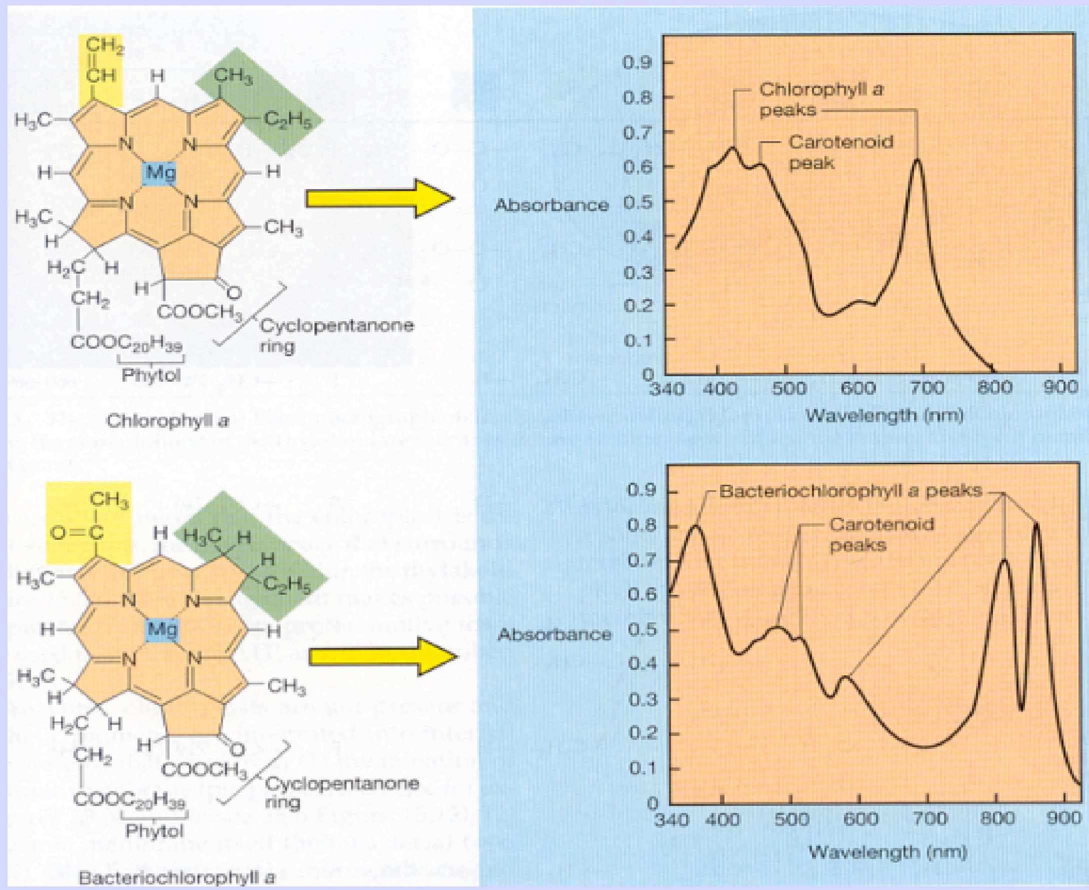
Fig. 9.29

“Plant” -vs- Bacterial Photosynthesis

Oxygenic/anoxygenic

E- donors: H_2, H_2S, etc.

Bacteriochorophylls



Bacterial Photosynthesis

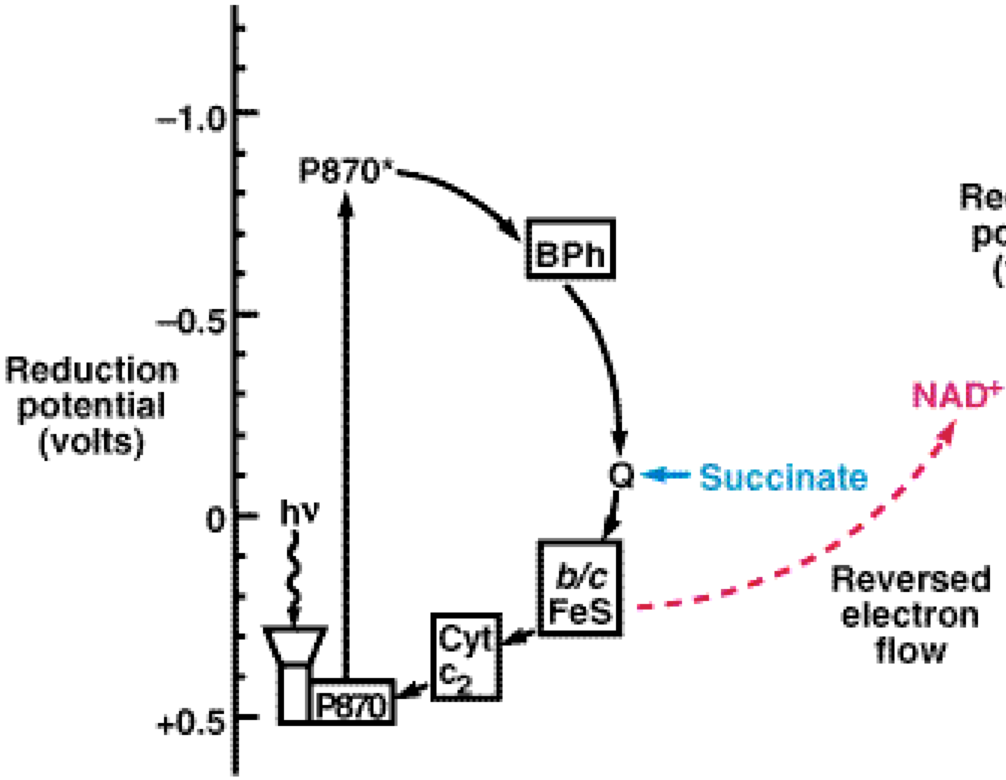


Fig. 9.31 (purple)
Chromatium, Rhodospirillum

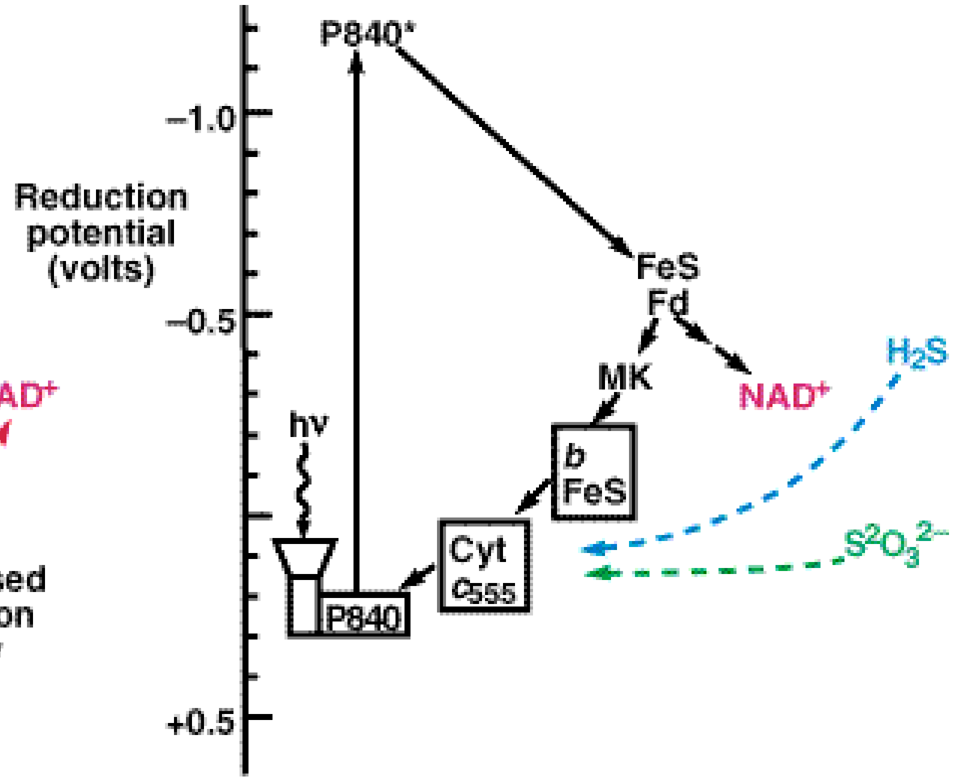
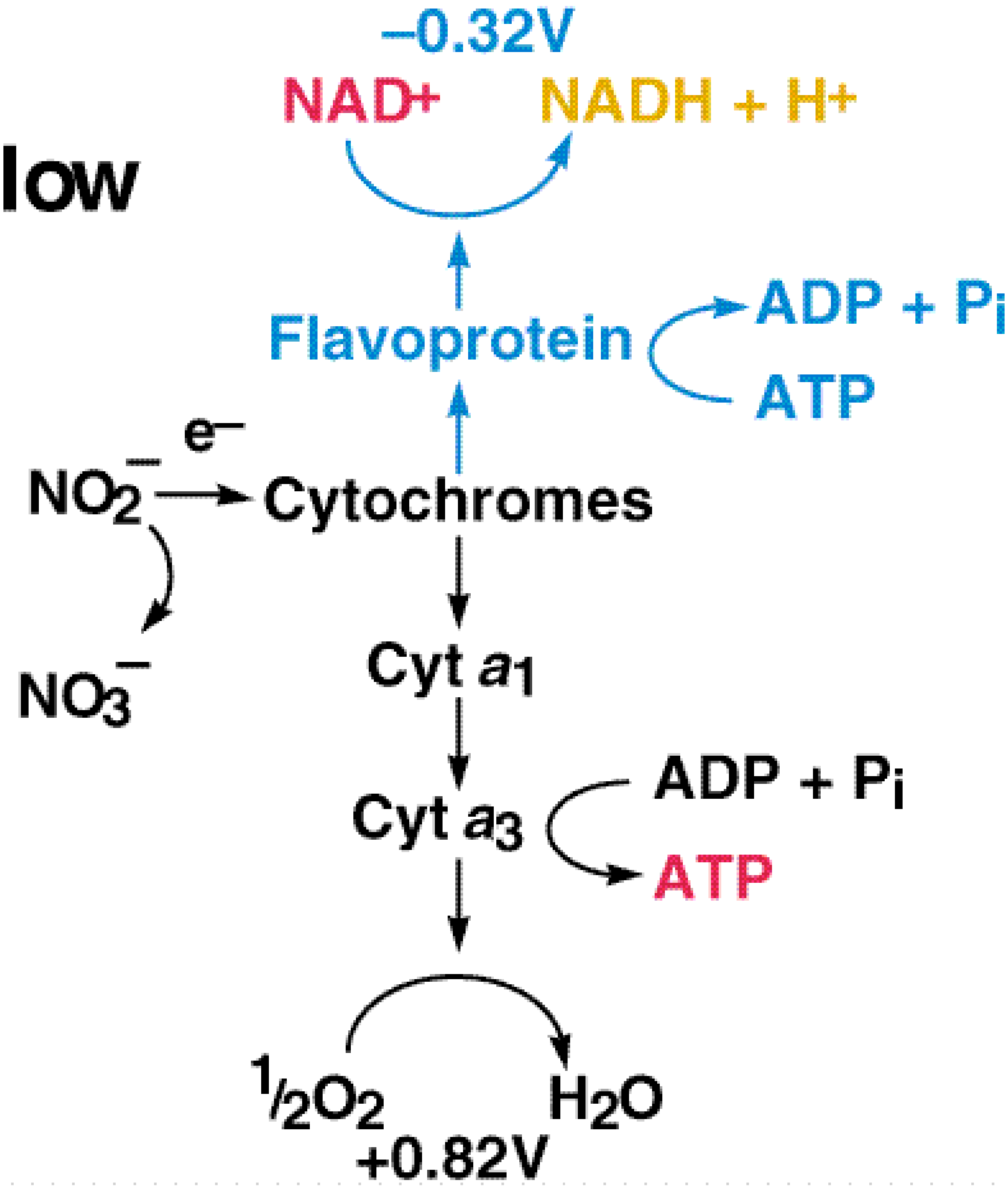
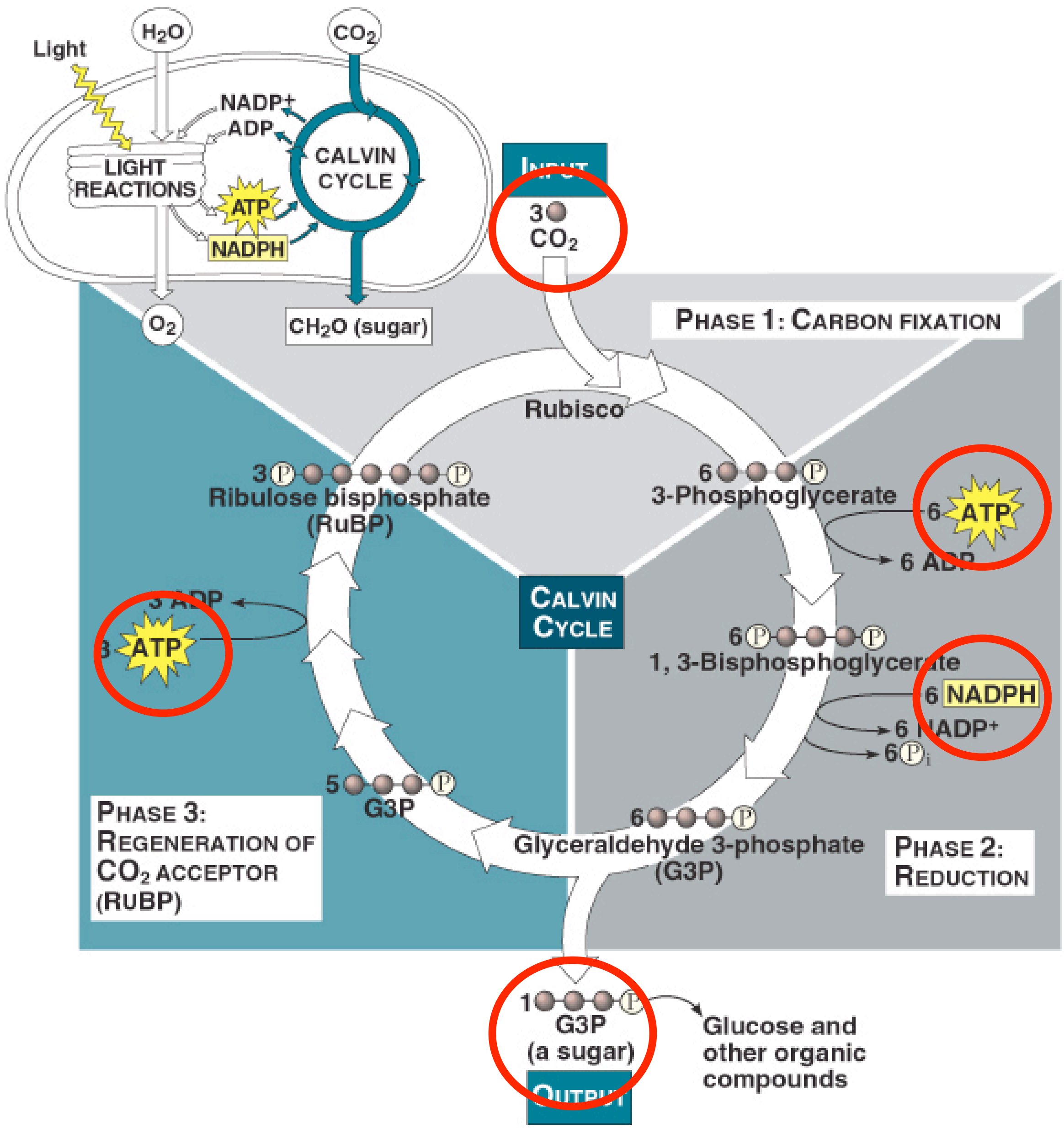
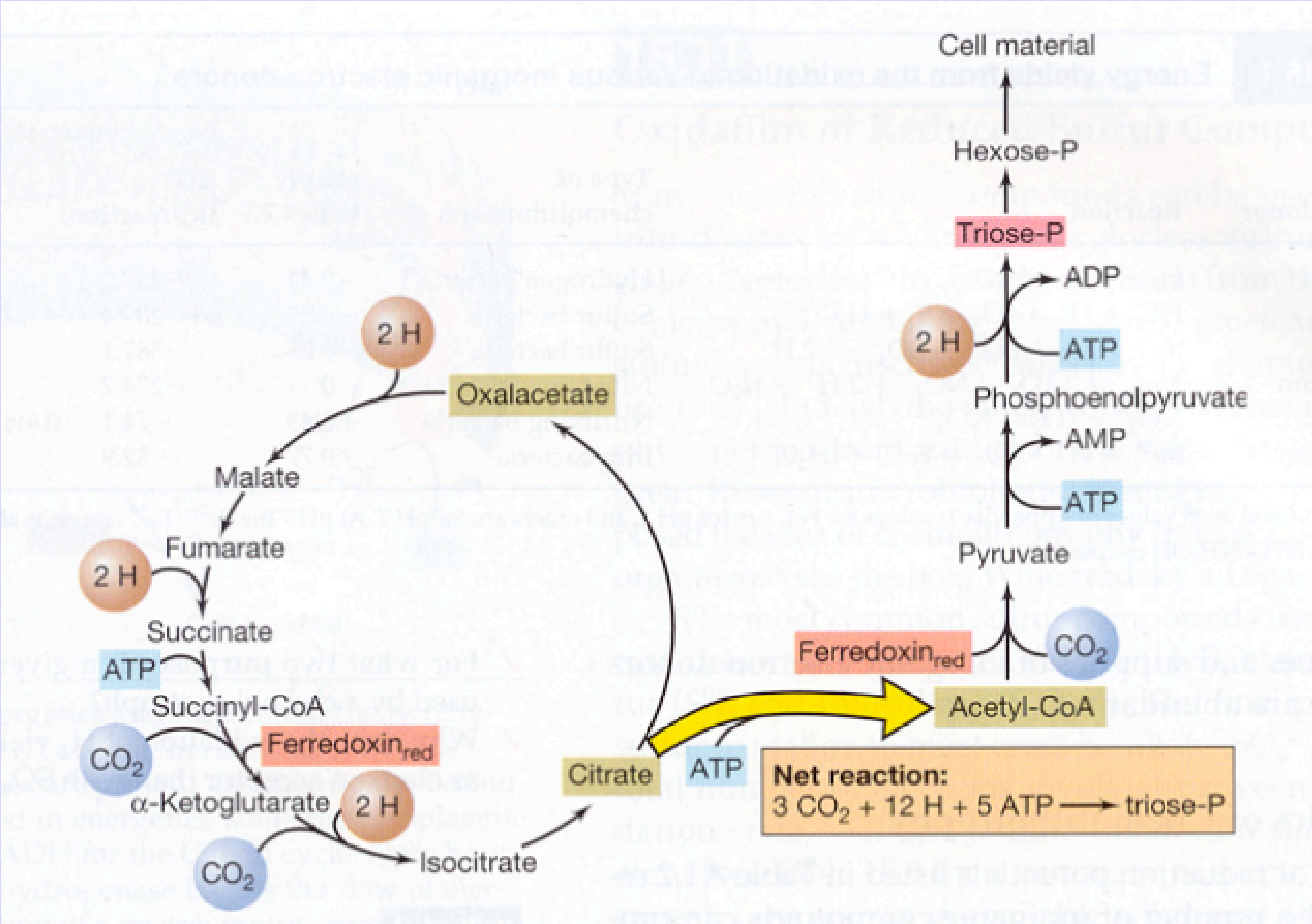


Fig. 9.33 (green)
Chlorobium, Chloroflexus

Reversed Electron Flow




Light
H_2O
CO_2
NADP+
ADP
LIGHT REACTIONS
CALVIN CYCLE
ATP
NADPH
O_2
CH_2O (sugar)
INPUT
3 CO_2
PHASE 1: CARBON FIXATION
Rubisco
3 Ribulose bisphosphate (RuBP)
6 3-Phosphoglycerate
6 ATP
6 ADP
CALVIN CYCLE
3 ADP
3 ATP
6 1, 3-Bisphosphoglycerate
6 NADPH
6 NADP+
6 Pi
5 G3P
6 Glyceraldehyde 3-phosphate (G3P)
PHASE 3: REGENERATION OF CO_2 ACCEPTOR (RUBP)
PHASE 2: REDUCTION
1 G3P (a sugar)
Glucose and other organic compounds


Cell material
Hexose-P
Triose-P
ADP
2 H
ATP
Phosphoenolpyruvate
AMP
ATP
Pyruvate
$Ferredoxin_{red}$
CO_2
Acetyl-CoA
2 H
Oxalacetate
Malate
Fumarate
2 H
Succinate
ATP
Succinyl-CoA
CO_2
$Ferredoxin_{red}$
α-Ketoglutarate
2 H
CO_2
Isocitrate
Citrate
ATP
Net reaction:
$3\ CO_2 + 12\ H + 5\ ATP \longrightarrow$ triose-P

Patterns of Energy Production

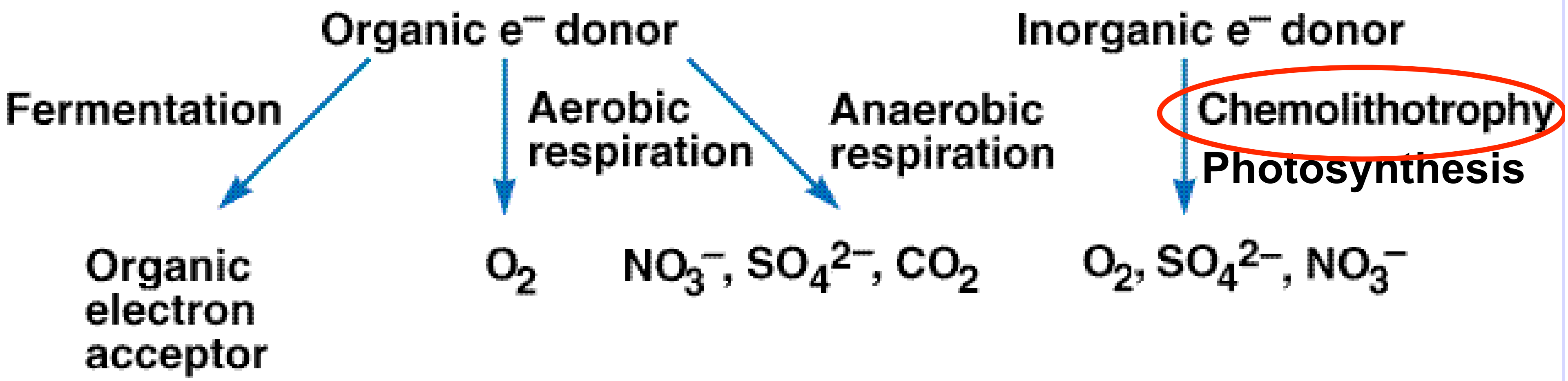
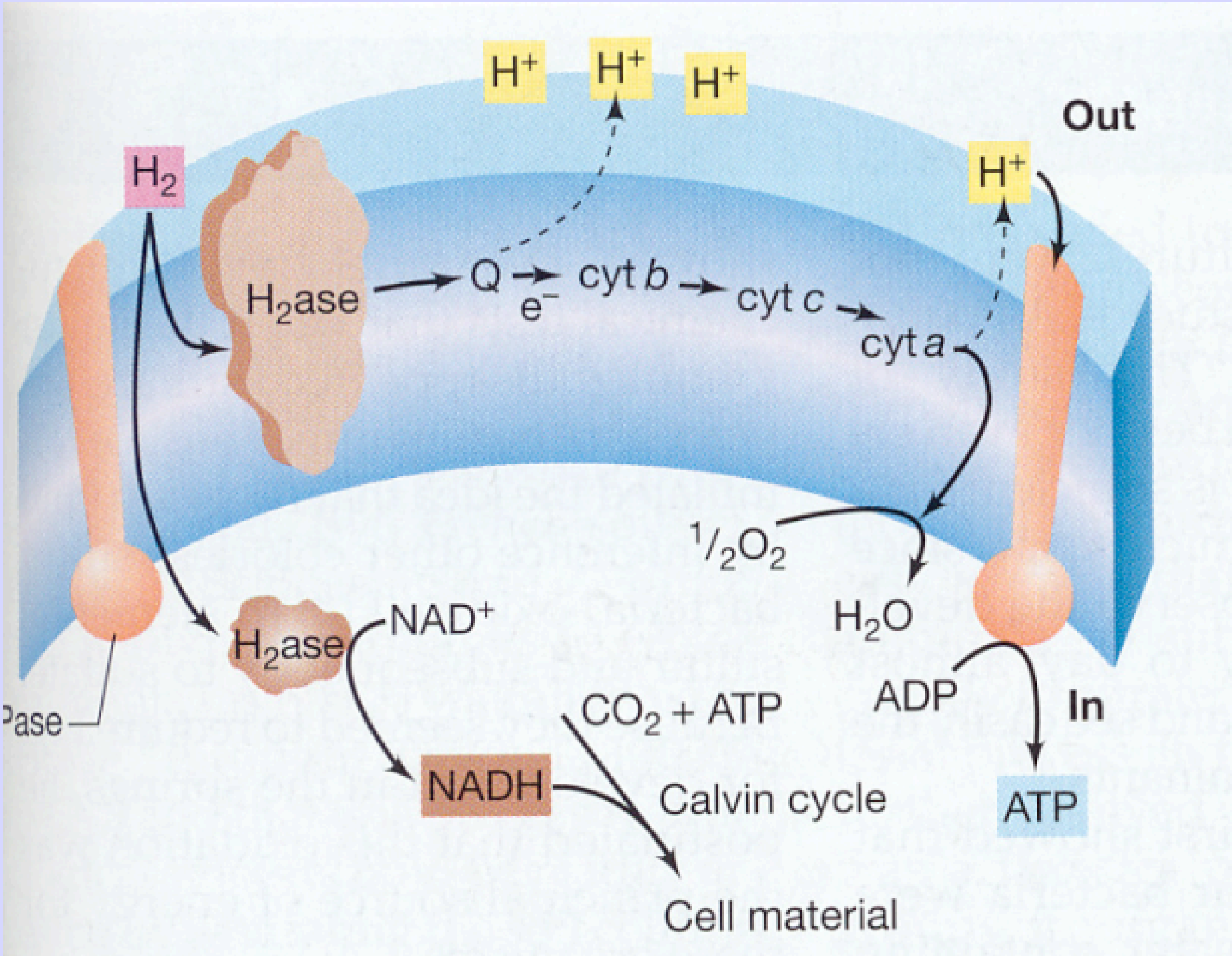


Table 9.5 Energy Yields from Oxidations Used by Chemolithotrophs

Reaction	$\Delta G^{o\prime}$ (kcal/mole)[a]
$H_2 + 1/2\ O_2 \longrightarrow H_2O$	–56.6
$NO_2^- + 1/2\ O_2 \longrightarrow NO_3^-$	–17.4
$NH_4^+ + 1\,1/2\ O_2 \longrightarrow NO_2^- + H_2O + 2H^+$	–65.0
$S^0 + 1\,1/2\ O_2 + H_2O \longrightarrow H_2SO_4$	–118.5
$S_2O_3^{2-} + 2O_2 + H_2O \longrightarrow 2SO_4^{2-} + 2H^+$	–223.7
$2Fe^{2+} + 2H^+ + 1/2\ O_2 \longrightarrow 2Fe^{3+} + H_2O$	–11.2

[a] The $\Delta G^{o\prime}$ for complete oxidation of glucose to CO_2 is –686 kcal/mole. A kcal is equivalent to 4.184kJ.



H+
H+
H+
Out
H2
H+
H2ase
Q
e−
cyt b
cyt c
cyt a
1/2O2
H2O
H2ase
NAD+
Pase
CO2 + ATP
ADP
In
NADH
Calvin cycle
ATP
Cell material