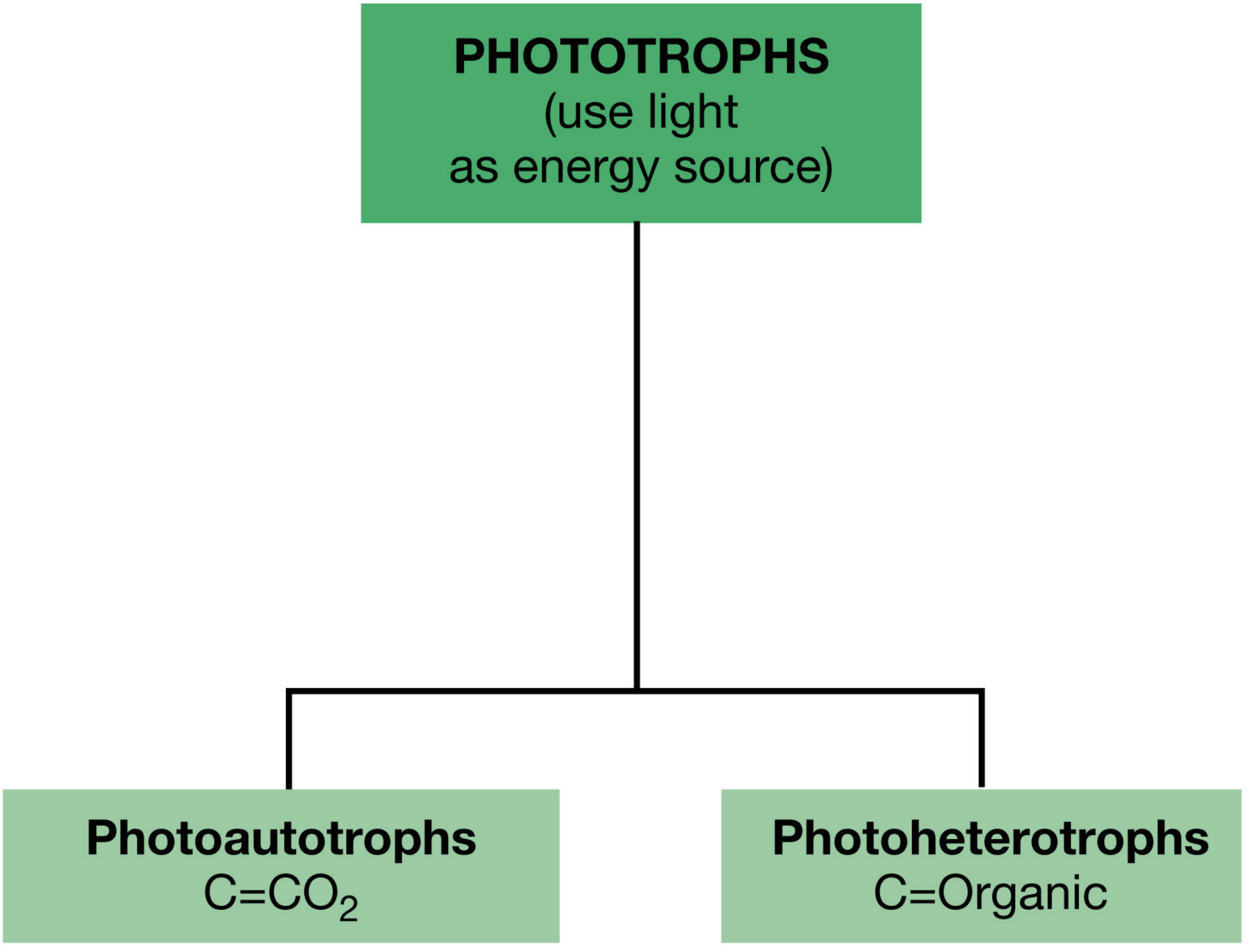
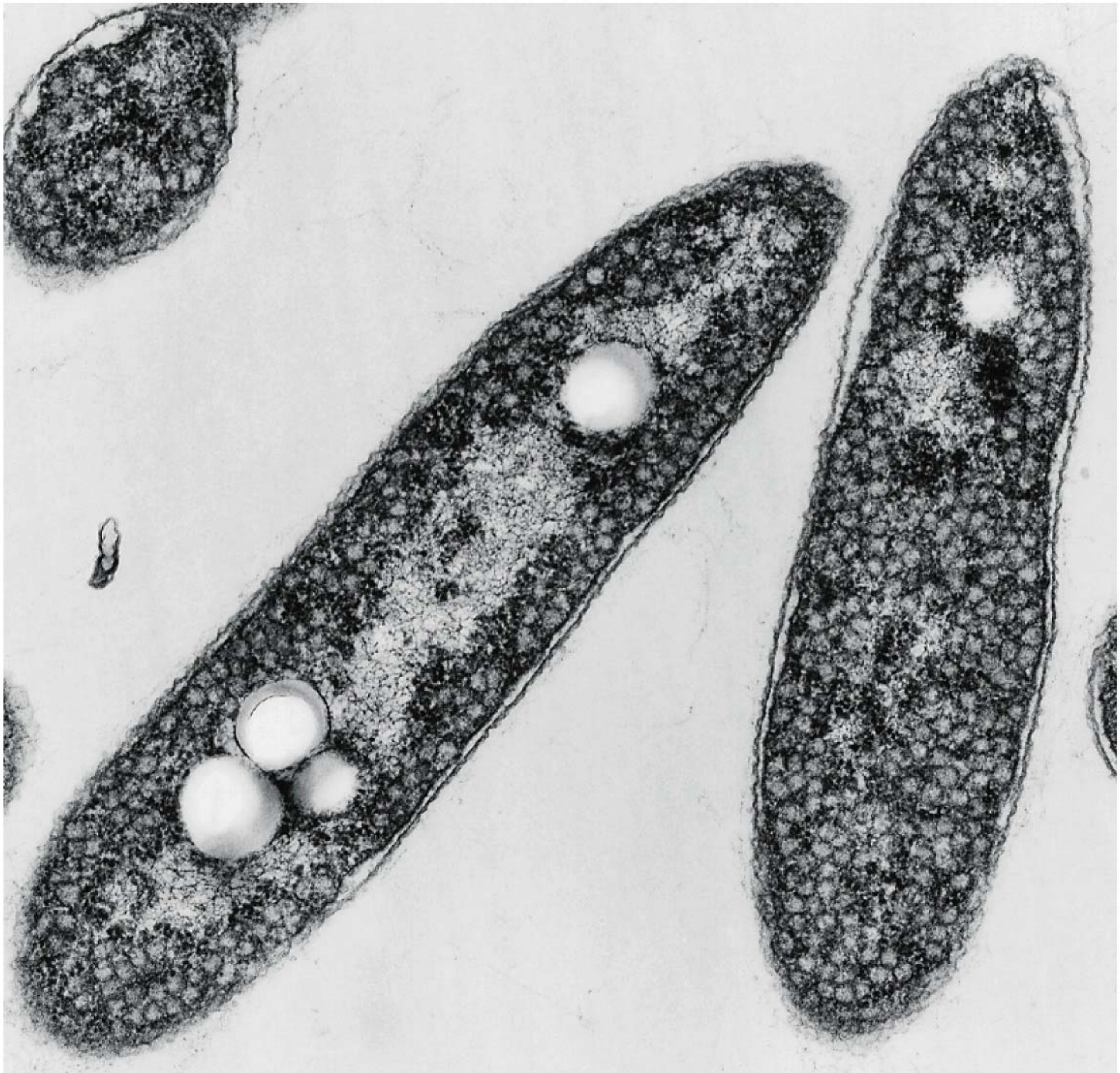
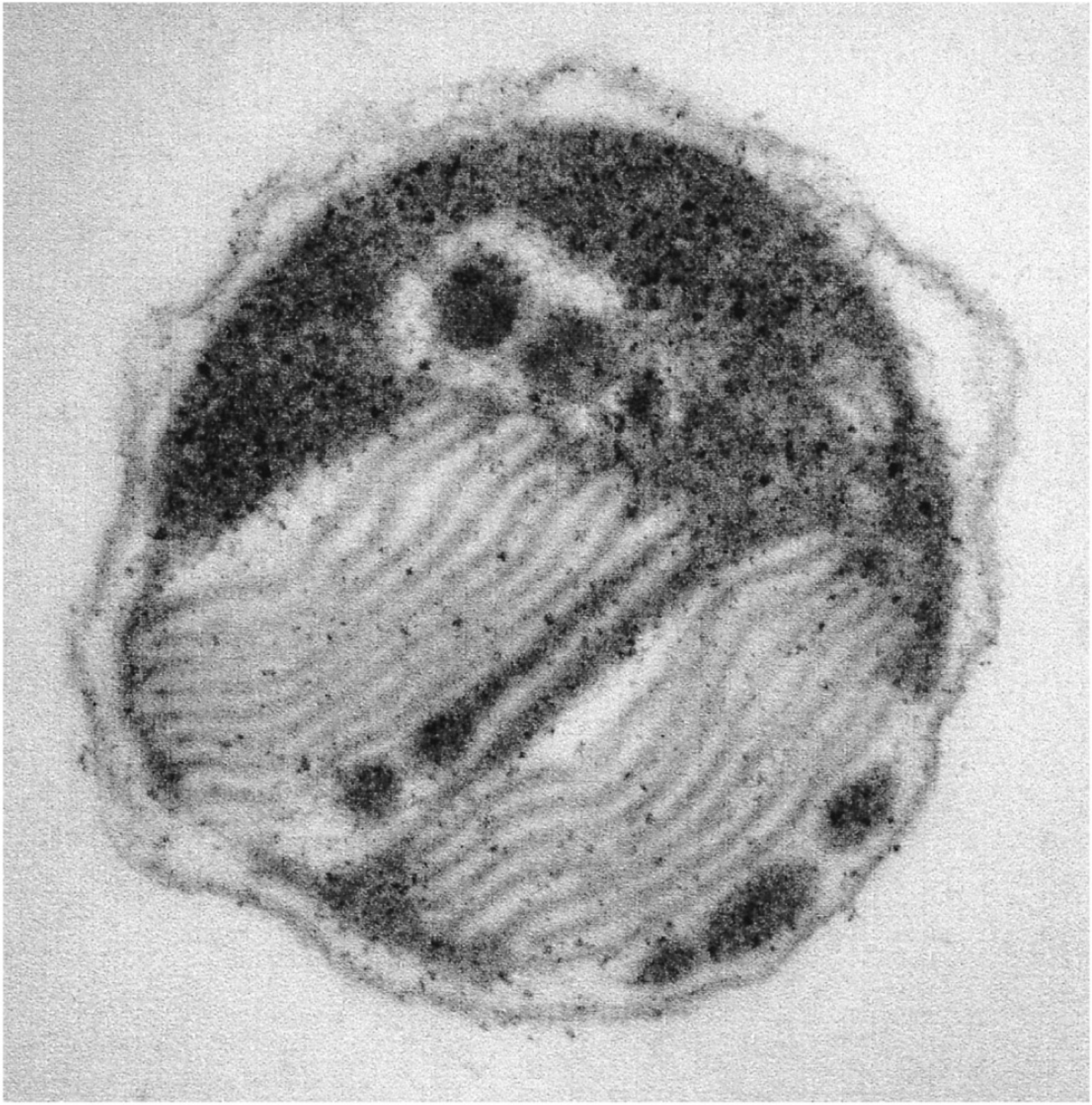

PHOTOTROPHS
(use light
as energy source)
Photoautotrophs
C=CO_2
Photoheterotrophs
C=Organic

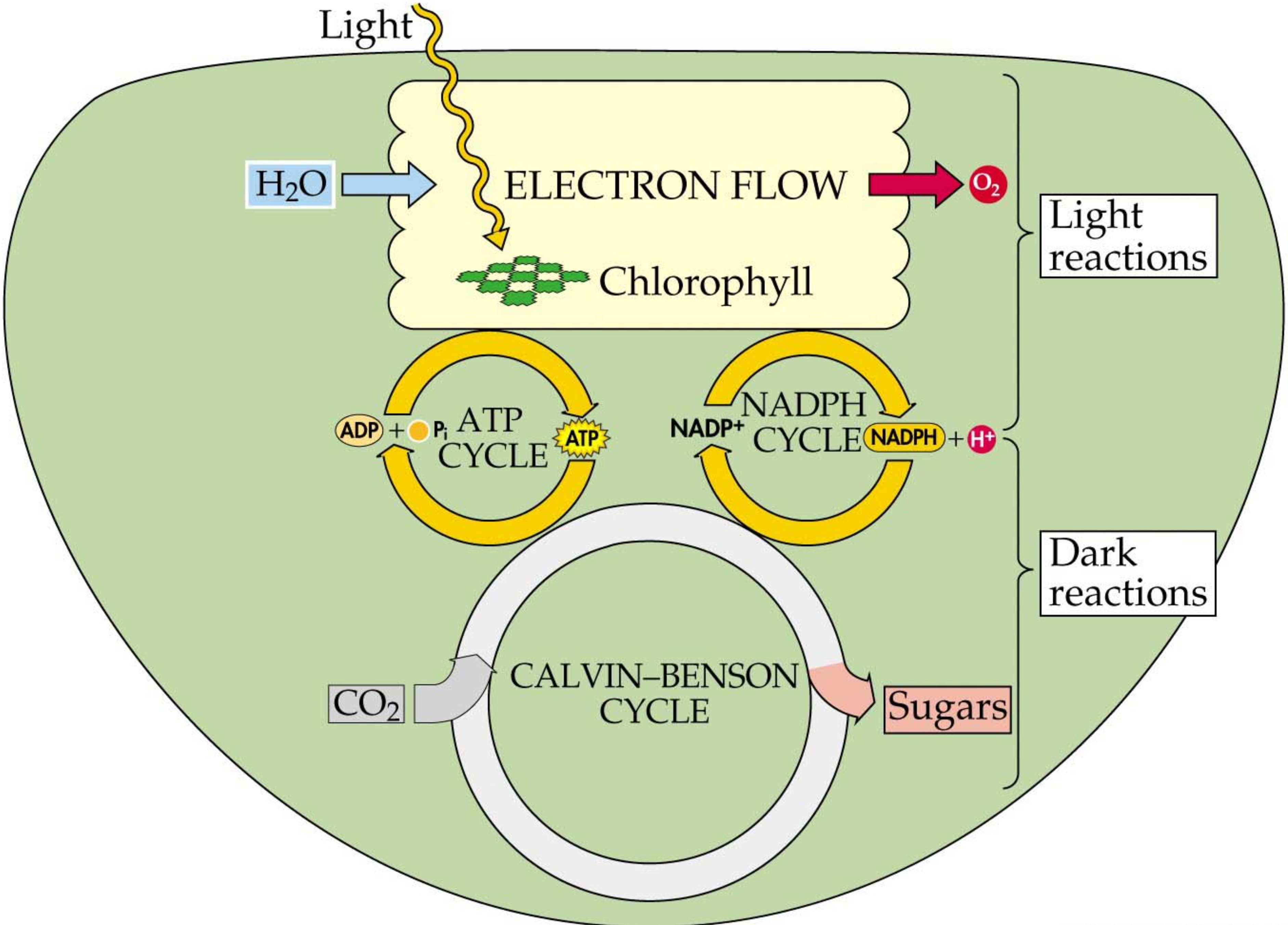


M.T. Madigan

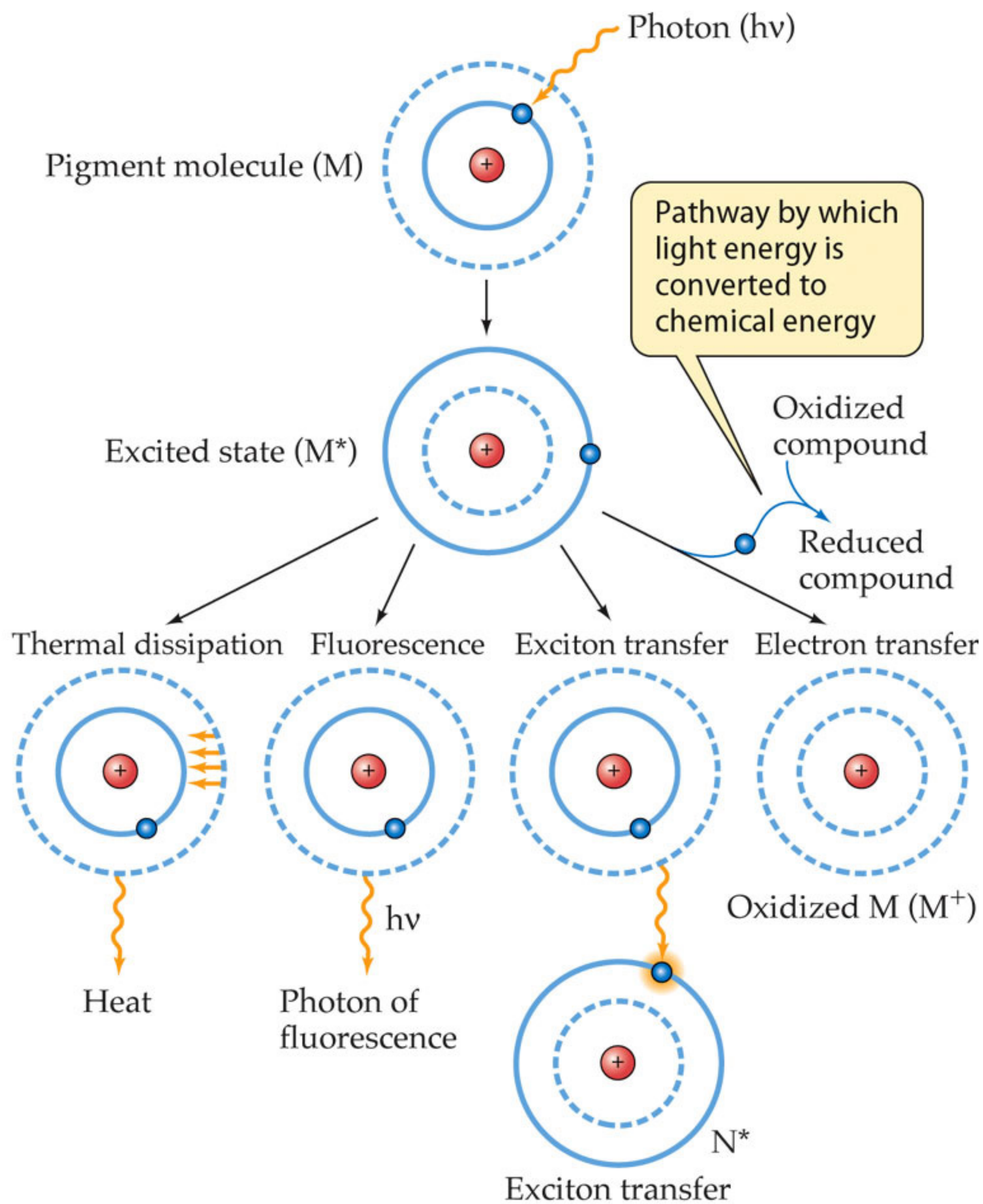
(a)

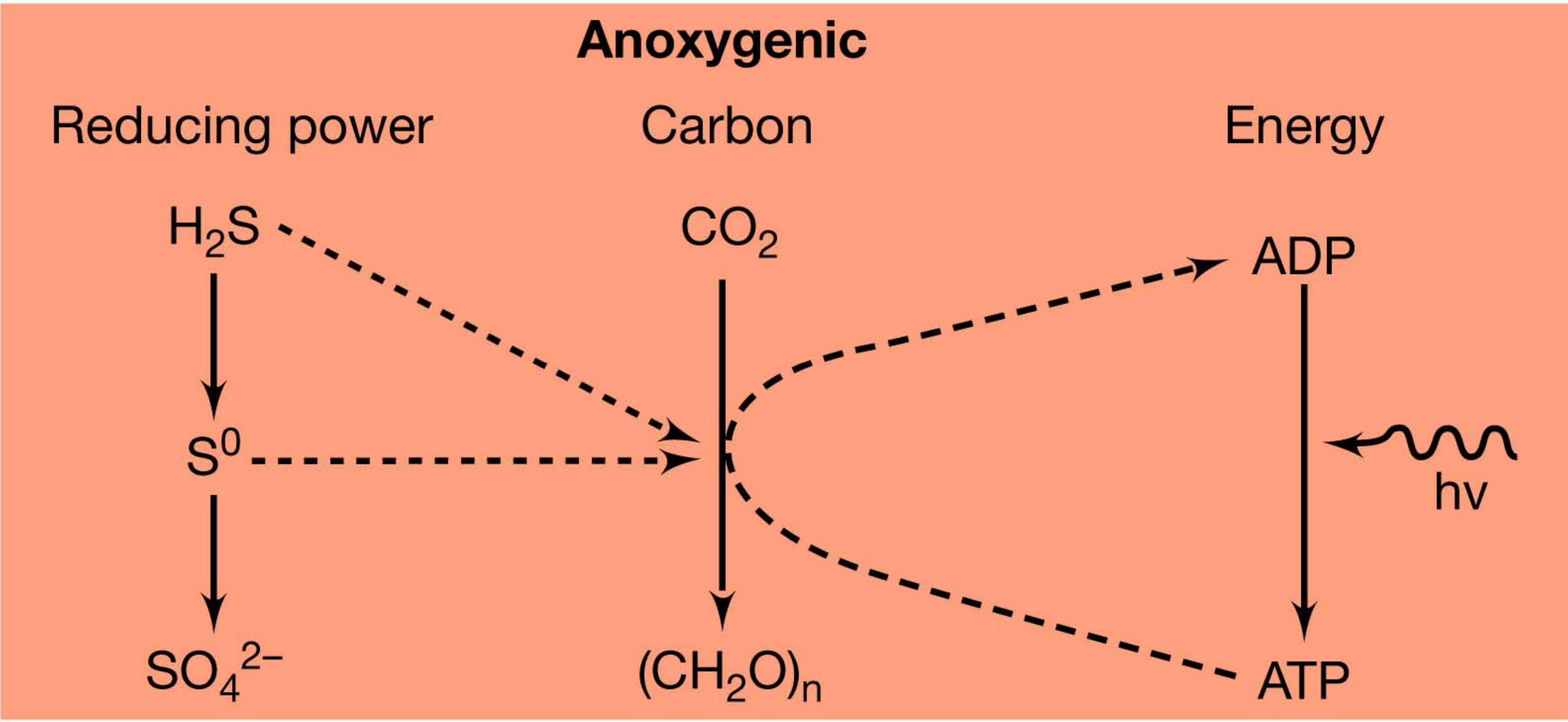

Steven J. Schmitt and M.T. Madigan

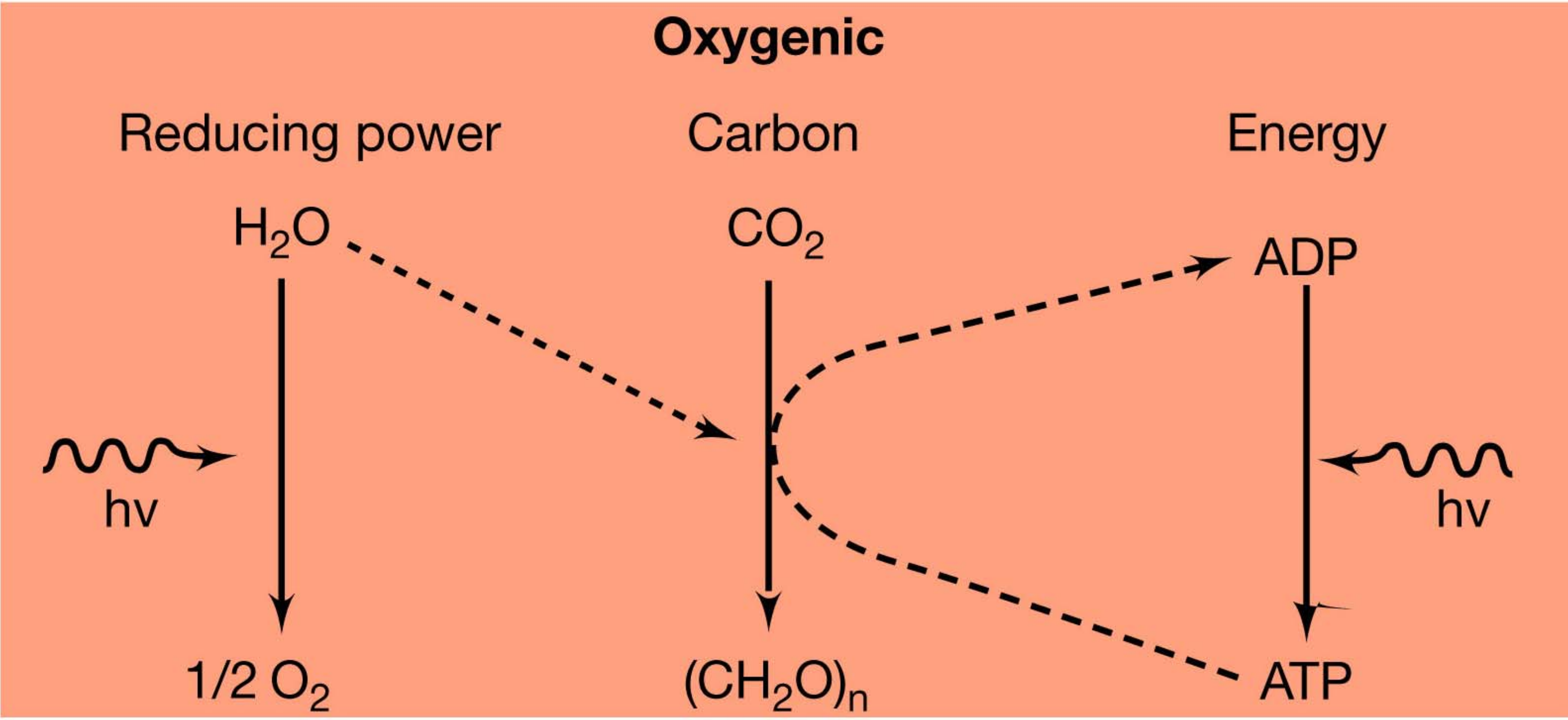
(b)


Light
H_2O
ELECTRON FLOW
O_2
Chlorophyll
Light reactions
ADP + P_i
ATP CYCLE
ATP
$NADP^+$
NADPH CYCLE
NADPH + H^+
Dark reactions
CO_2
CALVIN–BENSON CYCLE
Sugars

The possible fates of an excited electron



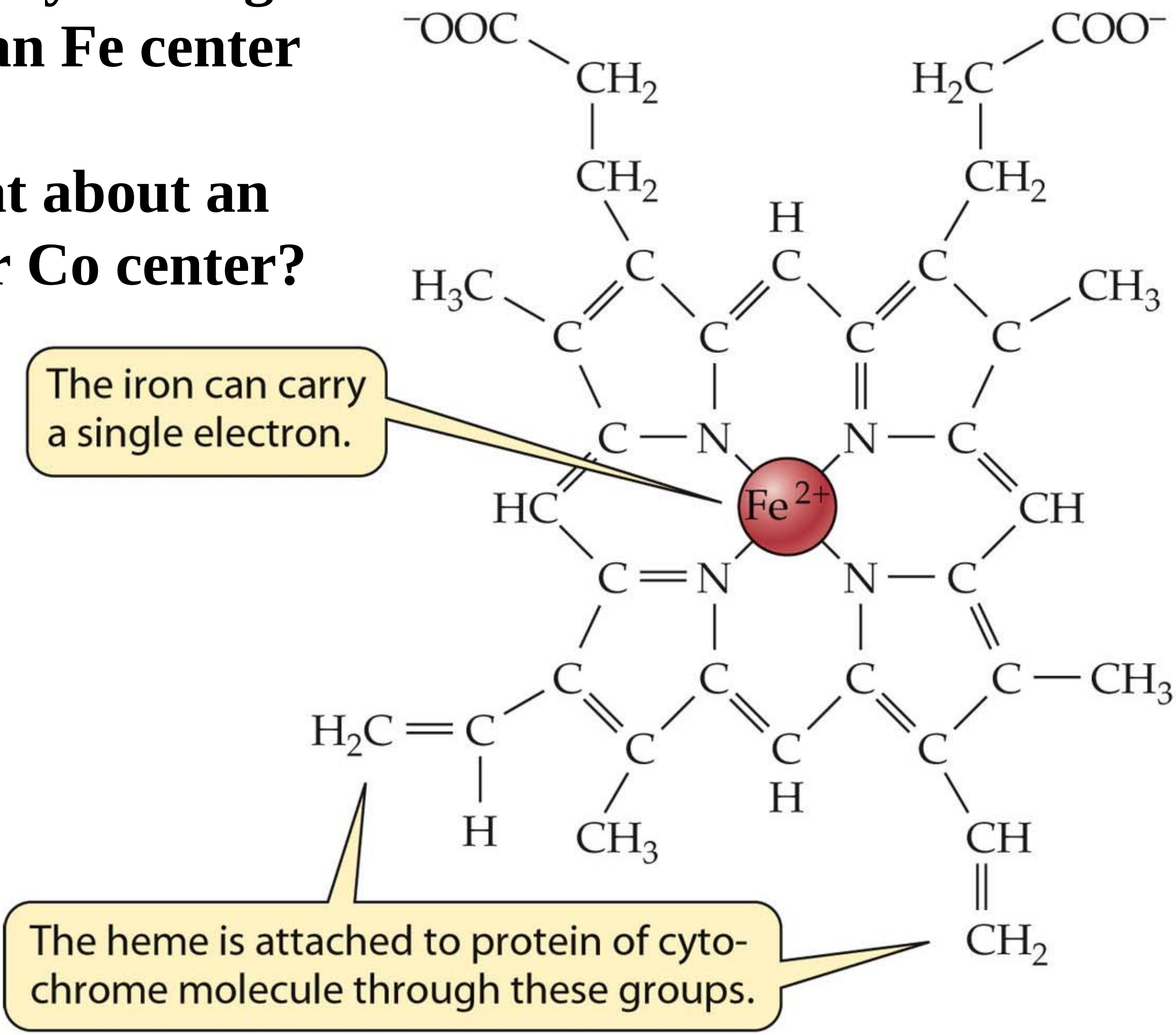

Anoxygenic
Reducing power
Carbon
Energy
H2S
S0
SO42−
CO2
(CH2O)n
ADP
ATP
hv

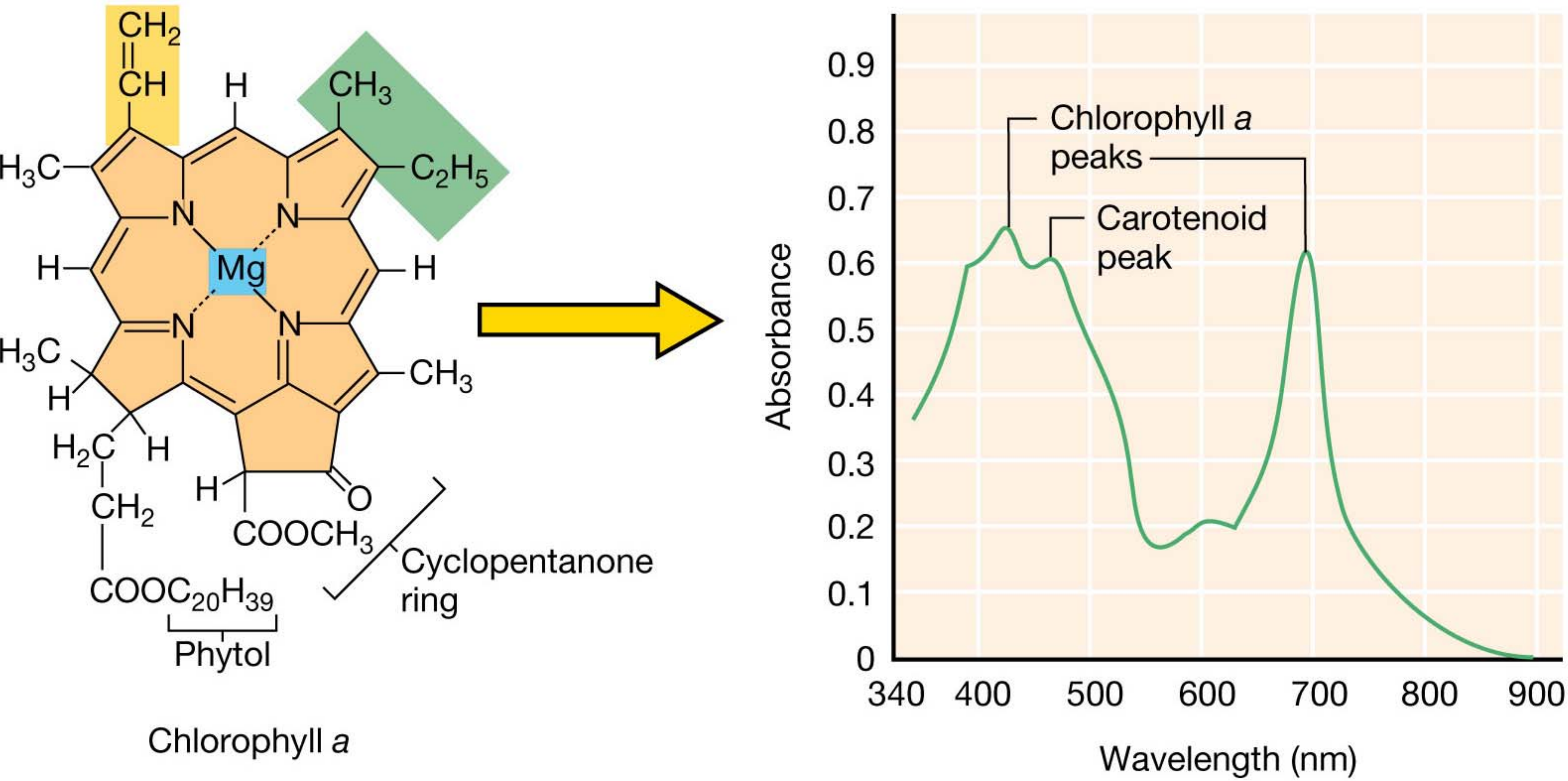


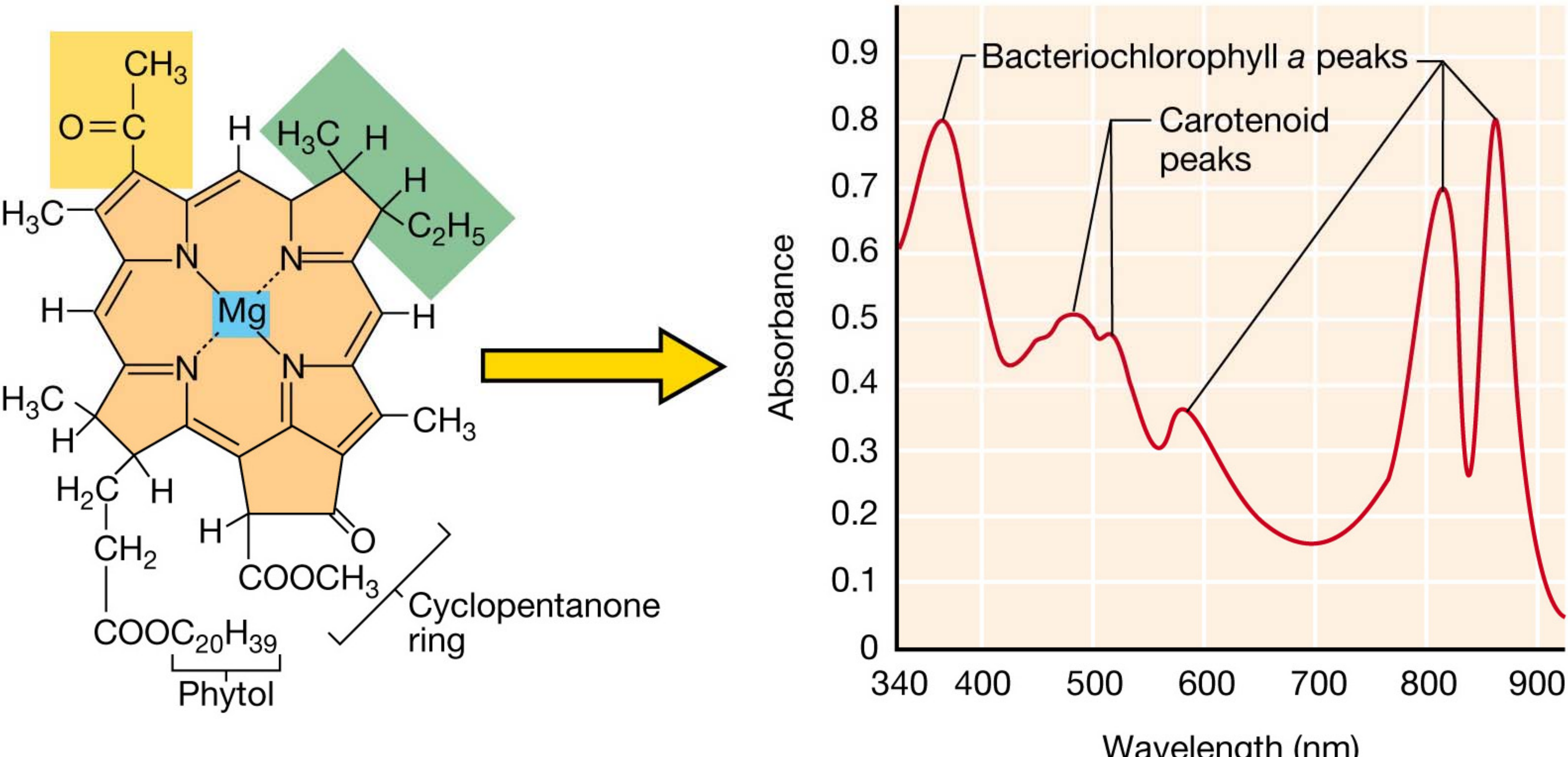
Oxygenic
Reducing power
Carbon
Energy
H_2O
CO_2
ADP
hv
hv
1/2 O_2
$(CH_2O)_n$
ATP

Porphyrin ring with an Fe center

What about an Mg or Co center?



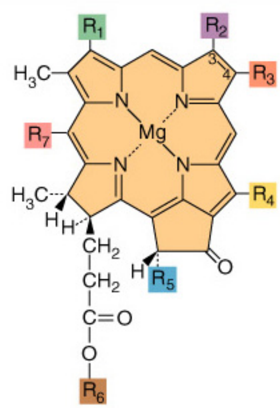

CH2
CH
H
CH3
H3C
C2H5
N
N
Mg
H
H
N
N
H3C
CH3
H
H2C
H
H
O
CH2
COOCH3
Cyclopentanone ring
COOC20H39
Phytol
Chlorophyll a
Chlorophyll a peaks
Carotenoid peak
Absorbance
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
340
400
500
600
700
800
900
Wavelength (nm)



Bacteriochlorophyll *a*

Pigment	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Absorption maxima (nm): *In vivo*	Absorption maxima (nm): Extract (methanol)
Bacterio-chlorophyll *a* (purple bacteria)	$-C(=O)-CH_3$	$-CH_3$[b]	$-CH_2-CH_3$	$-CH_3$	$-C(=O)-O-CH_3$	P/Gg[a]	$-H$	805 830–890	771
Bacterio-chlorophyll *b* (purple bacteria)	$-C(=O)-CH_3$	$-CH_3$[c]	$=C(H)-CH_3$	$-CH_3$	$-C(=O)-O-CH_3$	P	$-H$	835–850 1020–1040	794
Bacterio-chlorophyll *c* (green sulfur bacteria)	$-C(H)(OH)-CH_3$	$-CH_3$	$-C_2H_5$ $-C_3H_7$[d] $-C_4H_9$	$-C_2H_5$ $-CH_3$	$-H$	F	$-CH_3$	745–755	660–669
Bacterio-chlorophyll c_s (green nonsulfur bacteria)	$-C(H)(OH)-CH_3$	$-CH_3$	$-C_2H_5$	$-CH_3$	$-H$	S	$-CH_3$	740	667
Bacterio-chlorophyll *d* (green sulfur bacteria)	$-C(H)(OH)-CH_3$	$-CH_3$	$-C_2H_5$ $-C_3H_7$ $-C_4H_9$	$-C_2H_5$ $-CH_3$	$-H$	F	$-H$	705–740	654
Bacterio-chlorophyll *e* (green sulfur bacteria)	$-C(H)(OH)-CH_3$	$-C(=O)-H$	$-C_2H_5$ $-C_3H_7$ $-C_4H_9$	$-C_2H_5$	$-H$	F	$-CH_3$	719–726	646
Bacterio-chlorophyll *g* (heliobacteria)	$-C(H)=CH_2$	$-CH_3$[b]	$-C_2H_5$	$-CH_3$	$-C(=O)-O-CH_3$	F	$-H$	670, 788	765

[a]P, Phytyl ester ($C_{20}H_{39}O-$); F, farnesyl ester ($C_{15}H_{25}O-$); Gg, geranylgeraniol ester ($C_{10}H_{17}O-$); S, stearyl alcohol ($C_{18}H_{37}O-$).
[b]No double bond between C_3 and C_4; additional H atoms are in positions C_3 and C_4.
[c]No double bond between C_3 and C_4; an additional H atom is in position C_3.
[d]Bacteriochlorophylls *c*, *d*, and *e* consist of isomeric mixtures with the different substituents on R_3 as shown.



Bacteriochlorophyll Structures

Chloroplast Structure

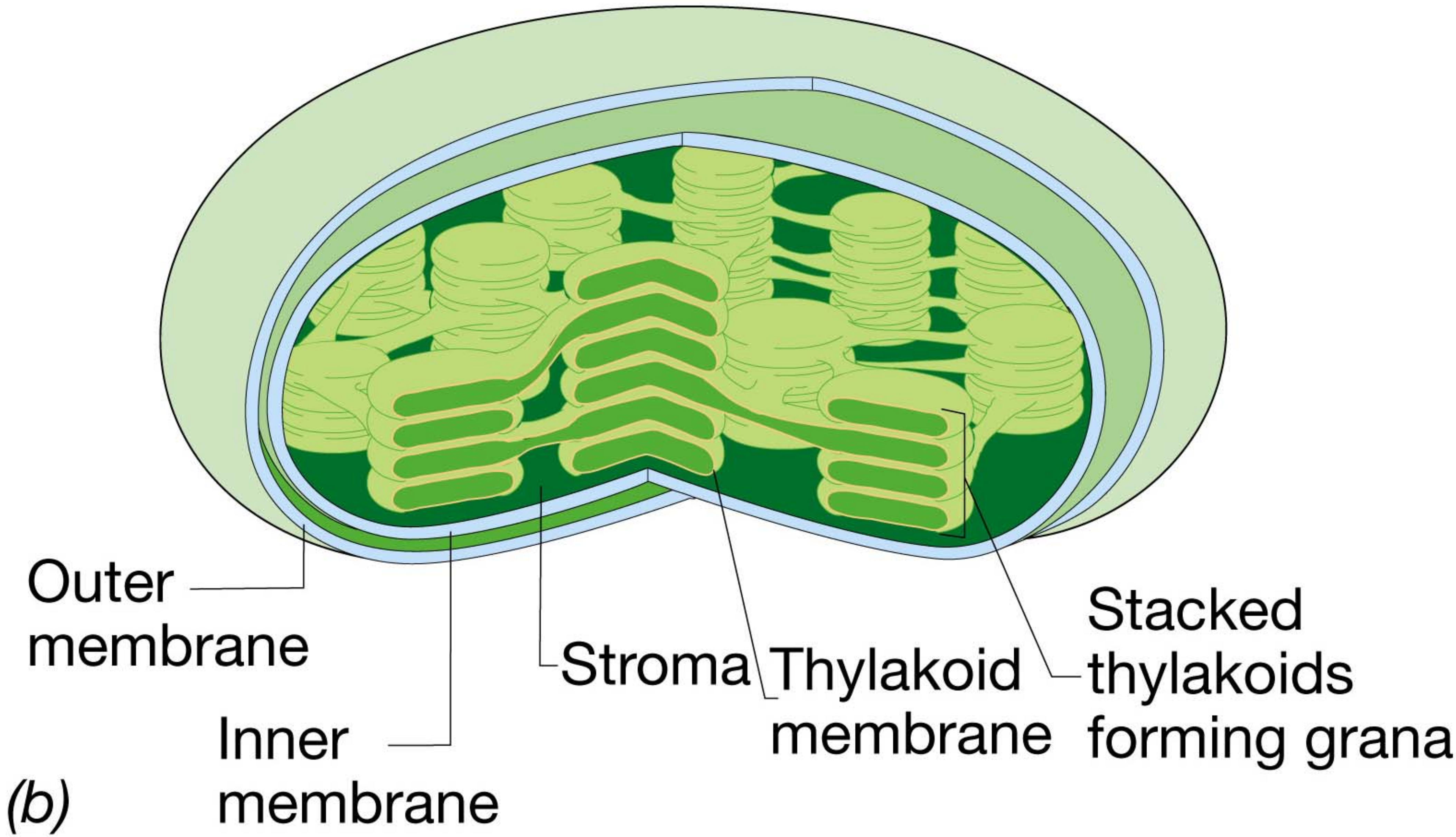
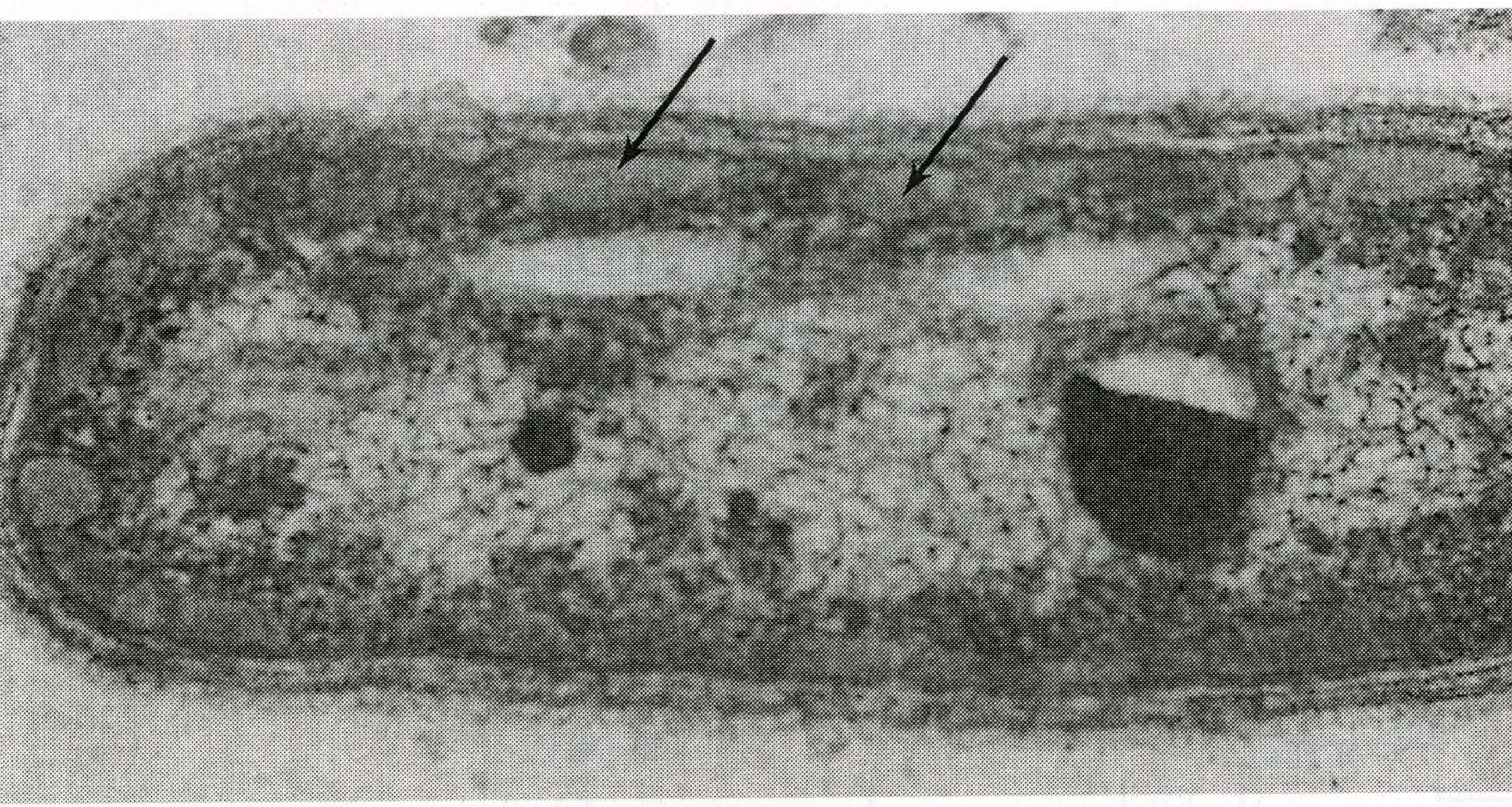


Table 9.1 Some general properties of the various photosynthetic bacteria

	Nonsulfur Purple Bacteria	Purple Sulfur Bacteria	Green Sulfur Bacteria	Cyano-bacteria	Helio-bacteria
Source of reducing power (e^-)	H_2, reduced organic	H_2S	H_2S	H_2O	Lactate, organic
Oxidized product	Oxidized organic	SO_4^{2-}	SO_4^{2-}	O_2	Oxidized organic
Source of carbon	CO_2 or organic	CO_2	CO_2	CO_2	Lactate pyruvate
Heterotrophic growth	Common	Limited[a]	Limited[a]	Limited[a]	Required

[a]Generally limited to assimilation of low molecular weight organics during autotrophic growth.

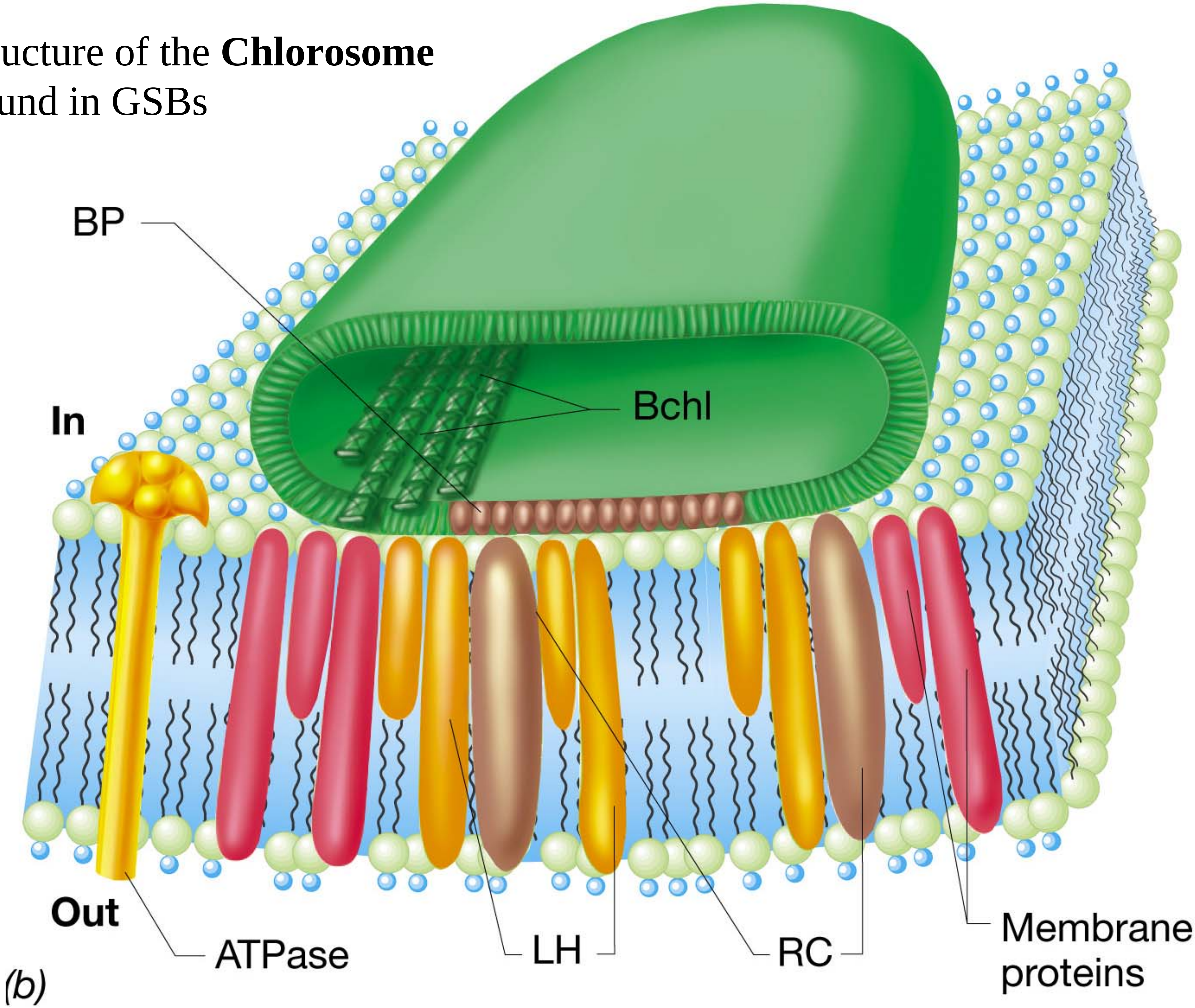
Structure and Location of the **Chlorosome**



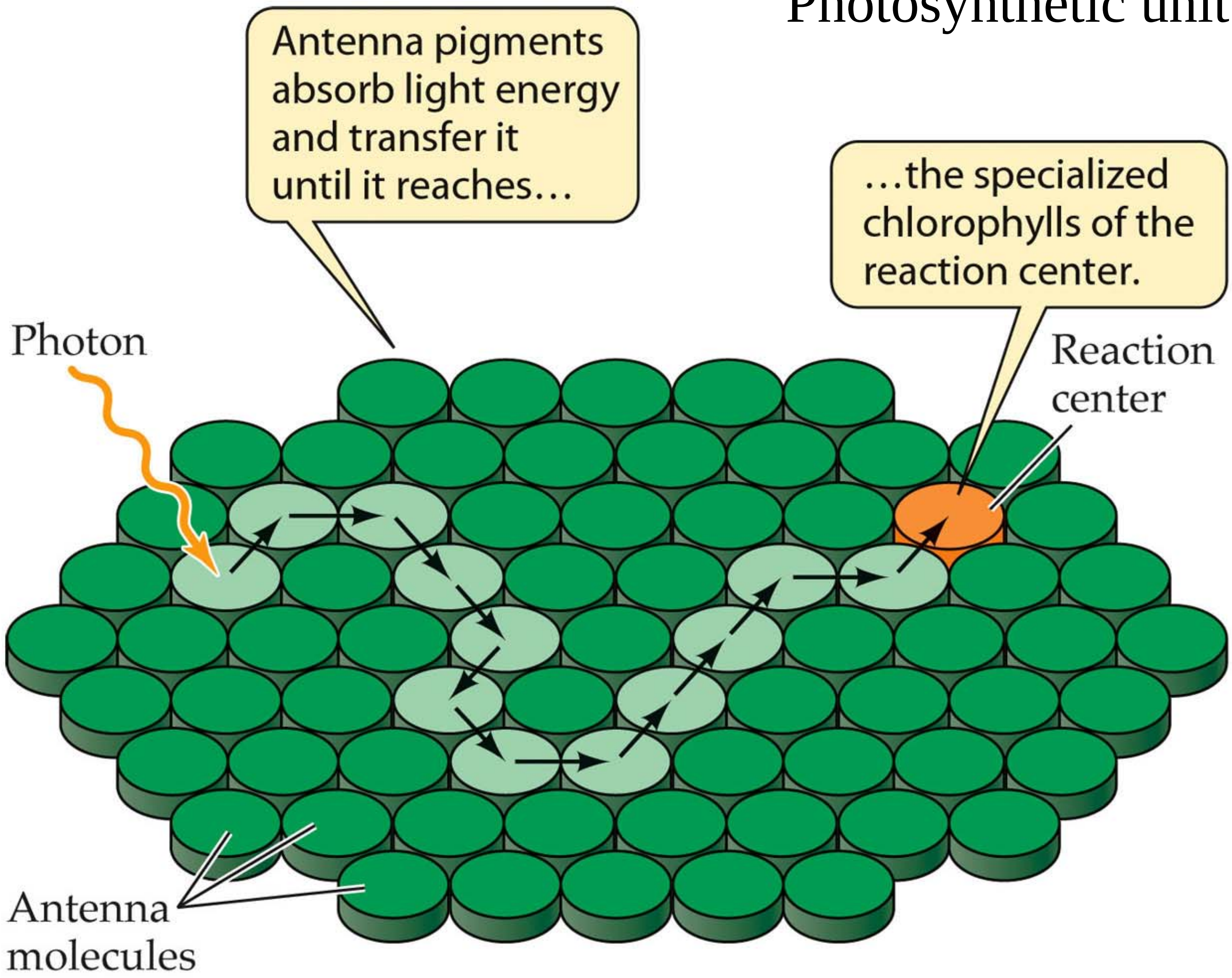
(a)

Found in GSBs

Structure of the **Chlorosome** Found in GSBs

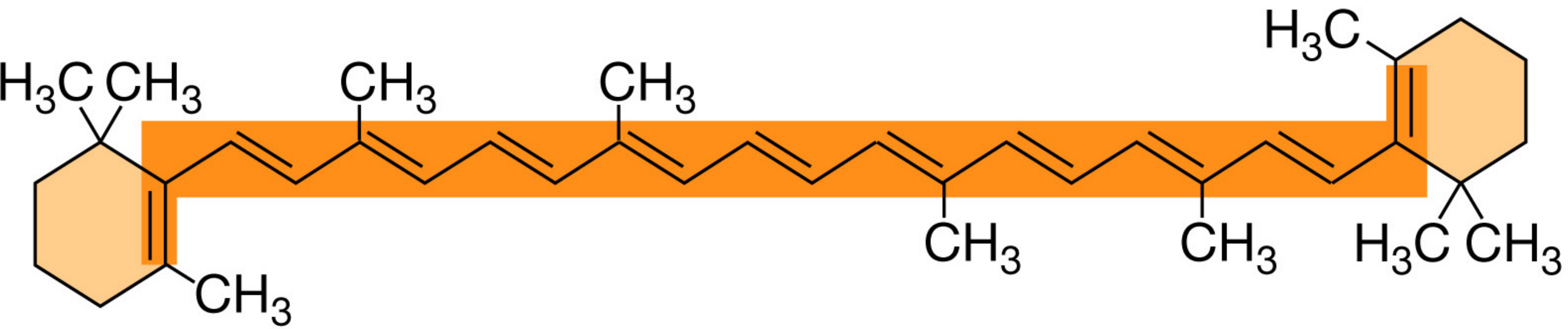


Photosynthetic unit



MICROBIAL LIFE , **Figure 9.2**

Beta-Carotene, a typical carotenoid



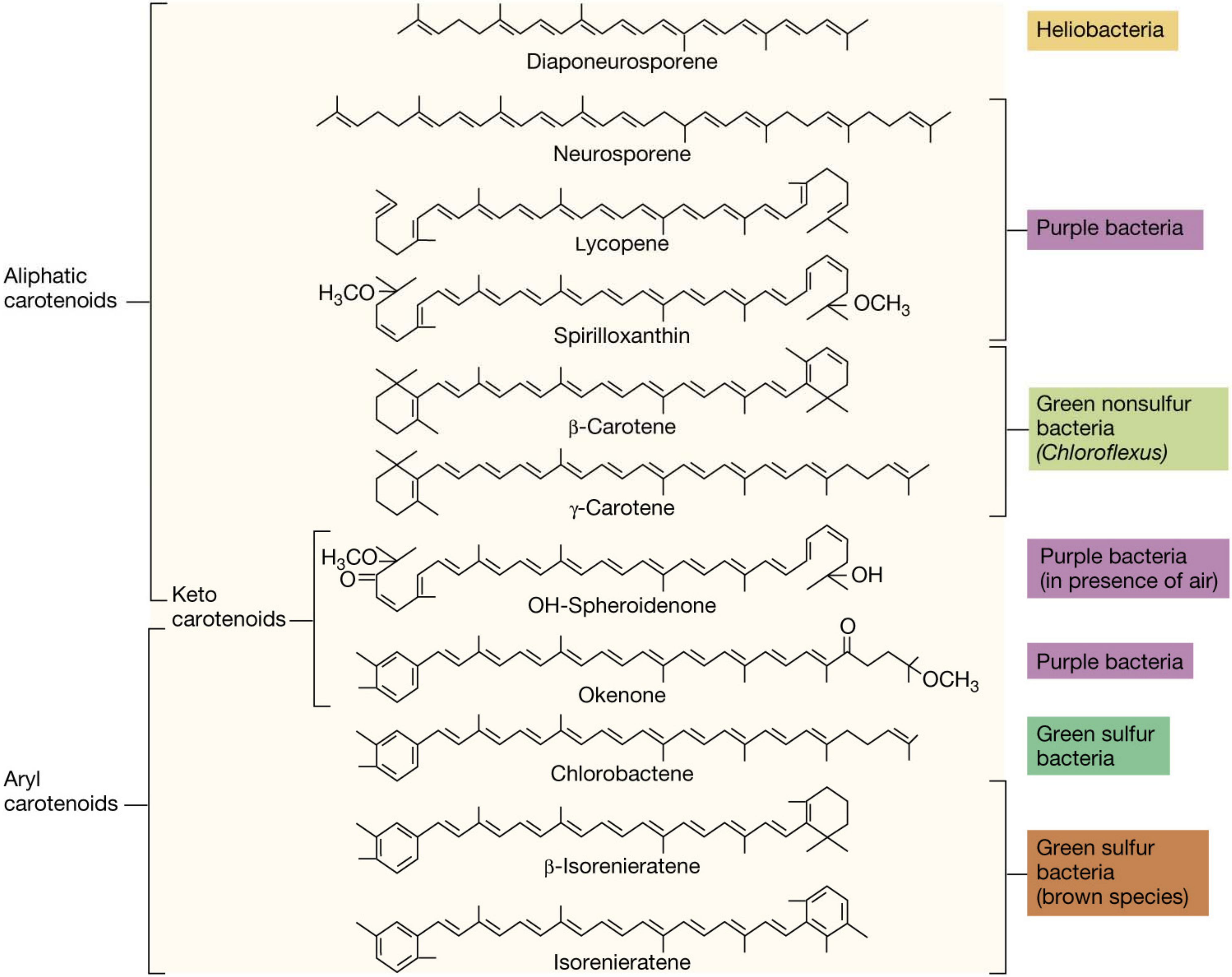
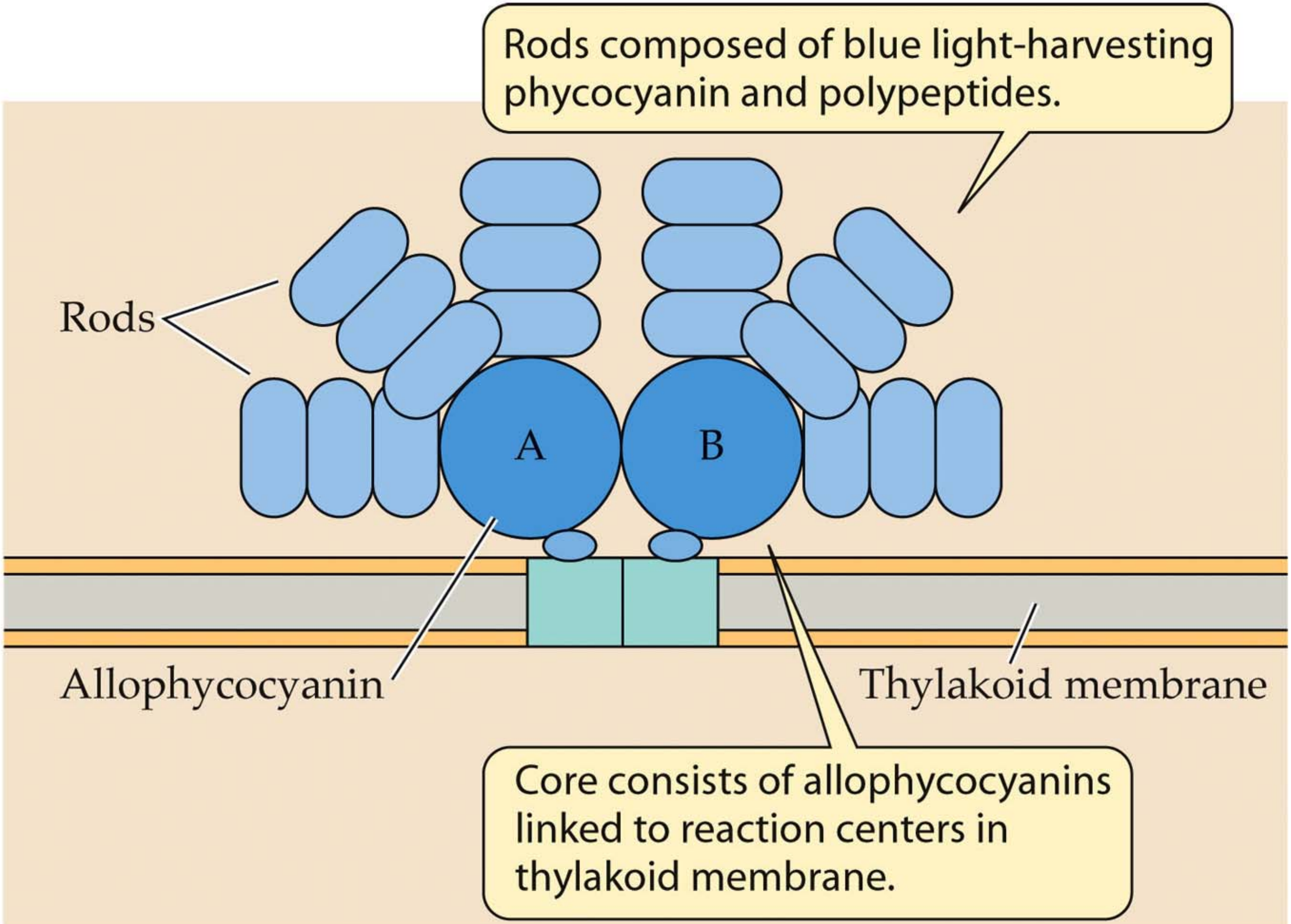

Heliobacteria
Diaponeurosporene
Neurosporene
Lycopene
Purple bacteria
H_3CO
Spirilloxanthin
OCH_3
Aliphatic carotenoids
β-Carotene
Green nonsulfur bacteria (Chloroflexus)
γ-Carotene
H_3CO
O
OH
OH-Spheroidenone
Purple bacteria (in presence of air)
Keto carotenoids
O
Okenone
OCH_3
Purple bacteria
Chlorobactene
Green sulfur bacteria
Aryl carotenoids
β-Isorenieratene
Green sulfur bacteria (brown species)
Isorenieratene

Table 9.2 The bacteriochlorophyll present in photosynthetic bacteria and primary acceptors involved in energy conserving reactions

	Electron Donor	Electron Acceptor
Purple nonsulfur bacteria	Bacteriochlorophyll *a* and *b*	Bacteriopheophytin *a*, Q_A, and Q_B
Green sulfur bacteria	Bacteriochlorophyll *c*, *d*, and *e*	Bacteriopheophytin *a* and FeS-protein
Cyanobacteria photosystem I	Chlorophyll *a*	Chlorophyll *a* and FeS-protein
Cyanobacteria photosystem II	Chlorophyll *a*	Pheophytin *a*, Q_A, Q_B, and plastoquinones
Heliobacteria	Bacteriochlorophyll *g*	Bacteriochlorophyll *c* and FeS-protein

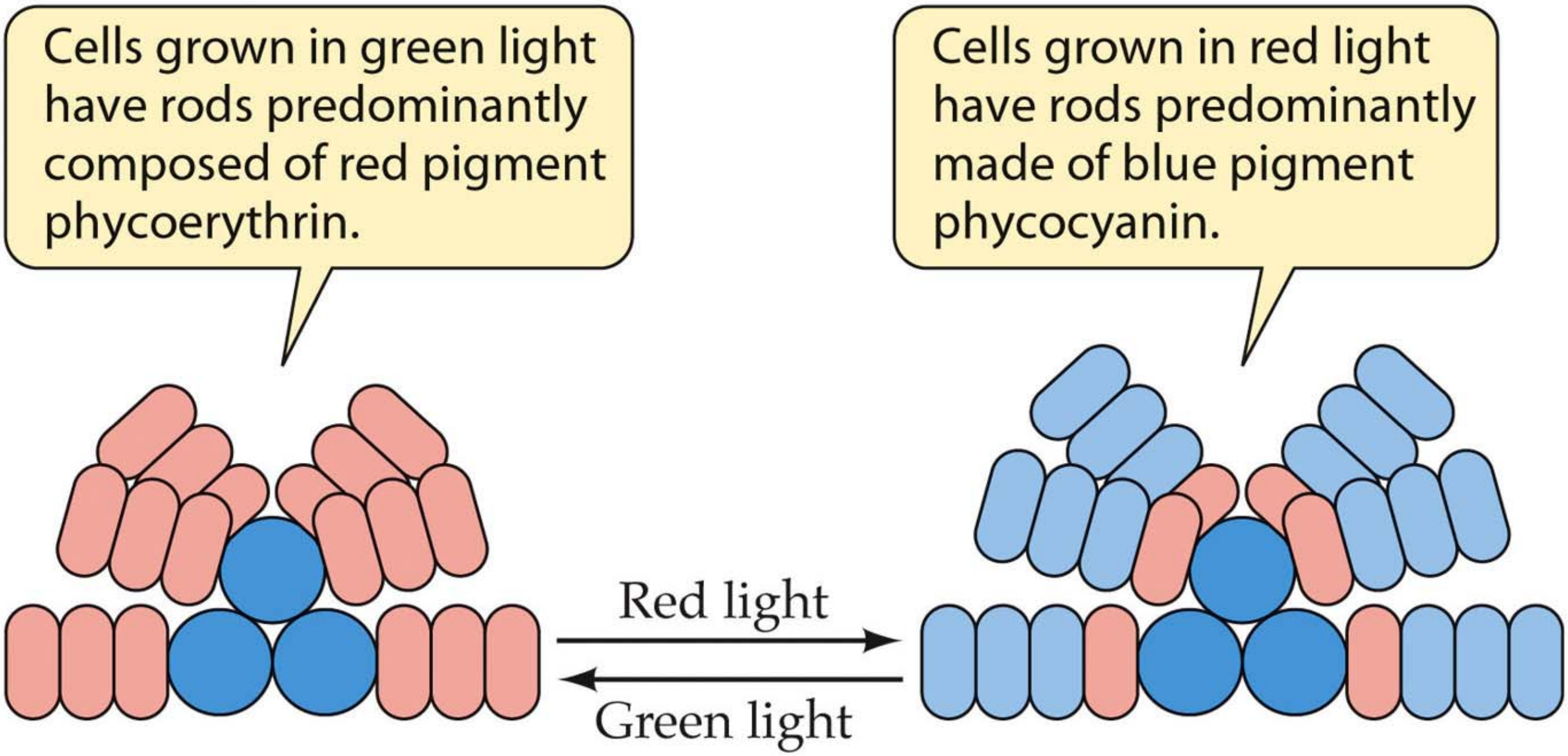
Structure and Location of **Phycobilisomes**

Phycobilisome of cyanobacteria

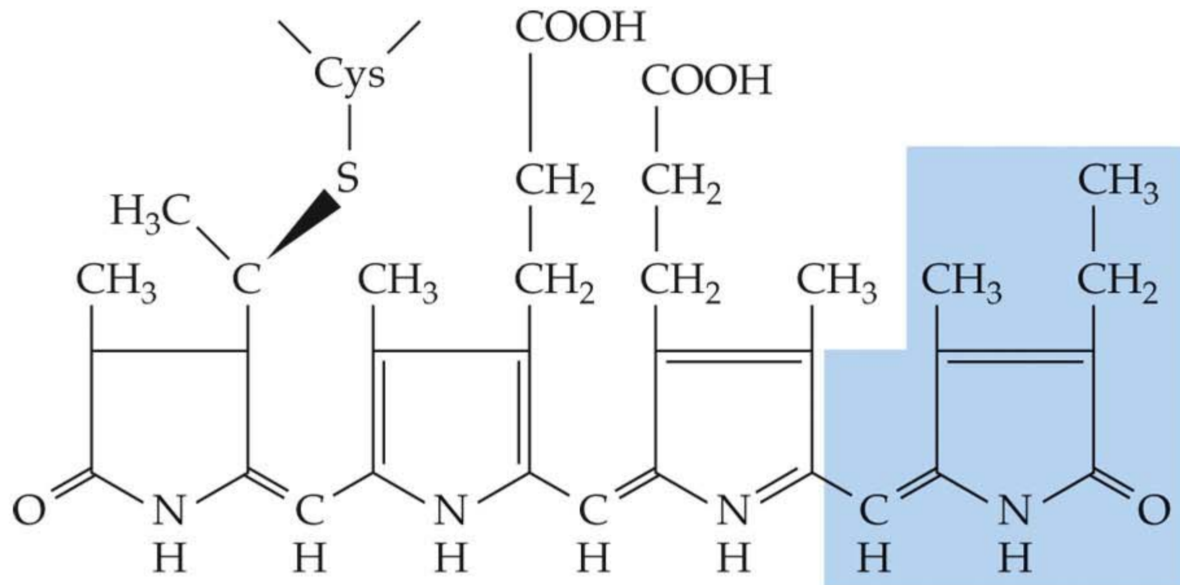


MICROBIAL LIFE, Figure 9.8

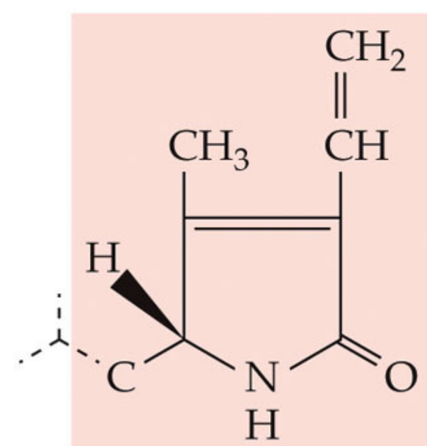
Chromatic adaptation of a phycobilisome



Chromophores of phycobilisomes

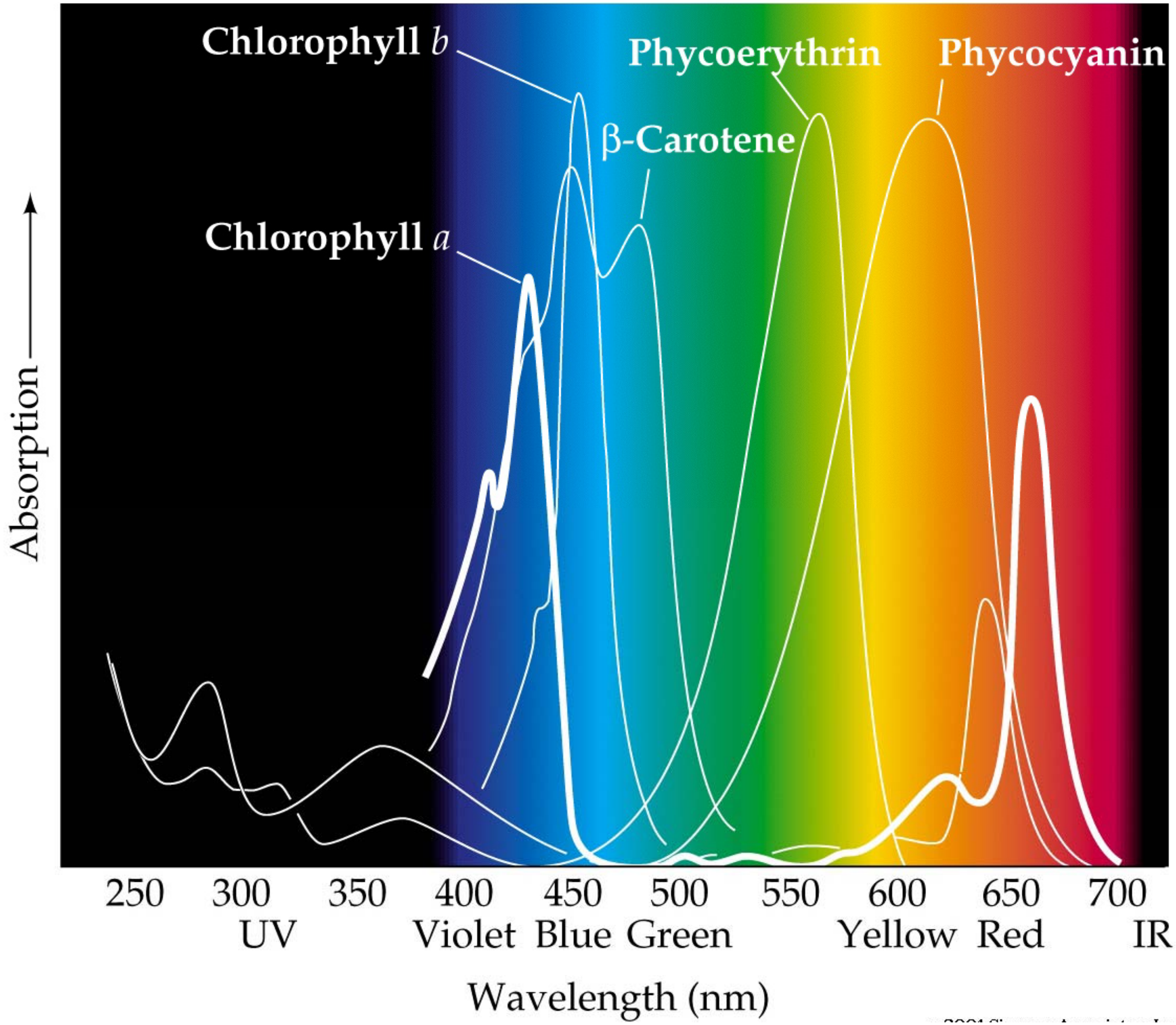


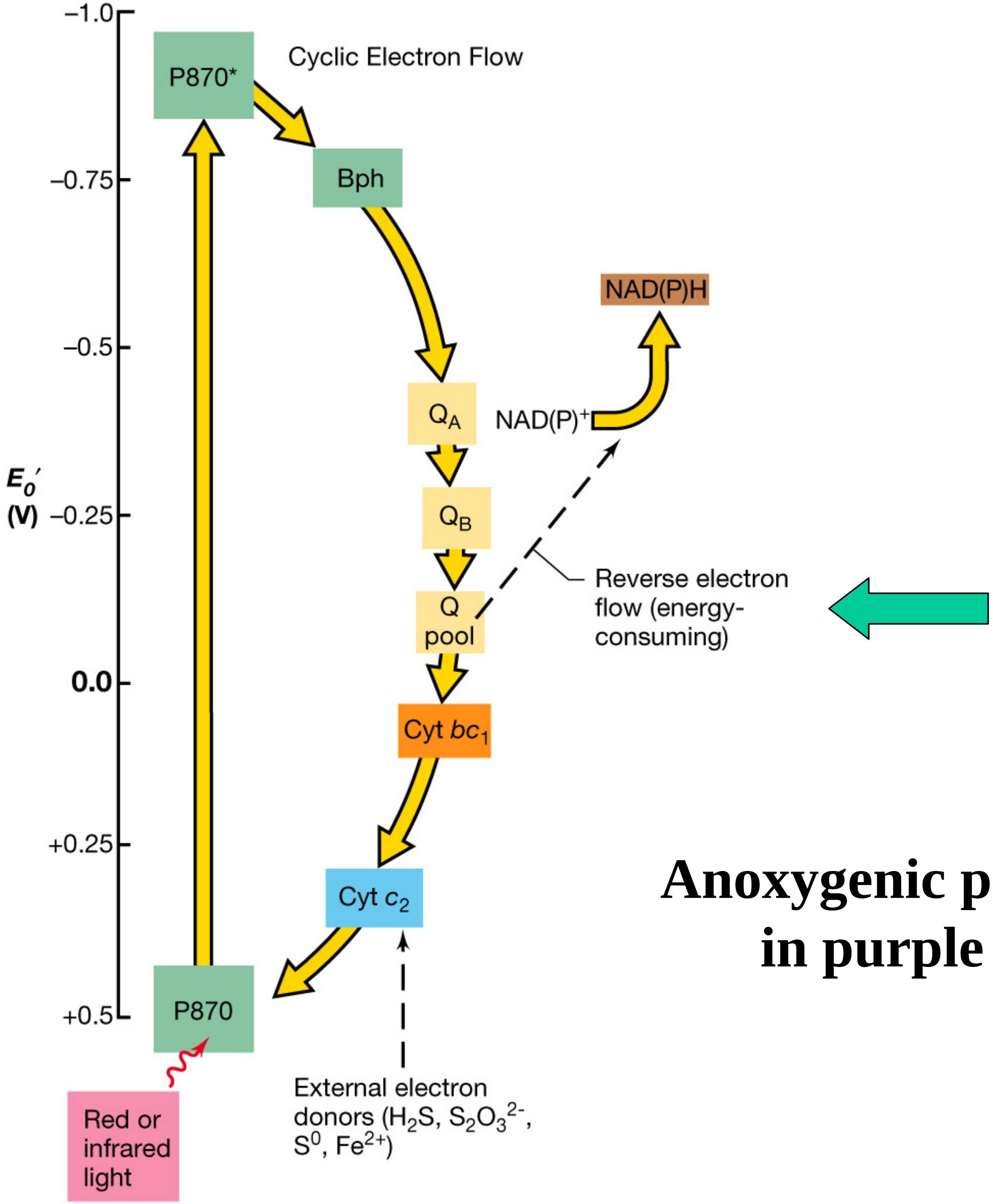
Phycocyanin (blue)



Phycoerythrin (red)

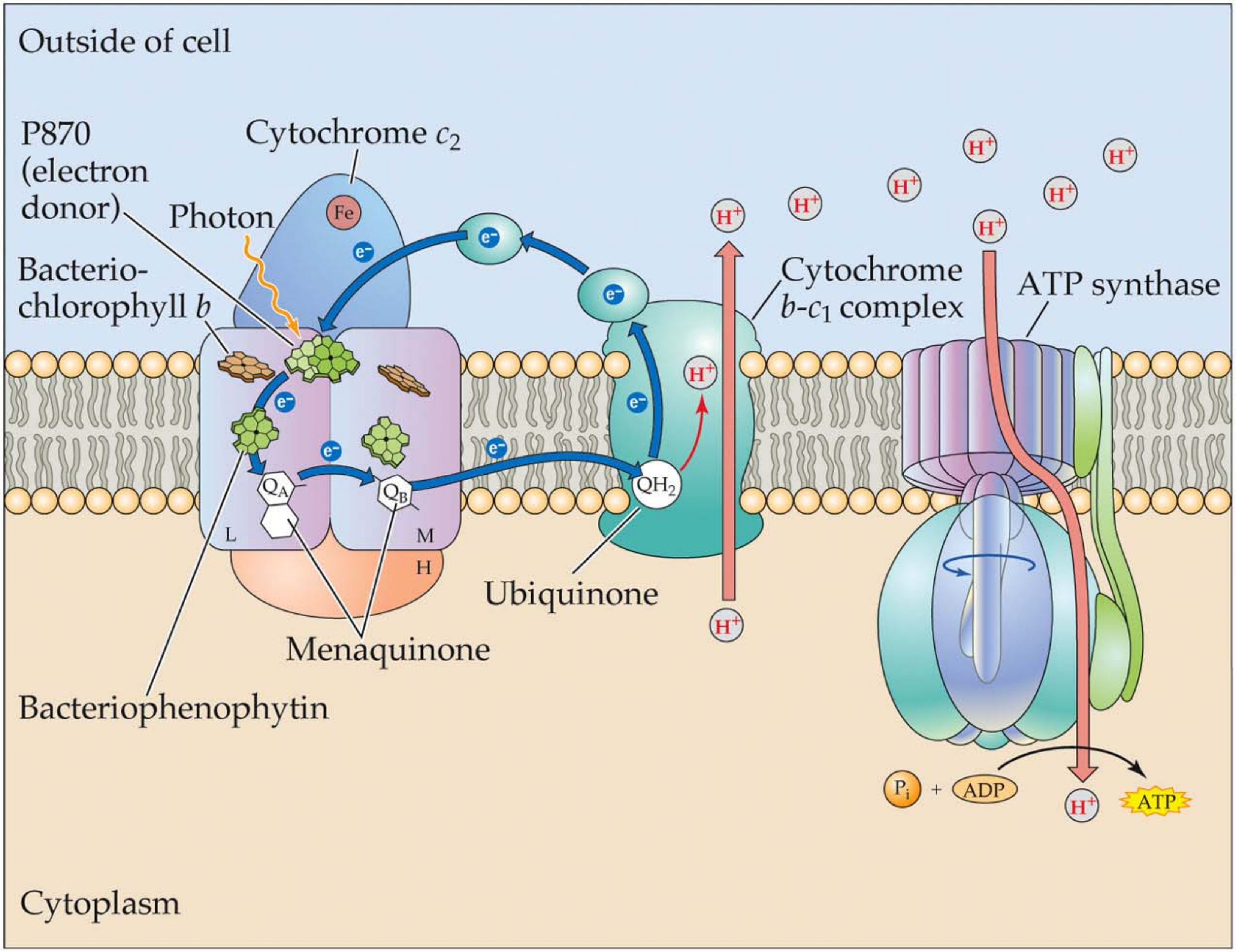
Absorption Spectra



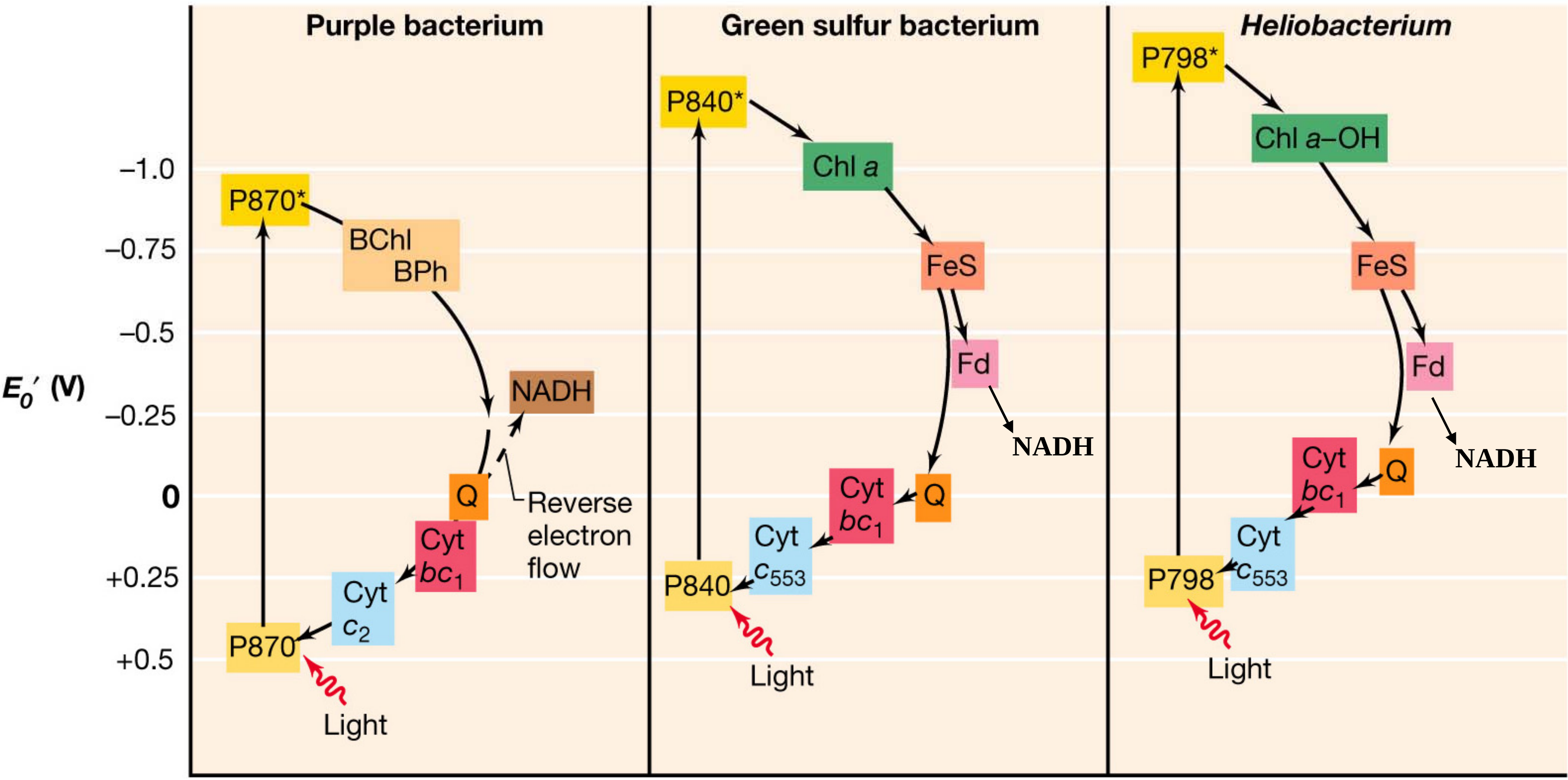


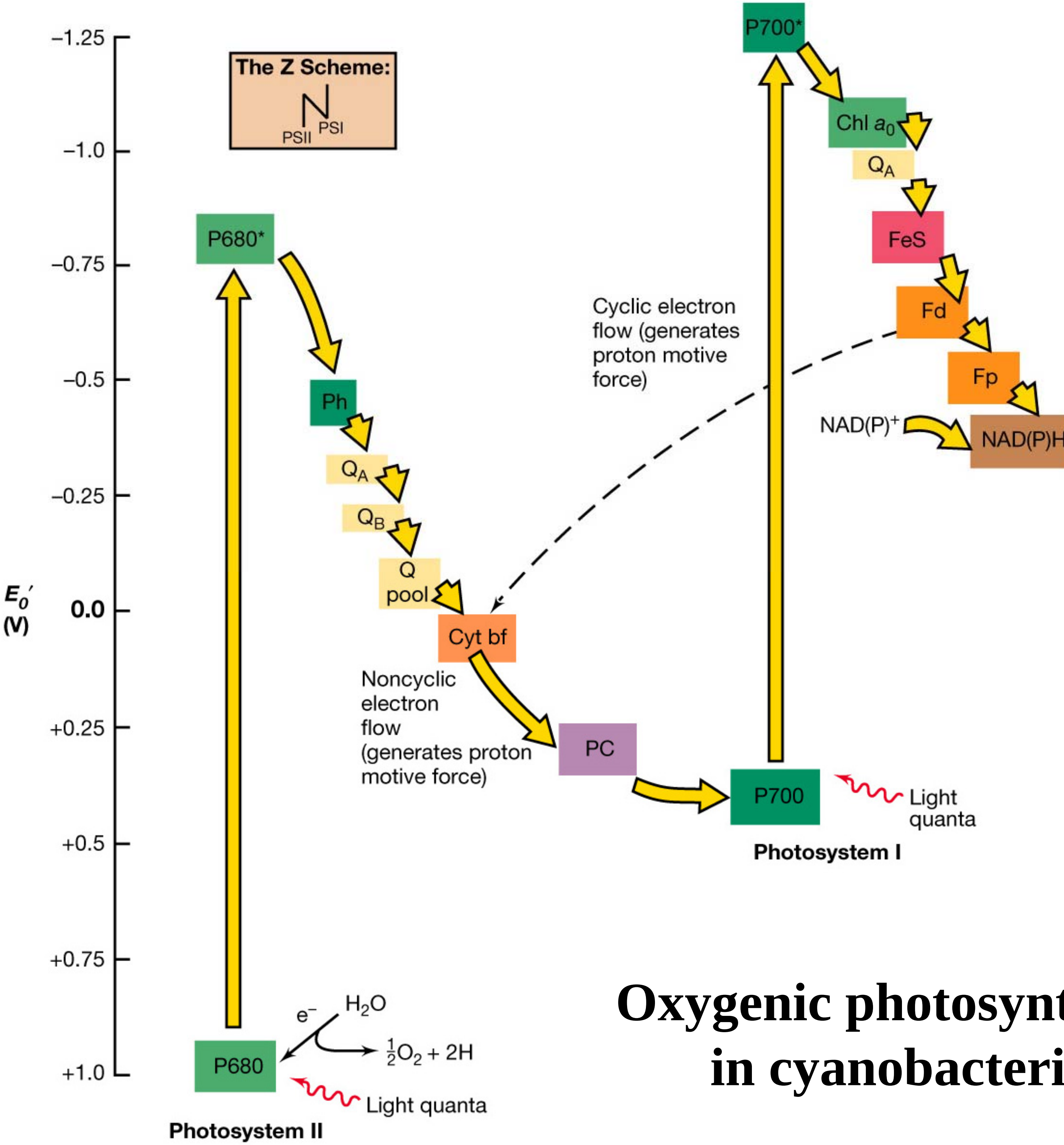
Anoxygenic photosynthesis in purple bacteria

Reaction center of purple nonsulfur bacteria



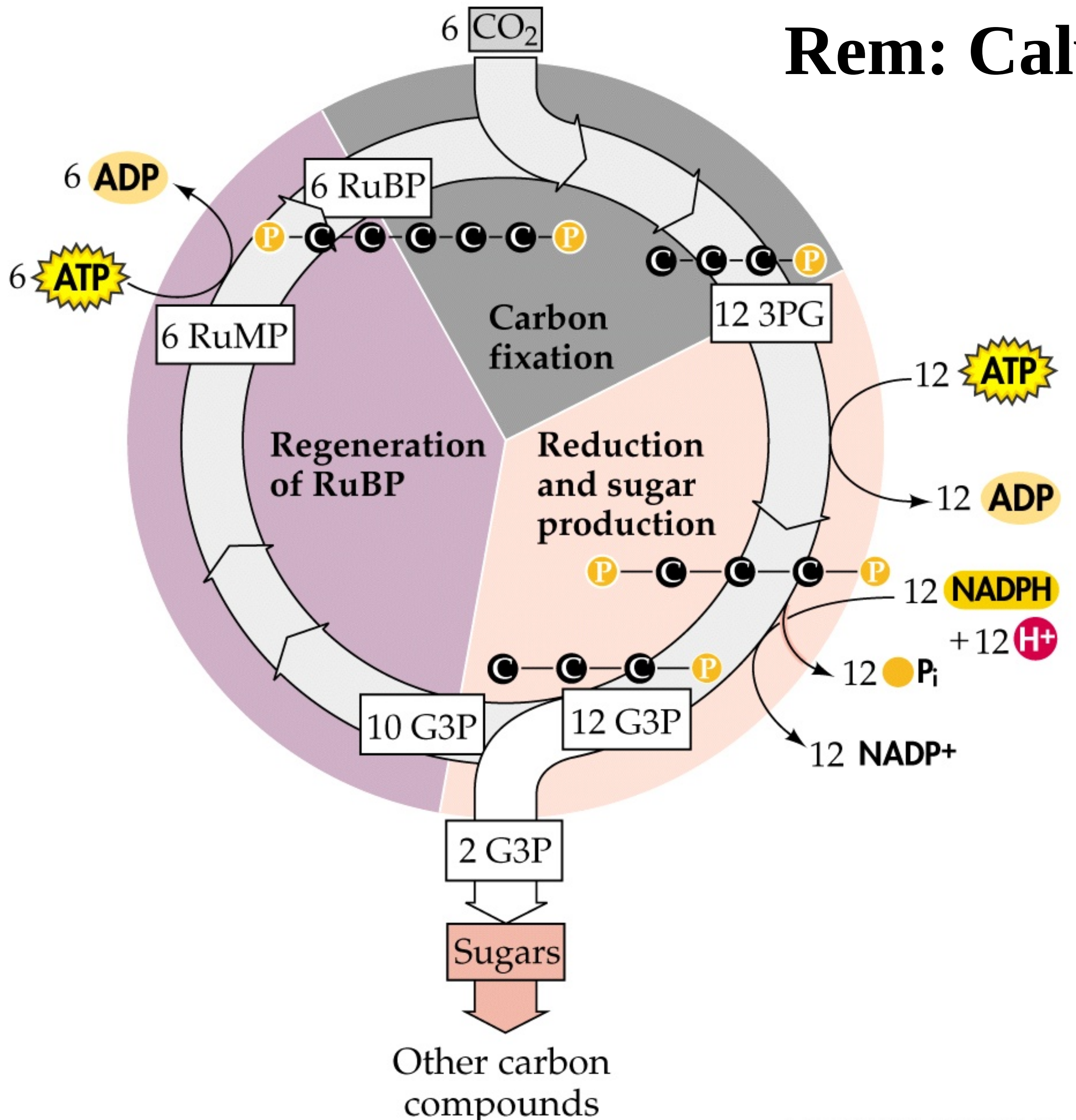
Electron flow in phototrophs

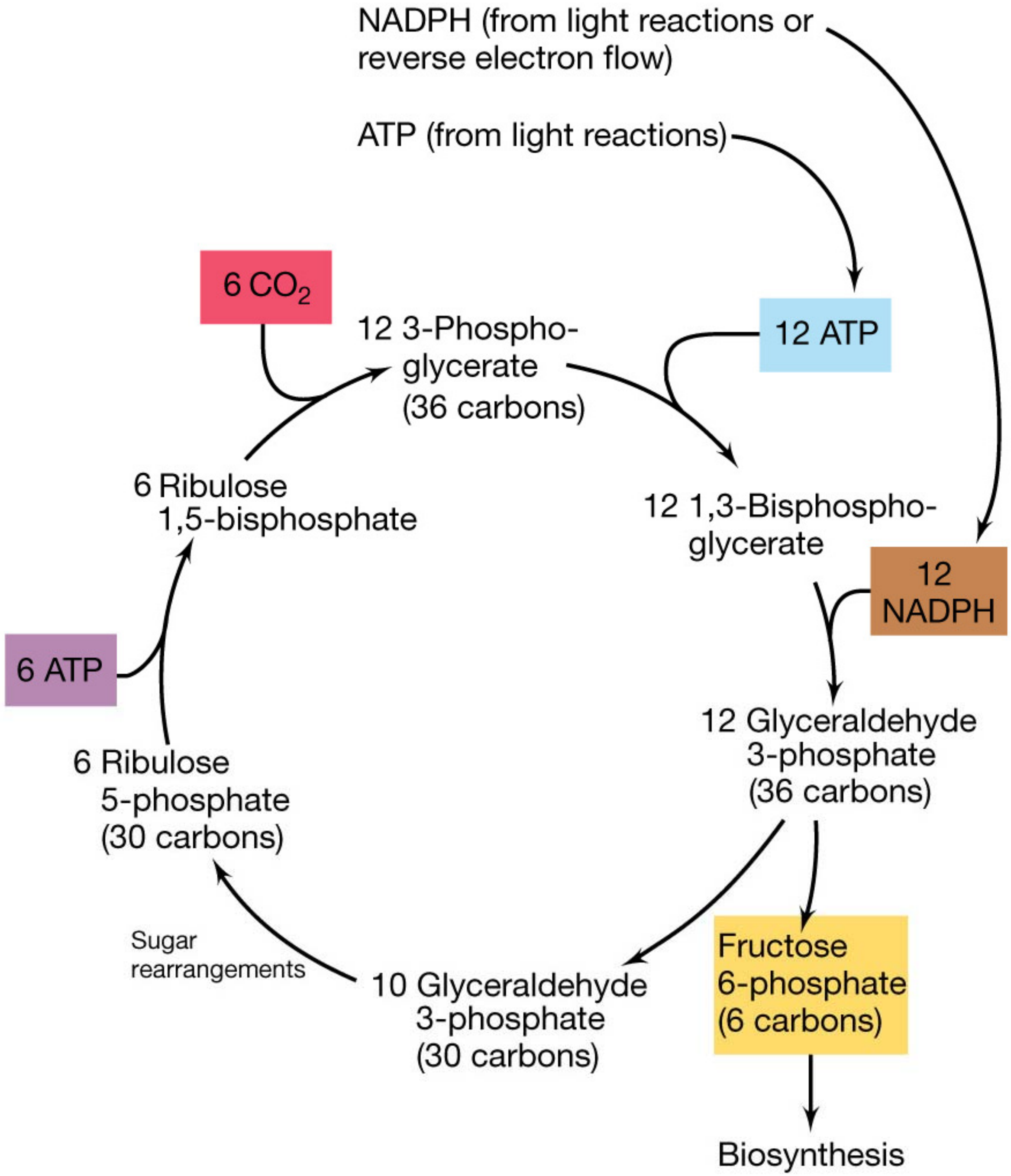




Oxygenic photosynthesis in cyanobacteria

Rem: Calvin Cycle



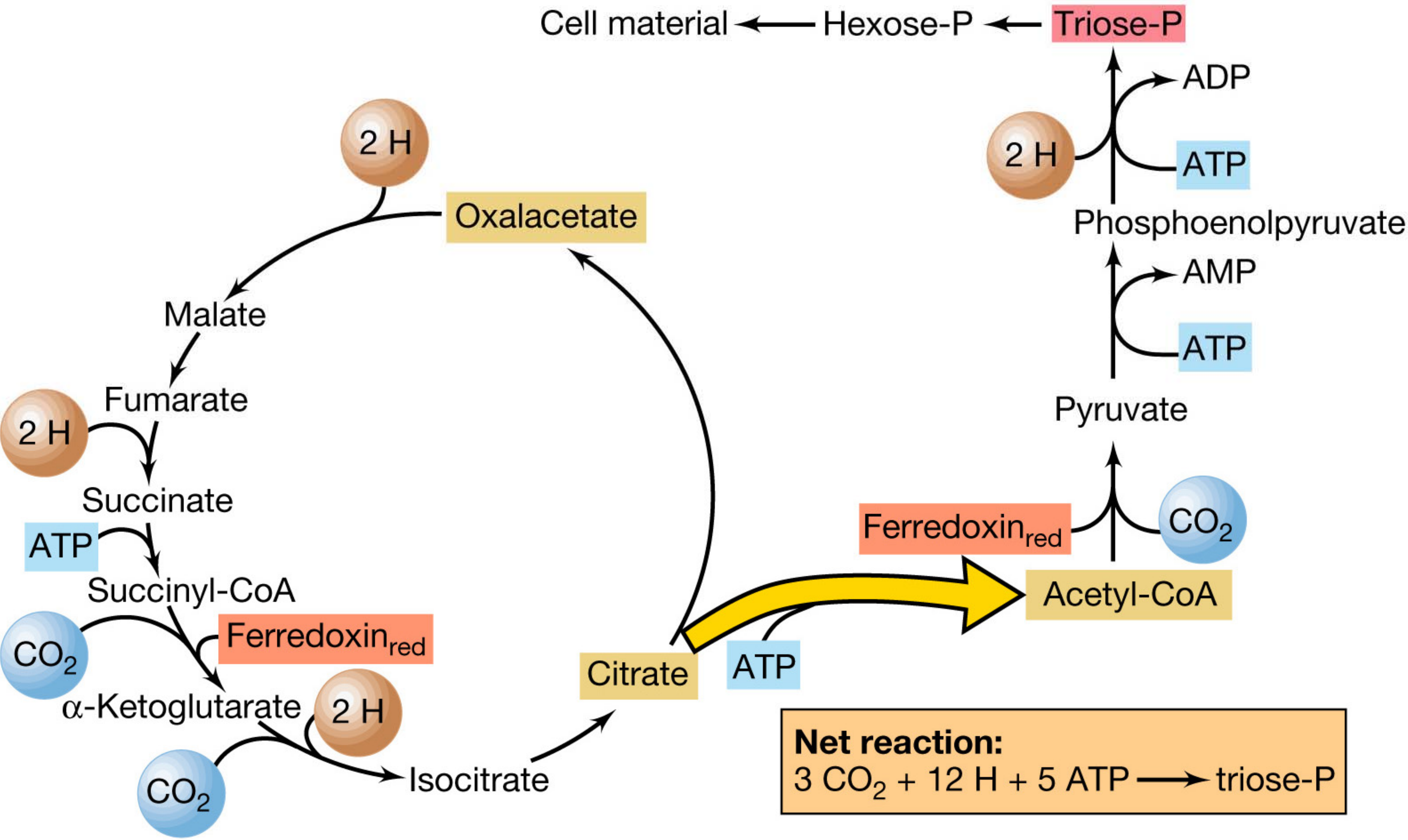


Overall stoichiometry:

$6\ CO_2 + 12\ NADPH + 18\ ATP \longrightarrow$

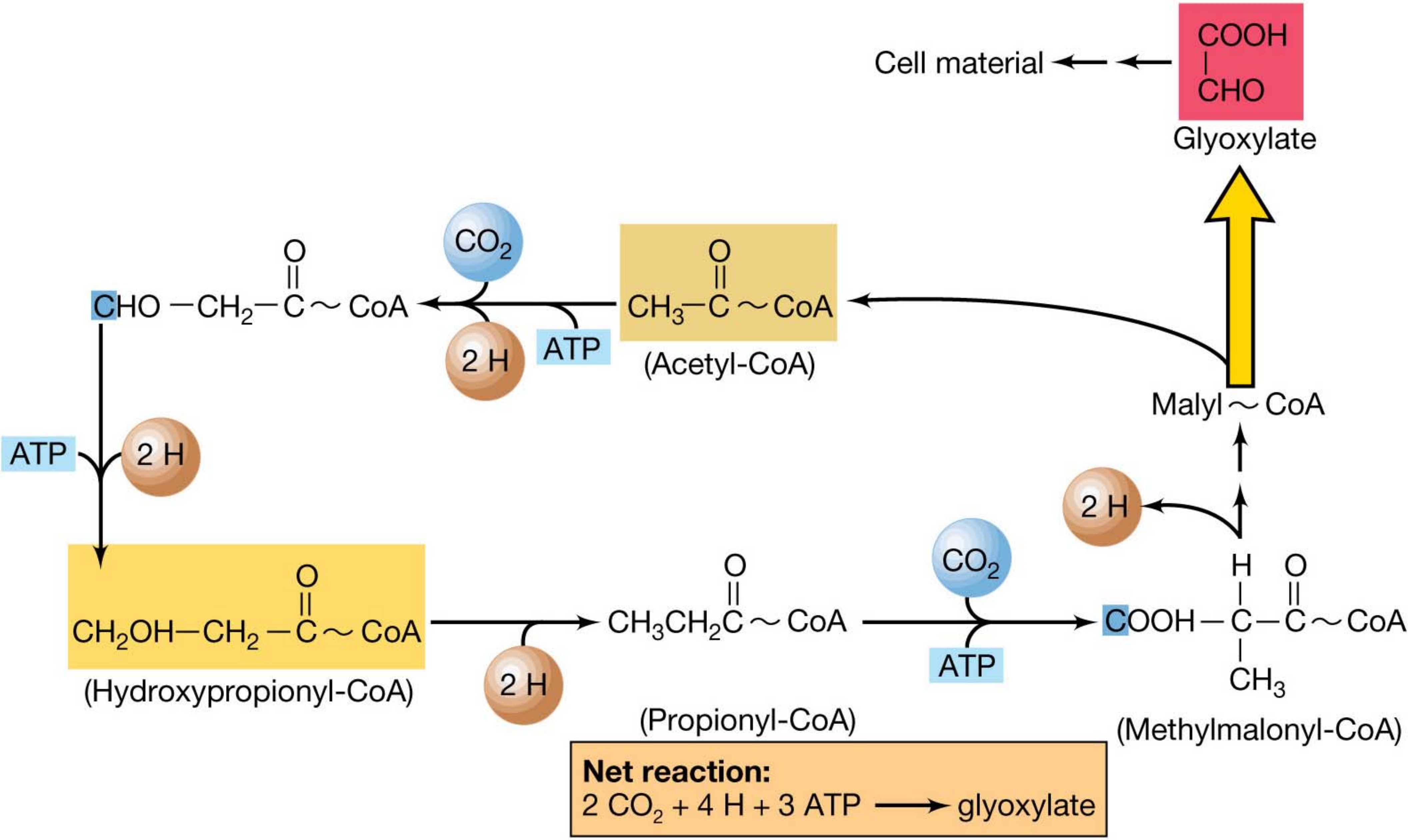
$C_6H_{12}O_6(PO_3H_2) + 12\ NADP^+ + 18\ ADP + 17\ P_i$

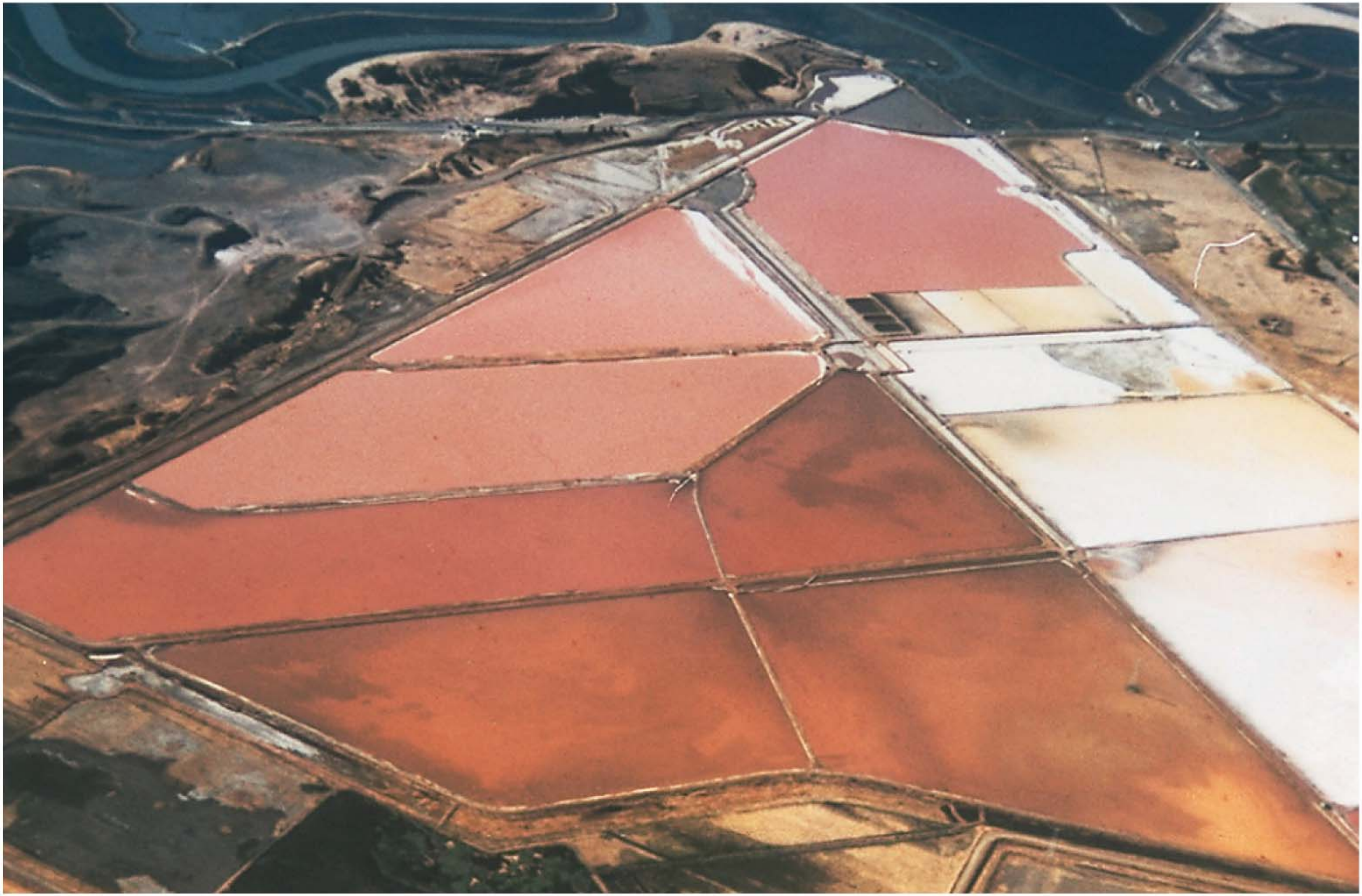
Reverse TCA in GSBs



Net reaction:
$3\ CO_2 + 12\ H + 5\ ATP \longrightarrow$ triose-P

Hydroxyproprionate in GNBs

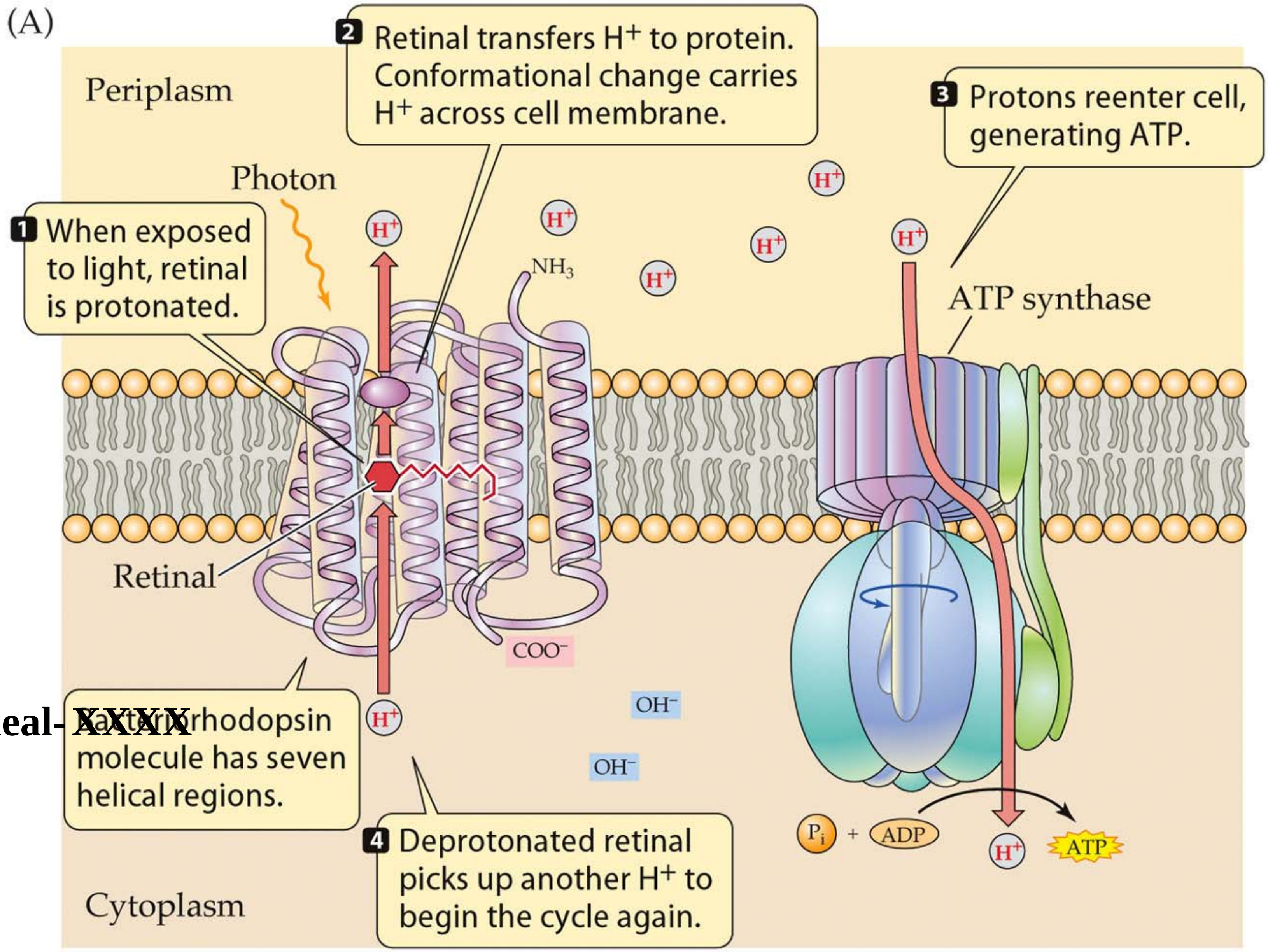




NASA

(b)

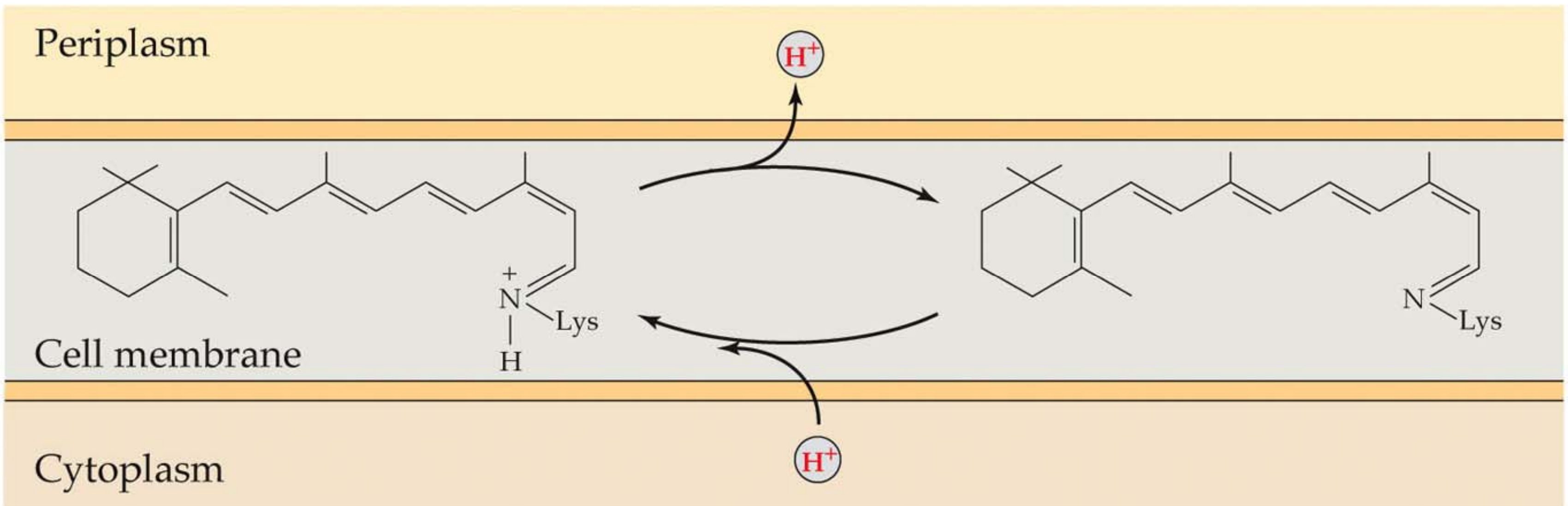
A light-driven proton pump of halophilic archaea



Archaeal- XXXX

Light-driven proton pump of halophilic archaea

(B)



Archaeal rhodopsin: retinal structure

Banded Iron Formations ~2.5 Bya

Oxygenic or anoxygenic photosynthesis: Fe^{2+}_{sol} to Fe^{3+}_{insol}