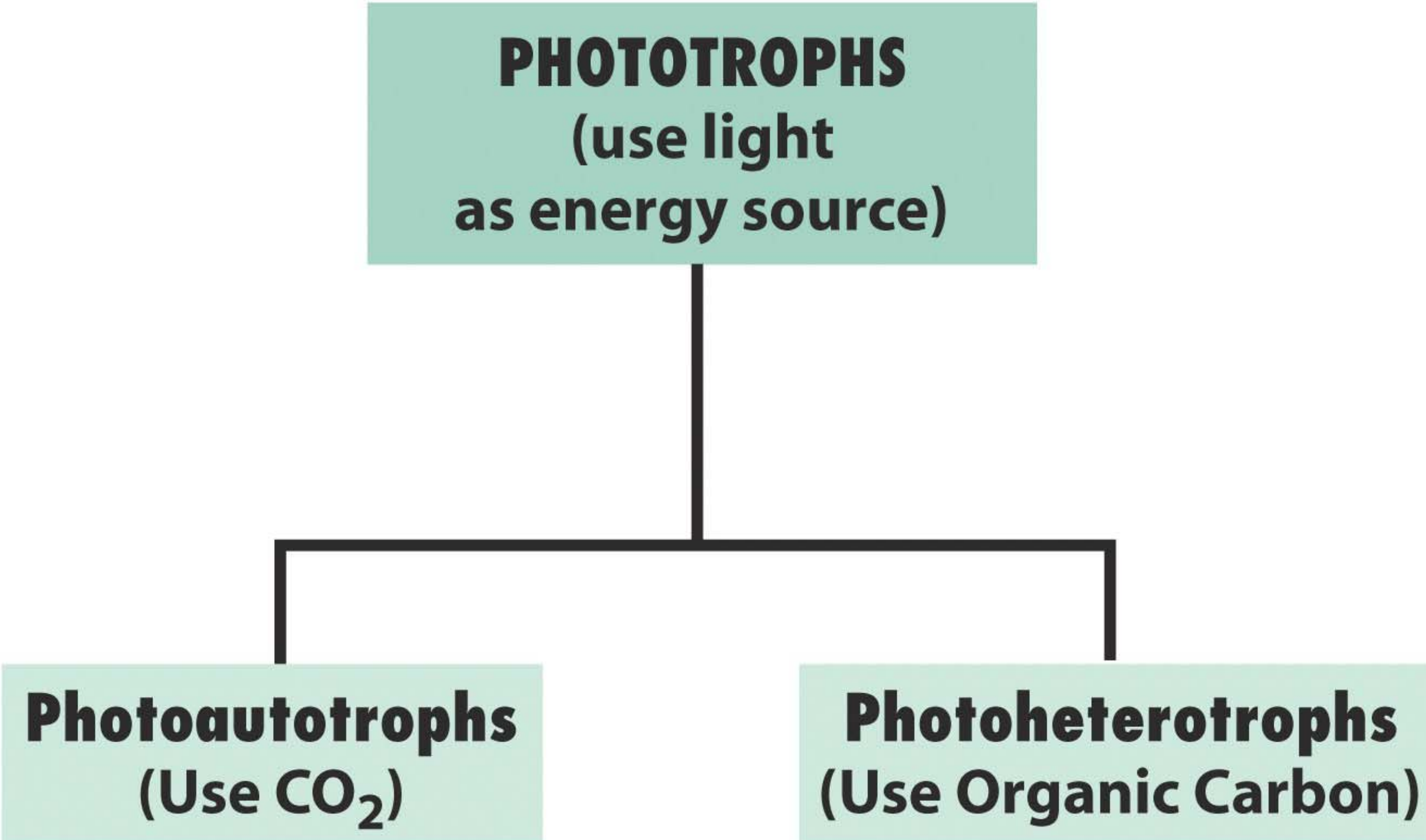
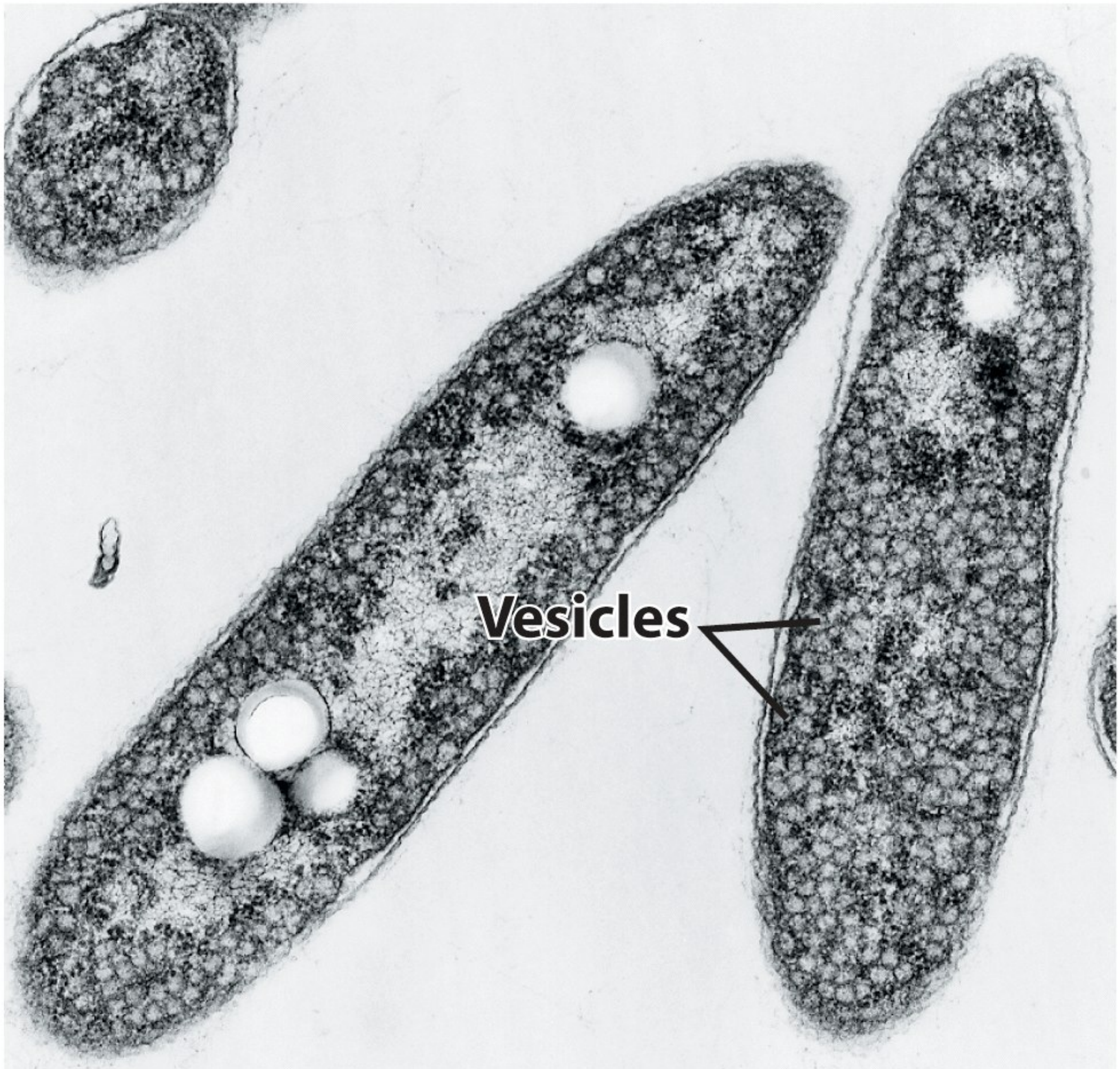
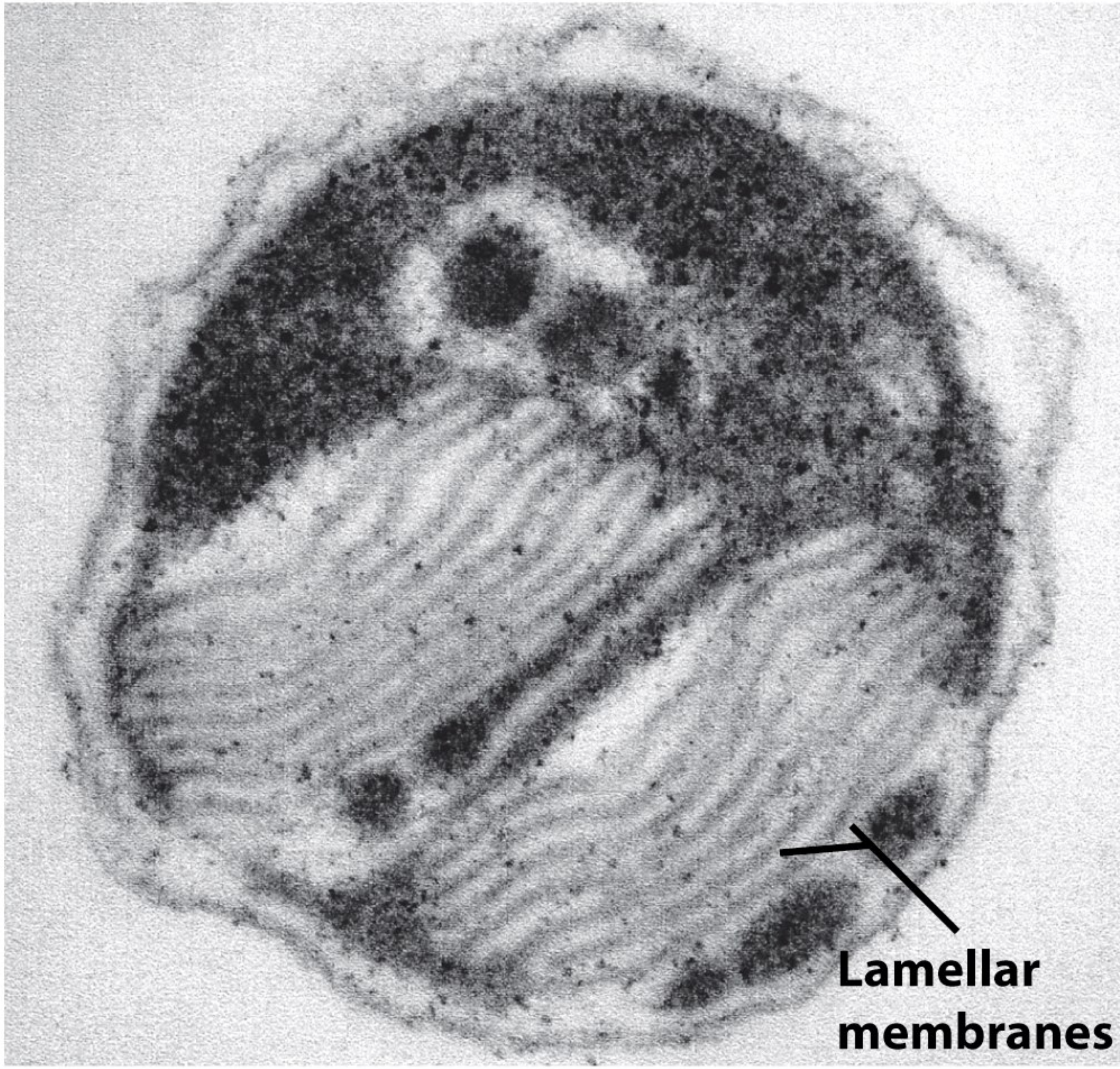
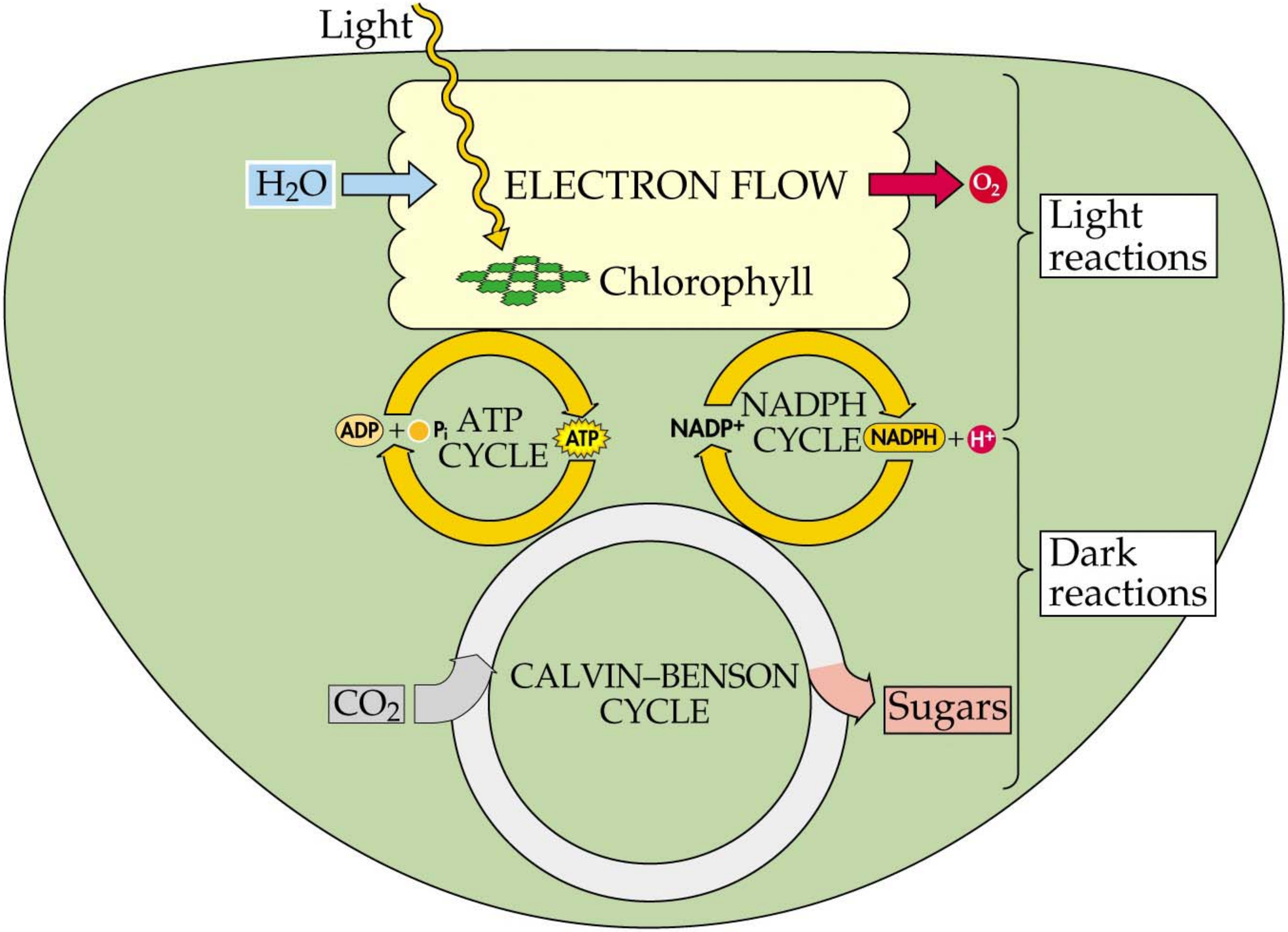
# More on
# Phototrophic Potential



PHOTOTROPHS
(use light
as energy source)
Photoautotrophs
(Use $CO_2$)
Photoheterotrophs
(Use Organic Carbon)

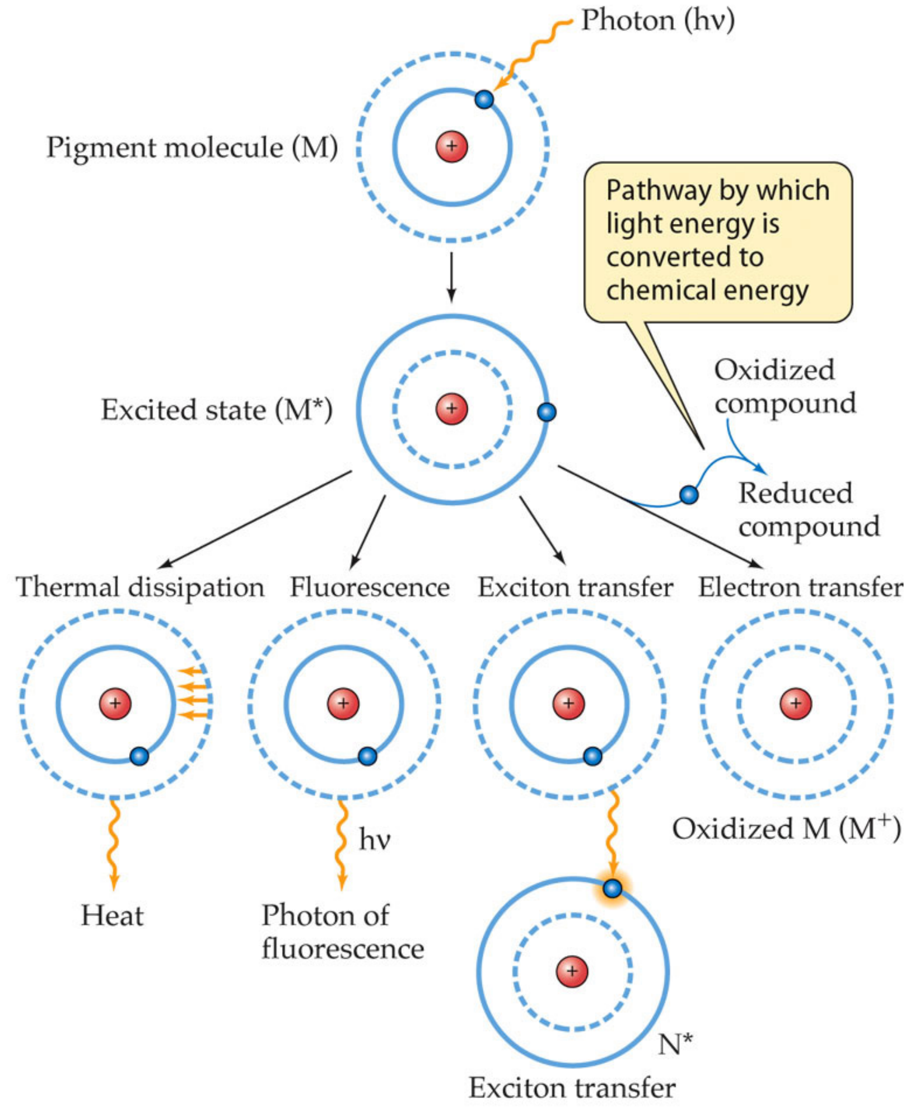

Vesicles

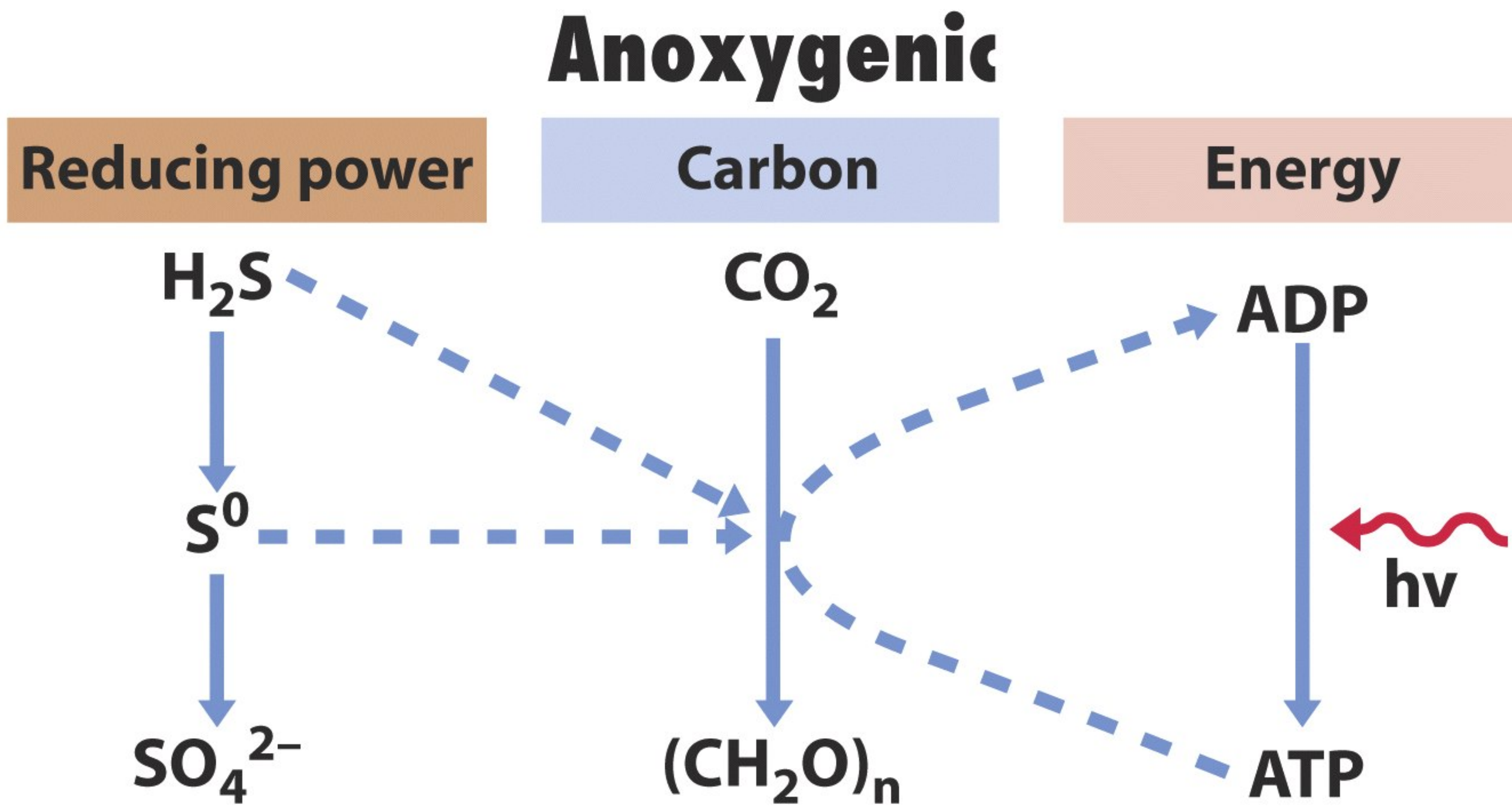

Lamellar
membranes



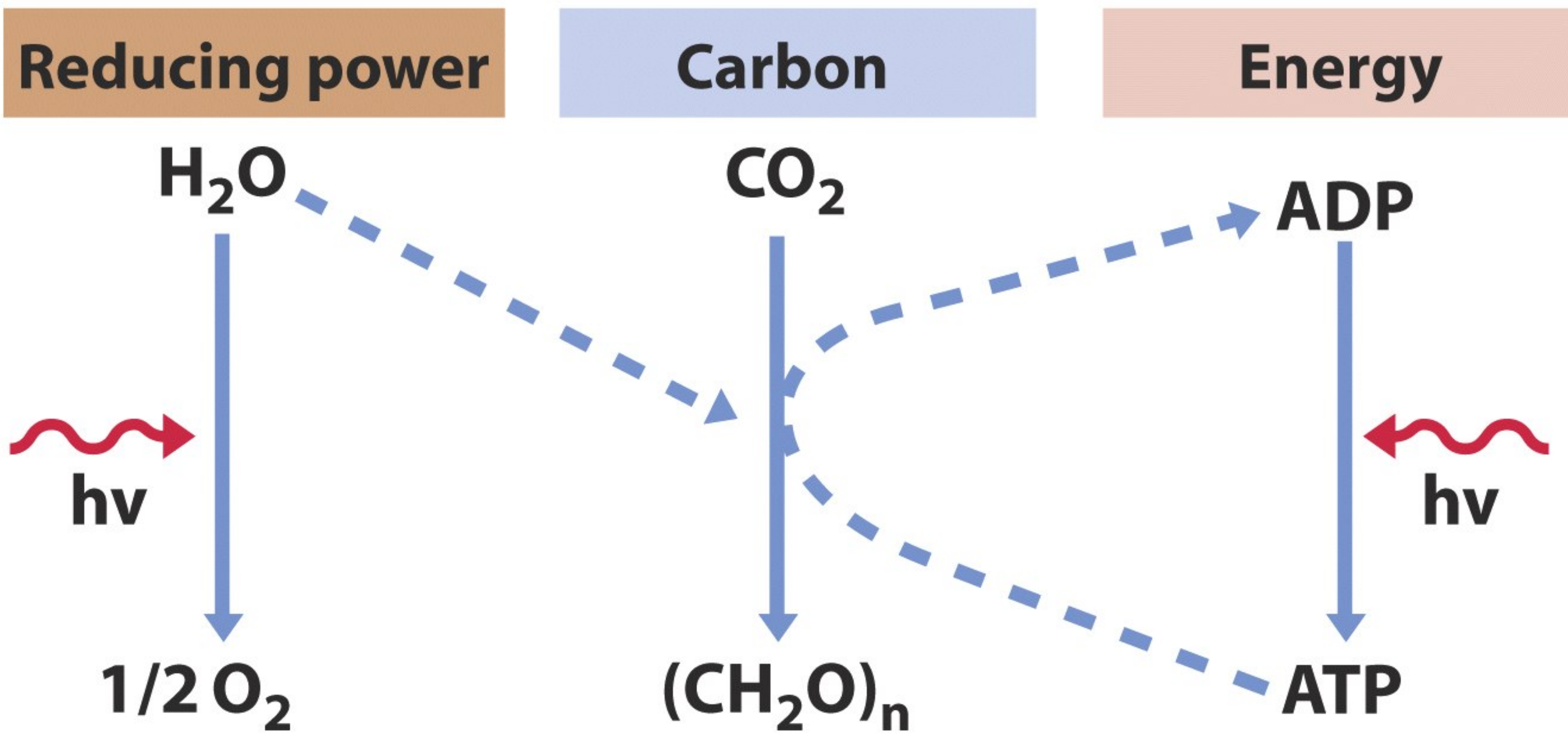
Light
H2O
ELECTRON FLOW
O2
Chlorophyll
Light reactions
ADP + Pi
ATP CYCLE
ATP
NADP+
NADPH CYCLE
NADPH + H+
Dark reactions
CO2
CALVIN–BENSON CYCLE
Sugars

# The possible fates of an excited electron




Anoxygenic
Reducing power
Carbon
Energy
$H_2S$
$S^0$
$SO_4^{2-}$
$CO_2$
$(CH_2O)_n$
ADP
ATP
hv

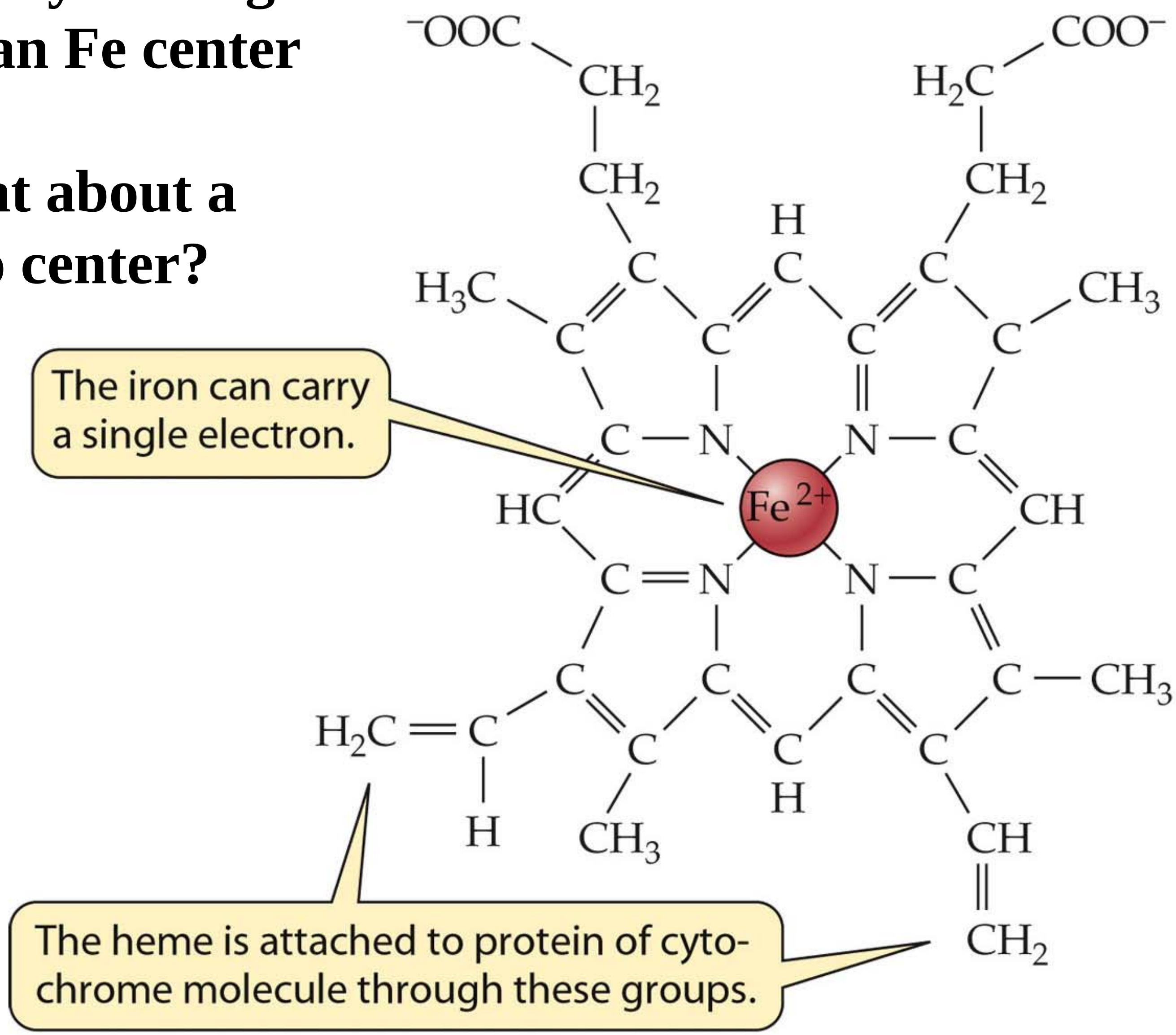
# Oxygenic

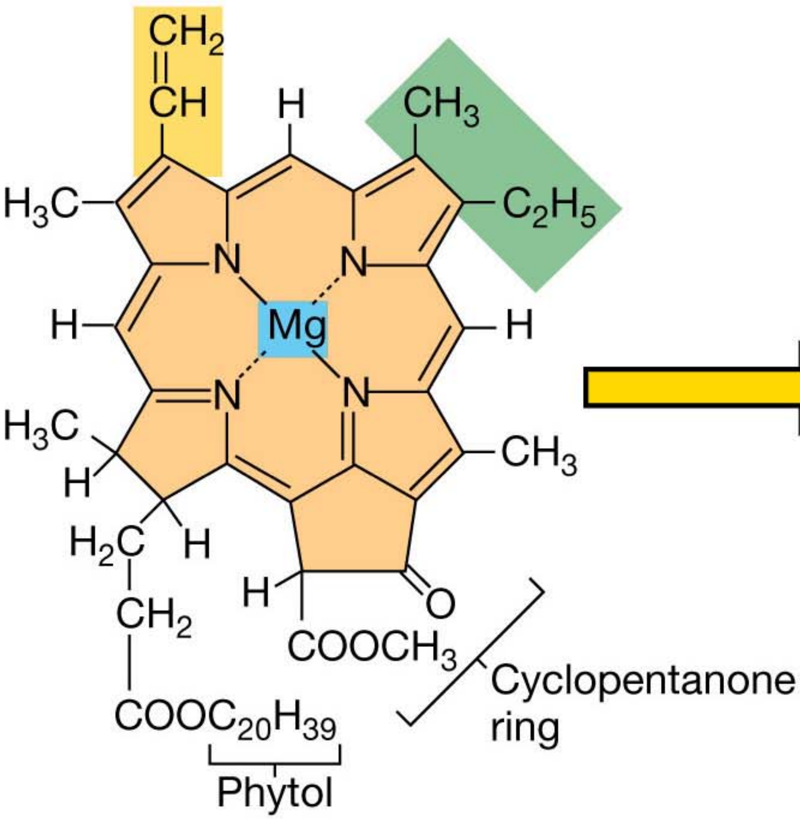



Wow!

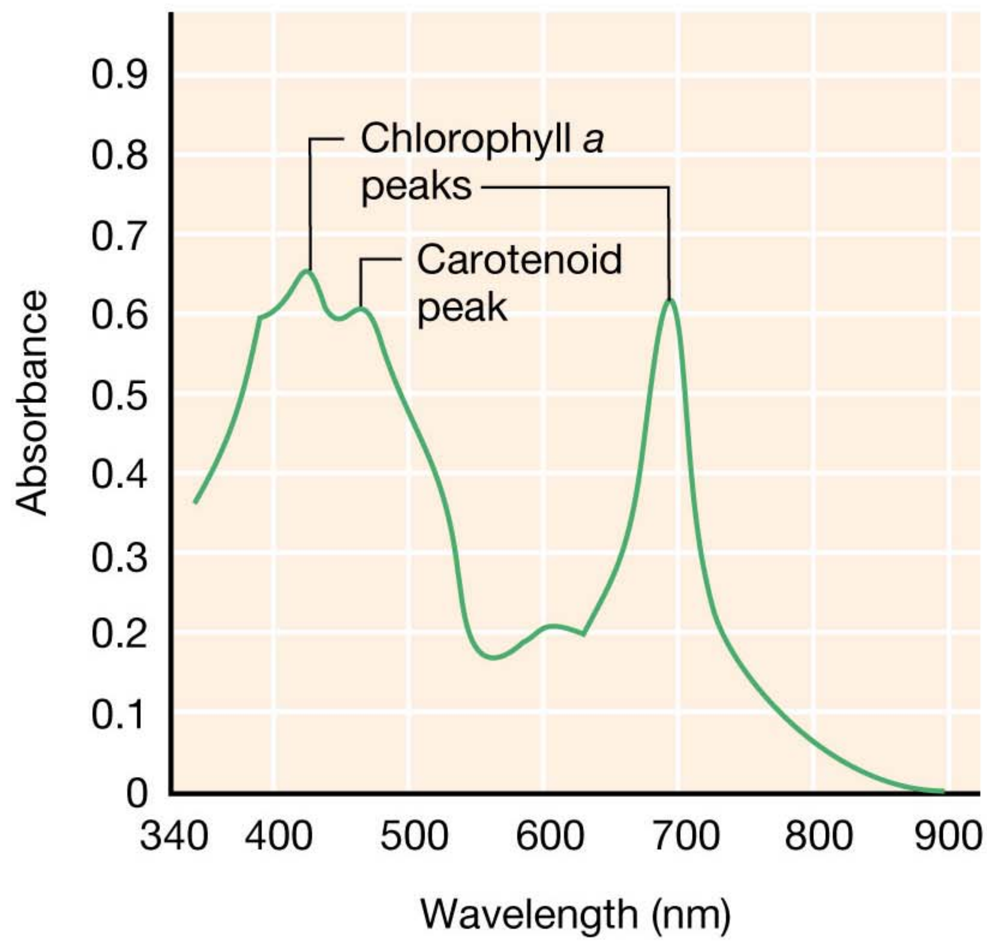
**Porphyrin ring with an Fe center**

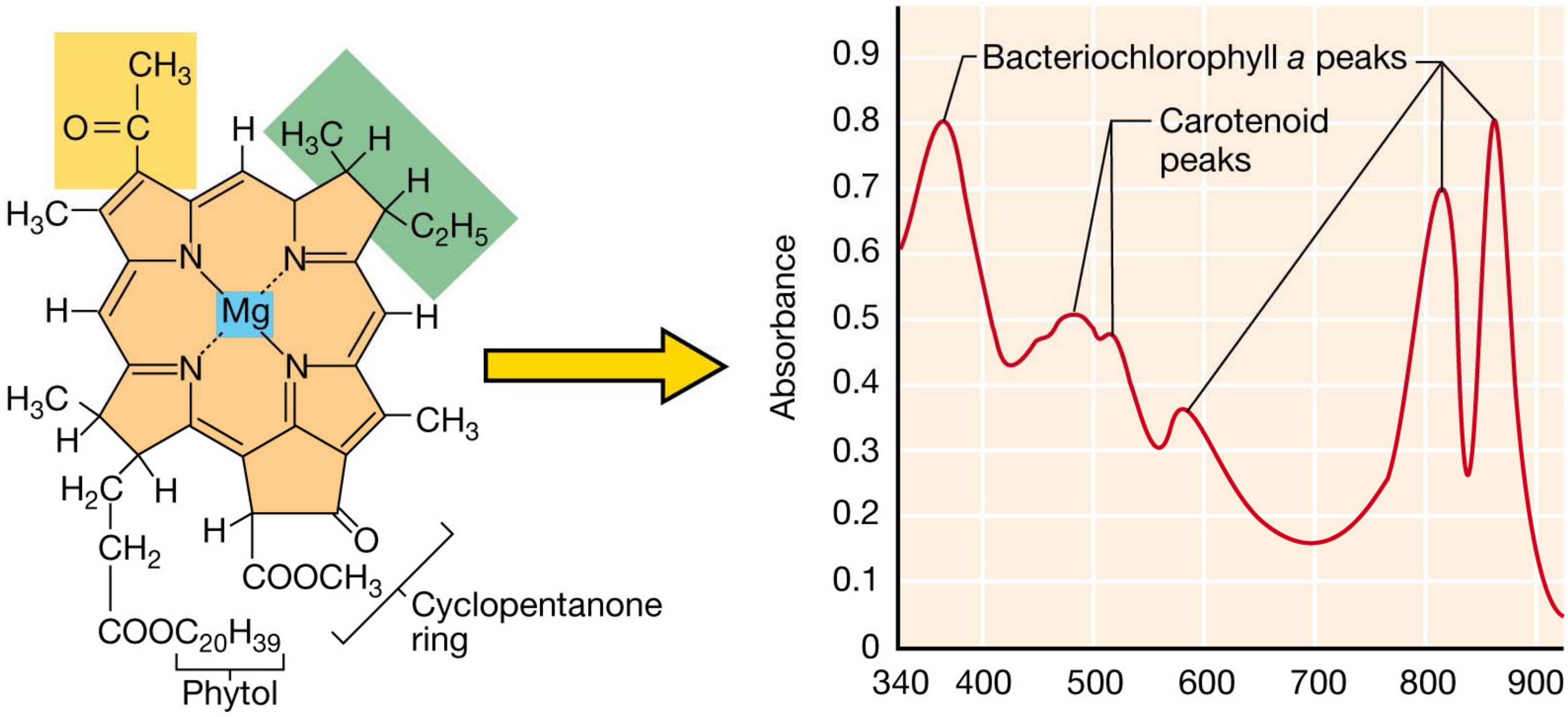
**What about a Co center?**






Chlorophyll *a*

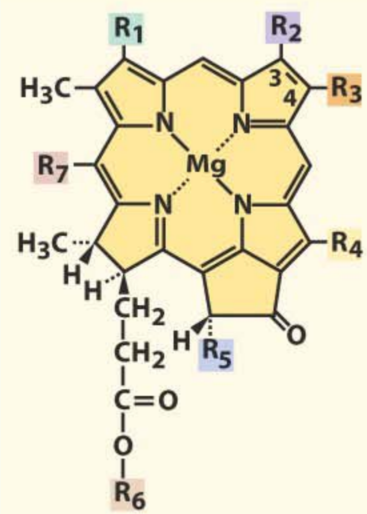





Bacteriochlorophyll *a*

# Bacteriochlorophyll Structures

| Pigment/Absorption maxima (*in vivo*) | $R_1$ | $R_2$ | $R_3$ | $R_4$ | $R_5$ | $R_6$ | $R_7$ |
|---|---|---|---|---|---|---|---|
| **Bchl *a*** (purple bacteria)/ 805, 830–890 | $-C(=O)-CH_3$ | $-CH_3$[b] | $-CH_2-CH_3$ | $-CH_3$ | $-C(=O)-O-CH_3$ | P/Gg[a] | $-H$ |
| **Bchl *b*** (purple bacteria)/ 835–850, 1020–1040 | $-C(=O)-CH_3$ | $-CH_3$[c] | $=C(H)-CH_3$ | $-CH_3$ | $-C(=O)-O-CH_3$ | P | $-H$ |
| **Bchl *c*** (green sulfur bacteria)/745–755 | $-C(H)(OH)-CH_3$ | $-CH_3$ | $-C_2H_5$<br>$-C_3H_7$[d]<br>$-C_4H_9$ | $-C_2H_5$<br>$-CH_3$ | $-H$ | F | $-CH_3$ |
| **Bchl $c_s$** (green nonsulfur bacteria)/740 | $-C(H)(OH)-CH_3$ | $-CH_3$ | $-C_2H_5$ | $-CH_3$ | $-H$ | S | $-CH_3$ |
| **Bchl *d*** (green sulfur bacteria)/705–740 | $-C(H)(OH)-CH_3$ | $-CH_3$ | $-C_2H_5$<br>$-C_3H_7$<br>$-C_4H_9$ | $-C_2H_5$<br>$-CH_3$ | $-H$ | F | $-H$ |
| **Bchl *e*** (green sulfur bacteria)/719–726 | $-C(H)(OH)-CH_3$ | $-C(=O)-H$ | $-C_2H_5$<br>$-C_3H_7$<br>$-C_4H_9$ | $-C_2H_5$ | $-H$ | F | $-CH_3$ |
| **Bchl *g*** (heliobacteria)/ 670, 788 | $-C(H)=CH_2$ | $-CH_3$[b] | $-C_2H_5$ | $-CH_3$ | $-C(=O)-O-CH_3$ | F | $-H$ |



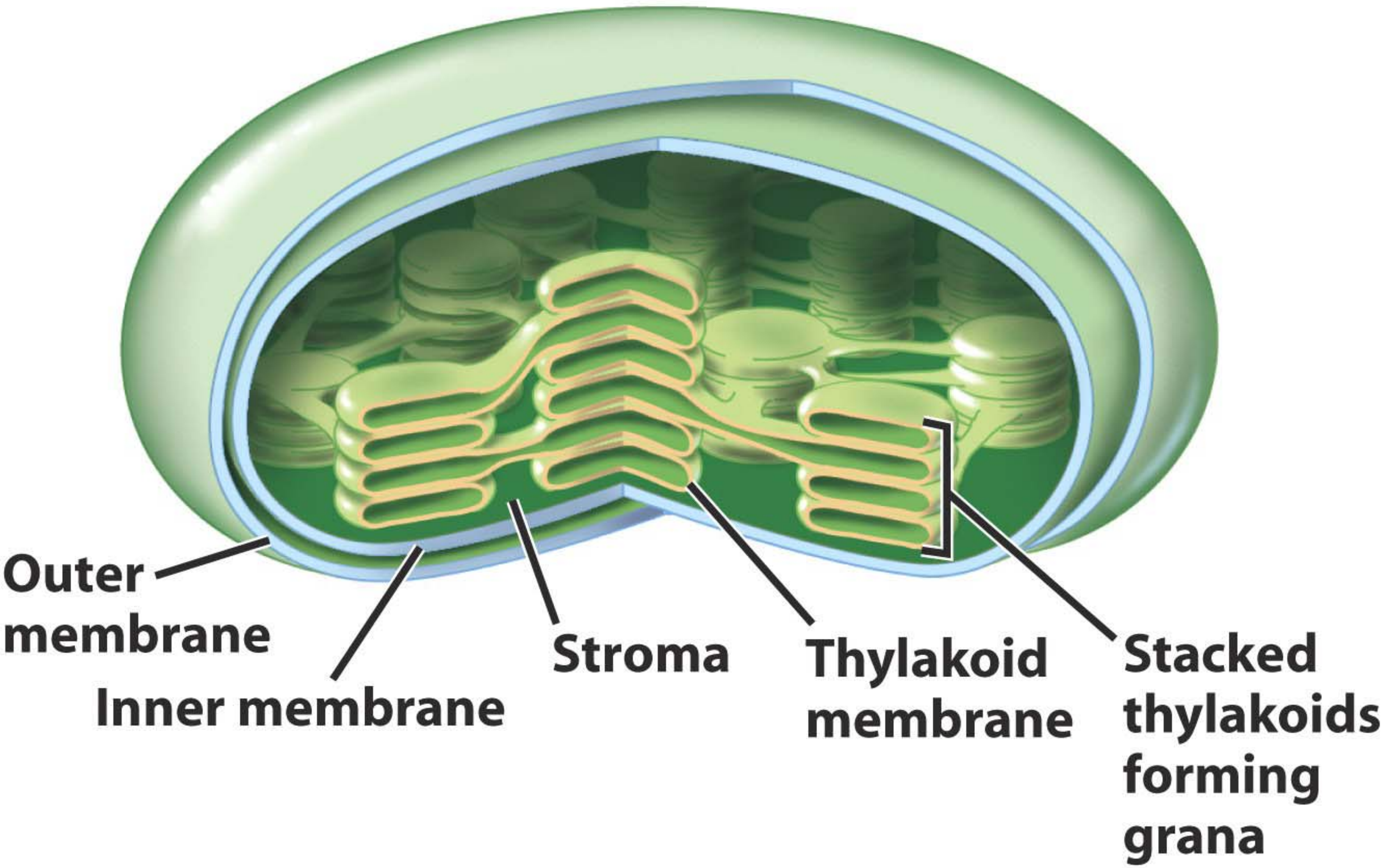

[a] P, Phytyl ester ($C_{20}H_{39}O-$); F, farnesyl ester ($C_{15}H_{25}O-$); Gg, geranylgeraniol ester ($C_{10}H_{17}O-$); S, stearyl alcohol ($C_{18}H_{37}O-$).

[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.

# Chloroplast Structure

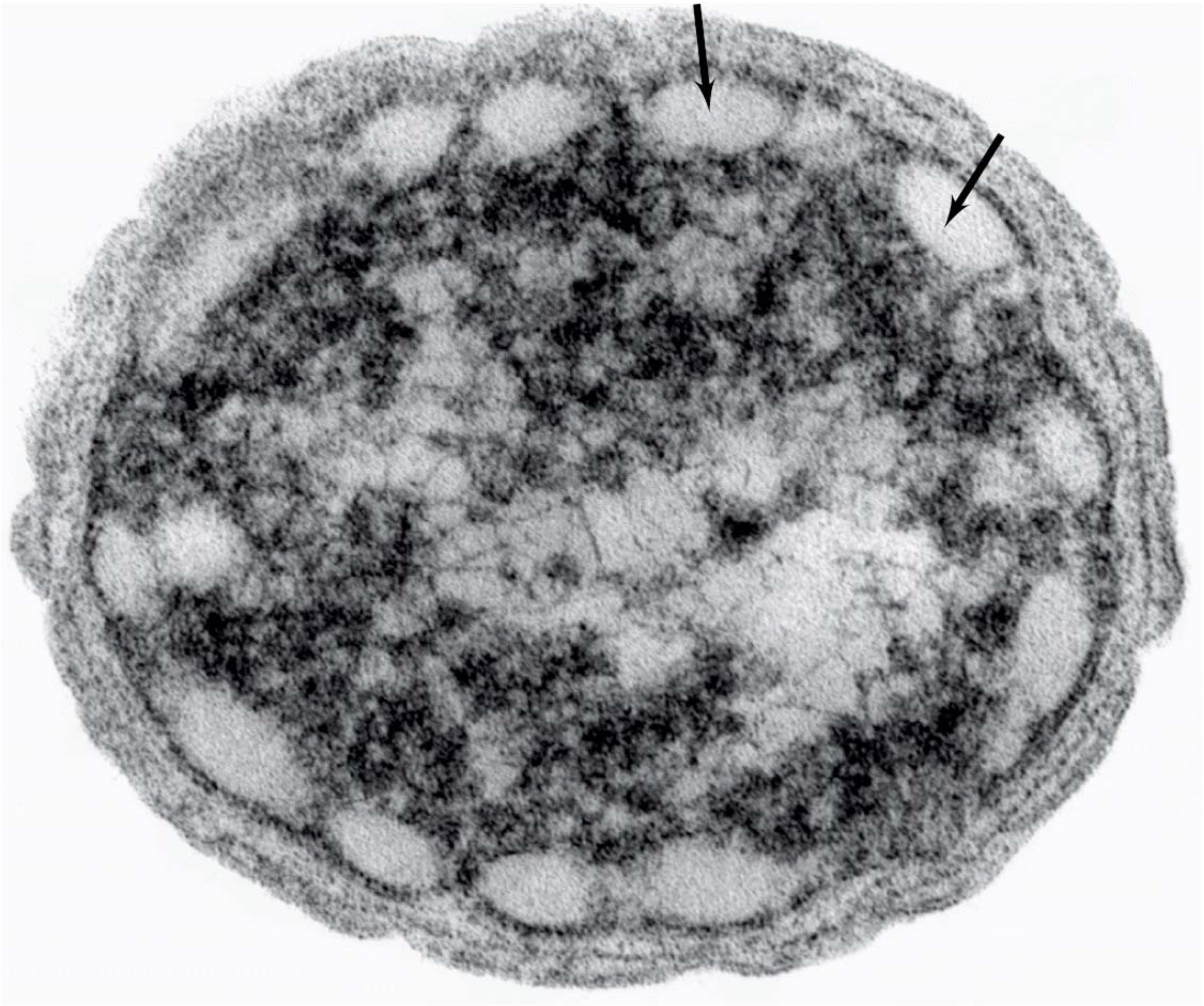


## Table 9.1 Some general properties of the various photosynthetic bacteria

| | 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 |

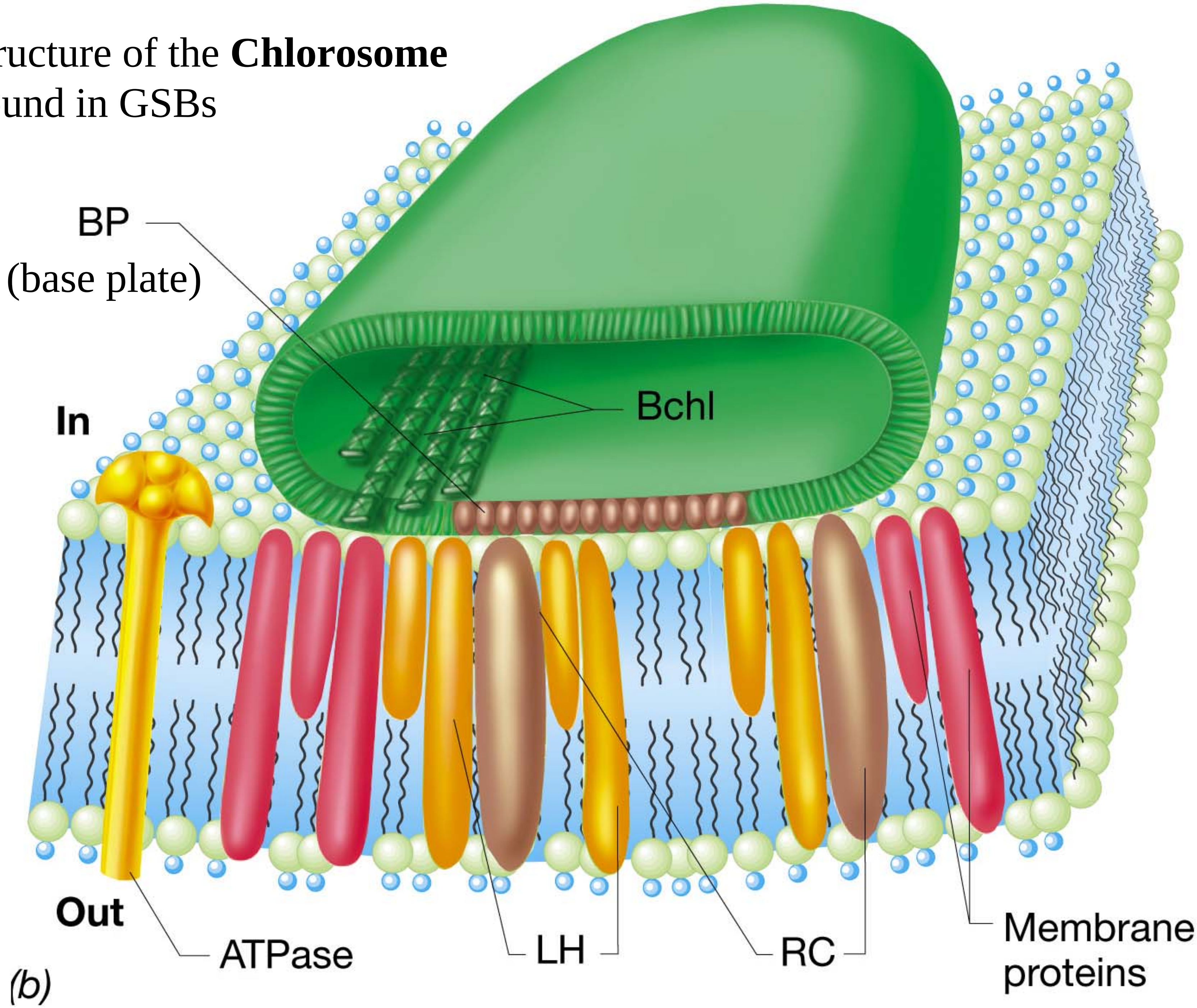
[a]Generally limited to assimilation of low molecular weight organics during autotrophic growth.

Structure and Location of the **Chlorosome**

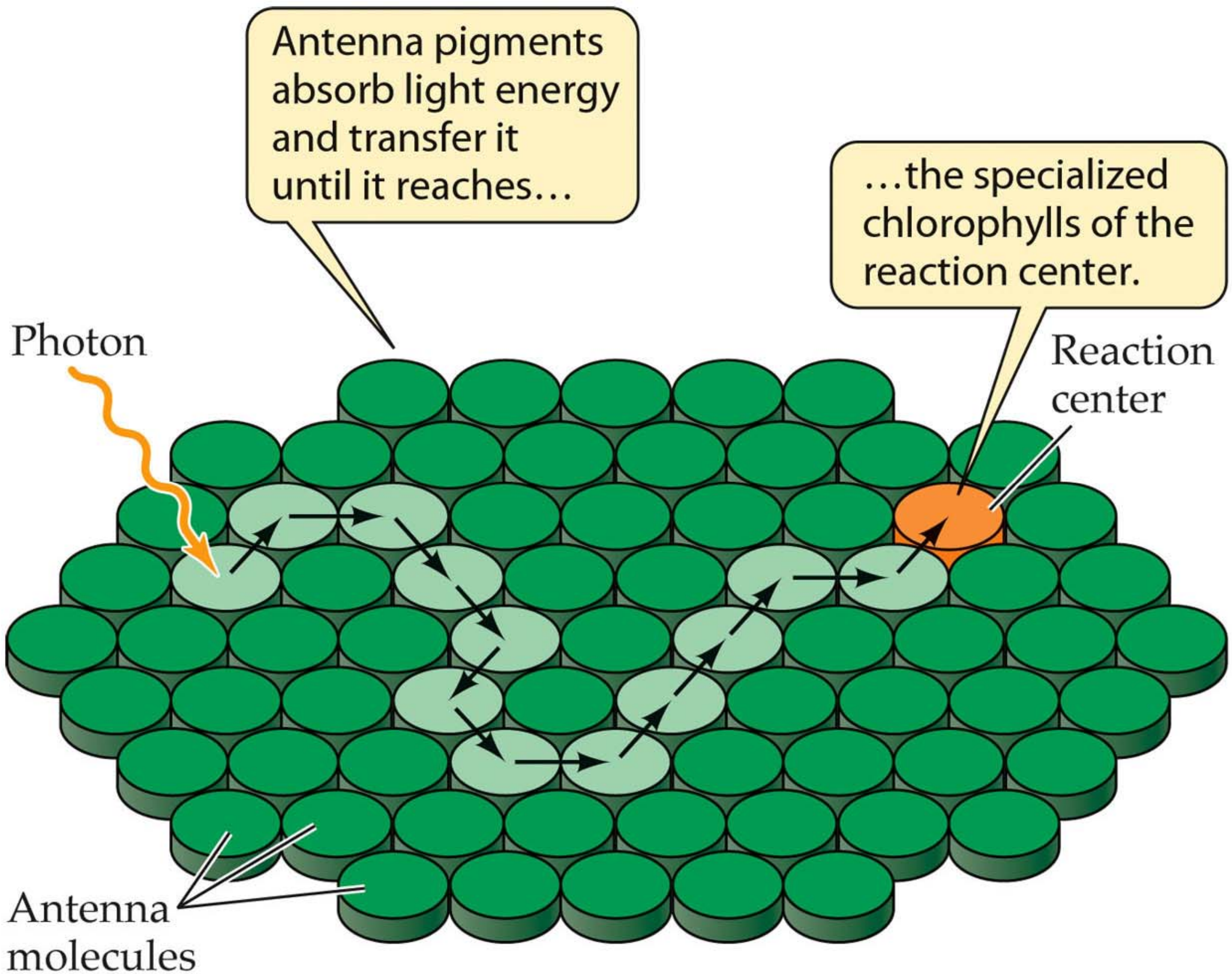


Found in GSBs

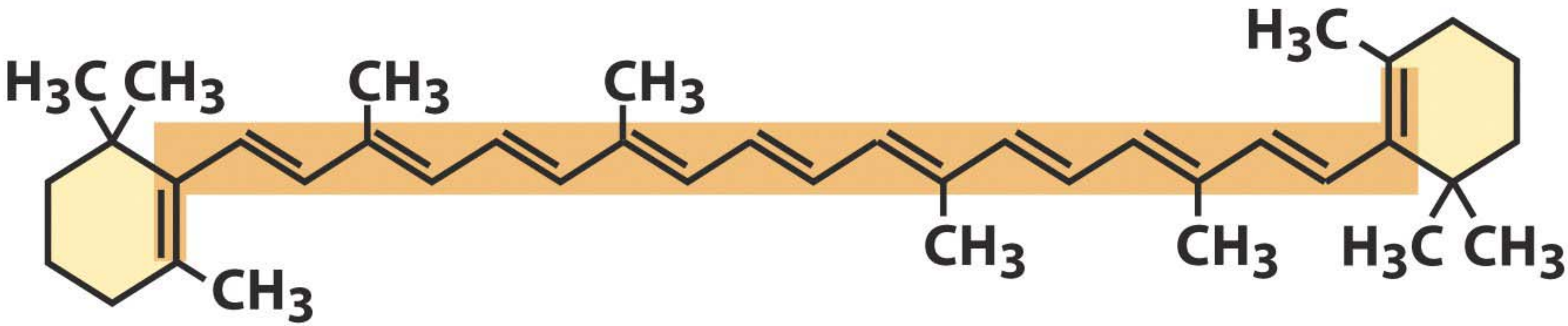
Structure of the **Chlorosome** Found in GSBs



# Photosynthetic unit



# Beta-Carotene, a typical carotenoid



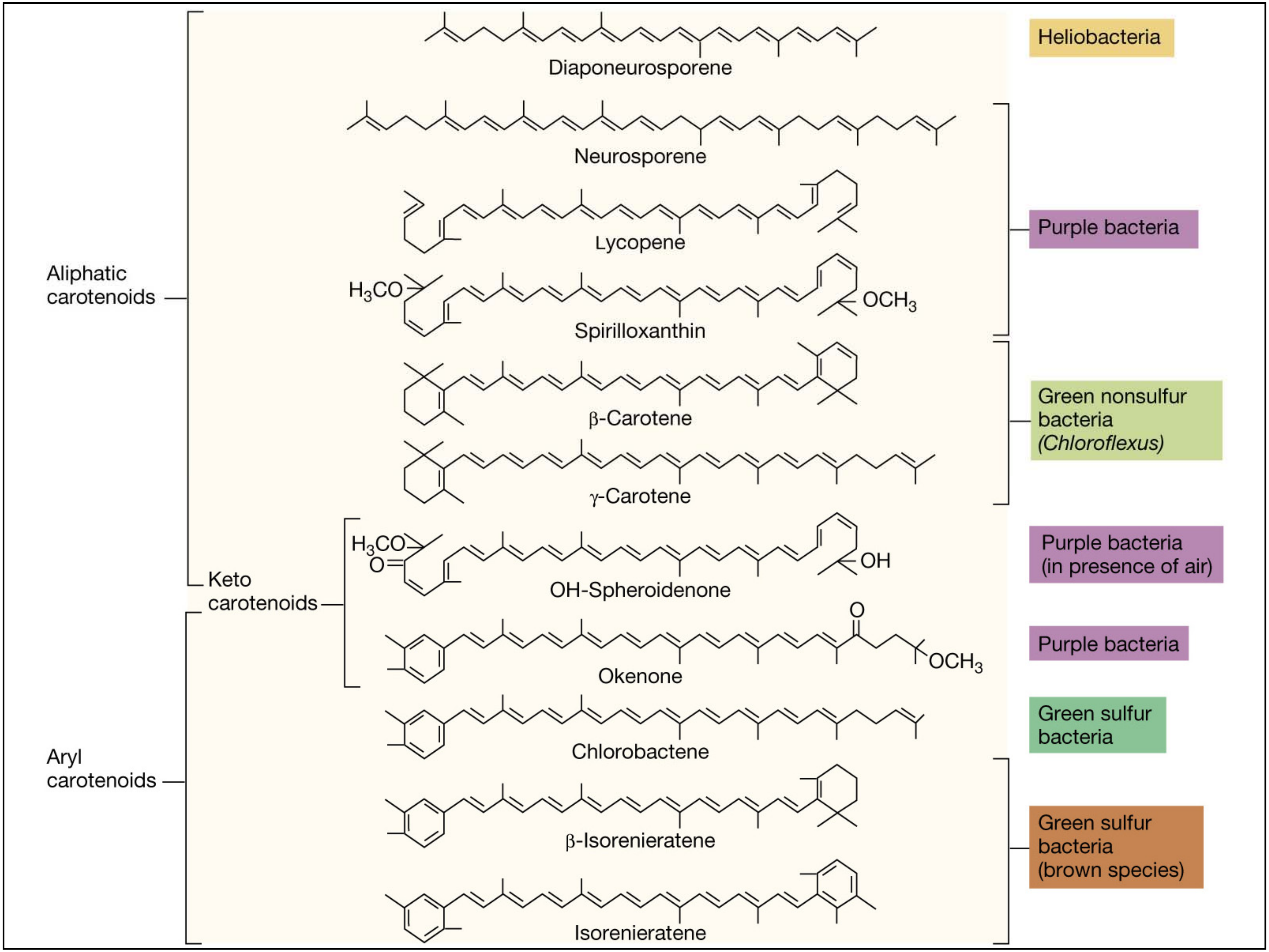
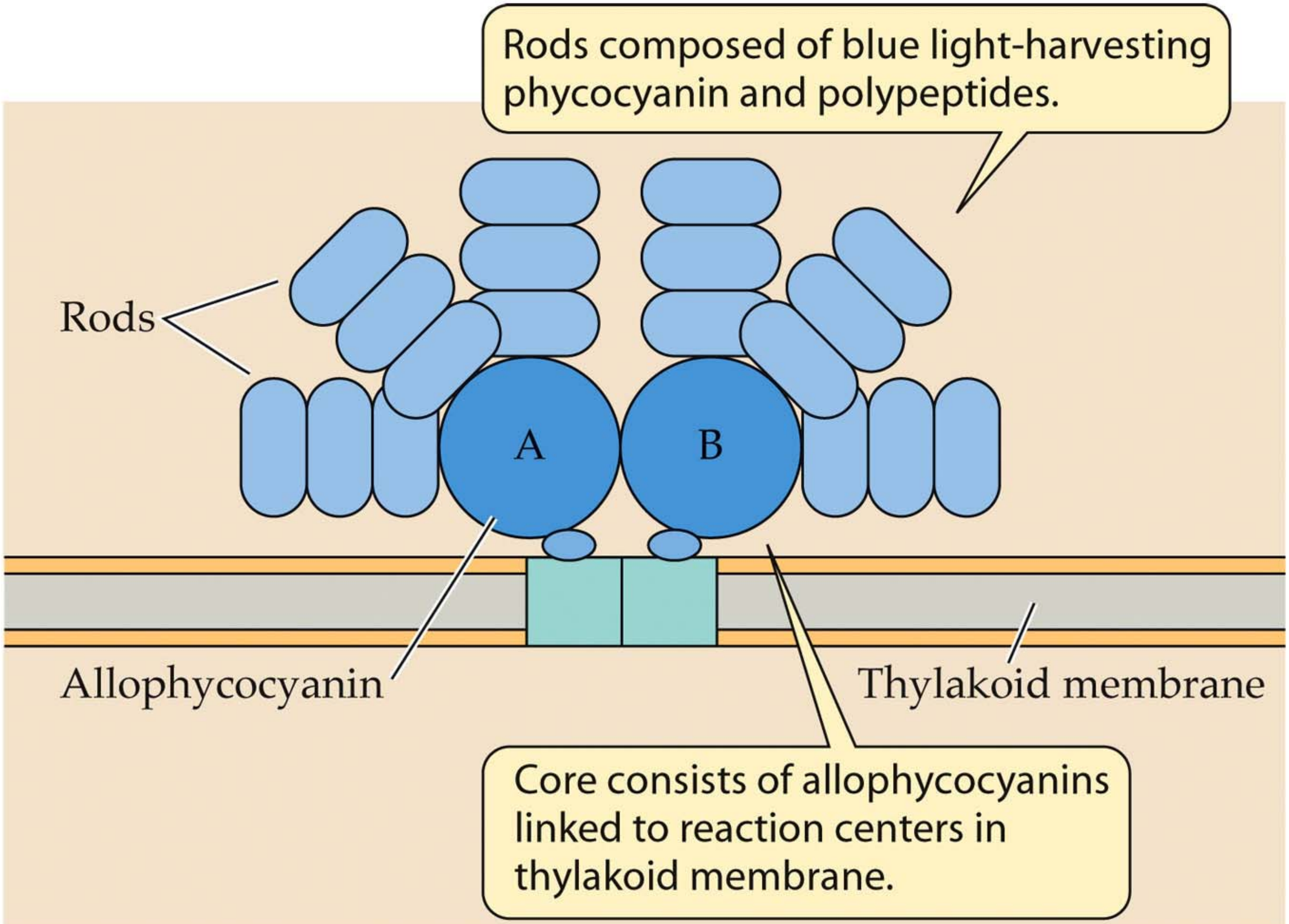

Heliobacteria
Diaponeurosporene
Neurosporene
Lycopene
Purple bacteria
Aliphatic carotenoids
H3CO
OCH3
Spirilloxanthin
β-Carotene
Green nonsulfur bacteria (Chloroflexus)
γ-Carotene
Keto carotenoids
H3CO
O
OH
OH-Spheroidenone
Purple bacteria (in presence of air)
O
OCH3
Okenone
Purple bacteria
Chlorobactene
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**

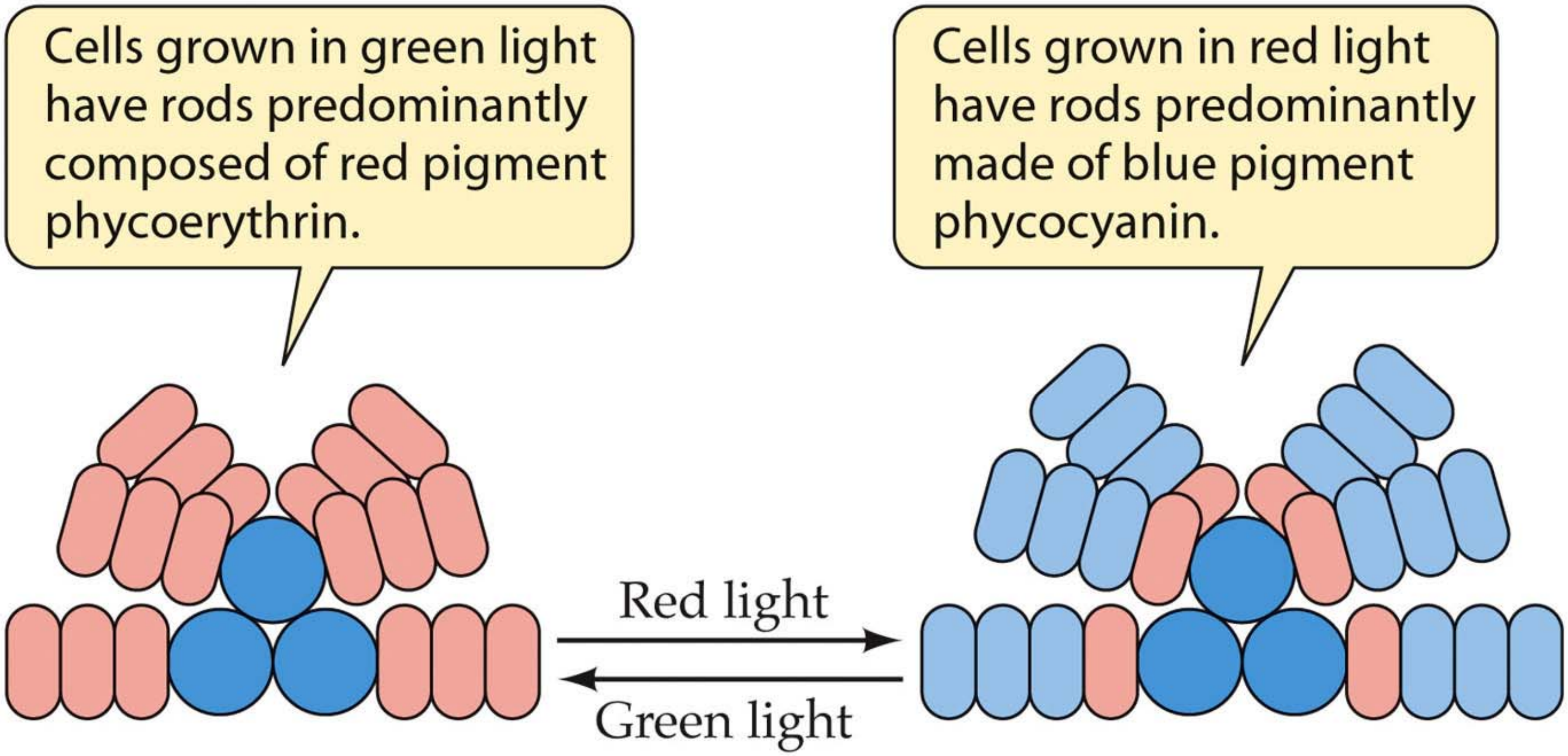
| | Electron Donor | Electron Acceptor |
|---|---|---|
| Purple nonsulfur bacteria | Bacteriochlorophyll *a* and *b* | Bacteriopheophytin *a*, $Q_A$, and $Q_B$ |
| Green sulfur bacteria | Bacteriochlorophyll *c*, *d*, and *e* | Bacteriopheophytin *a* and FeS-protein |
| Cyanobacteria photosystem I | 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**

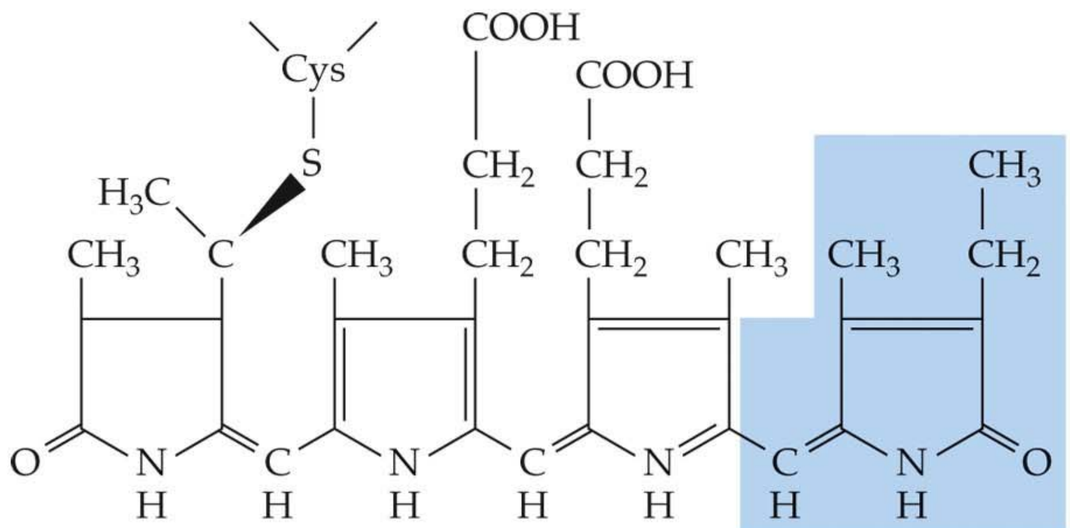
# Phycobilisome of cyanobacteria



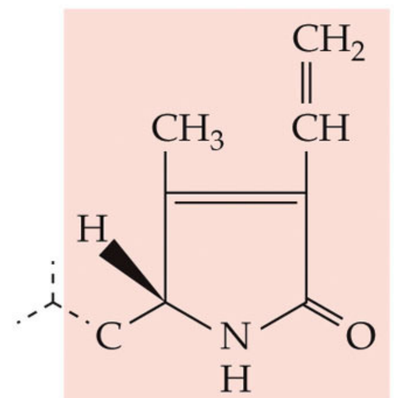
# Chromatic adaptation of a phycobilisome



# Chromophores of phycobilisomes

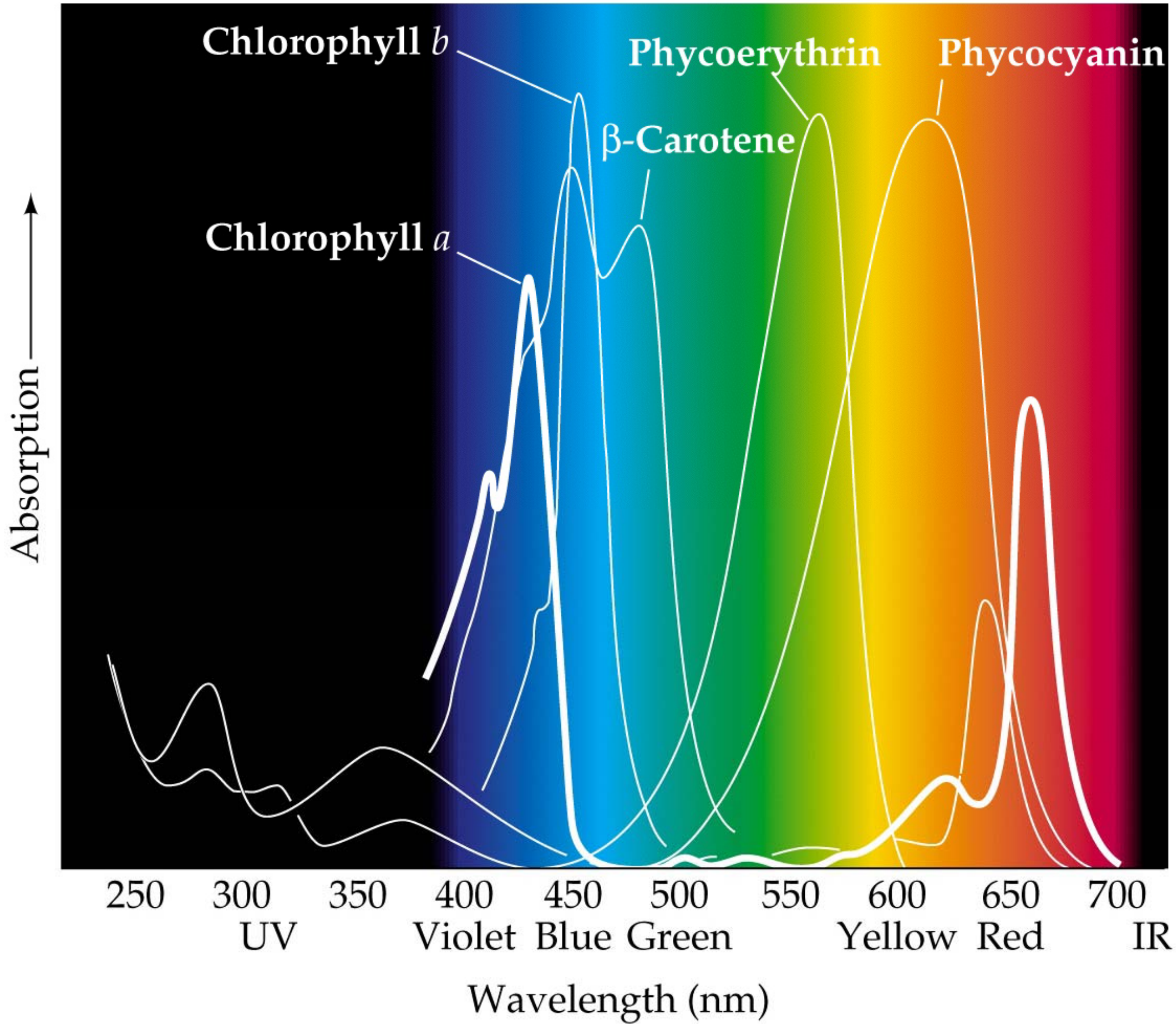


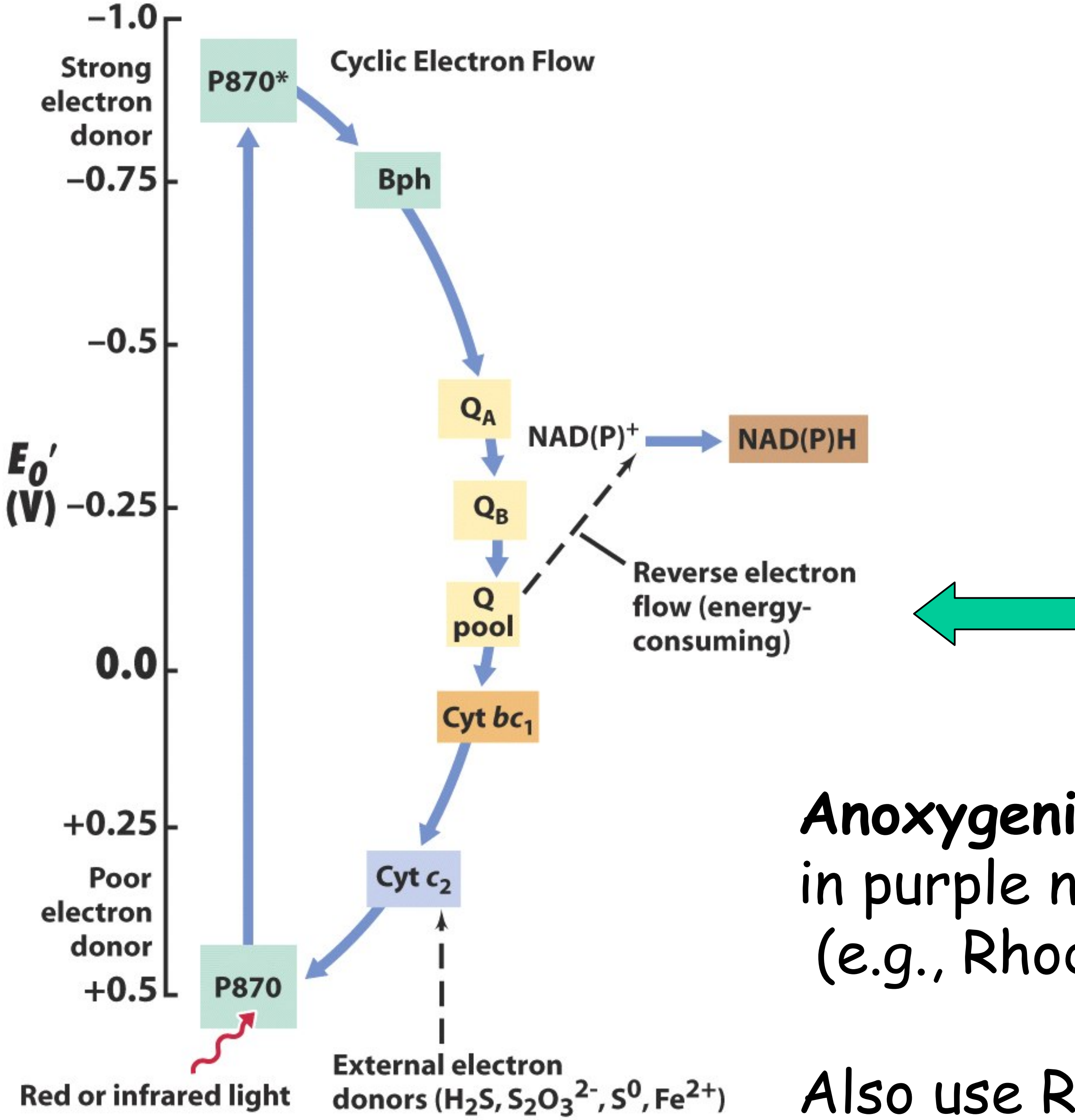

**Phycocyanin (blue)**




**Phycoerythrin (red)**

# Absorption Spectra for Cyanobacteria

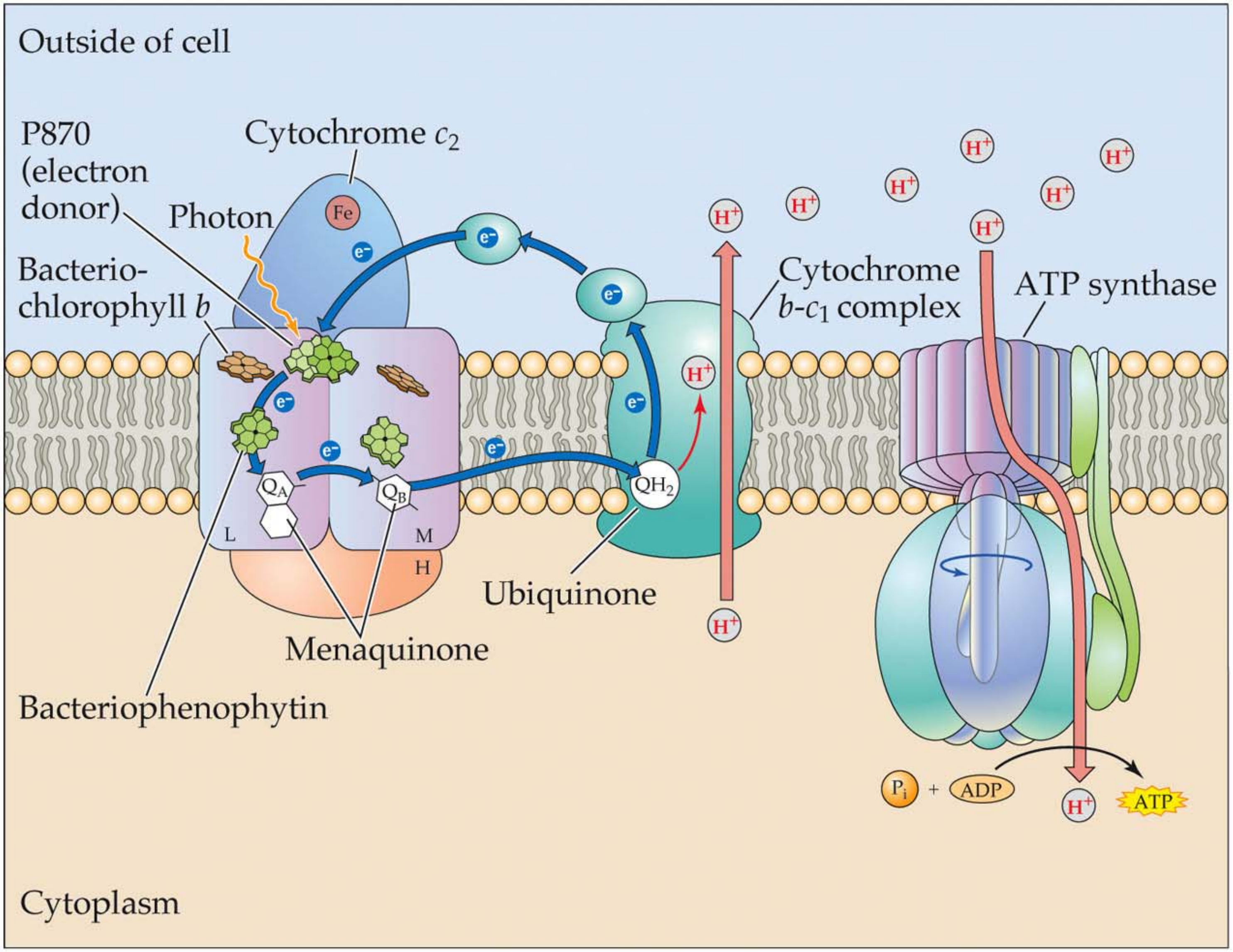





**Anoxygenic photosynthesis**
in purple nonsulfur bacteria
(e.g., Rhodobacter)

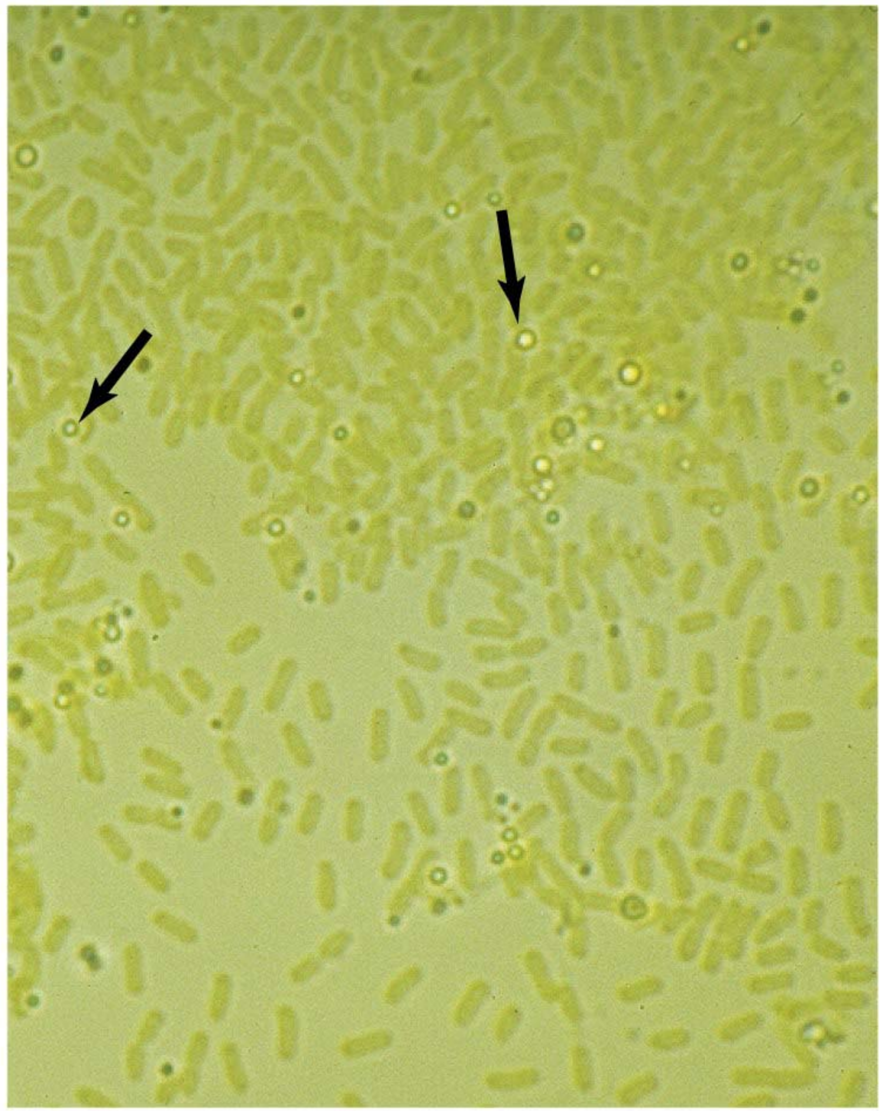
Also use REF: GNBs & PSBs

# Reaction center of purple nonsulfur bacteria

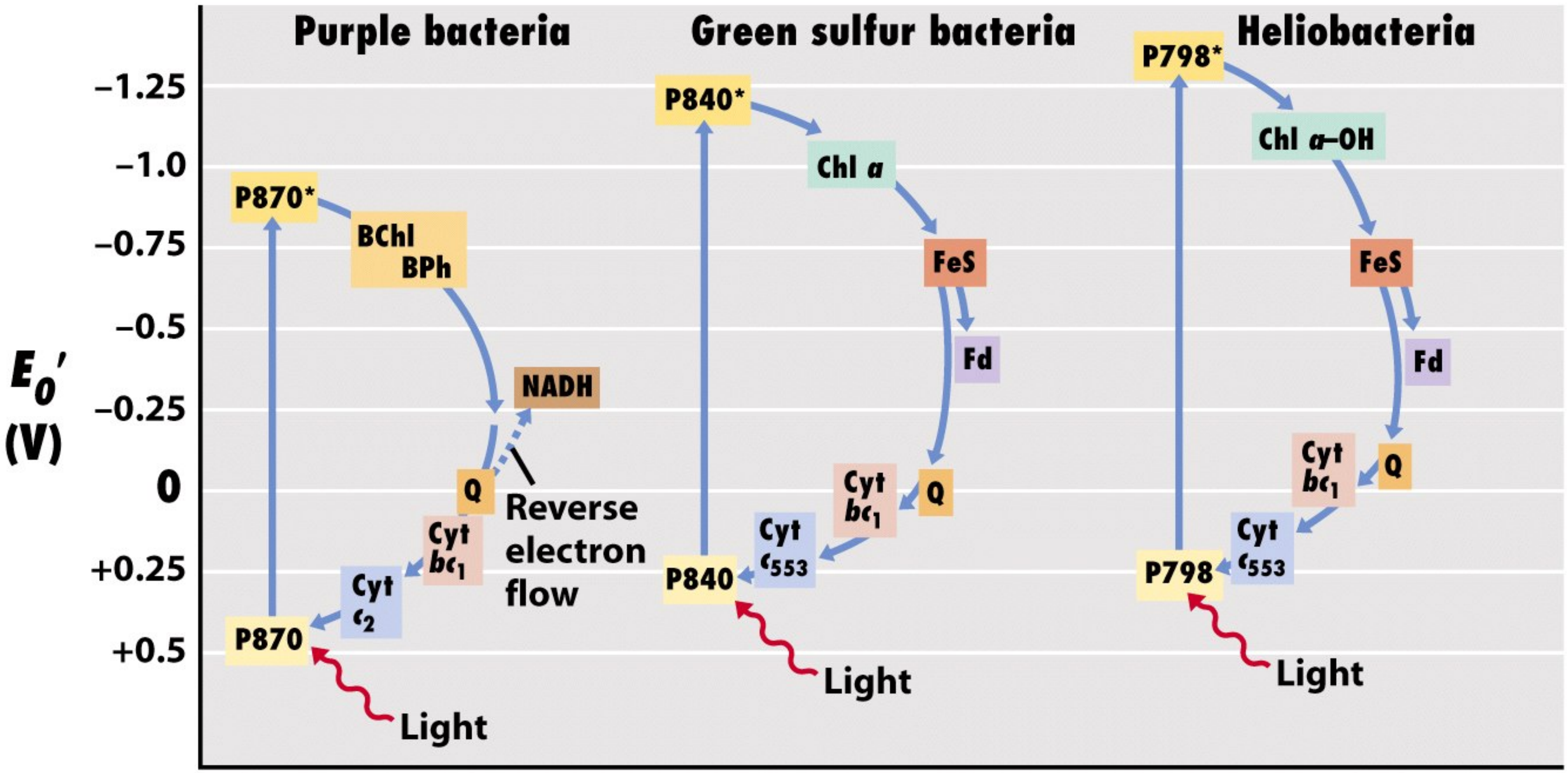


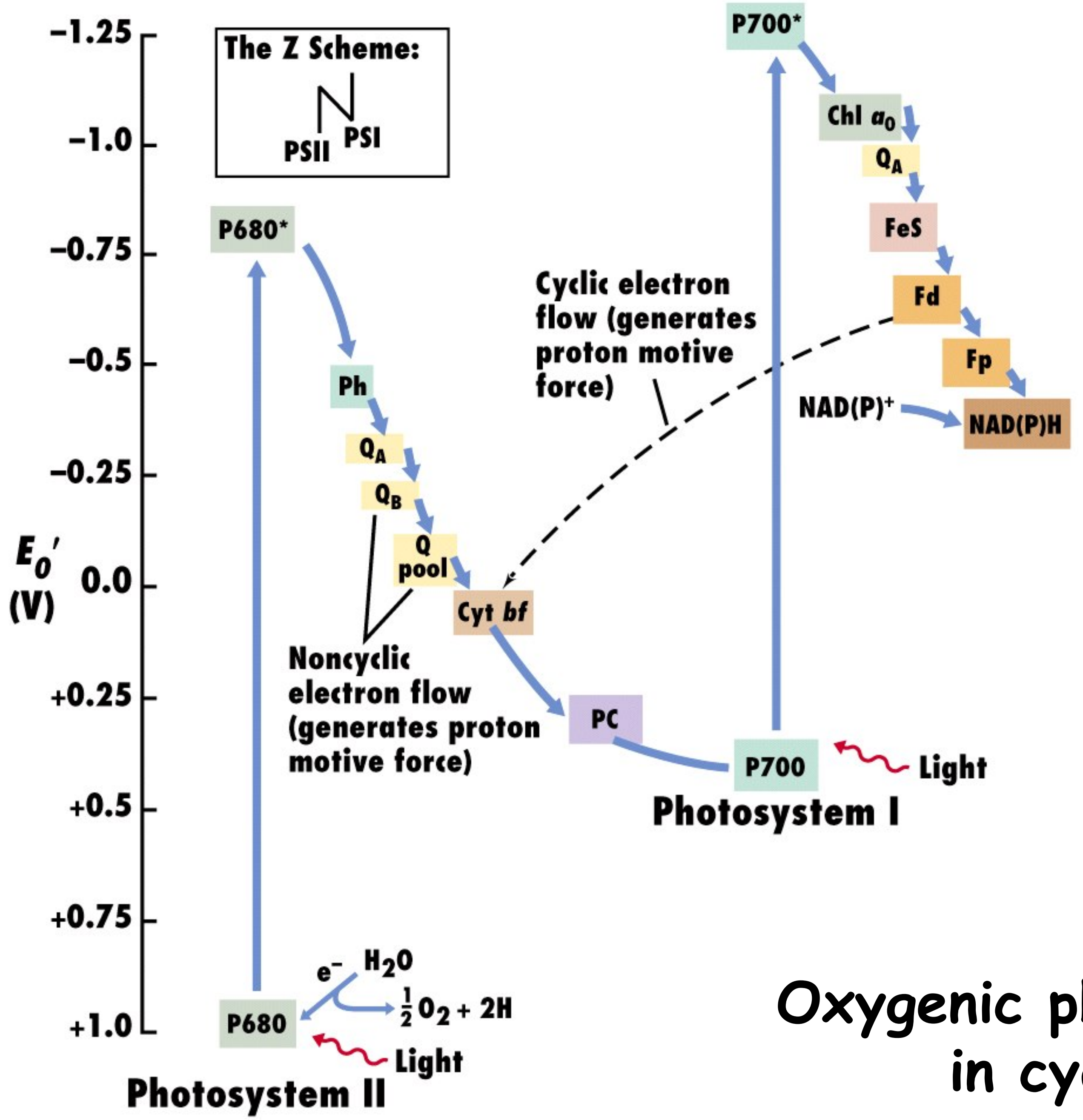
# Sulfur granules in purple sulfur bacteria e.g., Chromatium

# Sulfur granules in green sulfur bacteria
# e.g., Chlorobium



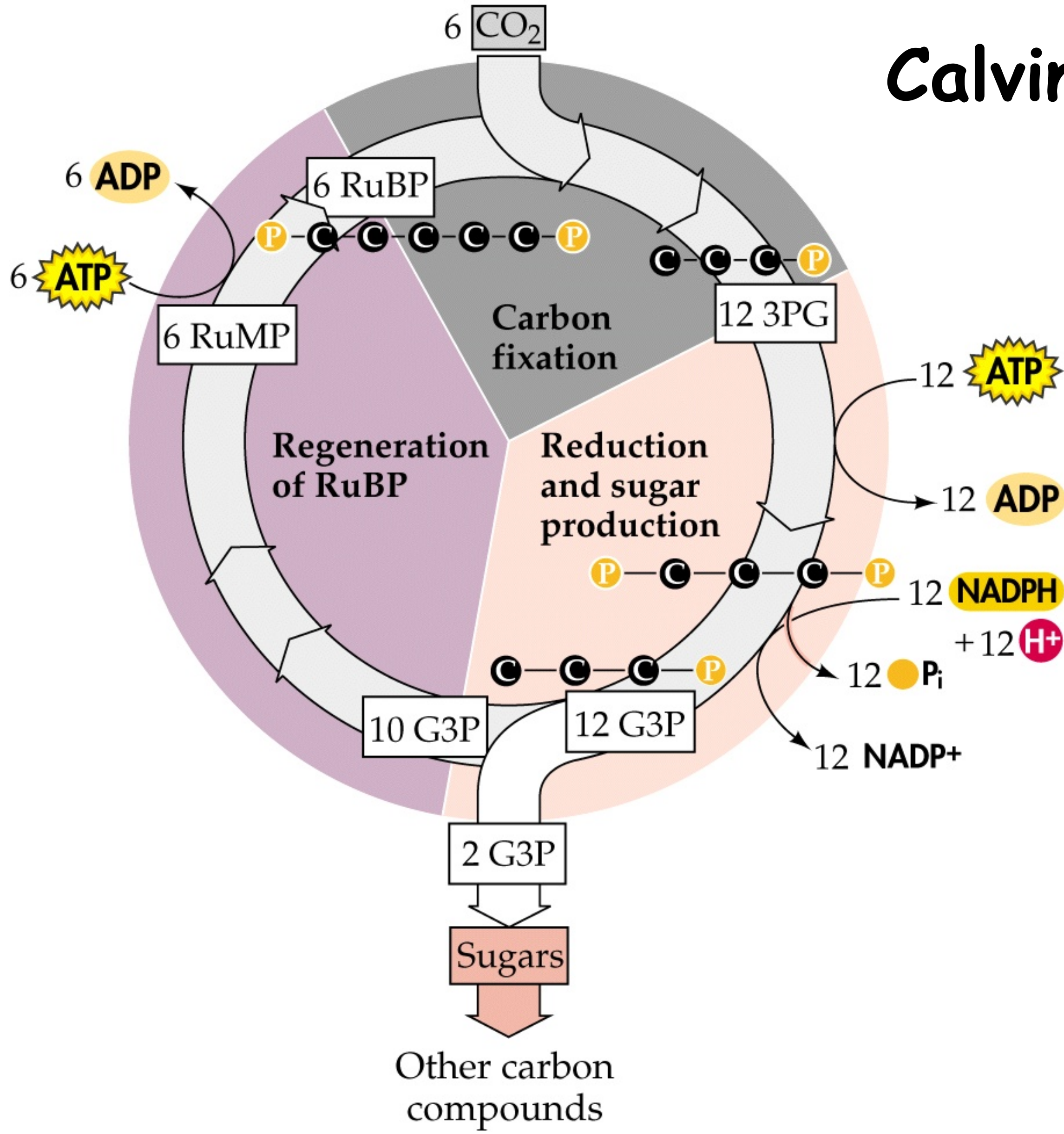
# Electron flow in phototrophs

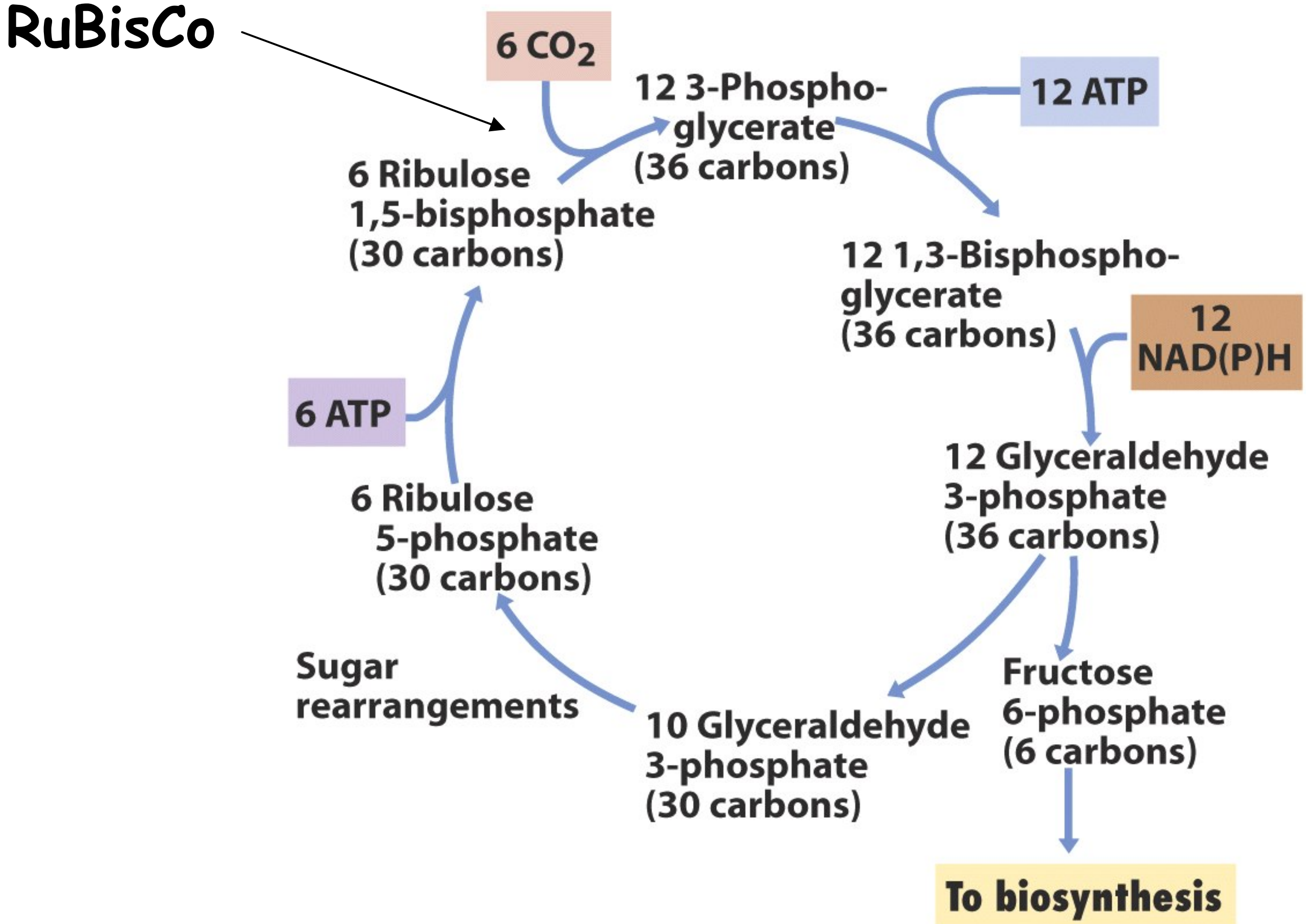





Oxygenic photosynthesis in cyanobacteria

# Calvin Cycle



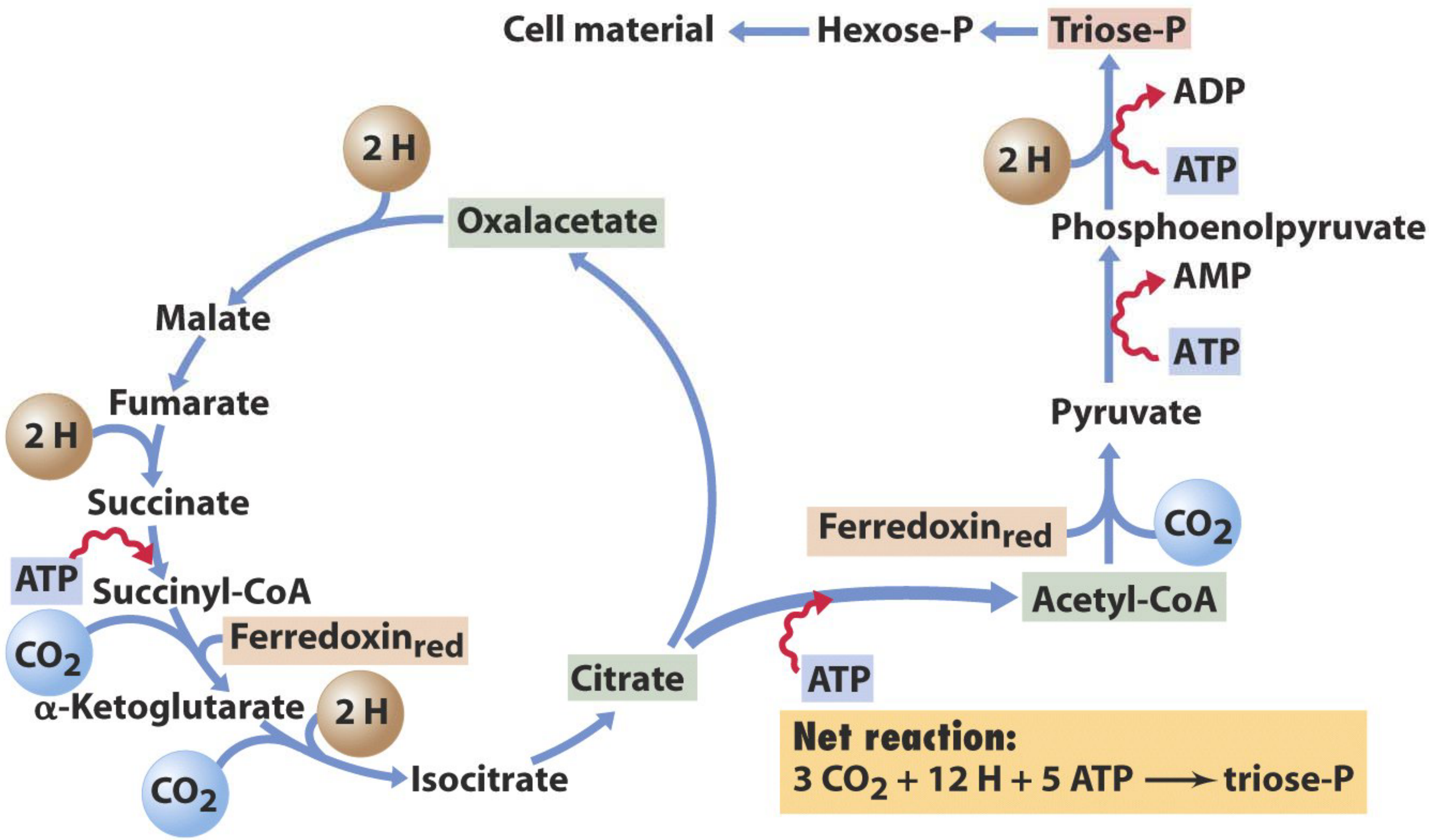



**Overall stoichiometry:**

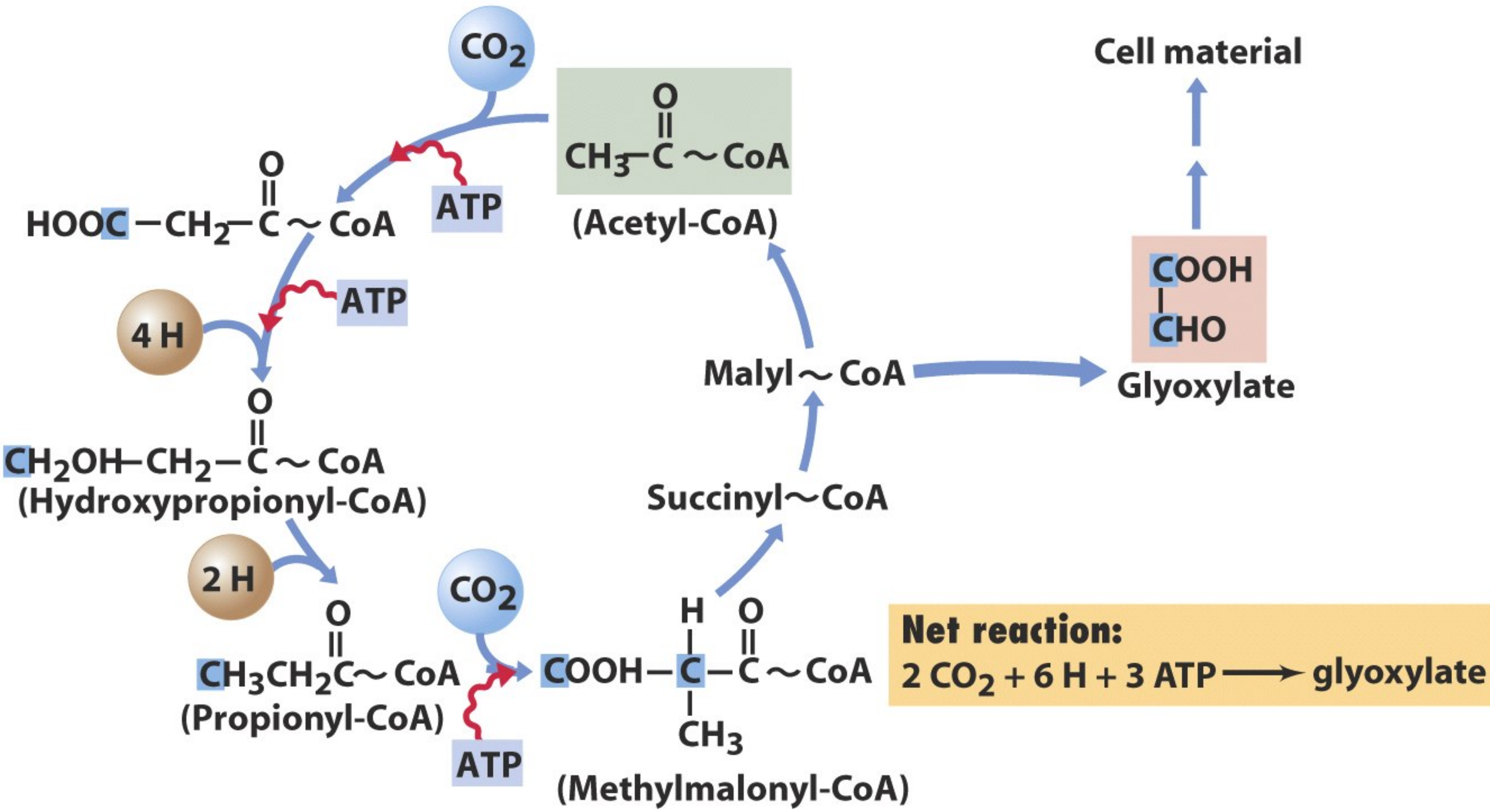
$6\ CO_2 + 12\ NADPH + 18\ ATP \longrightarrow$

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

# Reverse TCA in GSBs

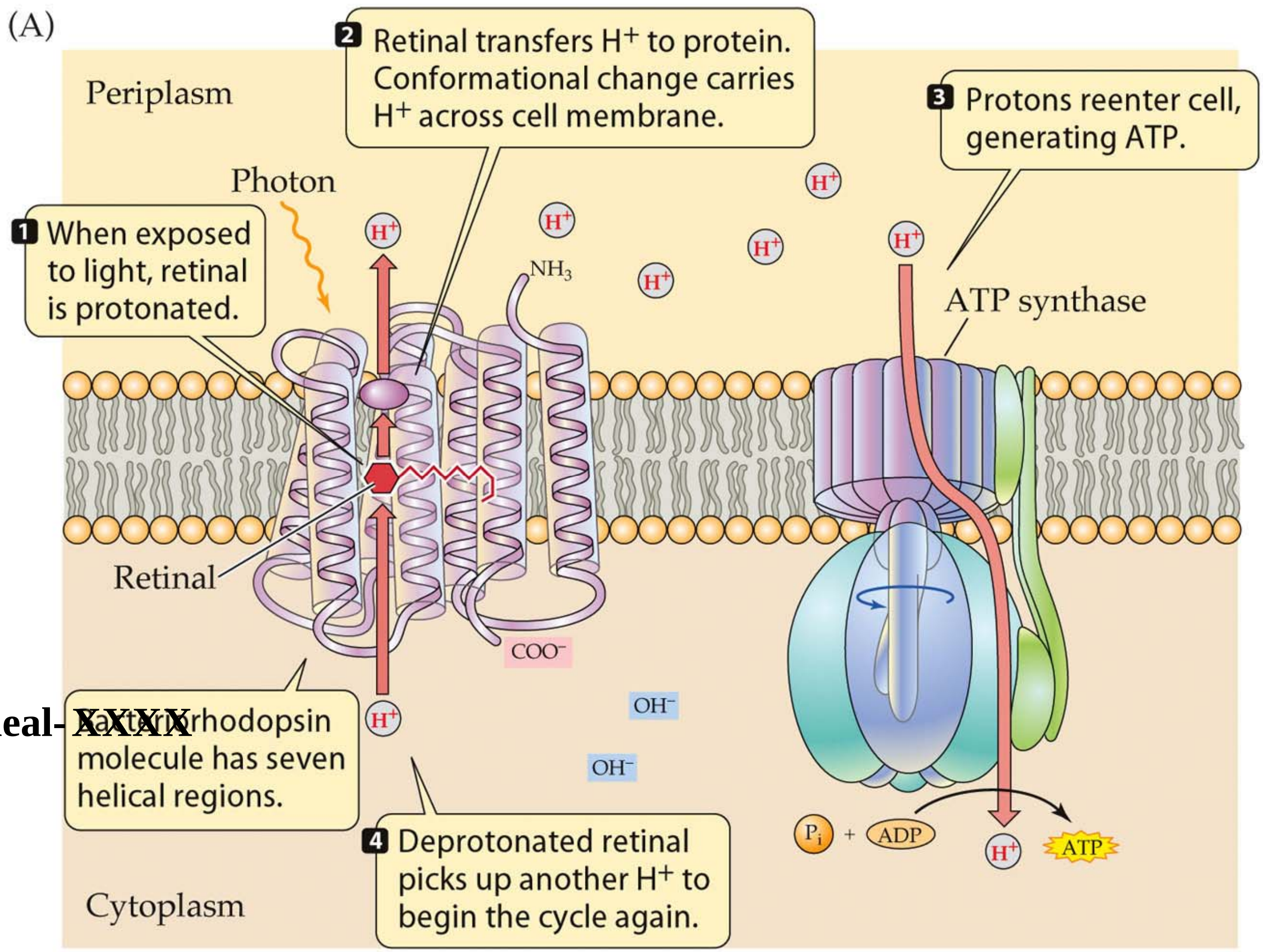


# Hydroxypropionate in GNBs



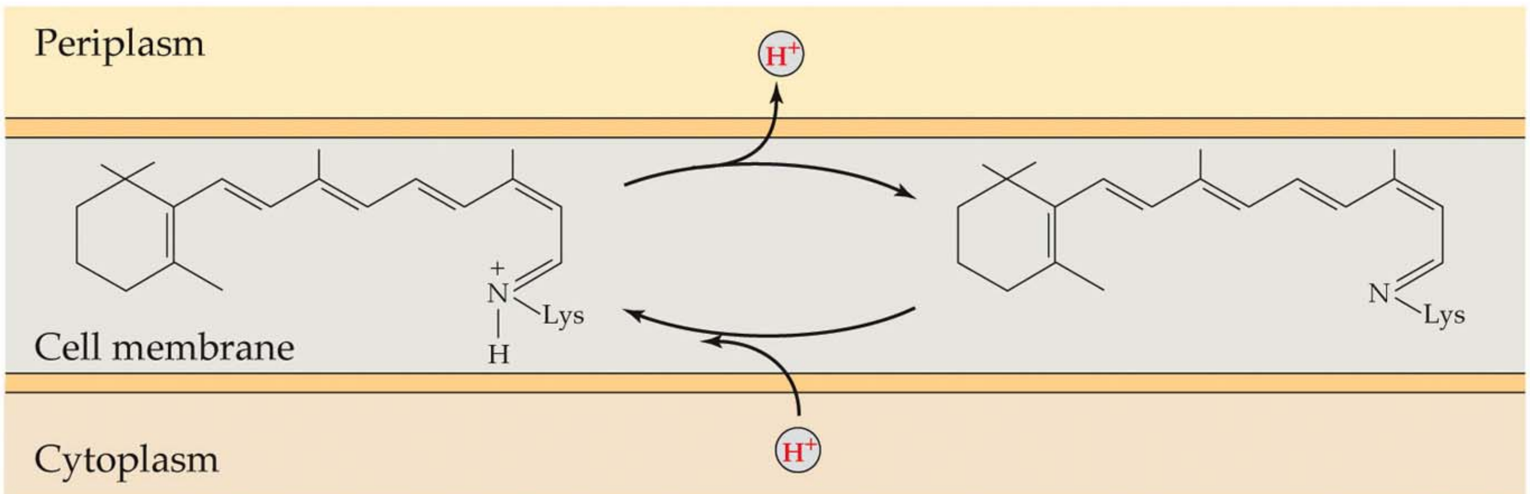
NASA

# A light-driven proton pump of halophilic archaea

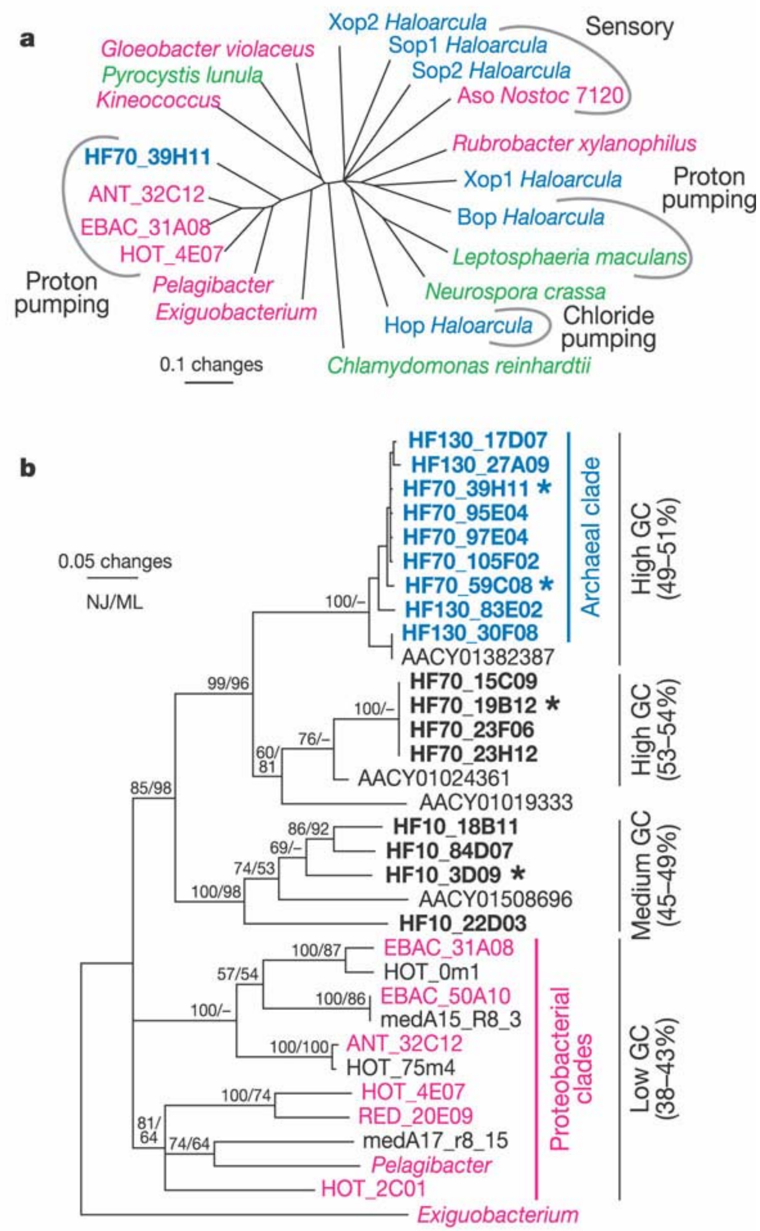



**Archaeal- XXXX**

# Light-driven proton pump of halophilic archaea




Archaeal rhodopsin: retinal structure




**Proteorhodopsin**
in marine *Bacteria*
and *Archaea*