MMG 301, Lecture 21   Photosynthesis

Questions for today:

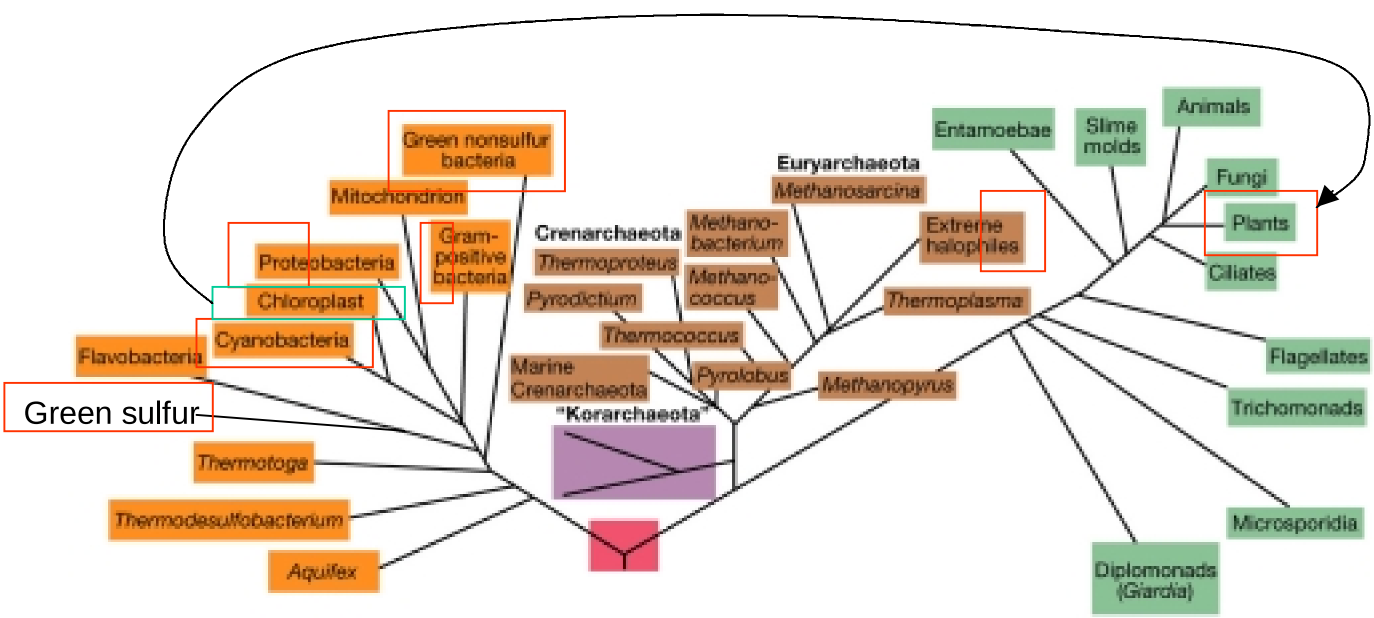
1. Which microorganisms carry out photosynthesis?

2. How is light energy absorbed?

3. What is <u>An</u>oxygenic Photosynthesis (and how is ATP and NAD(P)H made)?

4. What is <u>Oxygenic</u> Photosynthesis (and how is ATP and NAD(P)H made)?

Overview of Photosynthesis—who and how?

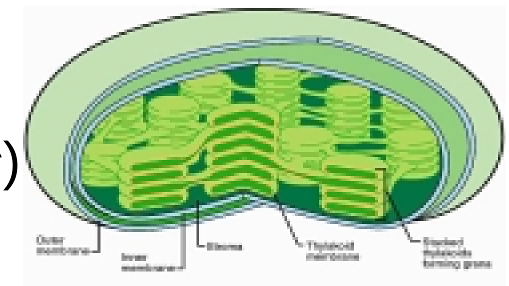


(when not fully enclosed, only some members are phototrophs)

Archaea: Some of the *Extreme Halophiles* use bacteriorhodopsin to pump protons (Lec. 5)

Eukaryotes: *Green plants and algae* use chloroplasts (derived by endosymbiosis) to carry out oxygenic photosynthesis (i.e., produce oxygen)(Lec. 6)

(e.g., *Chlamydomonas*)

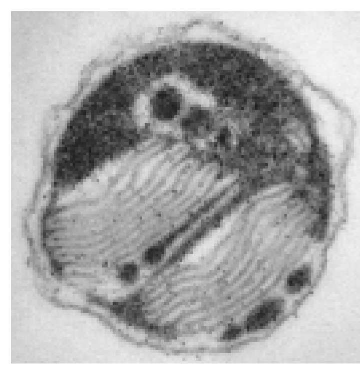


Bacteria: 4 groups

1. Cyanobacteria: Gram-negative, carry out oxygenic photosynthesis, ancestor of chloroplasts

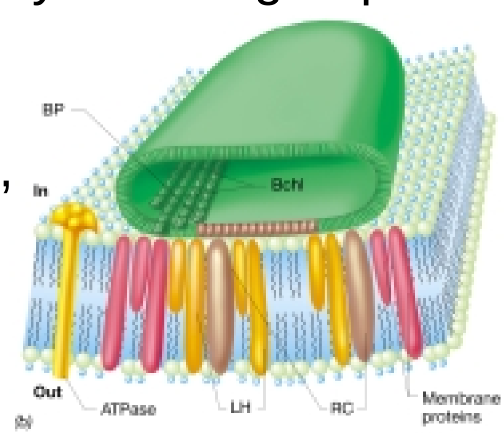
(e.g., *Oscillatoria*)

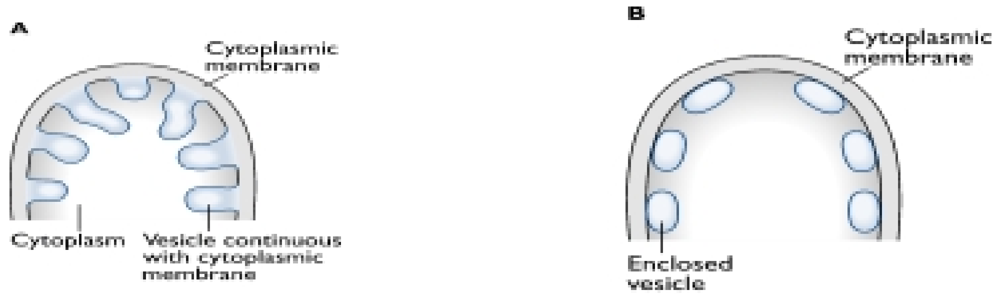
2. “purple bacteria”: dispersed within Proteobacteria, Gram-negative, carry out anoxygenic photosynthesis (no oxygen made) using components localized to invaginations of the cytoplasmic membrane called vesicles or lamellae



(e.g, *Rhodobacter*)

3. “green bacteria”: two phylogenetically distinct groups (sulfur and non-sulfur, with the green sulfur bacteria often having granules of sulfur within or attached to the cell), all are Gram negative, carry out anoxygenic photosynthesis, and possess chlorosomes with non-unit Membranes (e.g., *Chlorobium*)



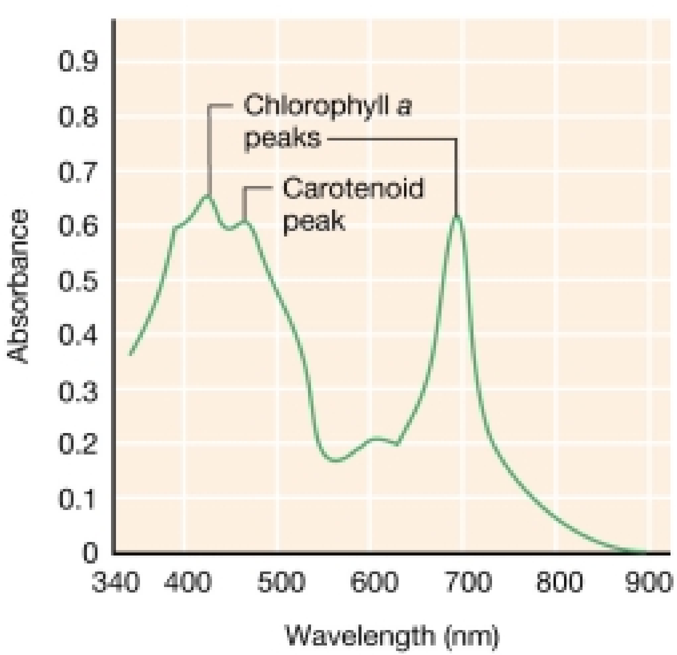


4. Heliobacteria: Gram-positive, carry out anoxygenic photosynthesis using components localized to cytoplasmic membrane. (e.g, *Heliobacterium*)

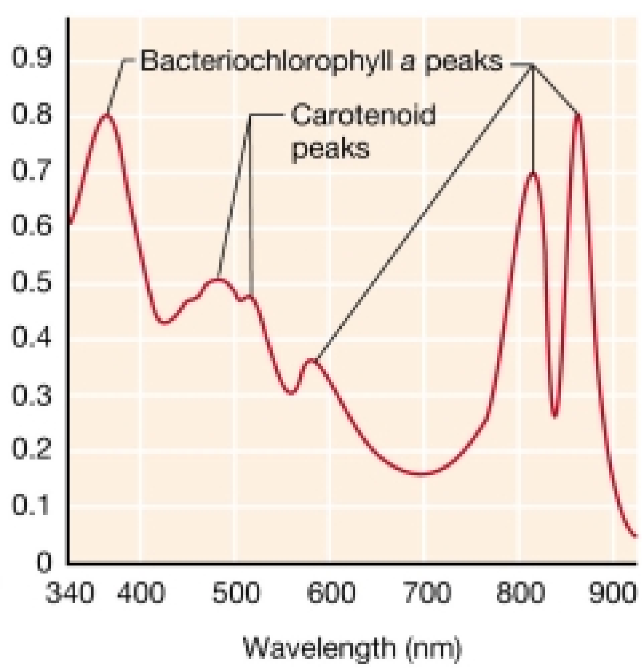
Photopigments—a colorful story!

<u>Light absorption by microorganisms</u>: different microbes absorb light energy at distinct wavelengths, base on the pigments they contain. This has important ecological implications!

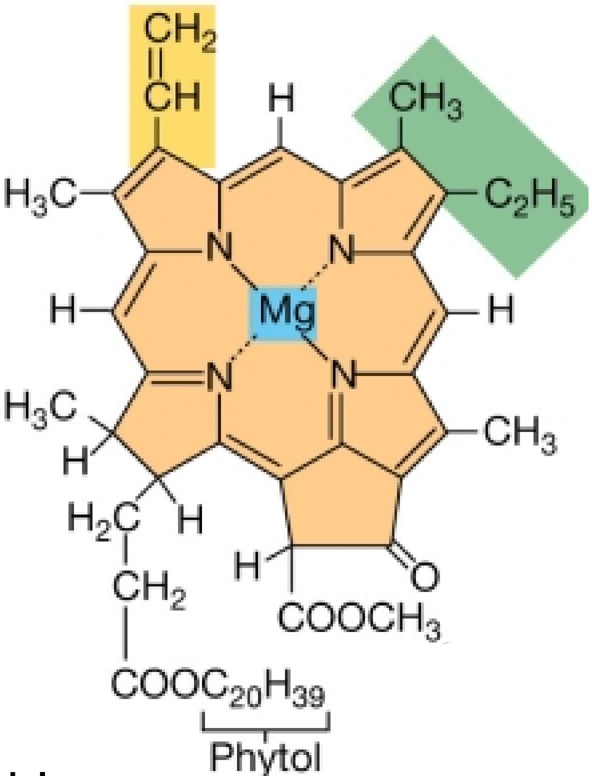
Green Alga



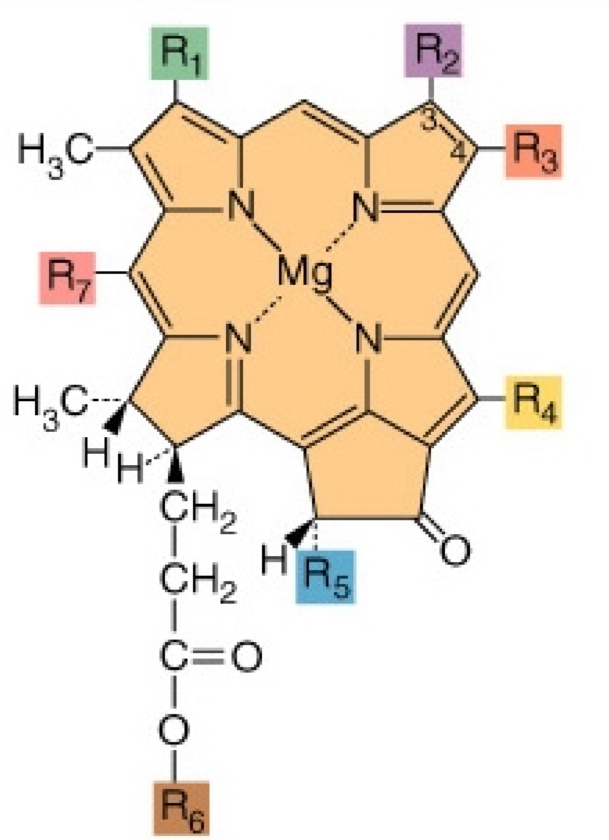
Purple Bacterium



<u>Chlorophyll</u>: eukaryotes have chlorophyll a, whereas different bacteria have various types of bacteriochlorophyll



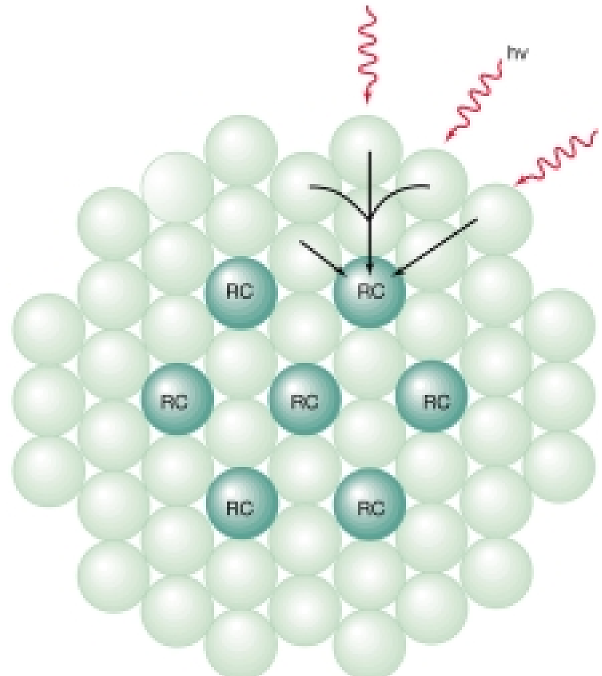
Chl a



Monitor the absorption to distinguish the type of Bchl present as a way to identify the type of microbe!

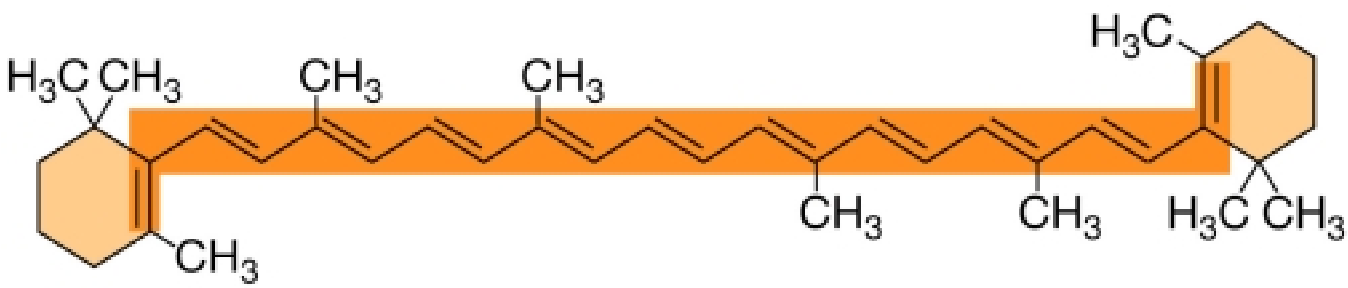
Pigment	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Absorption maxima (nm) In vivo	Absorption maxima (nm) Extract (methanol)
Bacterio-chlorophyll *a* (purple bacteria)	$-C(=O)-CH_3$	$-CH_3$[b]	$-CH_2-CH_3$	$-CH_3$	$-C(=O)-O-CH_3$	P/Gg[c]	$-H$	805 830–890	771
Bacterio-chlorophyll *b* (purple bacteria)	$-C(=O)-CH_3$	$-CH_3$[b]	$=C(H)-CH_3$	$-CH_3$	$-C(=O)-O-CH_3$	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

Both Chl and Bchl are membrane-bound and have dual roles: light harvesting (antenna) and a “special pair” the photoreaction center.



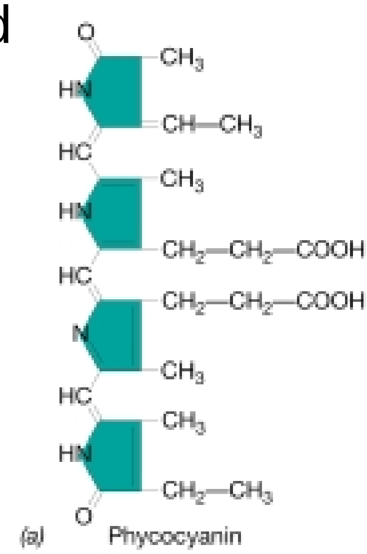
Other pigments also are typically membrane bound.

<u>Carotenoids</u>: diversity of compounds with extensive conjugation that are found in all phototrophs. **Beta-carotene**

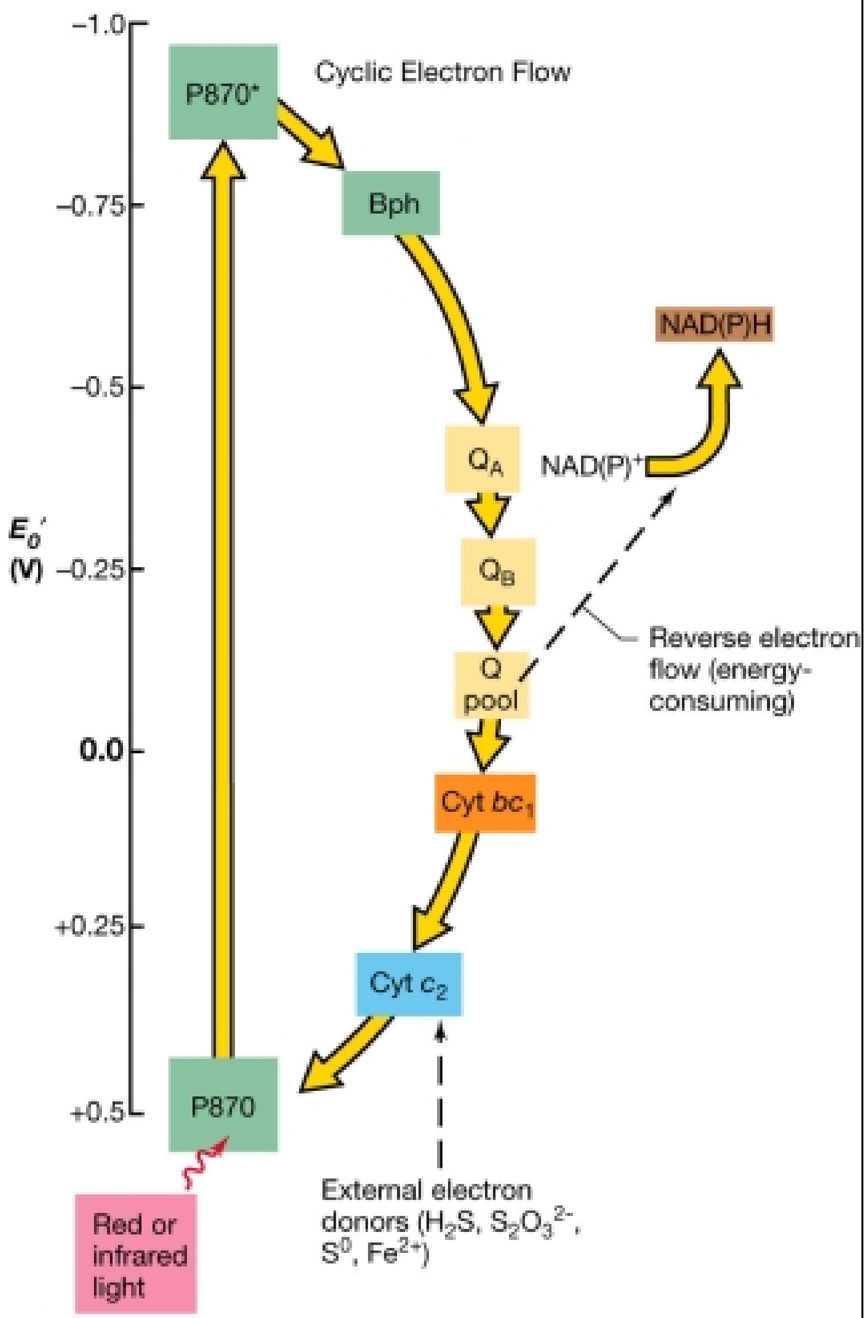


Depending on the structure, these may be yellow, red, brown, or green, and again can be used to identify species. Roles include light harvesting and *photoprotection.*

Cyanobacteria and algal chloroplasts contain *phycoerythrin* (red) and *phycocyanin* (blue): open chain tetrapyrroles



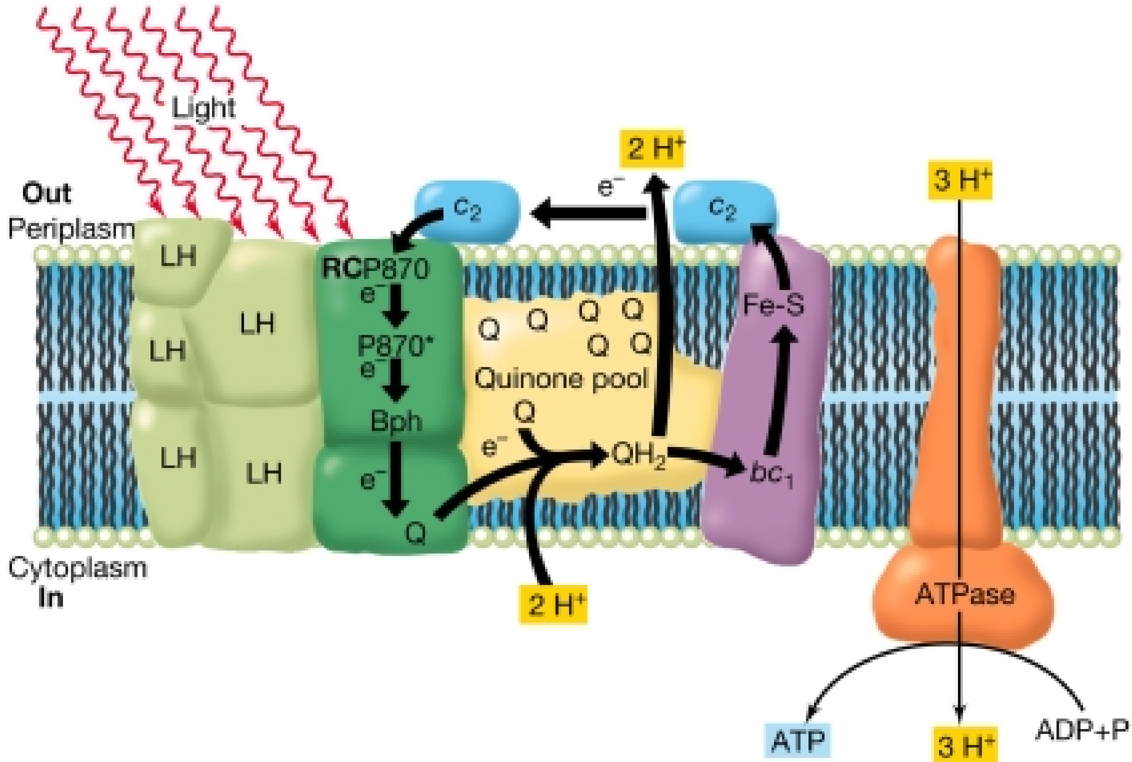
Anoxygenic Photosynthesis (in purple bacteria)



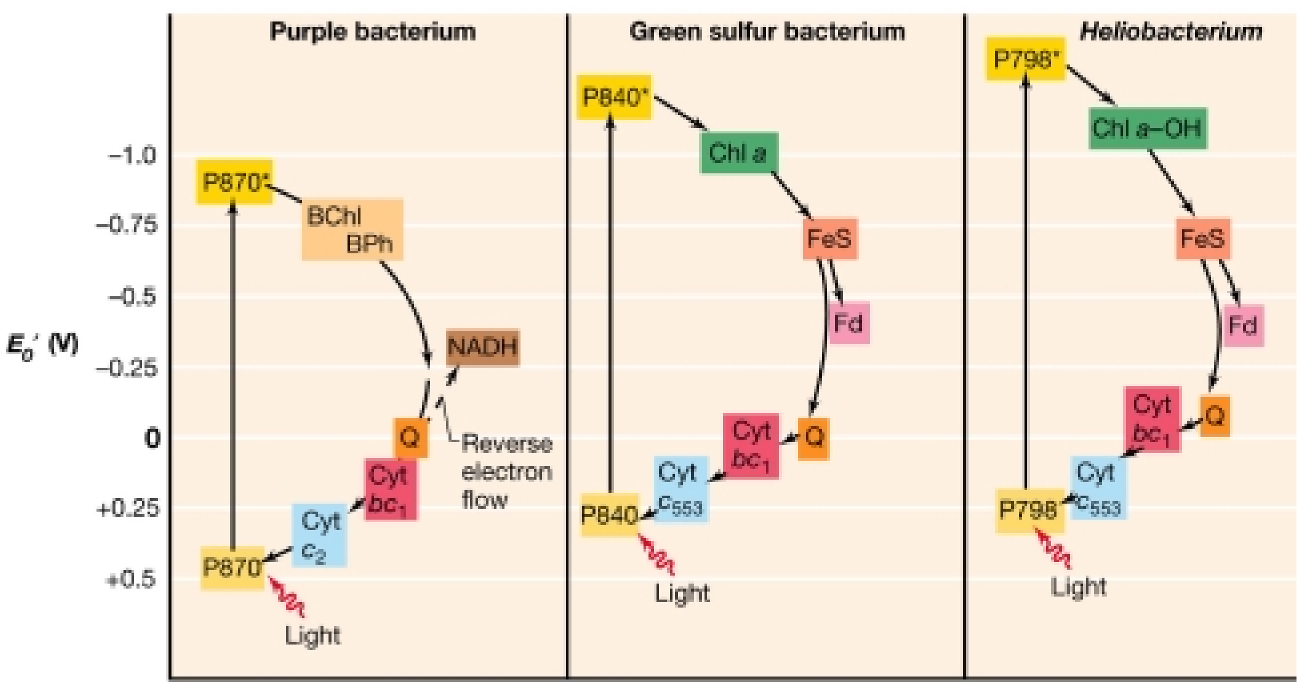
This process is often termed cyclic photophosphorylation

1. Key features:
2. Cyclic electron flow
3. Electron transfer reactions generate PMF
4. PMF drives ATP synthesis
5. Withdrawal of electrons for NAD reduction requires the presence of an external electron donor
6. Some ATP is burned to energize electrons for NAD reduction

How the protons are pumped

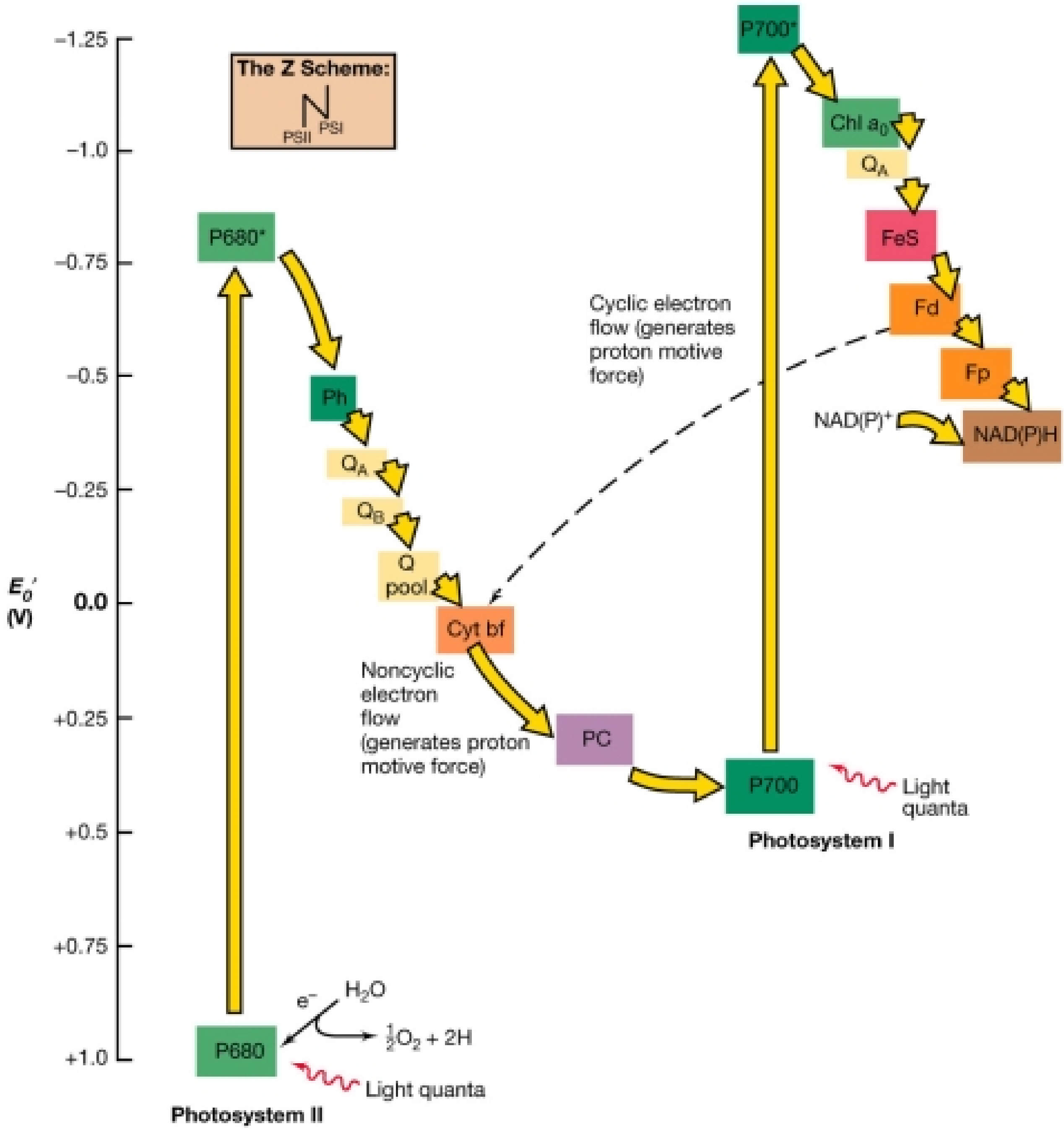


<u>Variations in other bacteria</u>: different components, no need for reverse electron flow



Oxygenic Photosynthesis

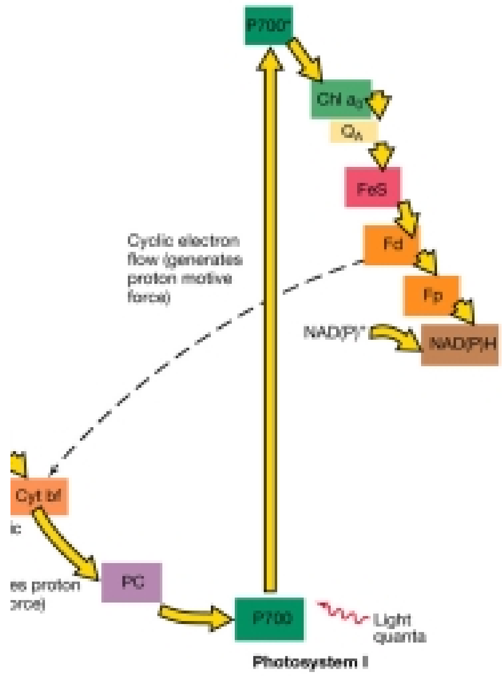
Two photosystems (P700 and P680) that are connected by an electron transport chain



Key points to understand: electron flow in PS I & PS II, method of NADP reduction, oxygen formation

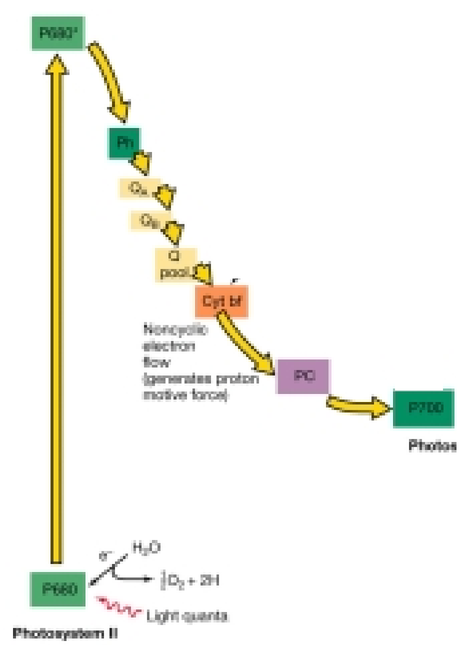
<u>PS I</u>

-- Absorbs light energy at 700 nm
-- Participates in cyclic electron flow that generates a PMF
-- Provides electrons for NADP reduction, but this requires a source of electrons



<u>PS II</u>

-- Absorbs light energy at 680 nm
-- Does not participate in cyclic electron flow
-- Provides electrons to PS II while generating a PMF
-- Uses water as a source of electrons (*an amazing reaction*!)
-- PC = plastocyanin (a 1-e carrier Cu protein
-- Oxygen formed at a 4Mn site



Things to think about regarding photosynthesis

- Where do phototrophic bacteria live? (some answers may surprise you!)

- How do different phototrophs co-exist in the same general environment?

- What is needed to synthesize the photosynthetic machinery in a phototroph? (e.g., what is needed to transform *E. coli* into a phototroph?)

- How does the photosynthetic machinery become assembled in bacteria? In algae?

- How could such a complex system evolve?