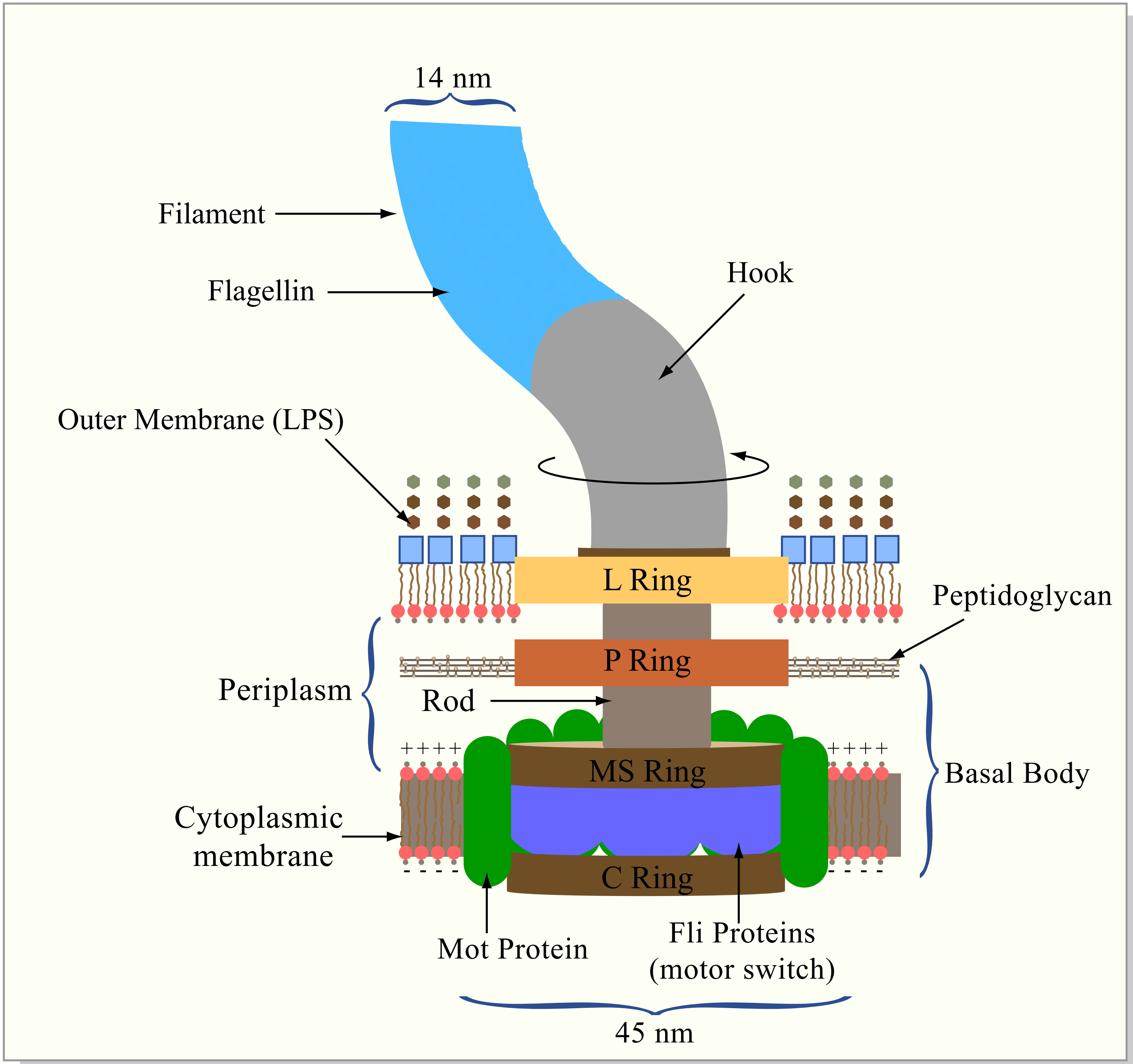
Systems Microbiolog

Weds Sept 13 - Ch 5 & Ch 17 (p 533-555)

Bioenergetics & Physiol.Diversi

- FINISH UP CHEMOTAXIS
- BASIC MODES OF ENERGY GENERATI
- THERMODYNAMICS OF GROWTH
- DIVERISTY IN ENERGY ACQUISITIO



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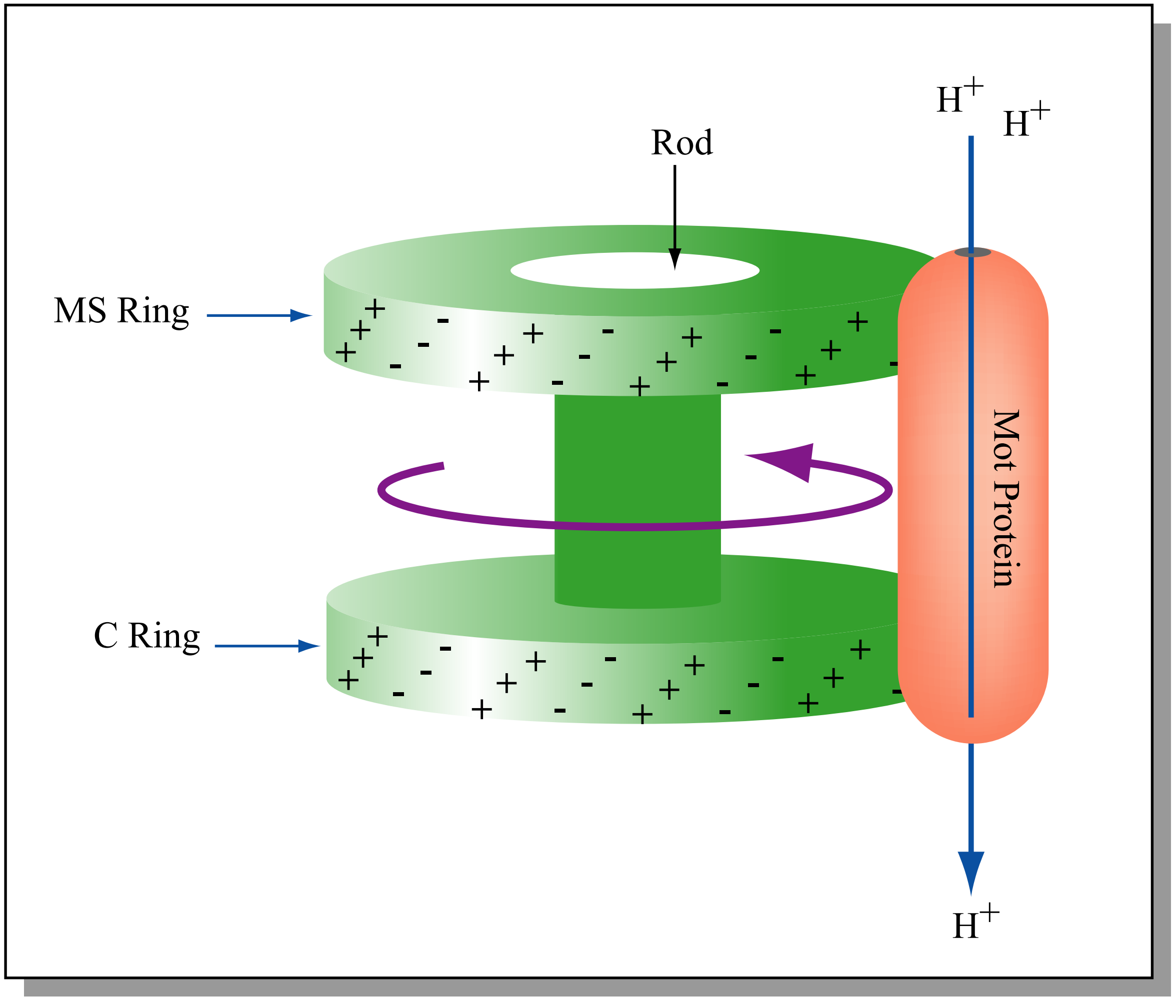

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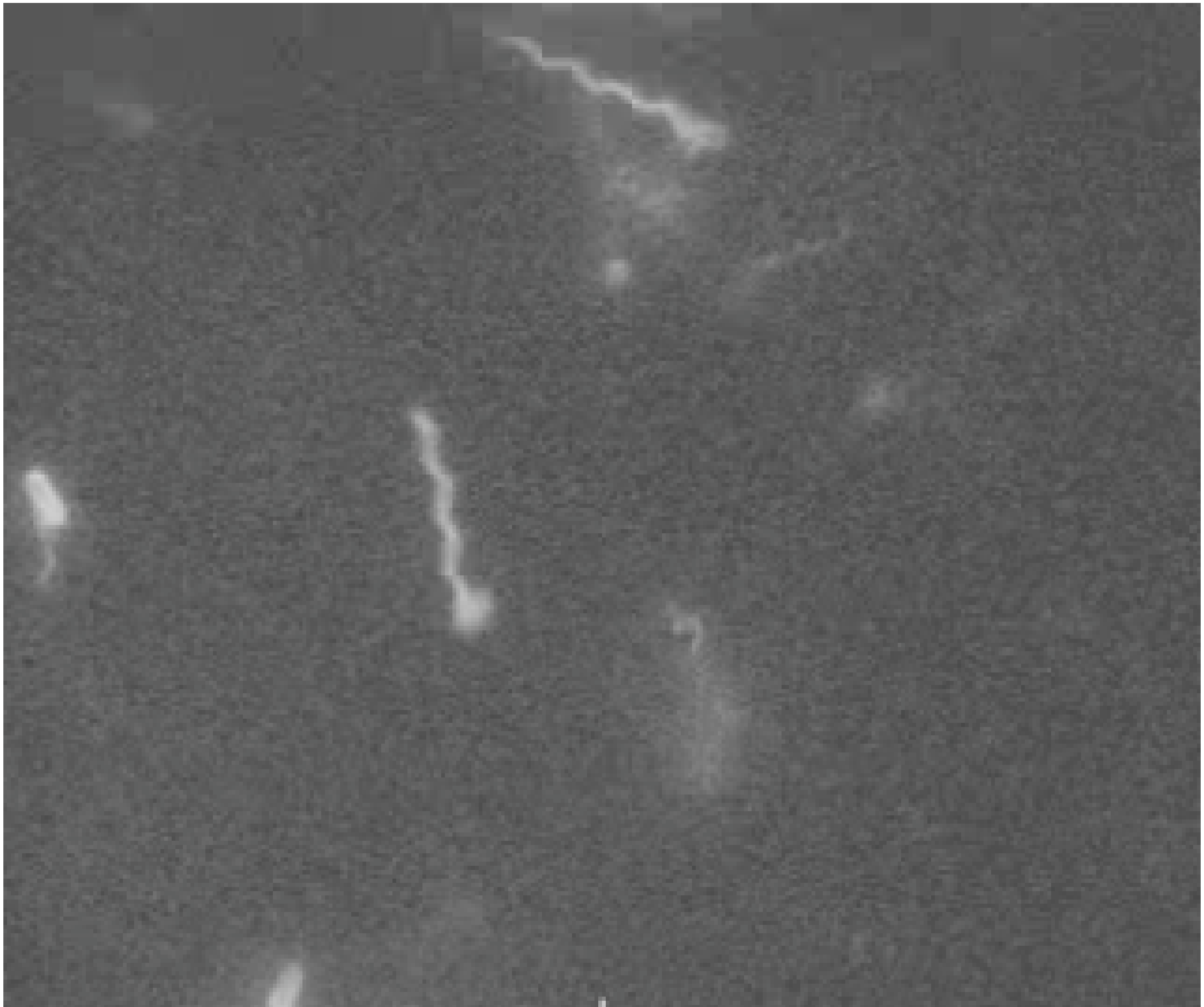


http://www.rowland.harvard.edu/labs/bacteria/projects_filament.html, Howard Berg

Filaments in the bundle are usually normal, i.e., left-handed helices with pitch about 2.5 μm and diameter about (
with the motors turning counterclockwise. During the tumble, one or more motors switch to clockwise, and their fi
leave the bundle and transform to semi-coiled, i.e., right handed helices with pitch about half of normal.

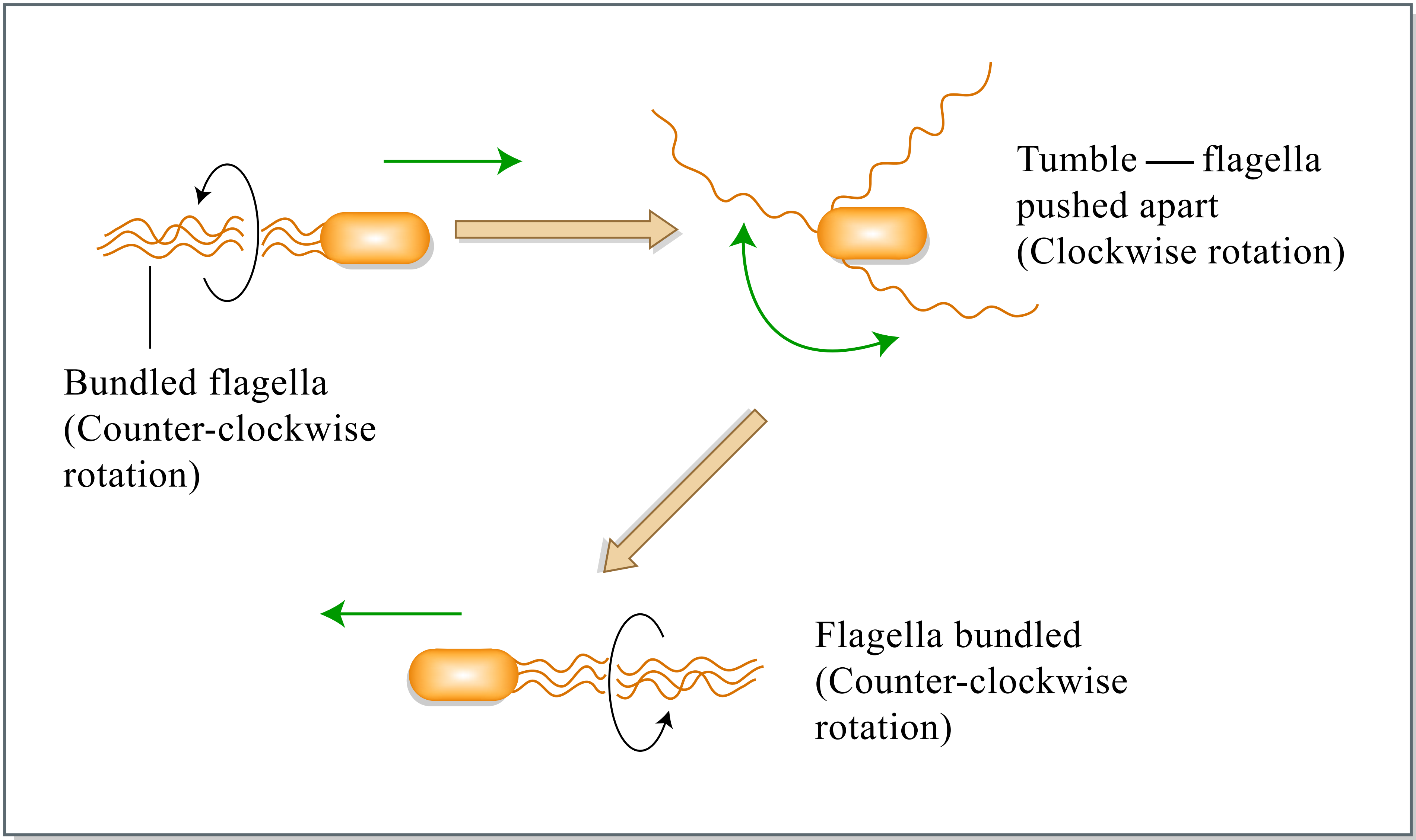


Figure by MIT OCW.

See Figure 4-62 in Madigan, Michael, and John Martinko. *Brock Biology of Microorganisms*. 11th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2006. ISBN: 0131443291.

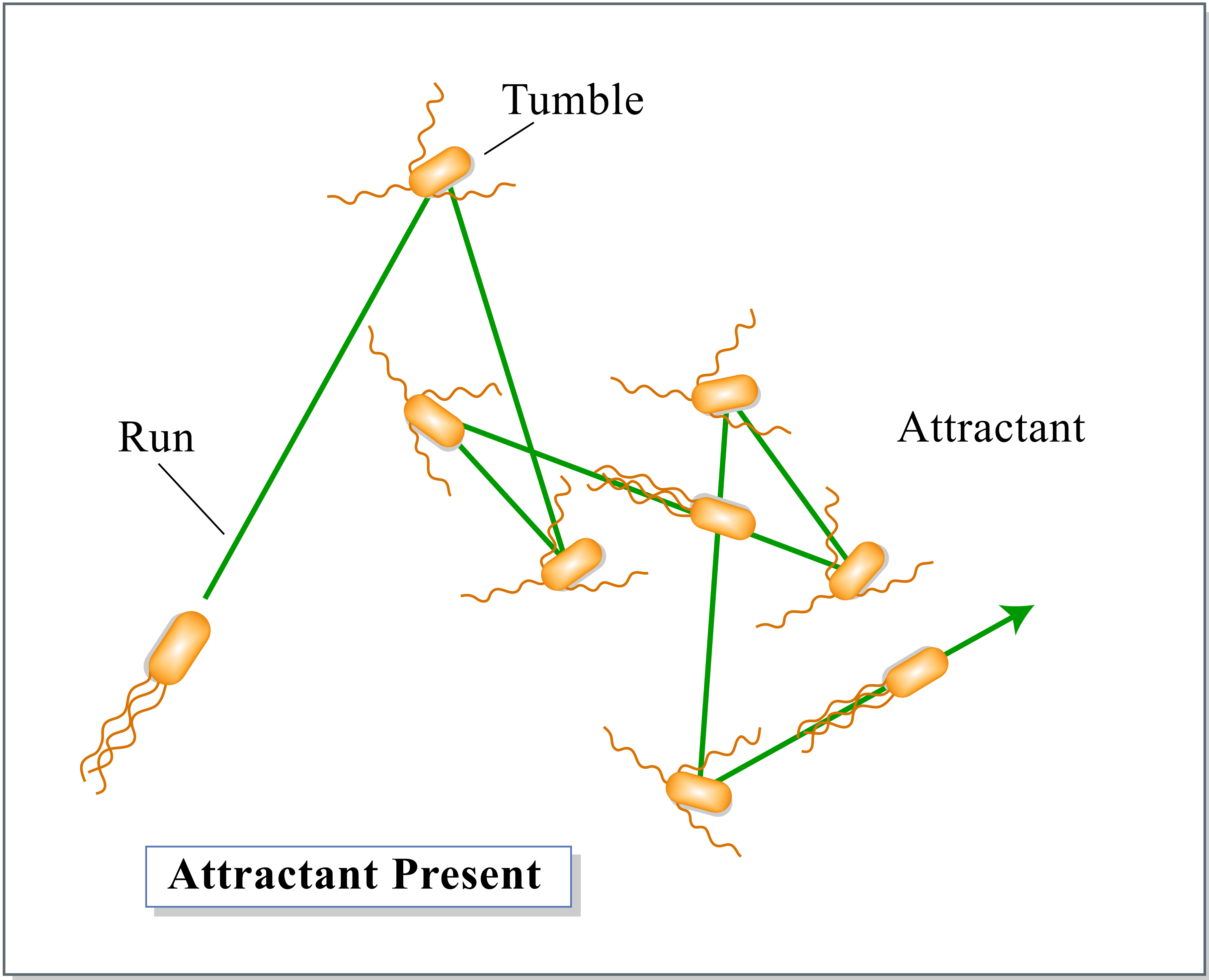


Figure by MIT OCW.

Chemotactic Signal transduction

Brock, ch 8.13, pp 226-227

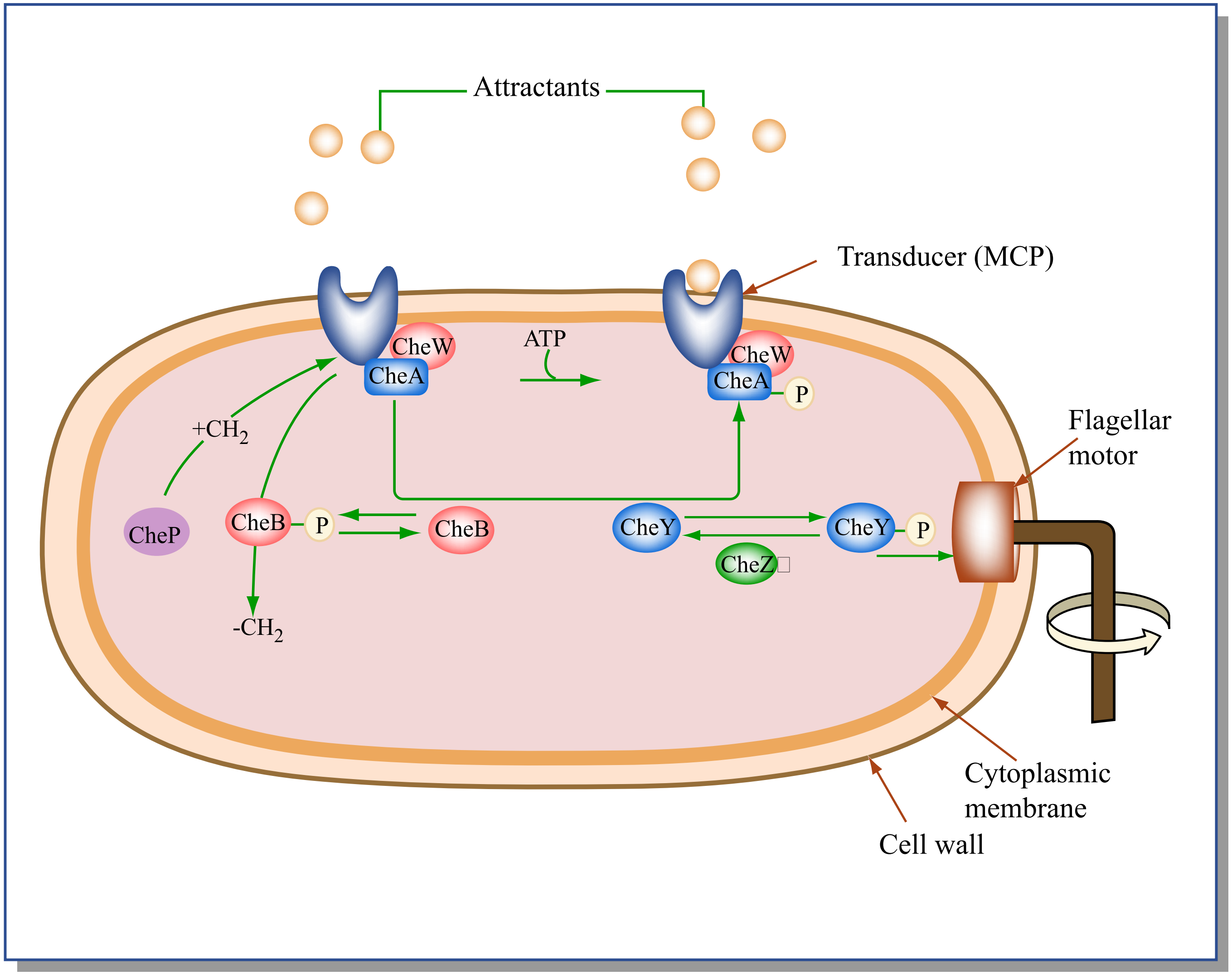


Figure by MIT OCW.

- CheA is coupled to the receptor through complex with CheW
- **Ligand free receptors stimulate autophosphorylation** of His residue of **CheA**
- **Attractant-bound receptors inhibit** CheA phosphorylation, repellent increases the level of phosphorylation
- **CheA donates phosphate** to **CheB** and **CheY**
- **Phosphorylated CheY** interacts with switch proteins in the flagellar motors to generate CW rotation (Motors rotate CCW by default)
- So the level of phospho-CheY determines the cell's swimming behavior
- Mutants that lack CheA or CheY have no mechanism to cause clockwise rotation of flagella and hence swim continually.

Methylation – another level of chemotaxis regulation (**Adaptation**)
(Cells can't sense absolulte concentration - only changes in conc. gradient over time)

In the presence of attractant – MCP is methylated by **CheR** (methyltransferase chemotaxis protein), catalyses transfer of methyl group from S-adenosylmethionine.

The level of methylation of MPC affects receptor sensitivity to attractant of repellent

Fully methylated receptor is not able to respond to attractant =>

CheA gets autophosphorylated,
CheA transfers phosphoryl group to CheB
CheB is a demethylase => removes methyl group from MCP
and restores its activity

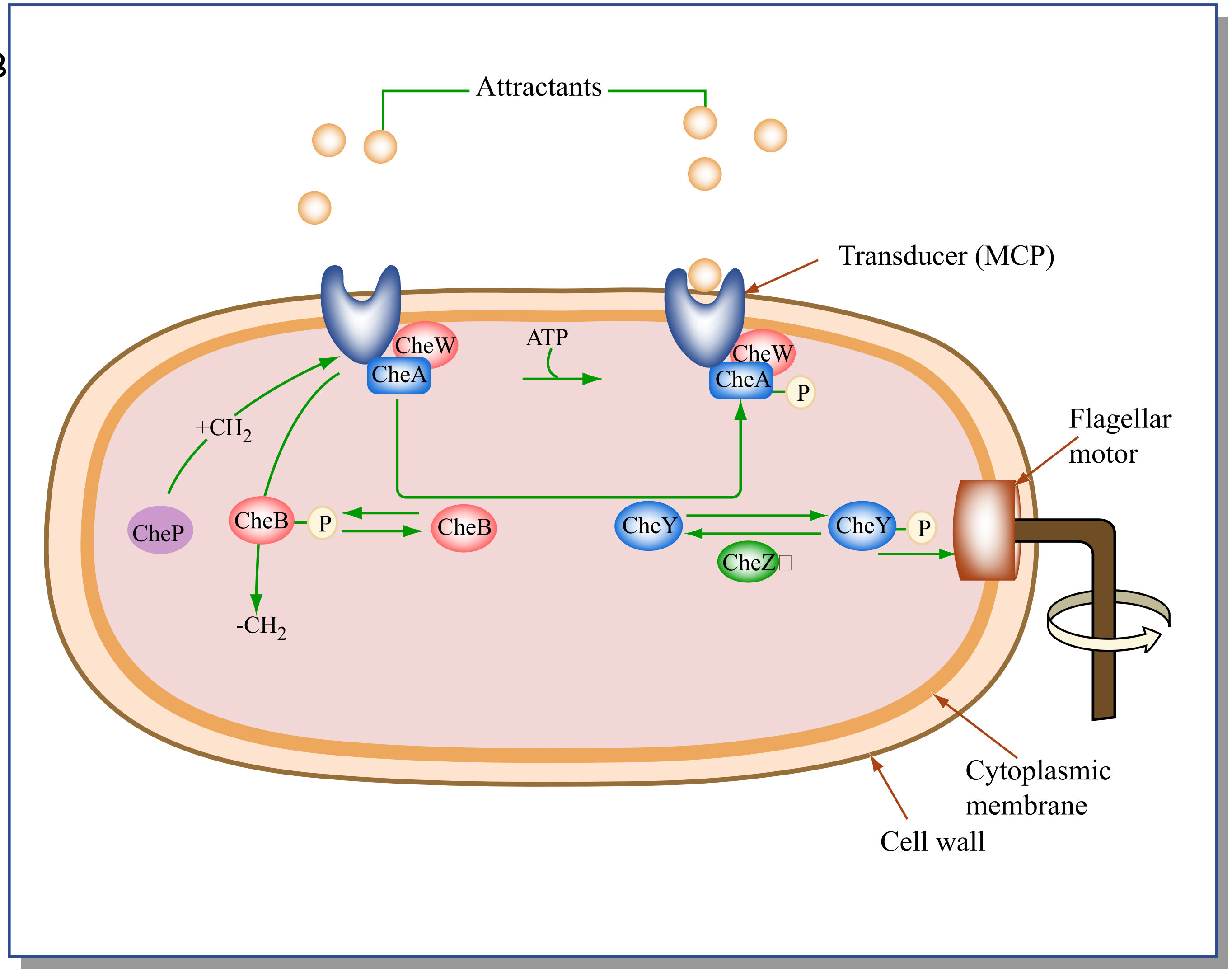


Figure by MIT OCW.

Chemotactic Signal transduction

Bacterial motility: How do pili pull? Dale Kaiser

Current Biology, Volume 10, Issue 21 , 1 November 2000, Pages R777-R780

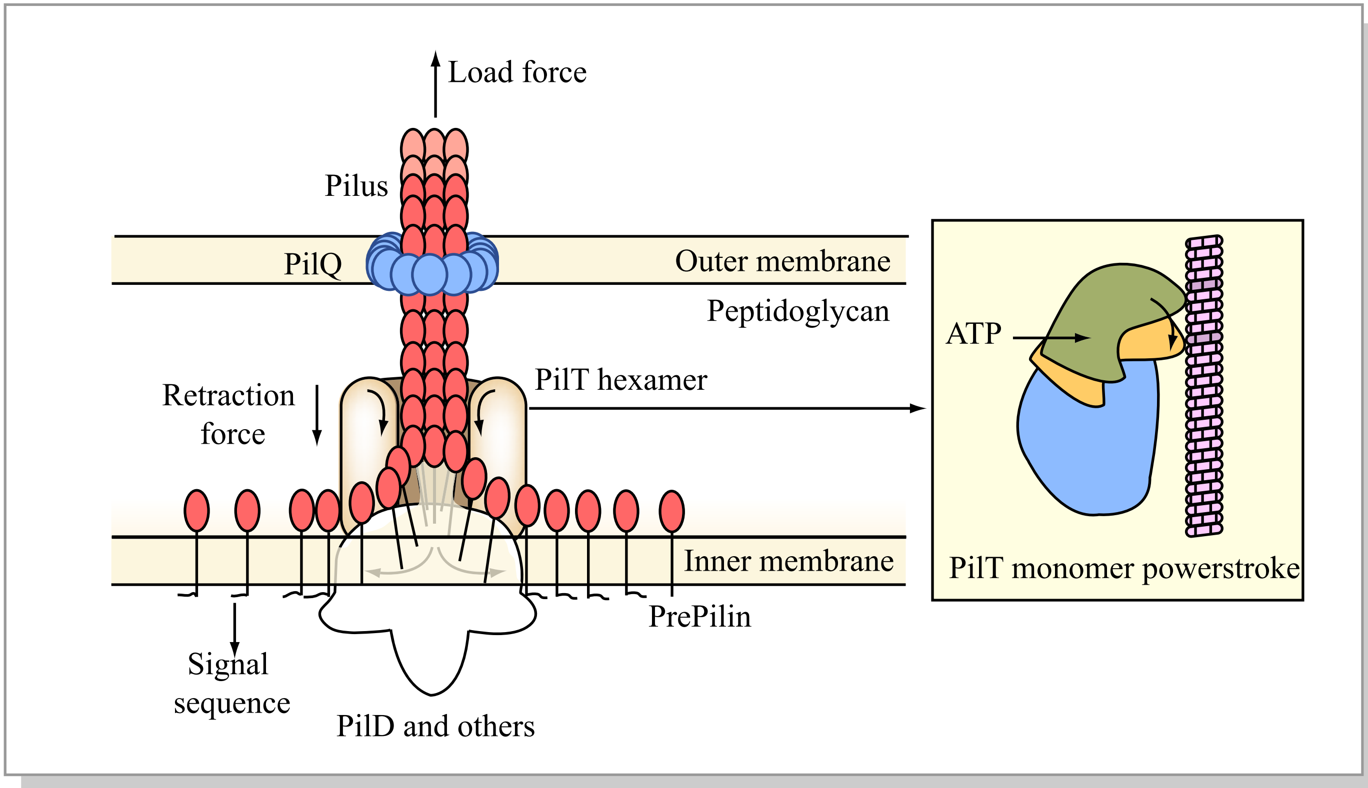


Figure by MIT OCW.

Cartoon interpretation of type IV pilus retraction

Images removed due to copyright restrictions.
See http://www.webcom.com/alexey/moviepage.html.

Grappling hook model for twitching motility

- the pilus fiber extends;

(2) the fiber binds to a substrate or to another cell;

(3) the fiber retracts (the power stroke)

FOR GROWTH AND BIOSYNTHESIS CELLS NE

1. Energy, in the form of ATP - produced from light energ oxidation of energy rich substrates, and proton translocating ATPase.

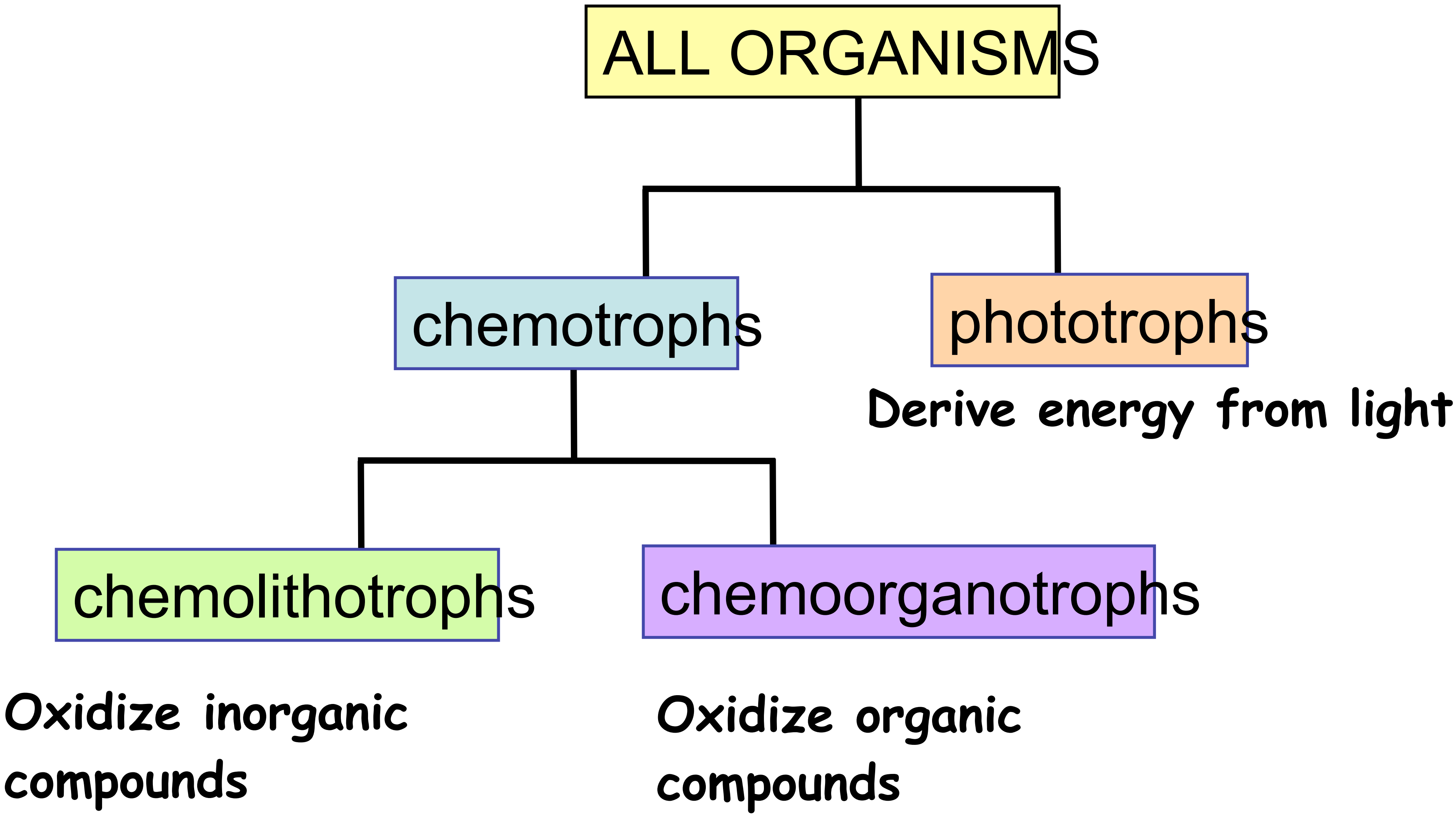
2. Reducing power, in the form of NADH, produced (mainly) by the oxidation of energy rich substrates and the reductior NAD^+.

3. Basic macronutrients: C,N,P,S (nmol to mmol in the envir Mg^{++}, K^+, Na^+, Ca^{++}

3. Micronutrients - Fe, Mo, Se, W, V, Zn, Ni, etc (also vit and other growth factors in some cases)

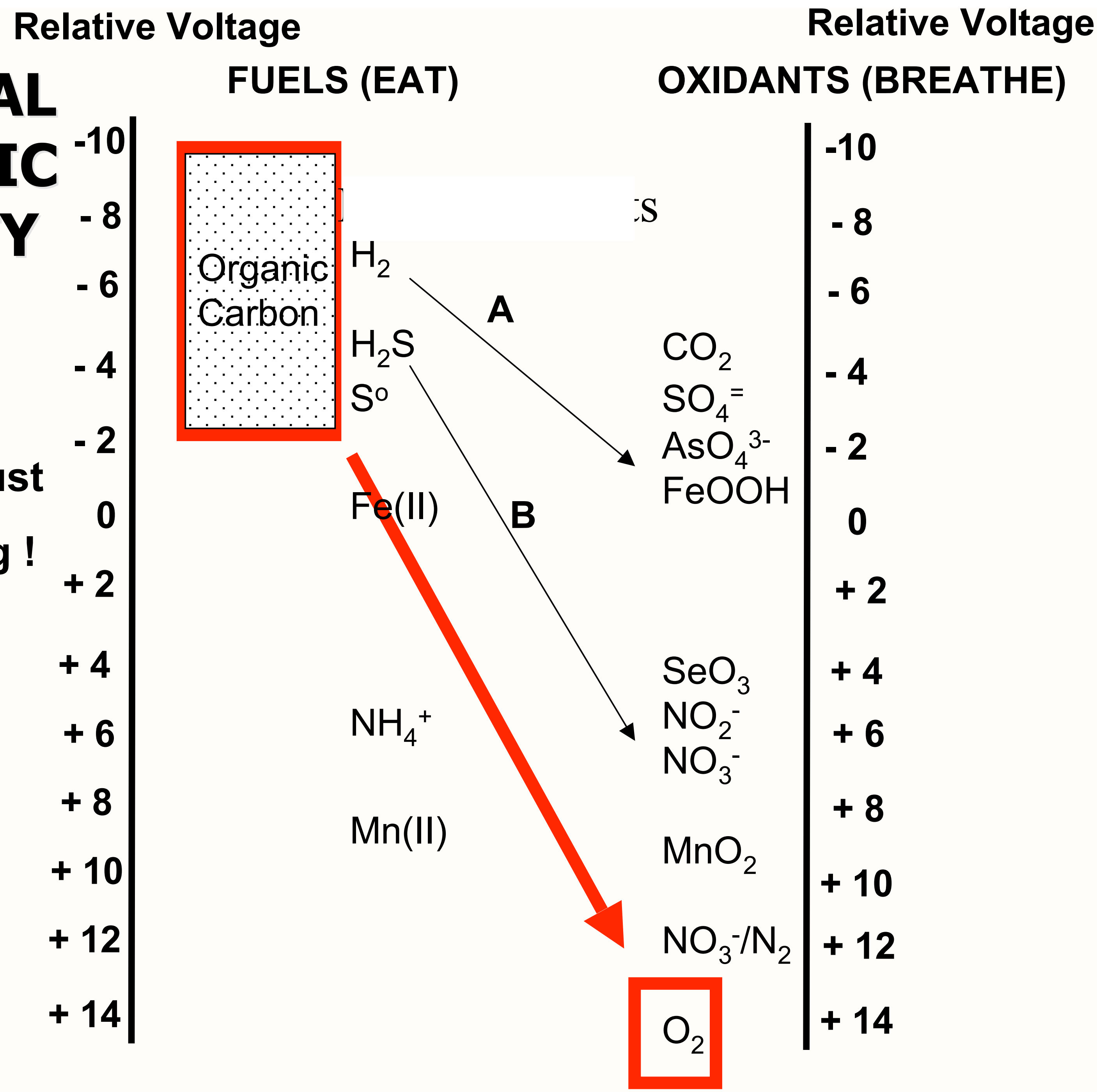
Tables of micronutrients and vitamins used by living organisms removed due to copyright restrictions.
See Tables 5-2 and 5-3 in Madigan, Michael, and John Martinko. *Brock Biology of Microorganisms.* 11th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2006. ISBN: 0131443291.

Where do organisms get their energy?



MICROBIAL METABOLIC DIVERSITY

Microbes can eat & breathe just about anything !



FREE ENERGY AND BIOENERGETI

For the chemical reaction : A -> B

Gibbs free energy change = $\Delta G = G_{products} - G_{reactants} = G_B - G$

A reaction with a negative ΔG releases energy, and is exergo

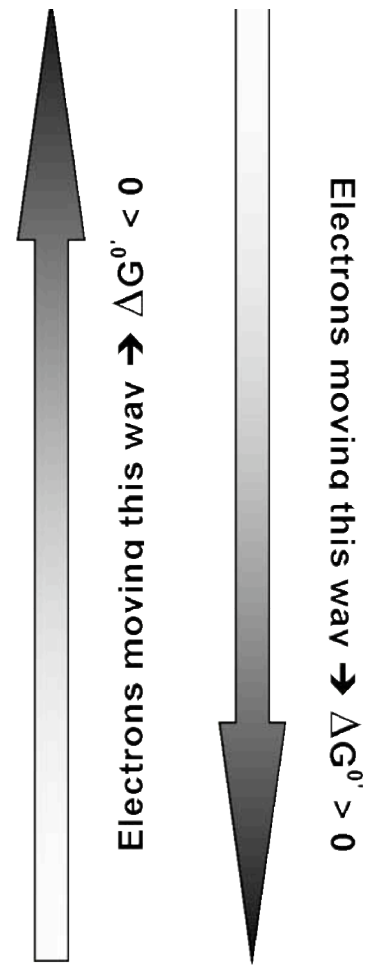
A reaction with a positive ΔG releases energy, and is enderg

Table 1. Standard reduction potential (E_0') values (at 25°C and pH 7)

Since e^- are being added to the reactants on the left sides of the equations, these reactions are showing **reduction** reactions.

'Good' electron acceptor

Half-Reaction			E_0' (V)
_ $O_2 + 2 H^+ + 2 e^-$	⇒	H_2O	+0.816
$Fe^{3+} + e^-$	⇒	Fe^{2+}	+0.771
$NO_3^- + 6 H^+ + 6 e^-$	⇒	_ $N_2 + 3 H_2O$	+0.75
$NO_3^- + 2 H^+ + 2 e^-$	⇒	$NO_2^- + H_2O$	+0.421
$NO_3^- + 10 H^+ + 8 e^-$	⇒	$NH_4^+ + 3 H_2O$	+0.36
$NO_2^- + 8 H^+ + 6 e^-$	⇒	$NH_4^+ + 2 H_2O$	+0.34
$CH_3OH + 2 H^+ + 2 e^-$	⇒	$CH_4 + H_2O$	+0.17
fumarate + 2 H^+ + 2 e^- ⇒	succinate		+0.031
$2 H^+ + 2 e^-$	⇒	H_2 (pH 0)	+0.00
oxaloacetate + 2 H^+ + 2 e^-	⇒	malate	-0.166
$CH_2O + 2 H^+ + 2 e^-$	⇒	CH_3OH	-0.18
pyruvate + 2 H^+ + 2 e^-	⇒	lactate	-0.185
acetaldehyde + 2 H^+ + 2 e^-	⇒	ethanol	-0.197
$SO_4^{2-} + 8 H^+ + 6 e^-$	⇒	$S + 4 H_2O$	-0.20
$SO_4^{2-} + 10 H^+ + 8 e^-$	⇒	$H_2S + 4 H_2O$	-0.21
$FAD + 2 H^+ + 2 e^-$	⇒	$FADH_2$	-0.219
$CO_2 + 8 H^+ + 8 e^-$	⇒	$CH_4 + 2 H_2O$	-0.24
$S + 2 H^+ + 2 e^-$	⇒	H_2S	-0.243
$N_2 + 8 H^+ + 6 e^-$	⇒	$2\ NH_4^+$	-0.28
$NAD^+ + H^+ + 2 e^-$	⇒	NADH	-0.320
$NADP^+ + H^+ + 2 e^-$	⇒	NADPH	-0.324
$2 H^+ + 2 e^-$	⇒	H_2 (pH 7)	-0.414
$CO_2 + 4 H^+ + 4 e^-$	⇒	1/6 glucose + H_2O	-0.43
$Fe^{2+} + 2 e^-$	⇒	Fe	-0.85



'Good' electron donors

Aerobic Respiration : O_2 is the terminal electron acceptor

Electrons are passed from NADH via the electron transport chai to oxygen. Simultaneously, protons are "pumped" outside cell.

Diagrams of the electron transport chain removed due to copyright restrictions.

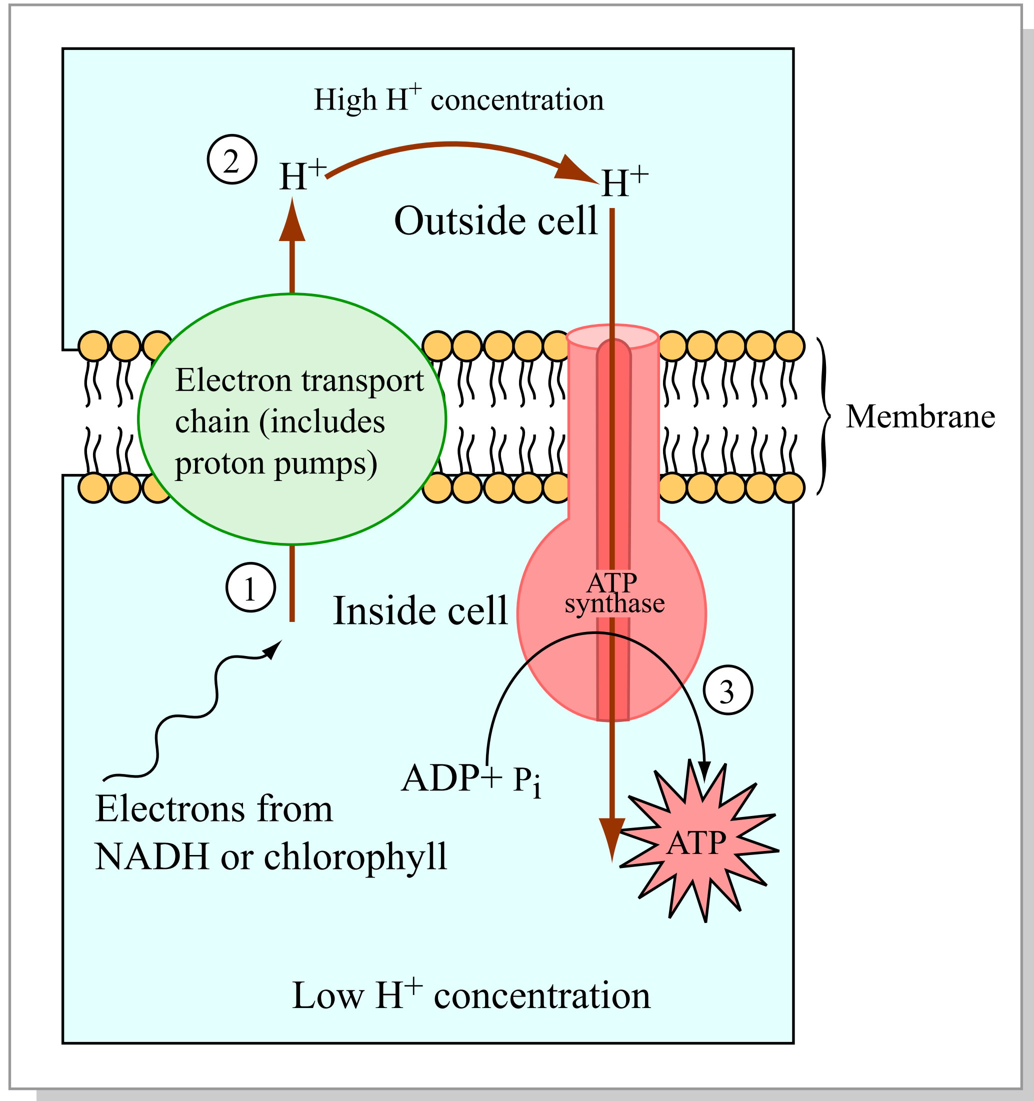


Figure by MIT OCW.

The enzyme ATPase can use the energy from the proton gradient to make ATP.

See Figures 5-21, 5-22a, and 5-20 in Madigan, Michael, and John Martinko. *Brock Biology of Microorganisms*. 11th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2006. ISBN: 0131443291.

METABOLIC DIVERSITY - Defining terms….

Modes of Nutrition - Some basic definitions

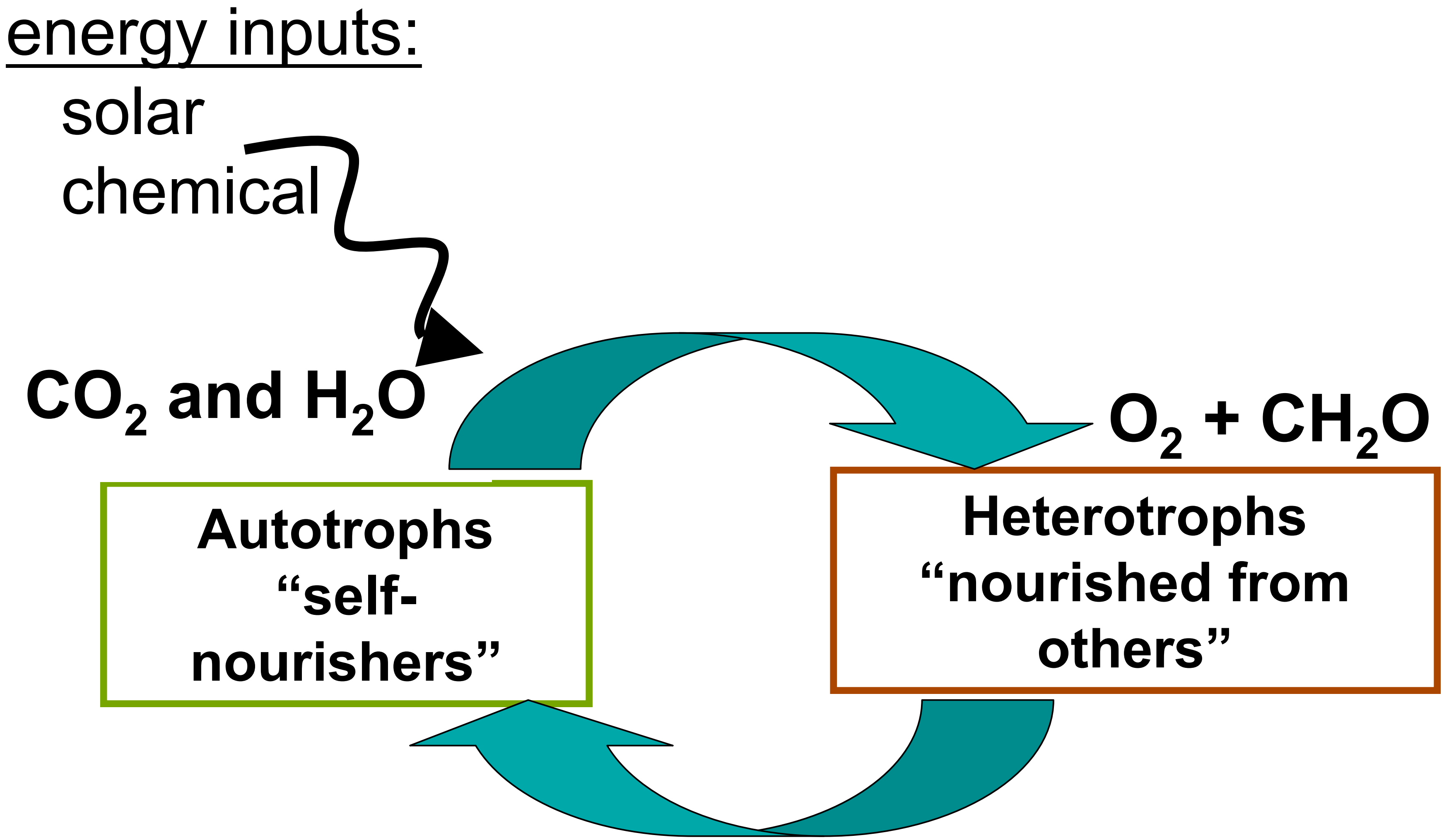
An organism needs a source of carbon, plus energy (ATP), plus reducing power (NADH
These may all come from the same source (e.g. glucose provides all three),
or they may come from different sources:

- **Where does the carbon come from?**
  a) Organic molecules - heterotrophs
  b) Inorganic - mainly CO_2 = autotrophs

- **Where does the energy come from?**
  a) Chemical reactions (redox reactions) - chemotrophs
  b) Light - phototrophs

- **What molecule is the electron donor?**
  a) Organic molecules - organotrophs
  b) Inorganic (e.g., H2O, H2, Sulfur) - lithotrophs

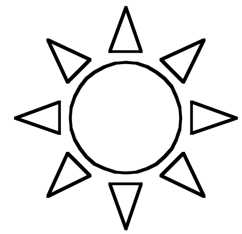
- **What molecule is the electron acceptor ?**
  a) O_2 = aerobic respiration
  b) Oxidants other than O_2 (SO_4, NO_3, FeIII) = anaerobic respiration


energy inputs:
solar
chemical
CO_2 and H_2O
$O_2 + CH_2O$
Autotrophs
"self-nourishers"
Heterotrophs
"nourished from others"

Bacterial photosynthesis (anoxygenic)

The original photosynthesizers on Earth likely did not produce oxygen. Their reactions in the light are slightly different because they use cyclic photosynthesis, and H_2S, organic carbon, and other sources for reducing power (not H_2O).

Who? bacteria (e.g. Purple or green sulfur bacteria. Also purple and green non-sulfur bacteria)
C Source? CO_2
Energy Source? Sunlight
Electron Donor? H_2S, organics, other
Where? In anaerobic, light conditions



Use bacteriochlorophyll, not chlorophyll in light reaction.

Light reaction is slightly different, in terms of pigments and electron transfer compounds.

Pigments absorb at slightly different wavelengths – allow these bacteria to absorb light that algae might not absorb. Absorption max at 890 nm

Write what you think overall reaction is:

$$2\,H_2S + CO_2 \longrightarrow CH_2O + 2\,S^0 + H_2O$$

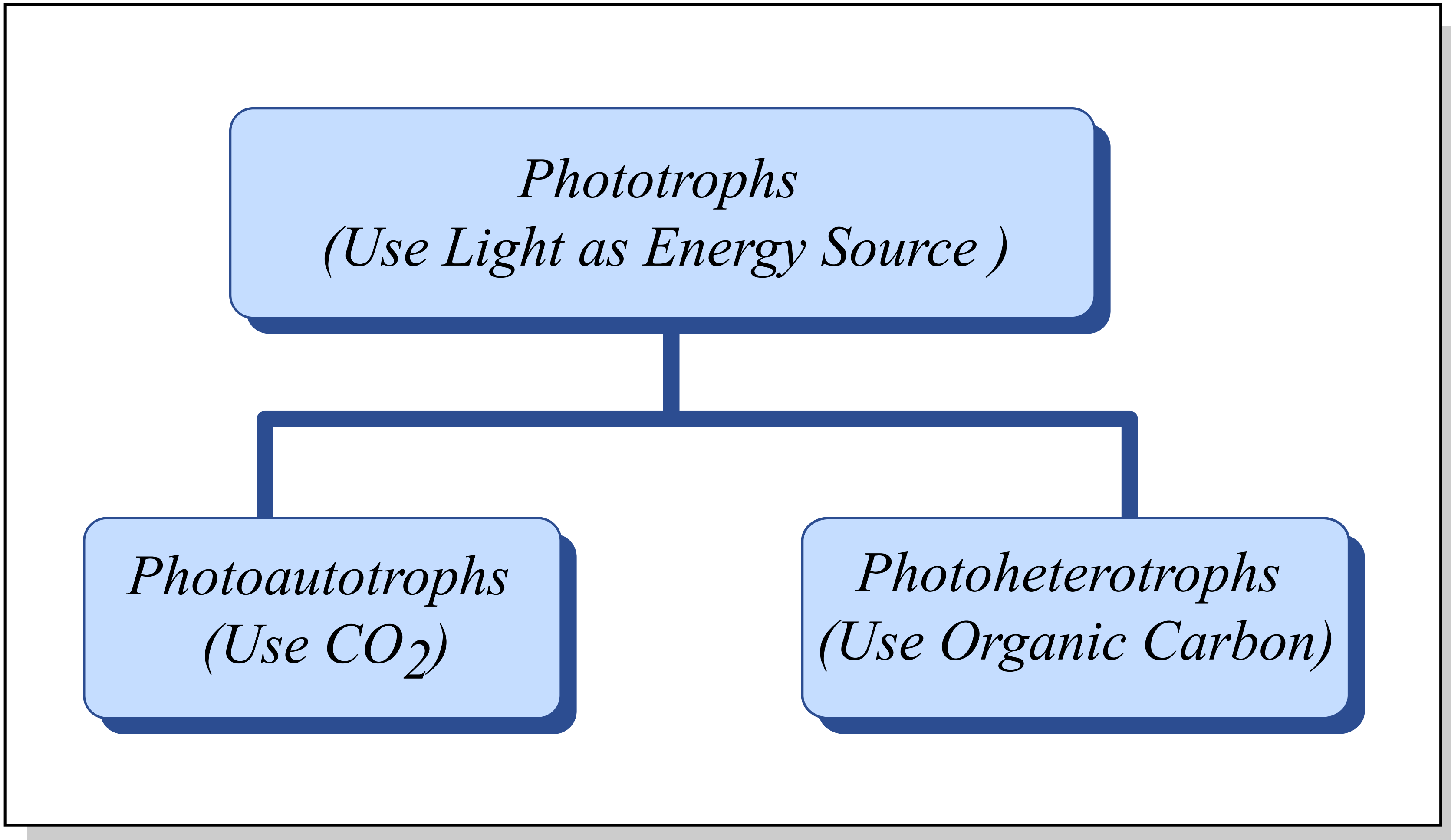


Figure by MIT OCW.

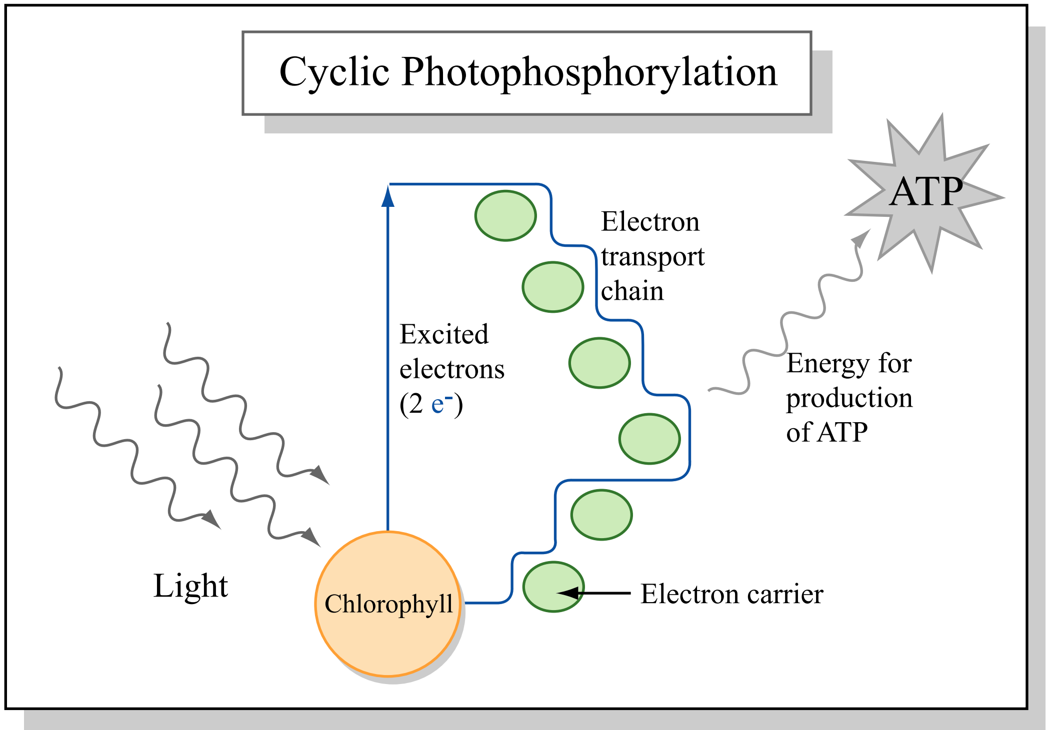


Figure by MIT OCW.

Anoxygenic photoautotrophs utilize cyclic photophosphorylation

LOTS OF DIVERSITY IN BACTERIAL ANOXYGENIC PHOTOTROP

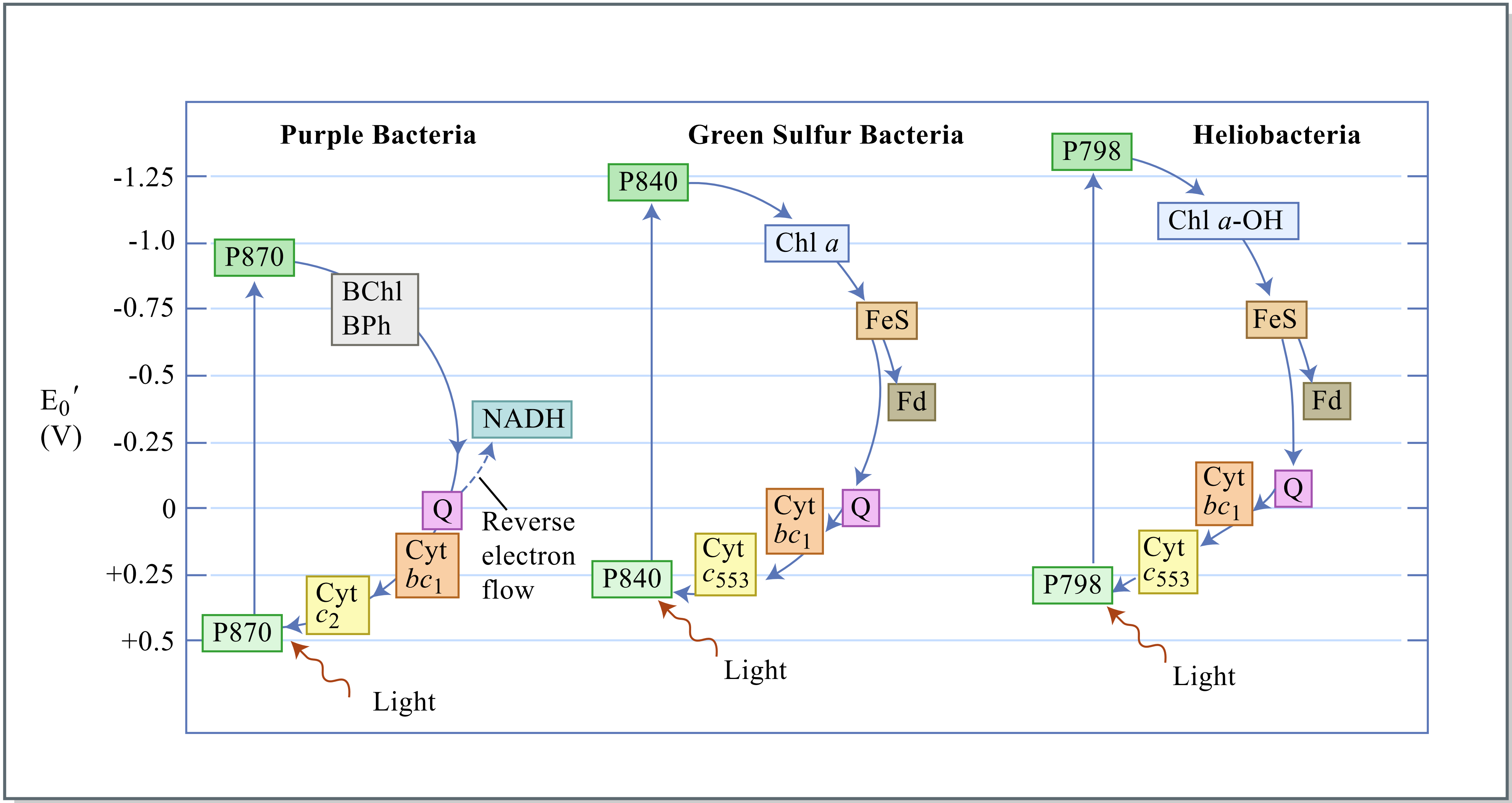


Figure by MIT OCW.

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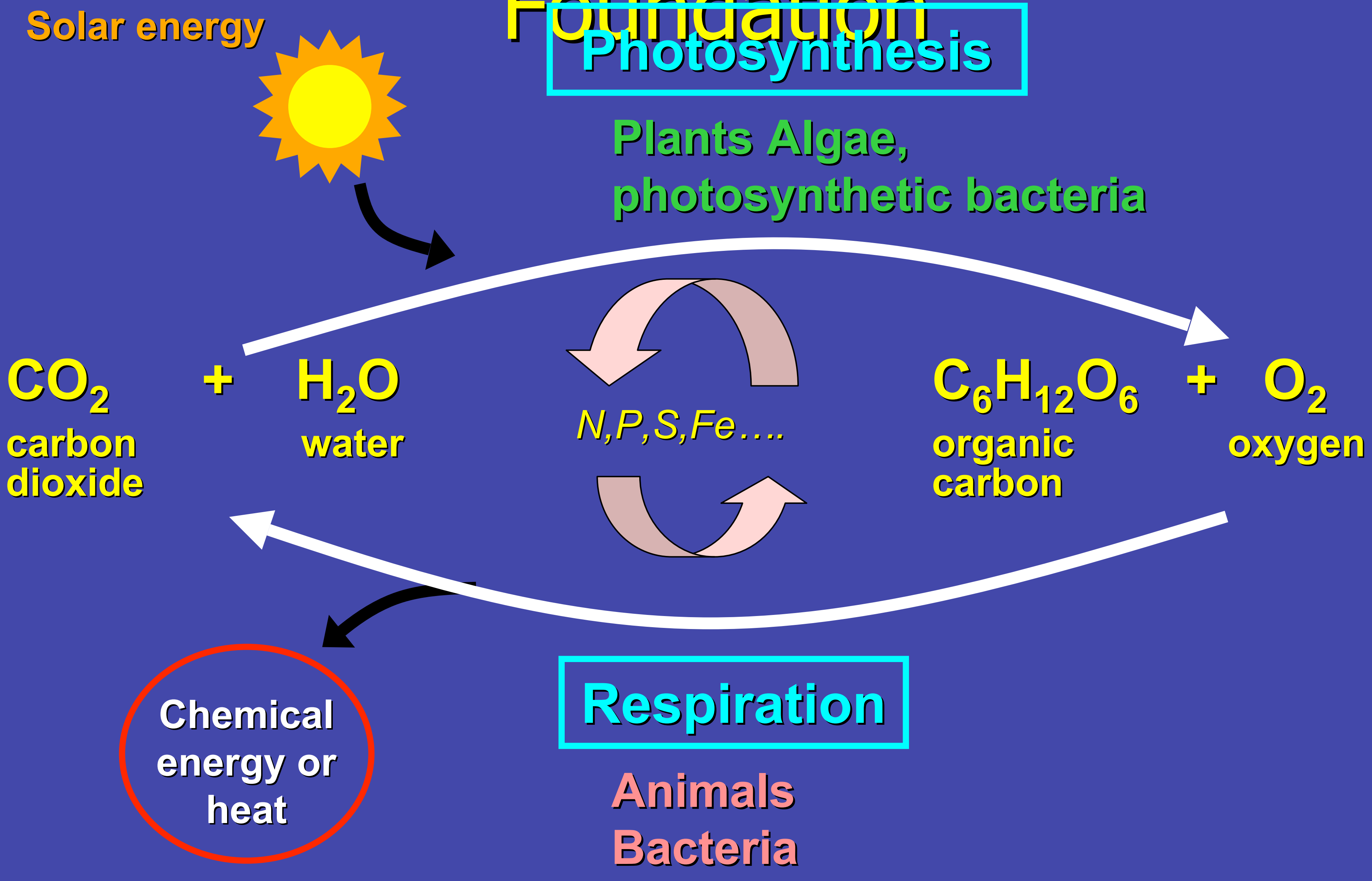
See Figures 17-15 and 17-3 in Madigan, Michael, and John Martinko. *Brock Biology of Microorganisms.* 11th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2006. ISBN: 0131443291.

Life on Earth Today: The Foundation



The Z scheme = oxygenic photosynthesis =
Noncyclic photsynthesis because electrons are not "recycled"

Diagrams of noncyclic photophosphorylation and the Z scheme removed due to copyright restrictions.

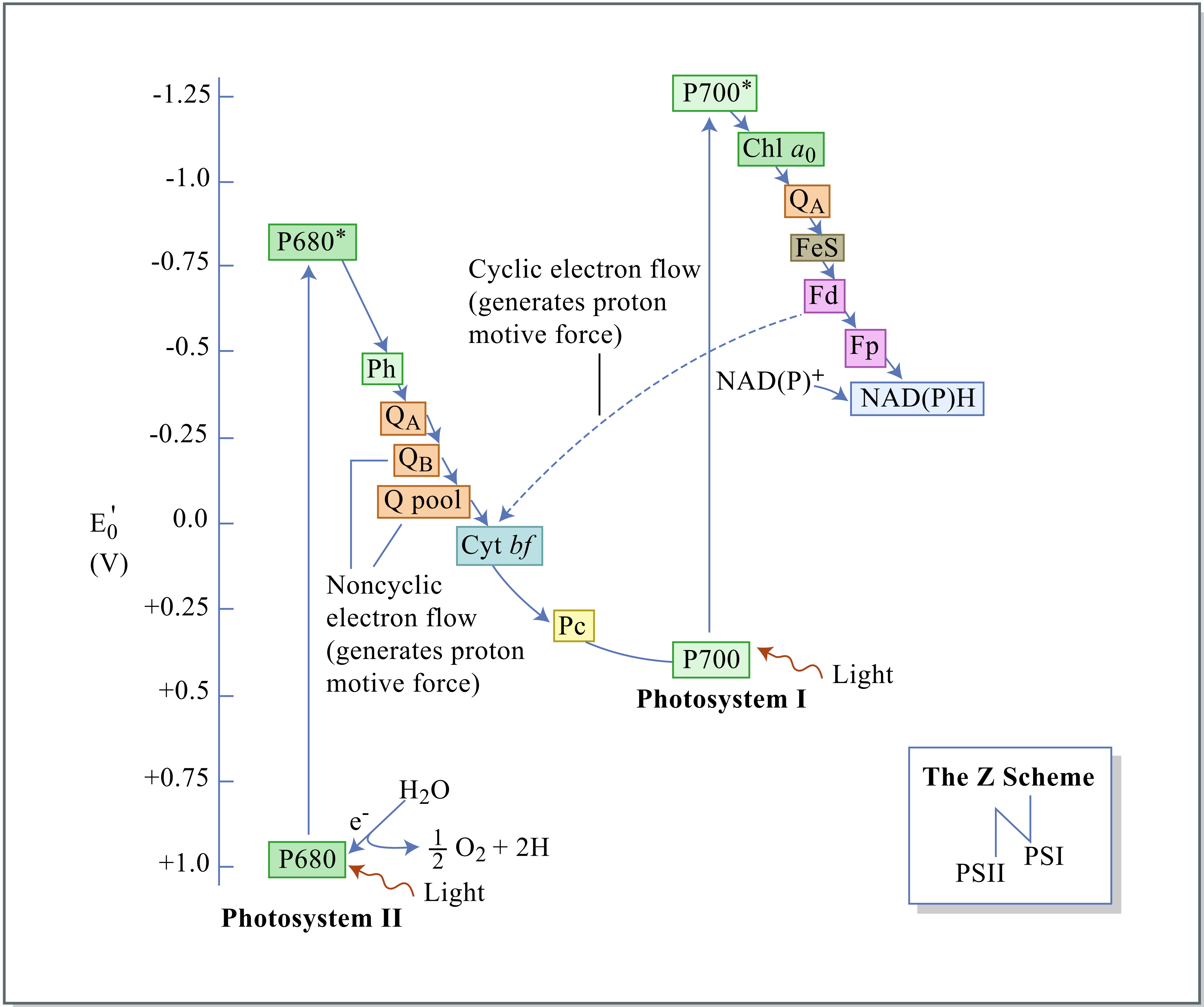


Figure by MIT OCW.