Metabolism: what you know and what might surprise you

Lecture

Chapter 5

Enzymes

Aerobic and anaerobic respiration

Lab

Streak plate subcultures

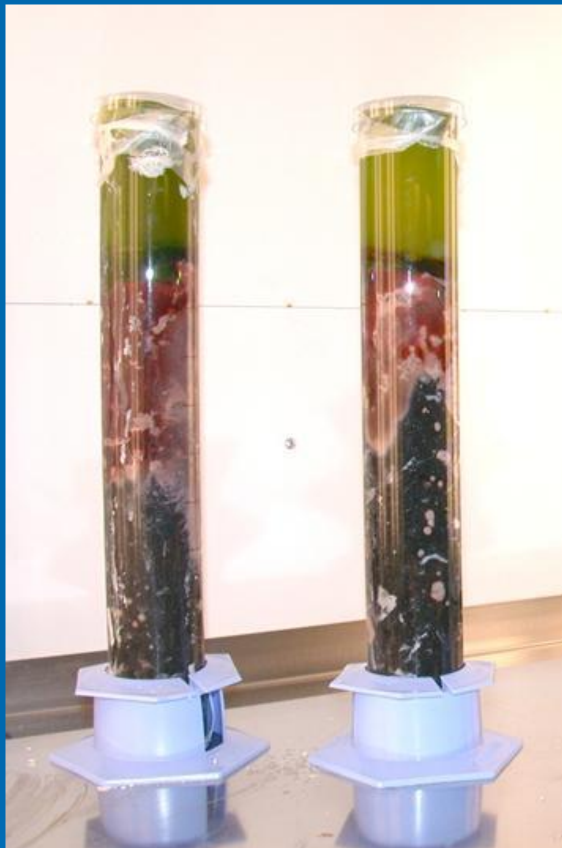
Staining: Gram stain

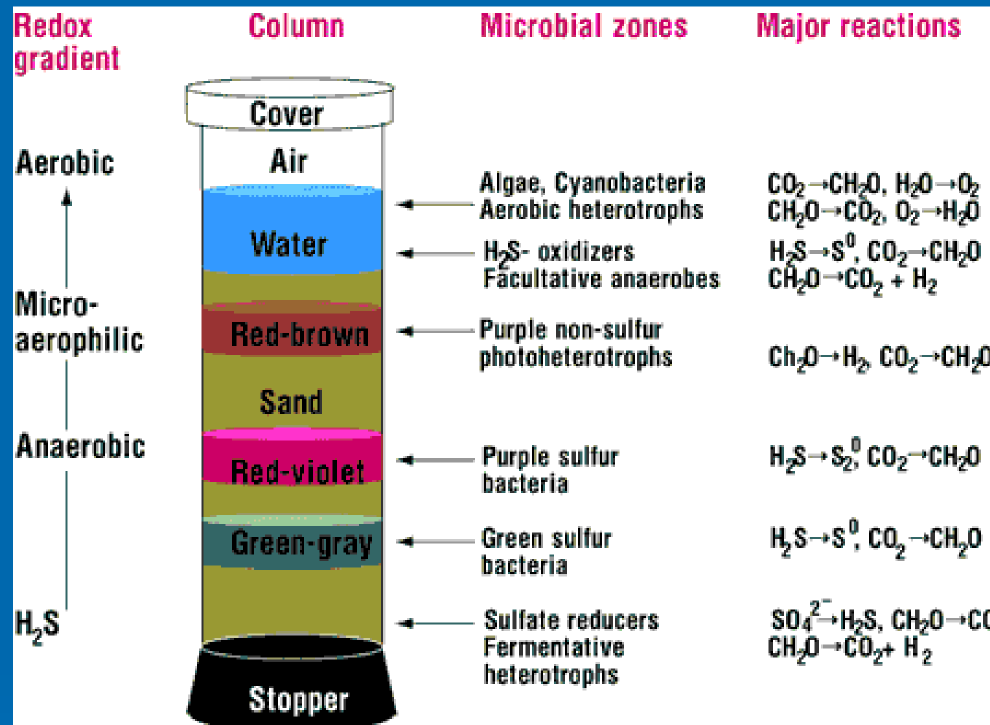
Motility

Pre-labs

Review Gram Staining and other assays

Microbial metabolic diversity- how is it possible?





Recipe:

500 ml mud from beach at low tide
10 g filter paper (cellulose)
1 g NH_4Cl
1 g KH_2PO_4
1 g $CaSO_4$
water

jan.ucc.nau.edu/.../lectures/lec23/lec23.html

Metabolism is possible through enzymatic diversity

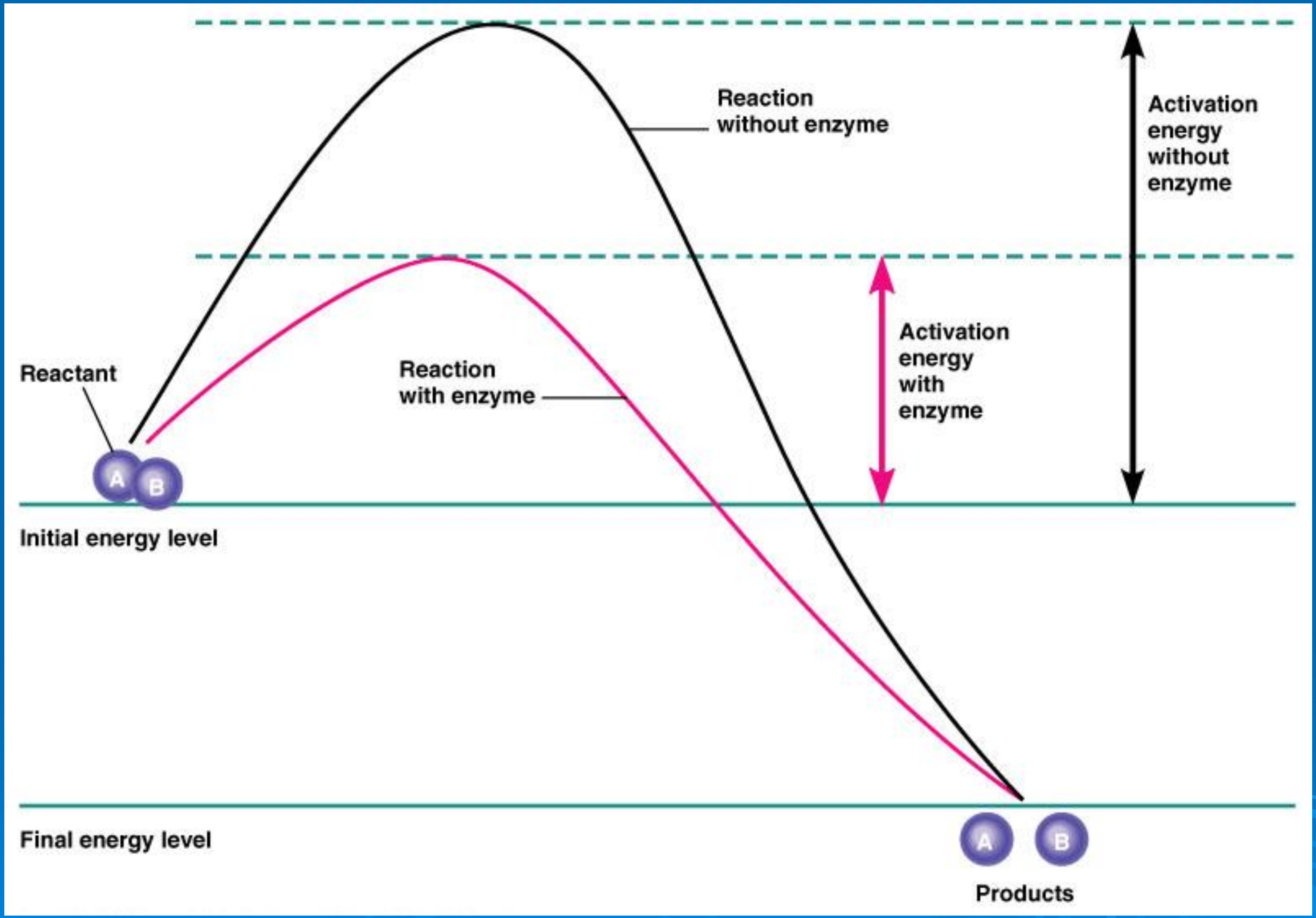
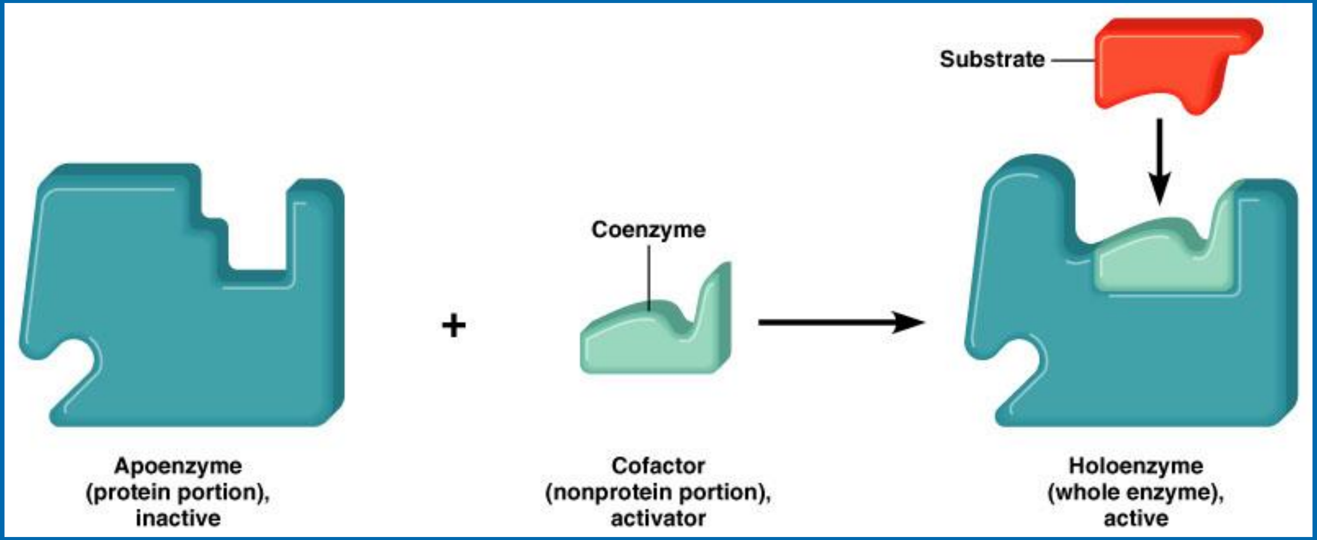


Figure 5.2

Enzyme structure



Cofactors

Ions of iron, zinc, magnesium and calcium

Coenzymes

Nicotinamide adenine dinucleotide (phosphate) - NAD^+/ $NADP^+$ from B vitamin niacin

Flavin adenine dinucleotide- FAD from B vitamin riboflavin

Figure 5.3

Effects on enzyme activity: temp and pH

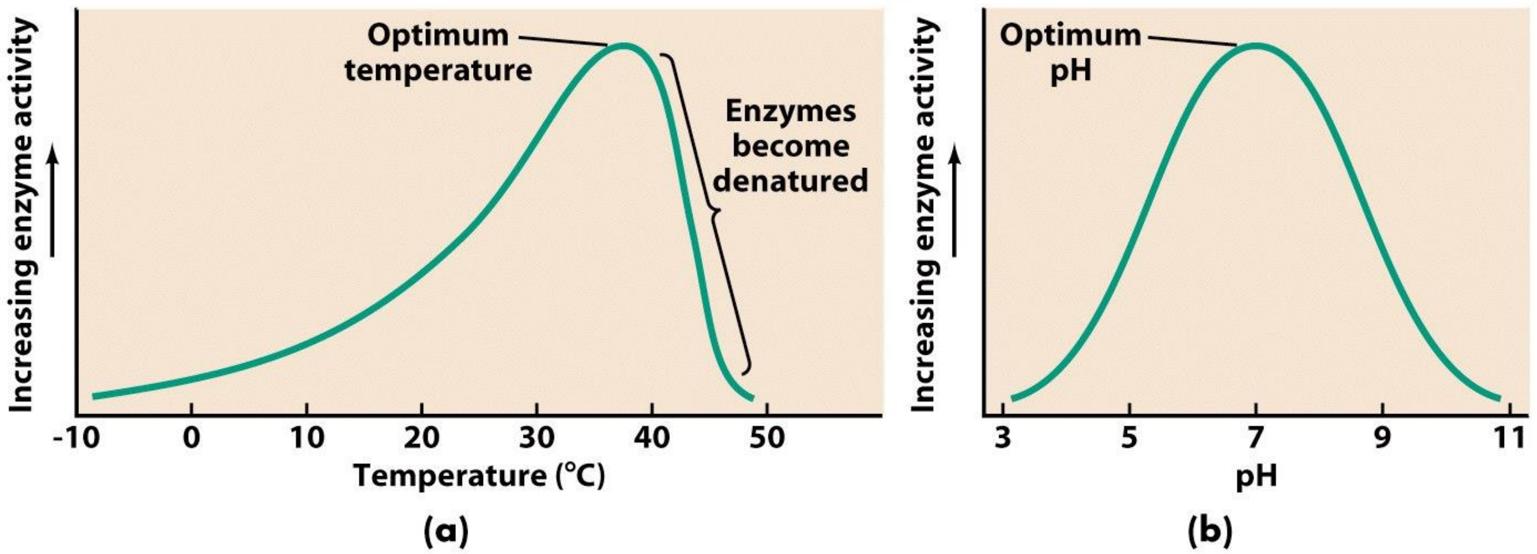


Figure 5-10 Microbiology, 6/e

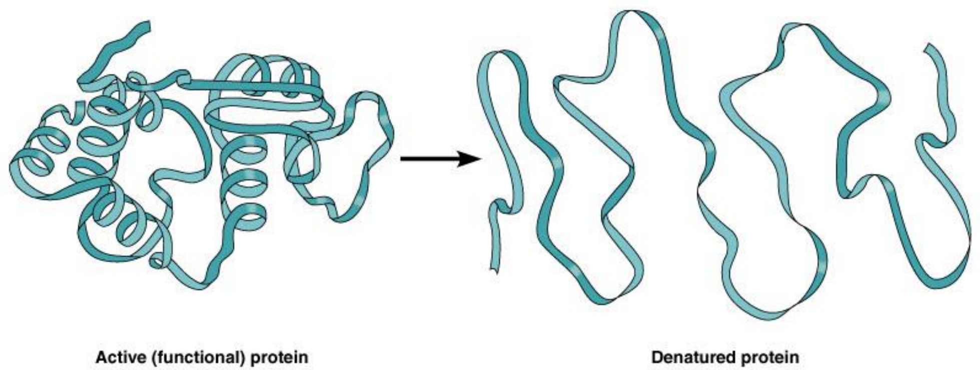
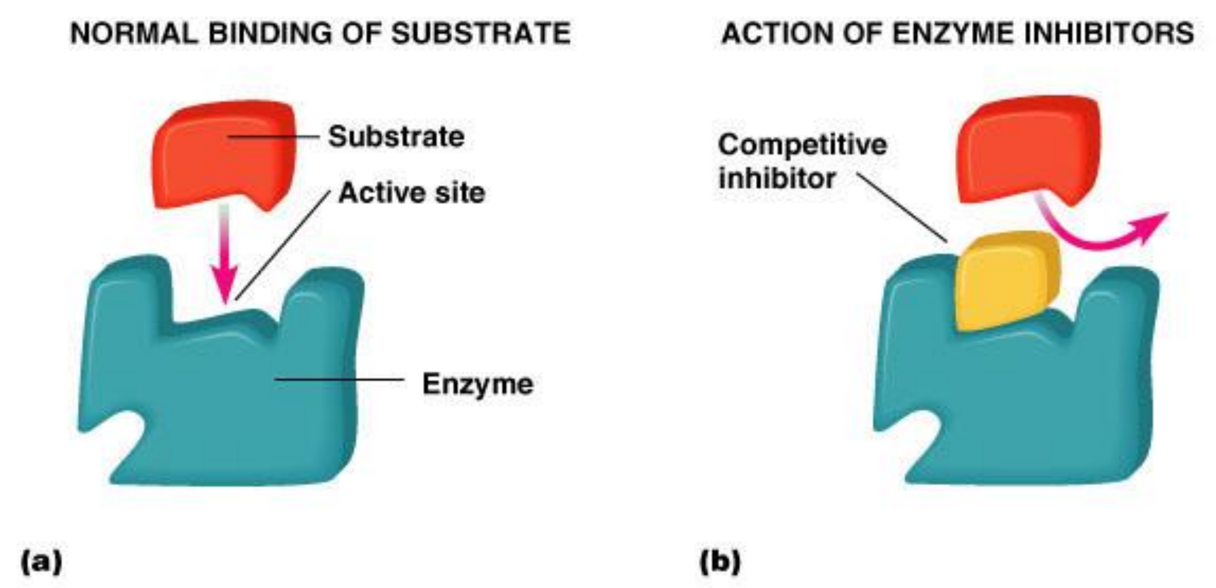


Figure 5.6

Effects on enzyme activity: competitive inhibition



Example:

Sulfa drugs

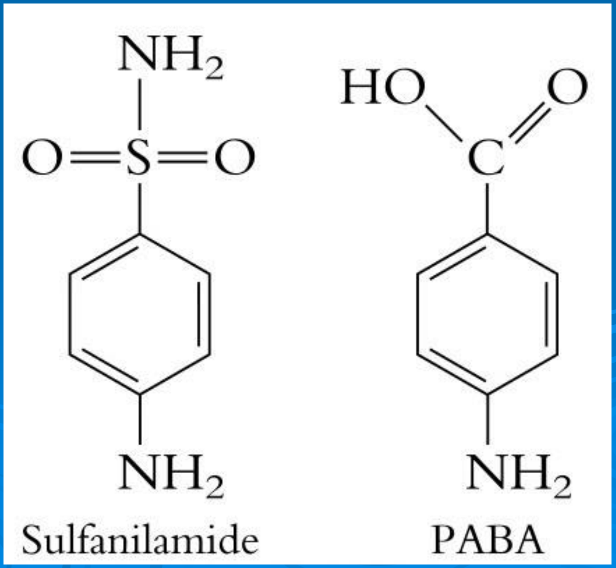
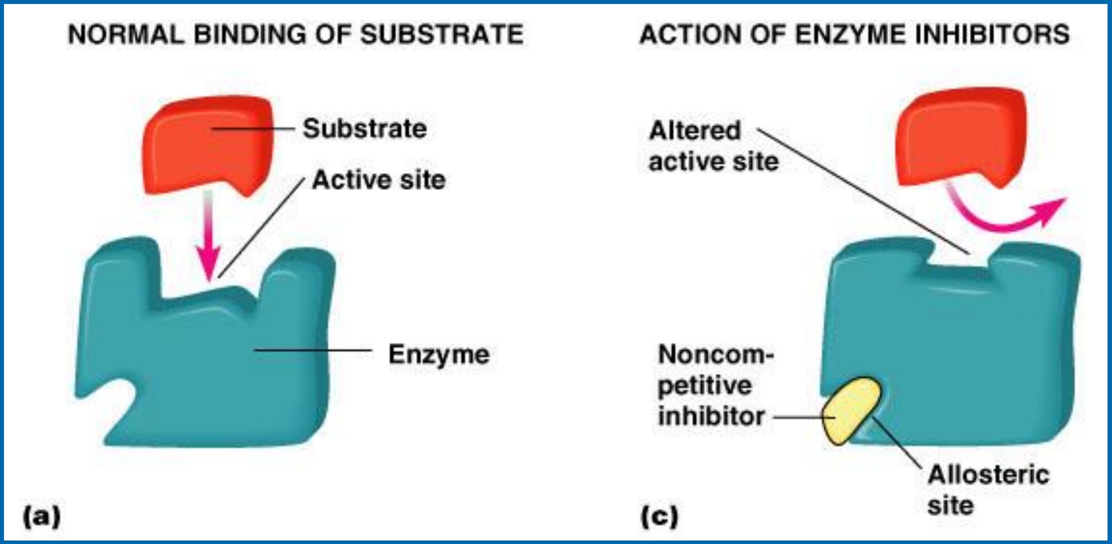
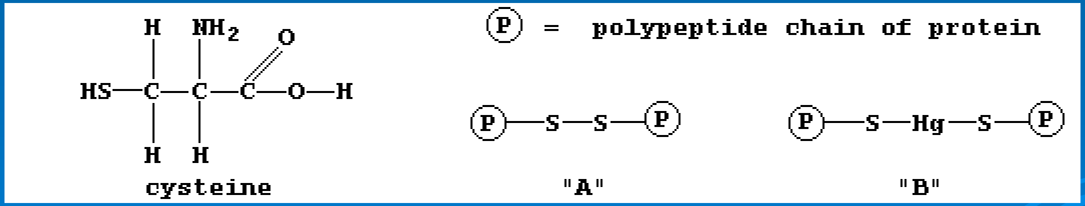


Figure 5.7

Effects on enzyme activity: noncompetitive inhibition





Example: Mercury poisoning

Figure 5.7

Effects on enzyme activity: feedback inhibition

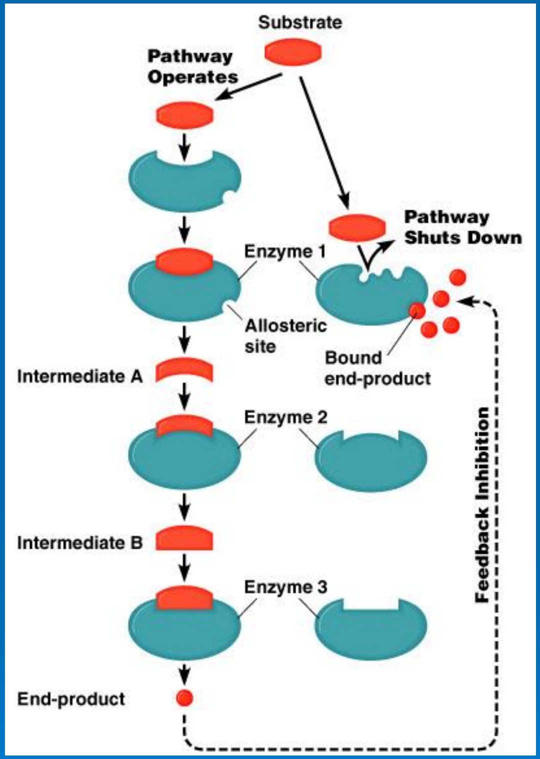
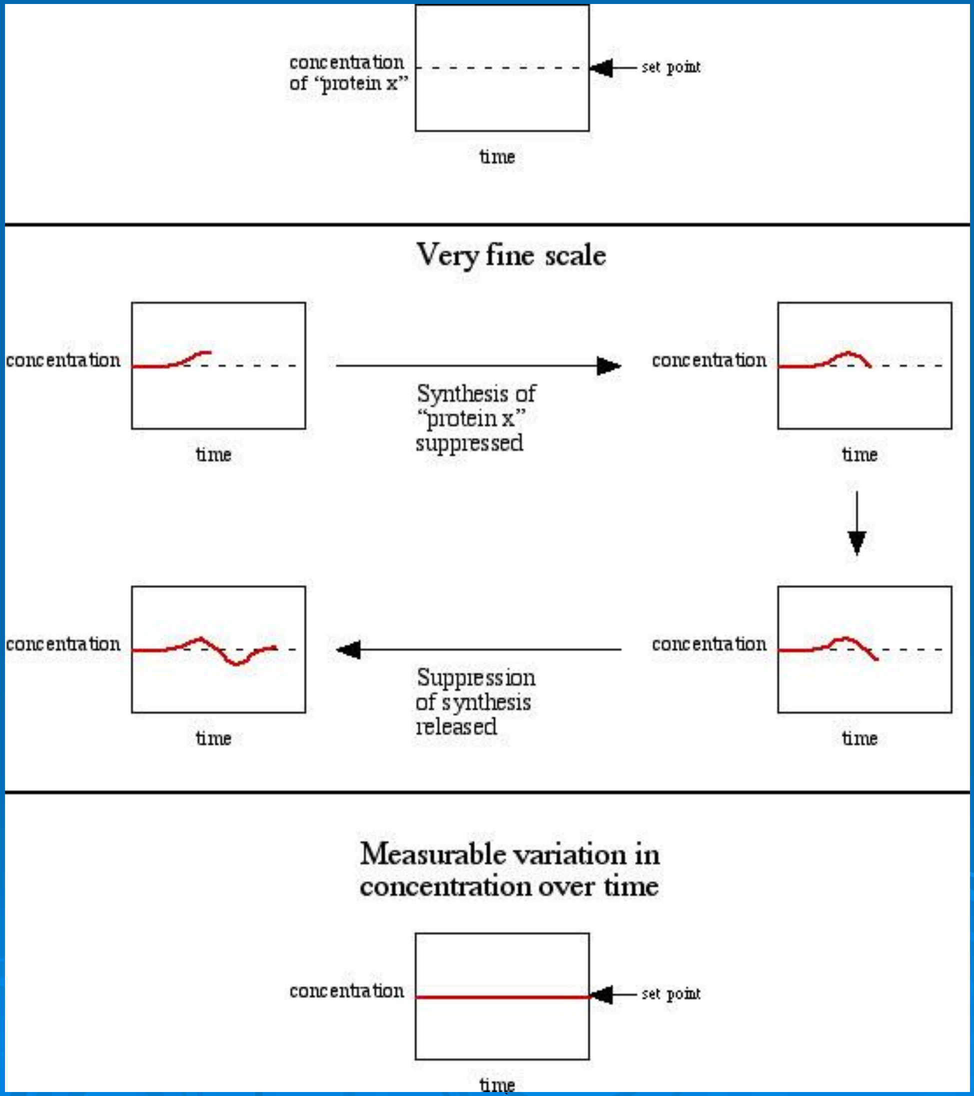


Figure 5.8

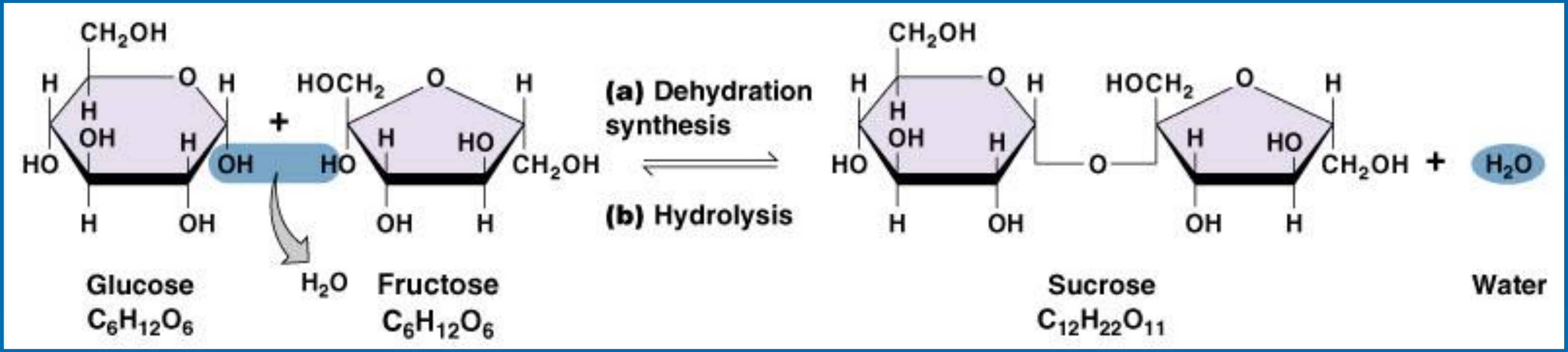


Pit Stop

Why would it be beneficial to have a fever during a bacterial infection? Why is a fever over 40° C often life threatening?

Metabolism:
catabolism and anabolism

anabolism~ dehydration synthesis~ condensation



catabolism~ hydrolysis~ decomposition

Figure 2.8

Redox reactions- the basis of metabolism

TABLE 5.1

Comparison of Oxidation and Reduction

Oxidation	Reduction
Loss of electrons (A)	Gain of electrons (B)
Gain of oxygen	Loss of oxygen
Loss of hydrogen	Gain of hydrogen
Loss of energy (liberates energy)	Gain of energy (stores energy in the reduced compound)
Exothermic; exergonic (gives off heat energy)	Endothermic; endergonic (requires energy, such as heat)

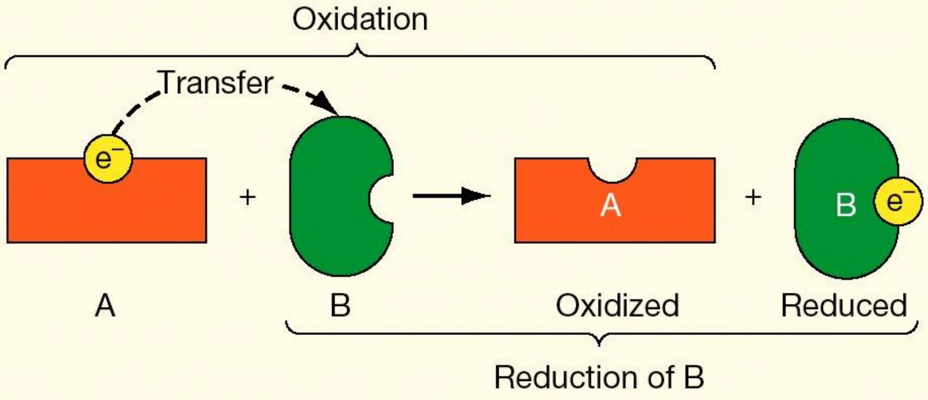


Table 5-1 Microbiology, 6/e

Redox reactions- the basis of metabolism

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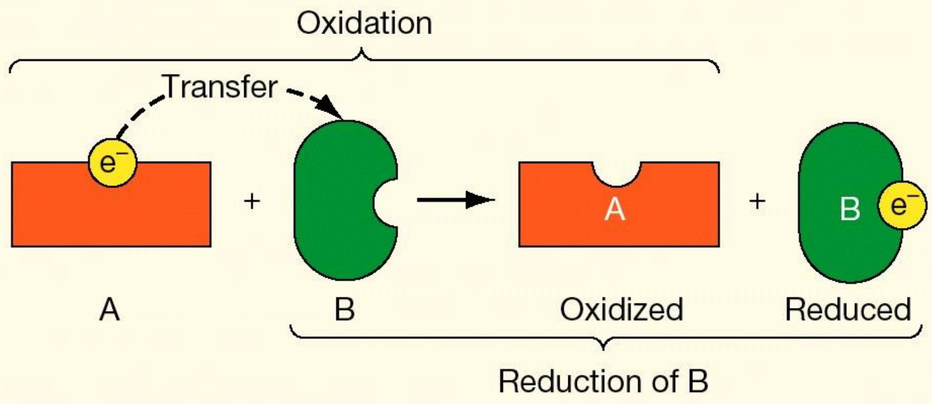
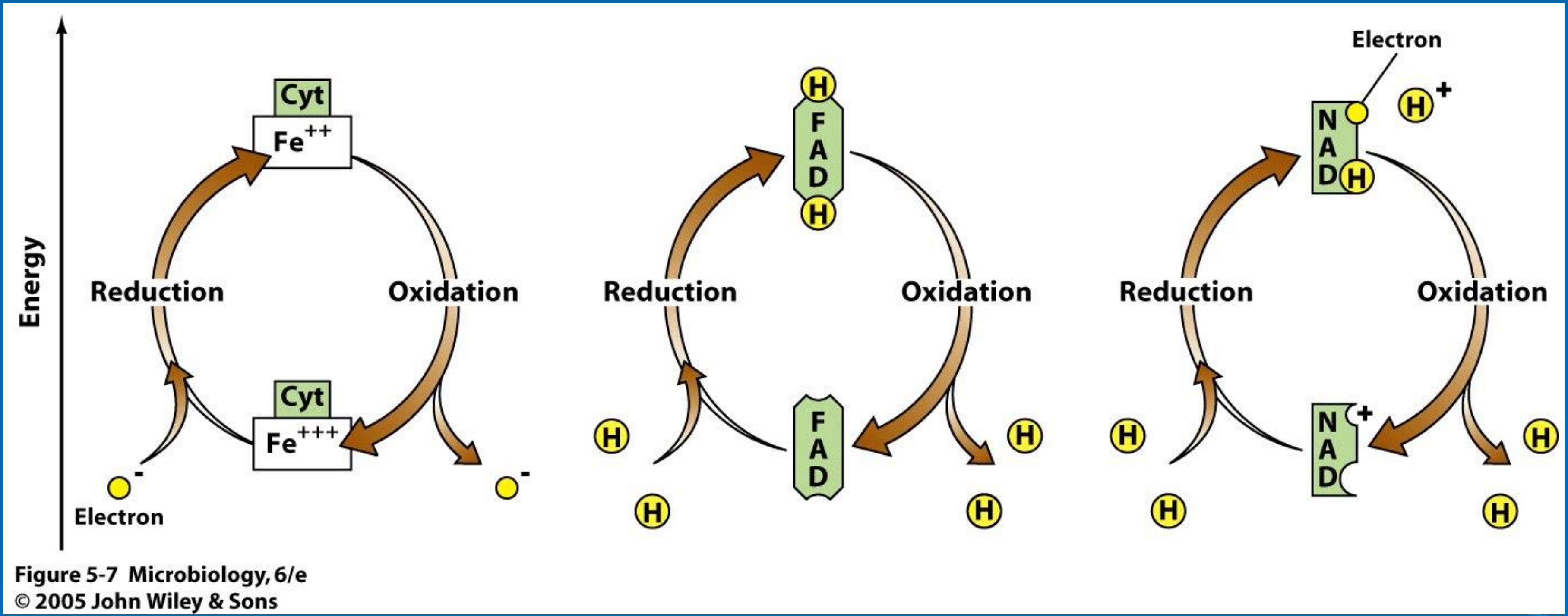


Table 5-1 Microbiology, 6/e

O I L **R I G**

Major electron carriers

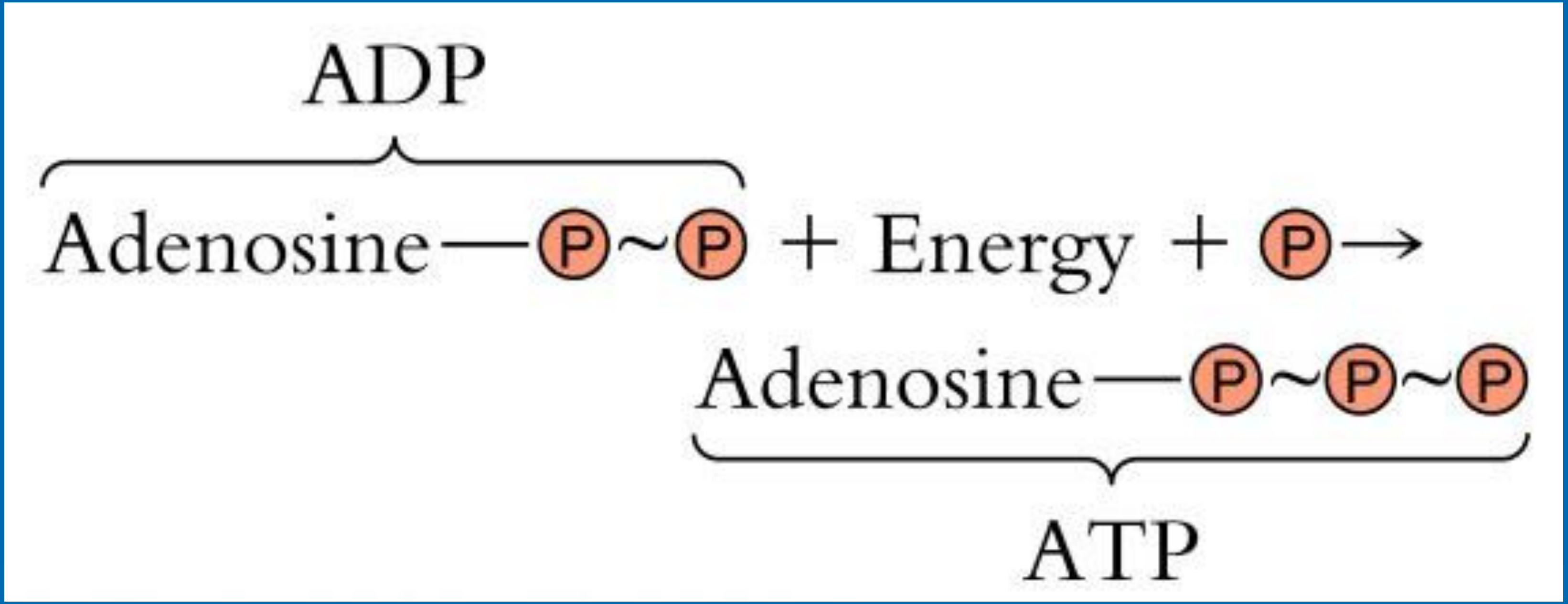


- FAD accepts two H^+/e- → FADH2

- NAD^+ accepts one H^+/ e- → NADH

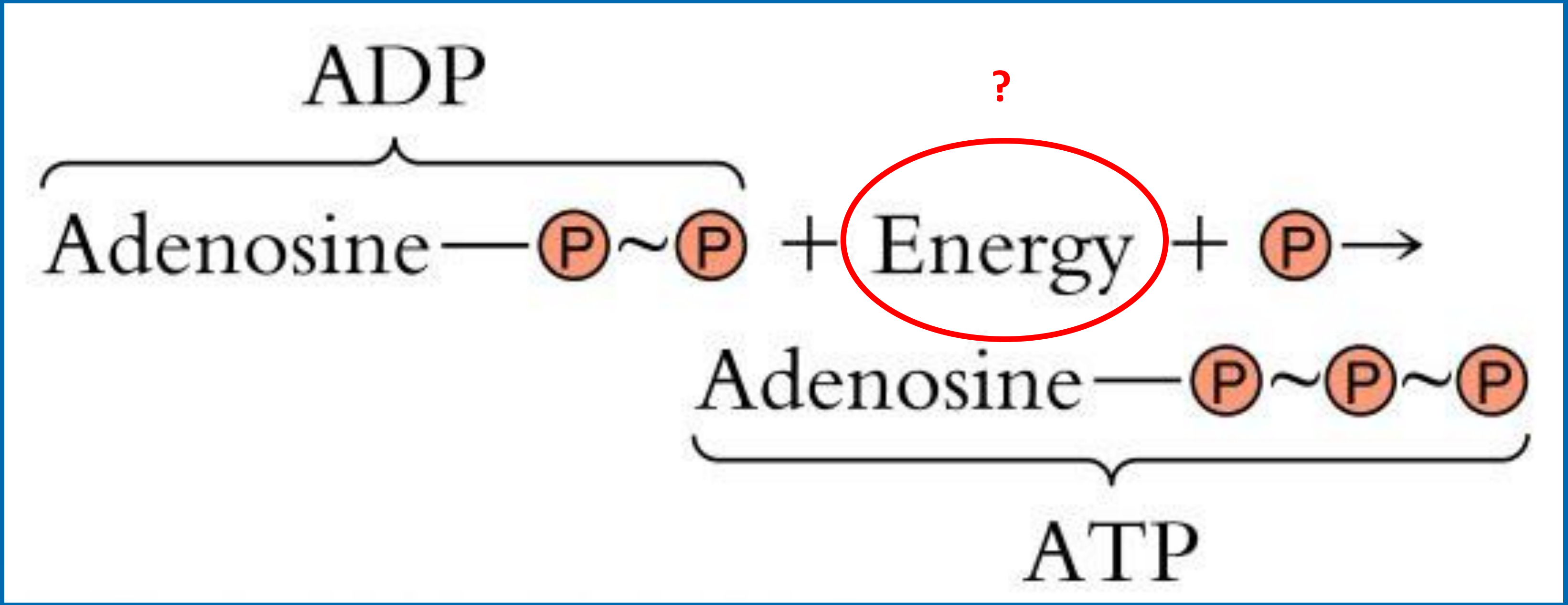
- Cytochromes accept e-

Phosphorylation reactions or HOW WE MAKE ATP



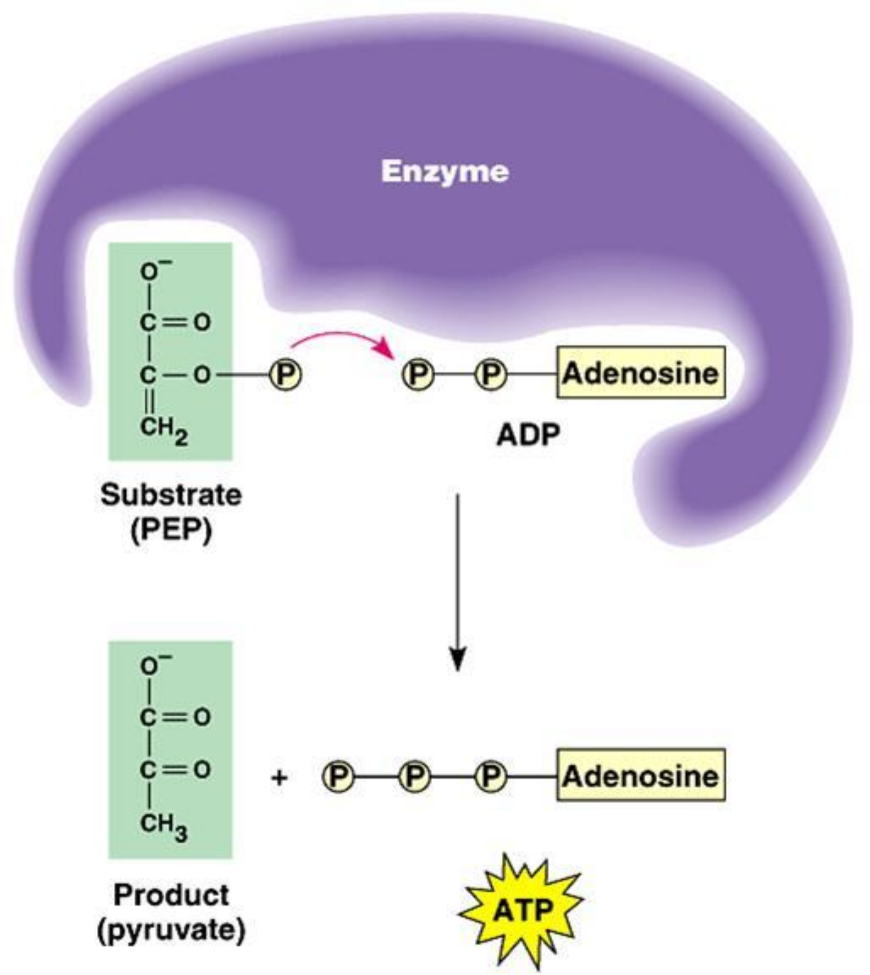
1. Substrate level phosphorylation
2. Oxidative phosphorylation
3. Photophosphorylation

Phosphorylation reactions or HOW WE MAKE ATP

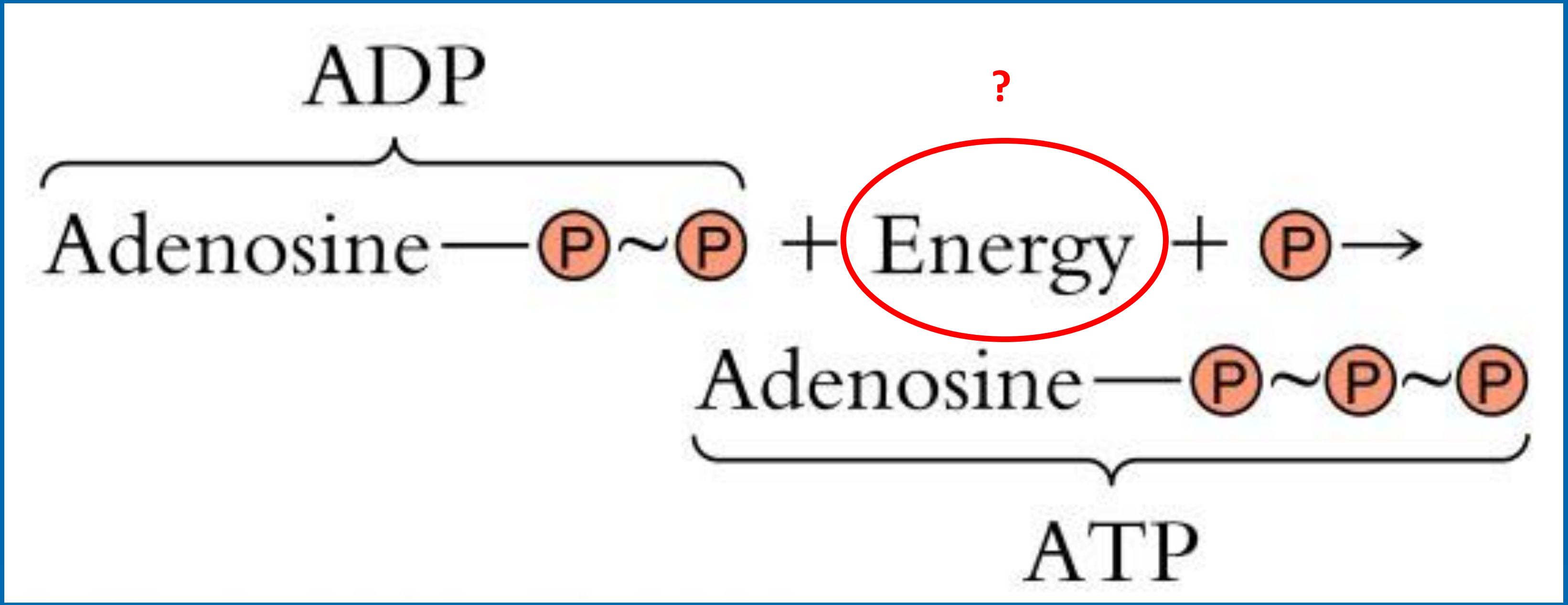


1. **Substrate level phosphorylation**
2. Oxidative phosphorylation
3. Photophosphorylation

1. Substrate level phosphorylation



Phosphorylation reactions or HOW WE MAKE ATP



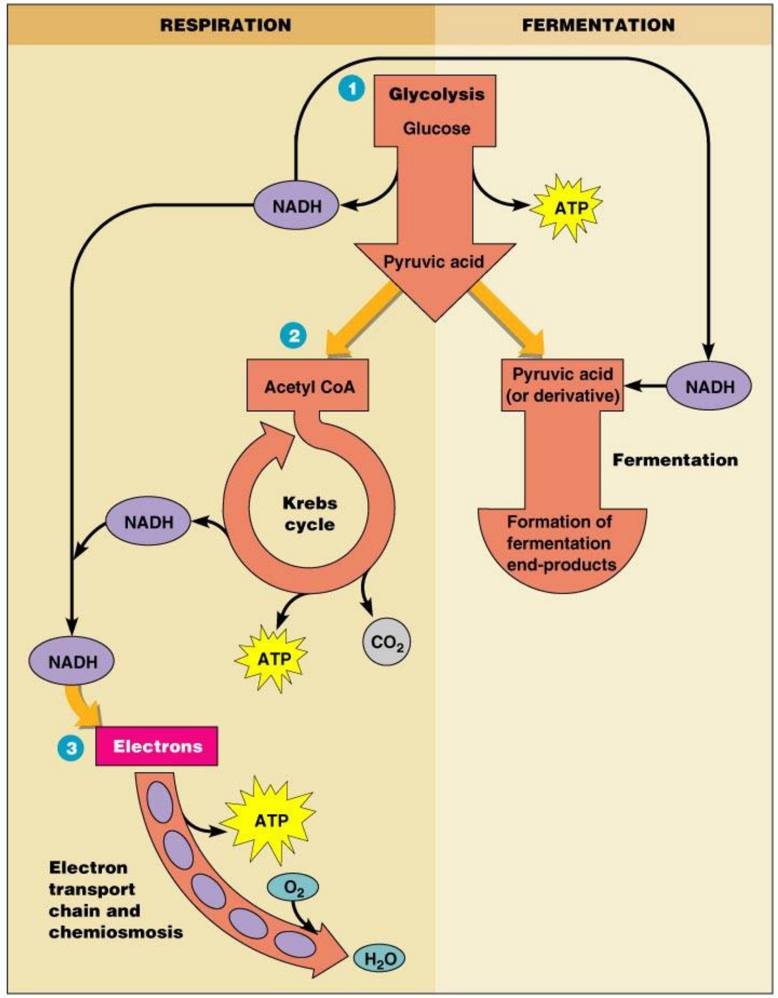
1. Substrate level phosphorylation

2. Oxidative phosphorylation

3. Photophosphorylation

2. Oxidative Phosphorylation
(Carbohydrate catabolism)

Aerobic respiration
Anaerobic respiration



Fermentation
- Alcohol ferm
- Lactic acid ferm
- Mixed acid ferm
- Butanediol ferm
- Butylic/butyric acid
- Etc.

Let's review: aerobic respiration

Steps:

1. Glycolysis

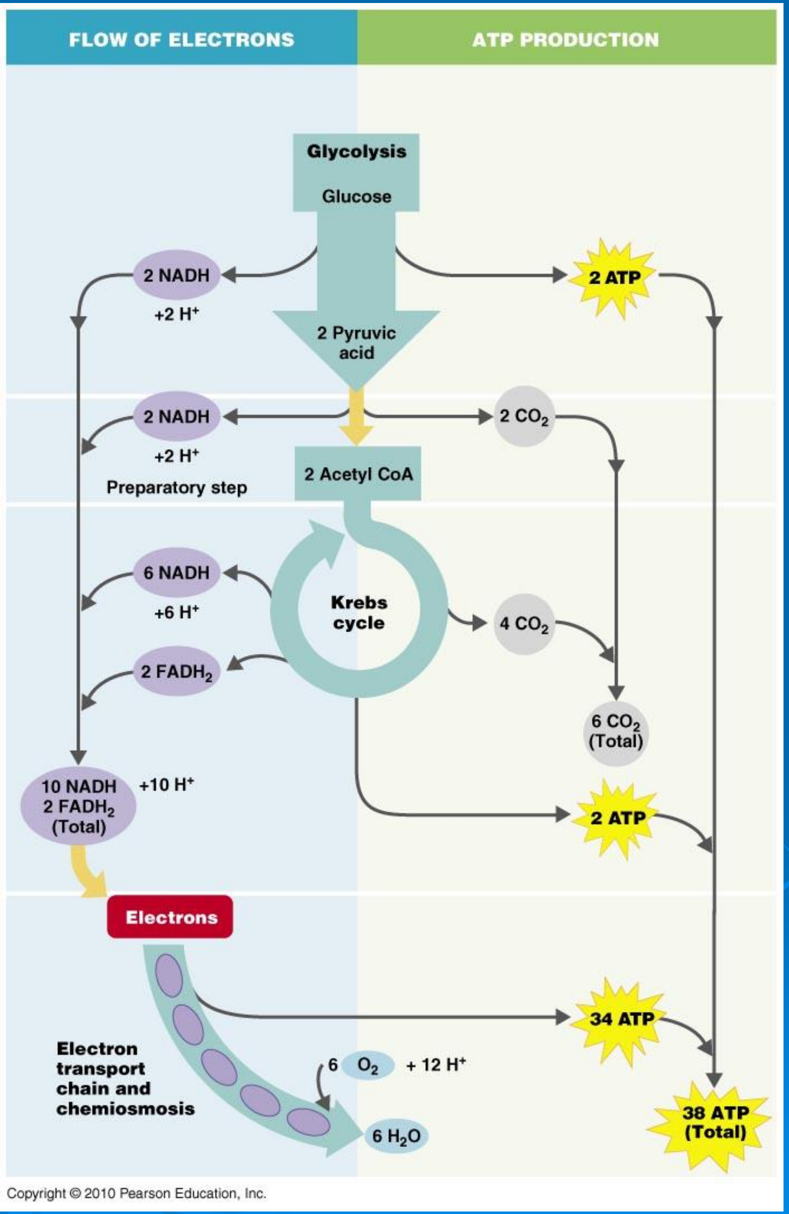
 1a. Pentose phosphate pathway
 1b. Entner-Doudoroff pathway

2. Transition/preparatory step

3. Krebs Cycle/ TCA

4. Electron transport chain (ETC)

Total energy output:



How does the ETC make so much ATP?

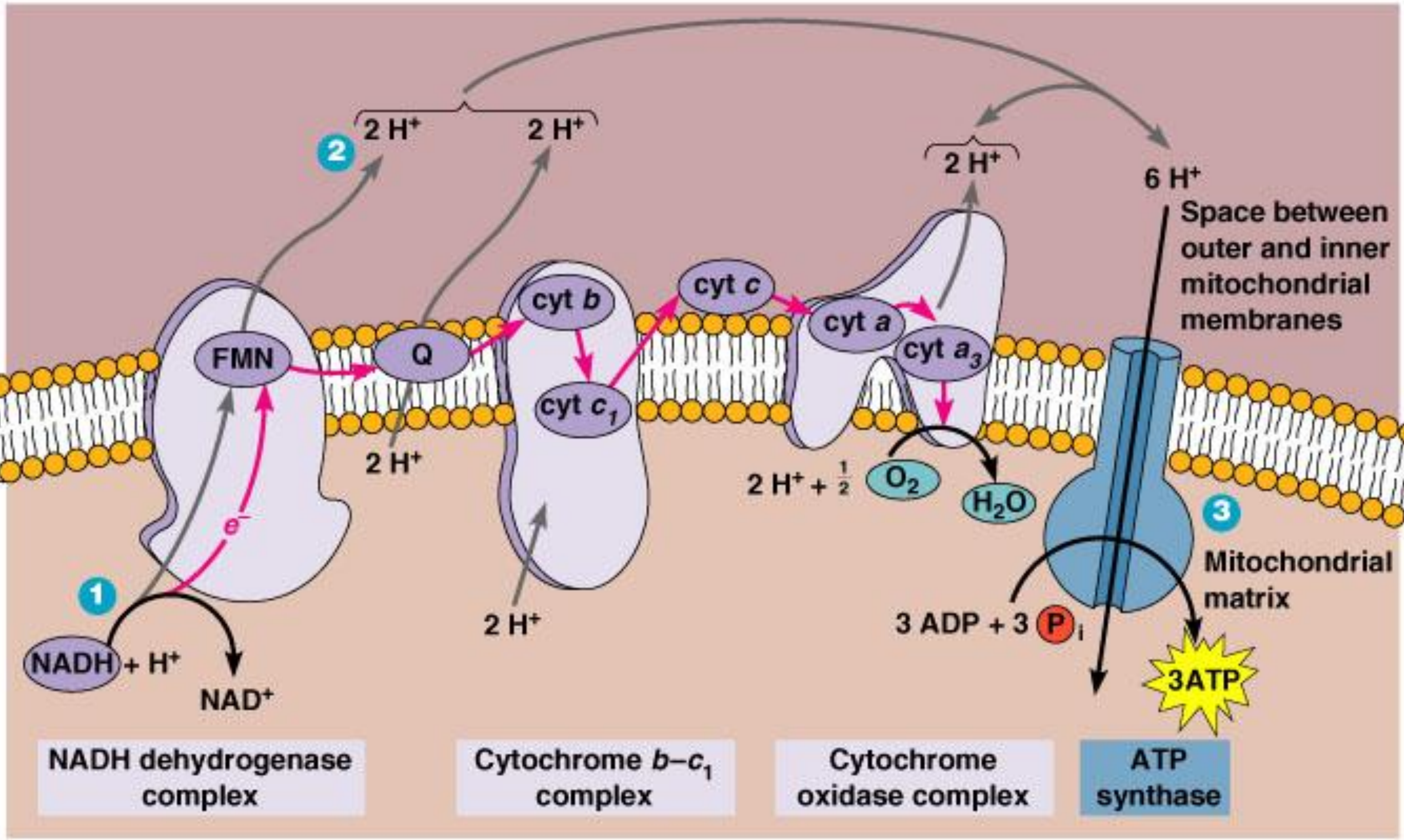
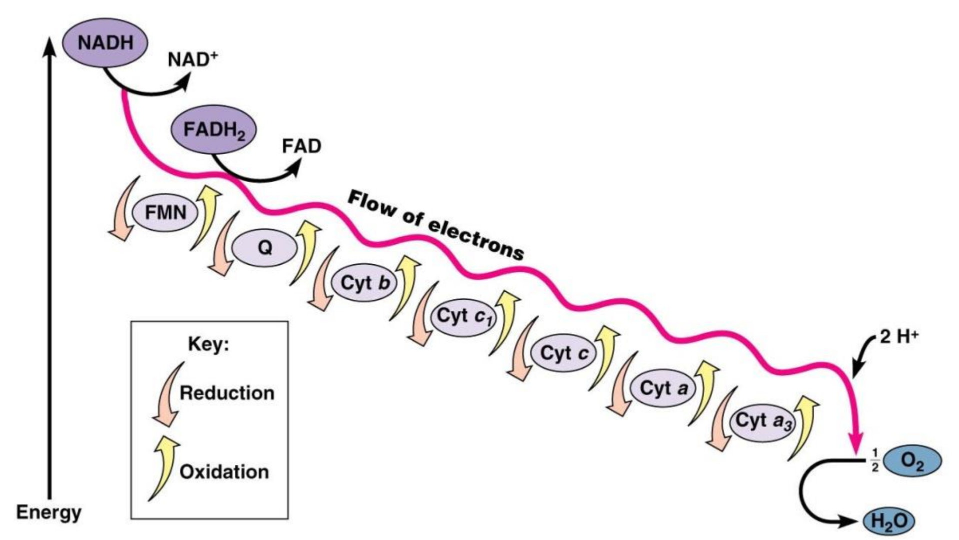


Figure 5.16

What is a terminal electron acceptor?

In
aerobic respiration=
oxygen



In
anaerobic respiration=
no oxygen

Bacteria	Electron acceptor	Products
Pseudomonas, Bacillus	NO_3^-	NO_2^-, $N_2 + H_2O$
Desulfovibrio	SO_4^-	$H_2S + H_2O$
methanogens	CO_3^{2-}	$CH_4 + H_2O$

Figure 5.14 (2 of 2)

Anaerobic respiration

Steps:

1. Glycolysis

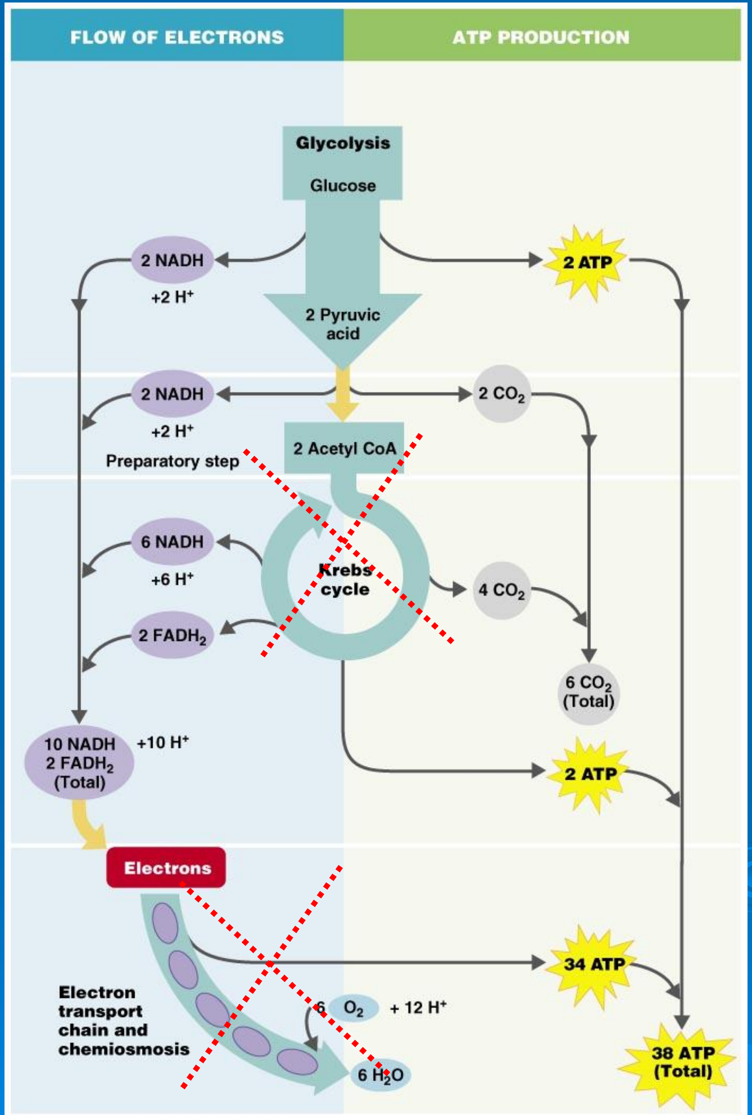
   1a. Pentose phosphate pathway
   1b. Entner-Doudoroff pathway

2. Intermediate step

3. Krebs Cycle/ TCA

4. Electron transport chain (ETC)

Total energy output:



Independent Study

1. Review the light dependent and light independent reactions of photosynthesis (see Figure 5.25 and 5.26).

***Print out and bring **APO-2: A Metabolism Case Study** for next class.

More cool microbial metabolism

Lecture

Continue Chapter 5
Fermentation
Photophosphorylation
Microbial metabolic diversity

APO 2: Case study in fermentation

Lab

Acid fast, spore and capsule stains

Pre-labs
Using the Spectrophotometer and
Exam Review

Let's review: aerobic respiration

Steps:

1. Glycolysis

   2 substrate level ATP
   2 NADH

1a. Pentose phosphate pathway

1b. Entner-Doudoroff pathway

2. Transition/preparatory step

   $2CO_2$
   2 NADH

3. Krebs Cycle/ TCA

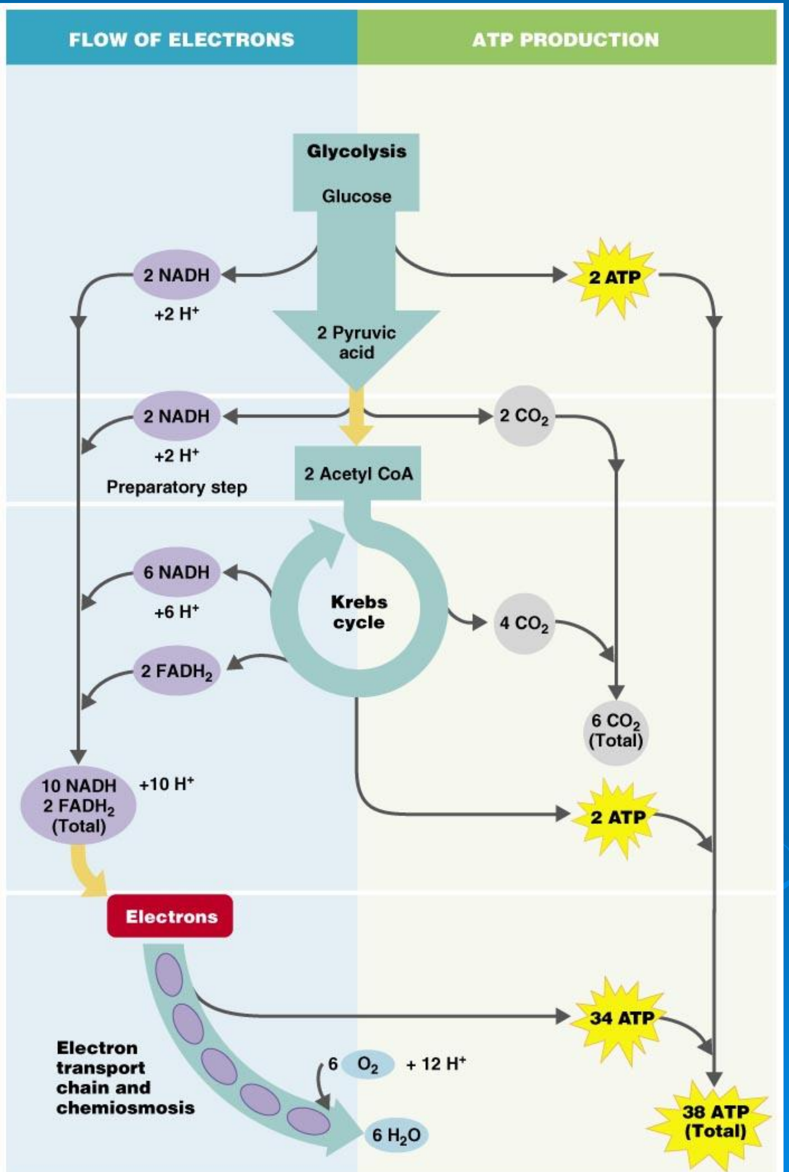
   2 substrate level ATP
   4 CO_2
   6 NADH
   2 $FADH_2$

4. Electron transport chain (ETC)

   34 ATP

Total energy output:

38 ATP (prokaryotes)
36 ATP (eukaryotes)



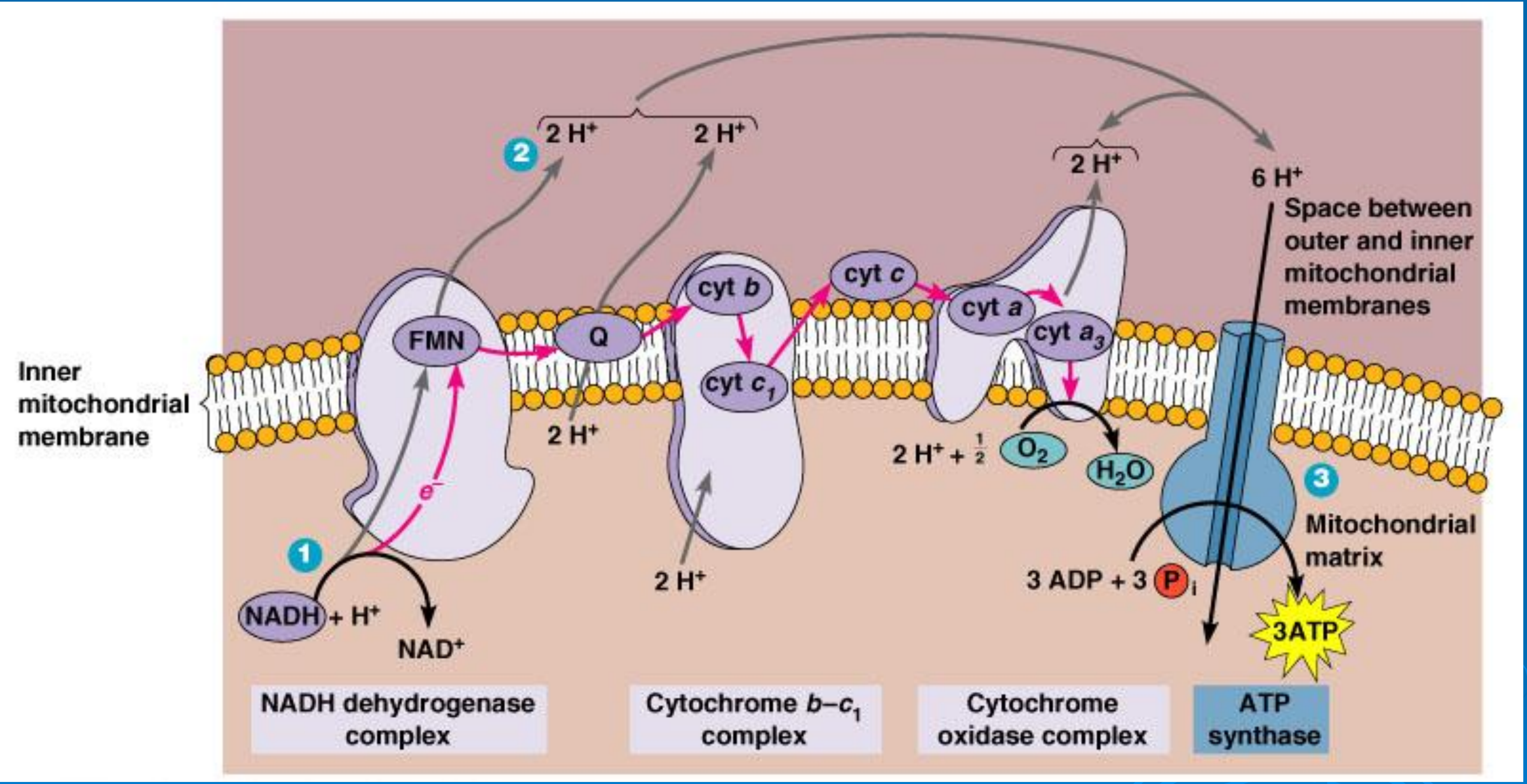
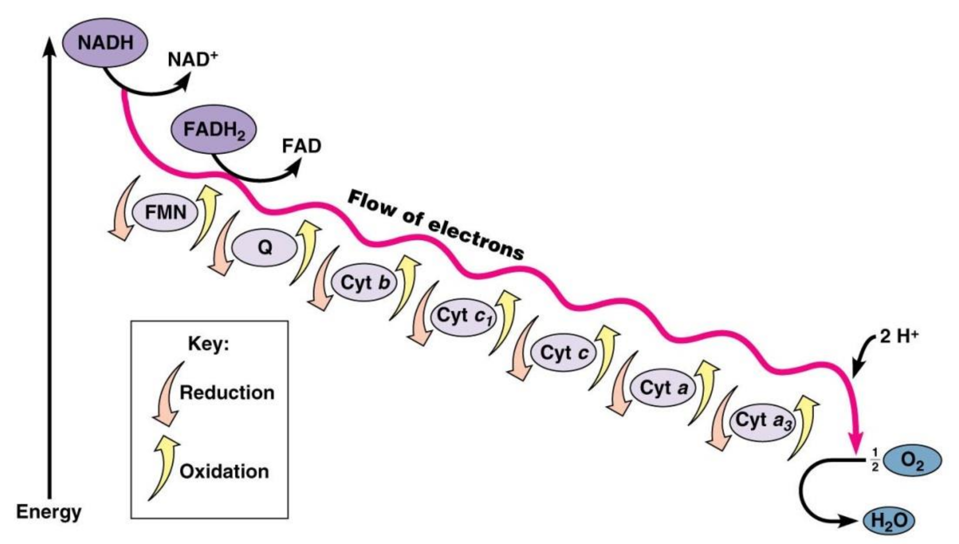

2 H+
2 H+
2
2 H+
6 H+
Space between outer and inner mitochondrial membranes
Inner mitochondrial membrane
FMN
Q
cyt b
cyt c
cyt a
cyt a3
cyt c1
2 H+
2 H+ + 1/2 O2
H2O
3
Mitochondrial matrix
e−
1
2 H+
3 ADP + 3 P i
NADH + H+
NAD+
3ATP
NADH dehydrogenase complex
Cytochrome b–c1 complex
Cytochrome oxidase complex
ATP synthase

Figure 5.16

What is a terminal electron acceptor?

In
aerobic respiration=
oxygen



In
anaerobic respiration=
no oxygen

Bacteria	**Electron acceptor**	**Products**
Pseudomonas, Bacillus	NO_3^-	NO_2^-, $N_2 + H_2O$
Desulfovibrio	SO_4^-	$H_2S + H_2O$
methanogens	CO_3^{2-}	$CH_4 + H_2O$

Figure 5.14 (2 of 2)

Anaerobic respiration

Steps:

1. Glycolysis

   2 substrate level ATP
   2 NADH

   1a. Pentose phosphate pathway
   1b. Entner-Doudoroff pathway

2. Intermediate step

   $2CO_2$
   2 NADH

3. Krebs Cycle/ TCA

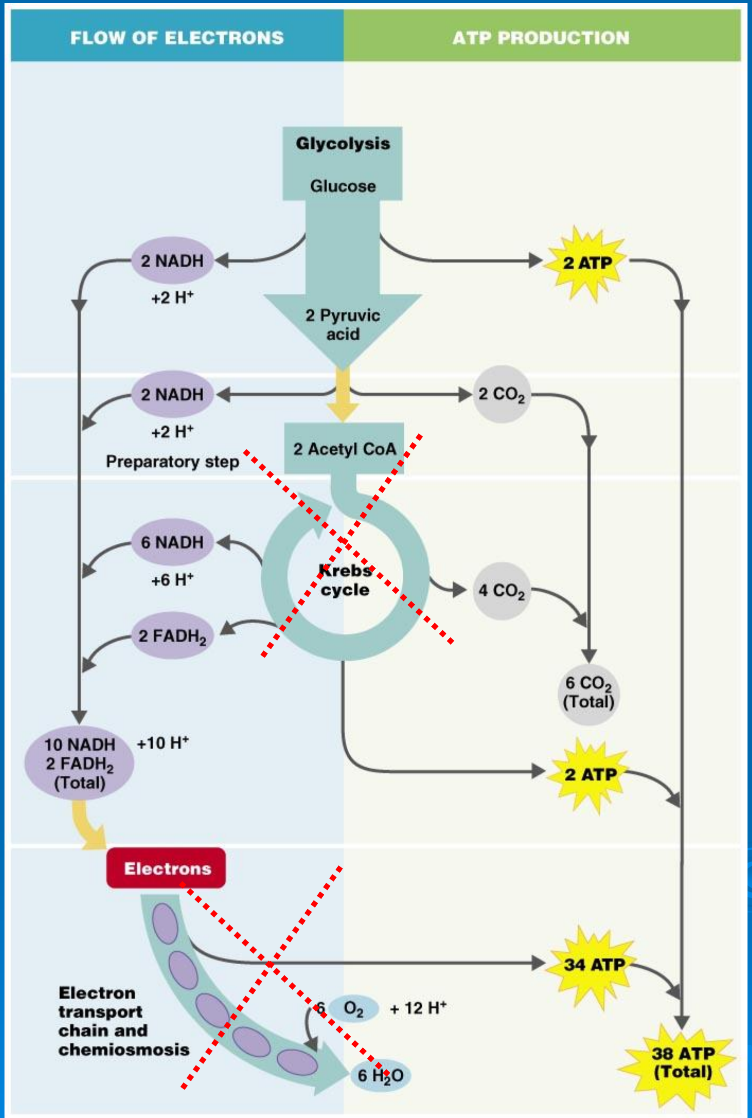
   partially utilized

4. Electron transport chain (ETC)

   partially utilized

Total energy output:

Varied, between 2-38 ATP



Varieties of fermentation

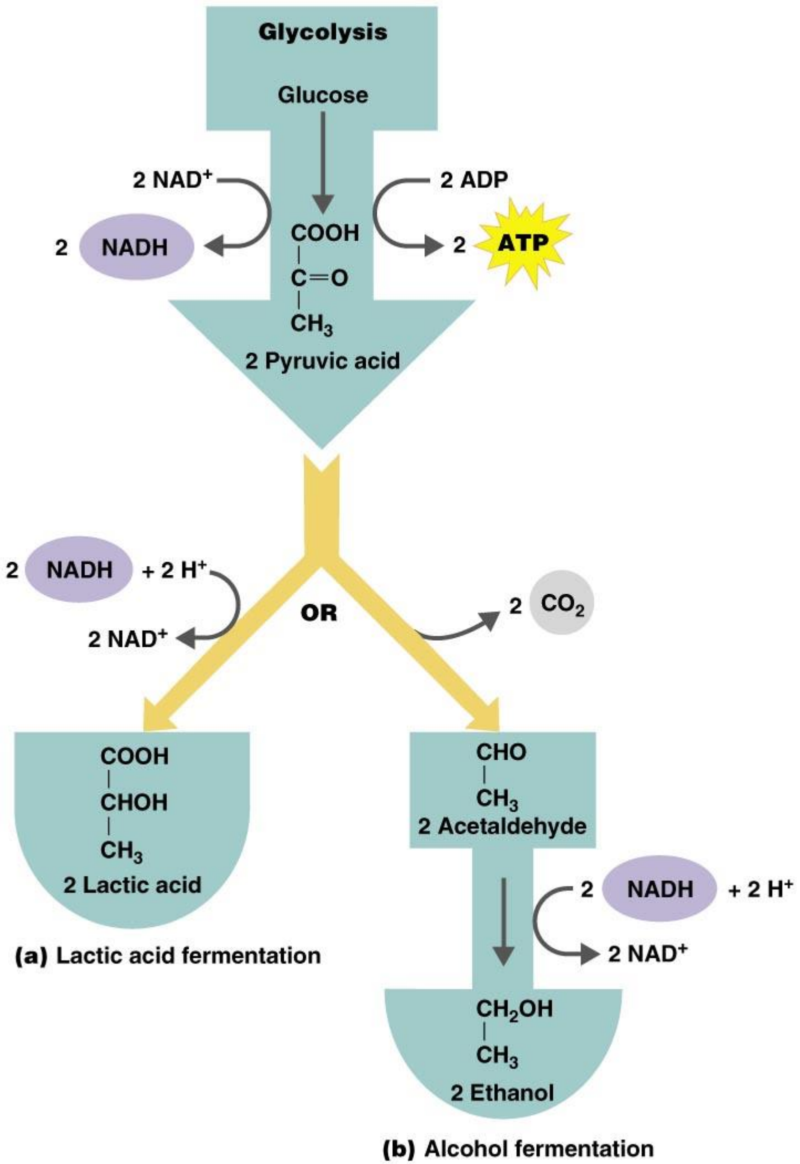
Steps:

1. Glycolysis

2 substrate level ATP
2 NADH

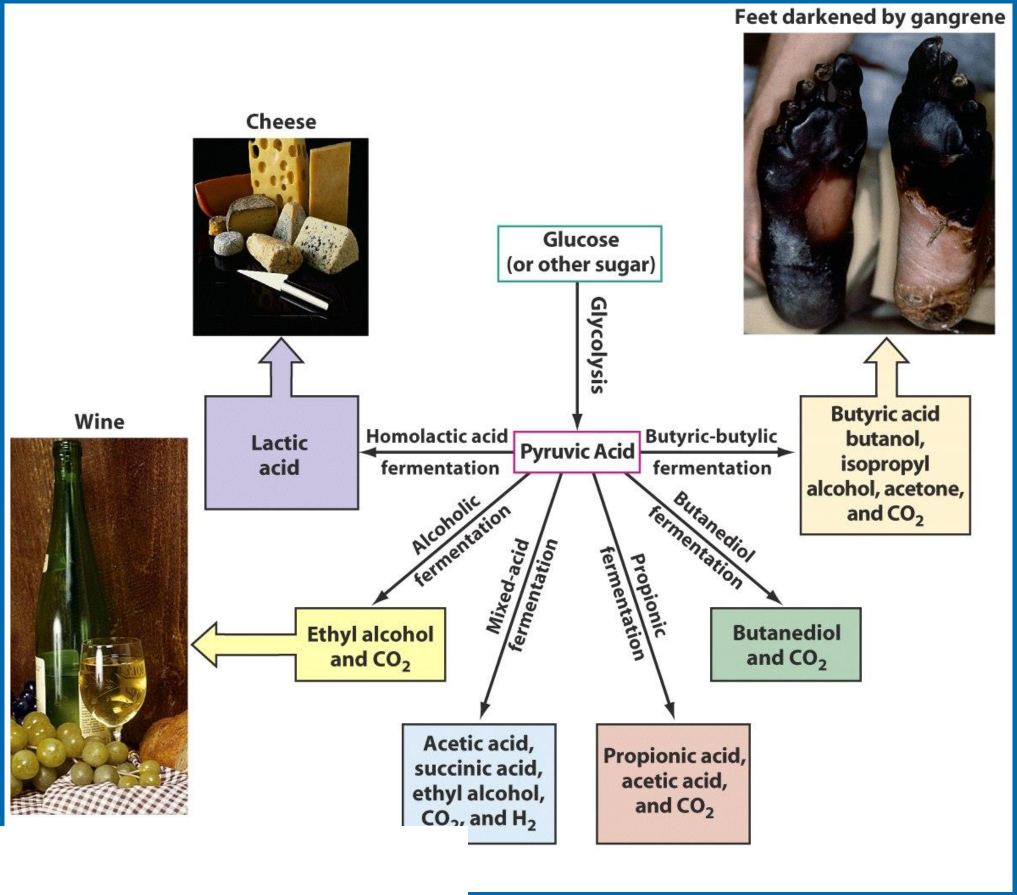
2. Fermentative pathway

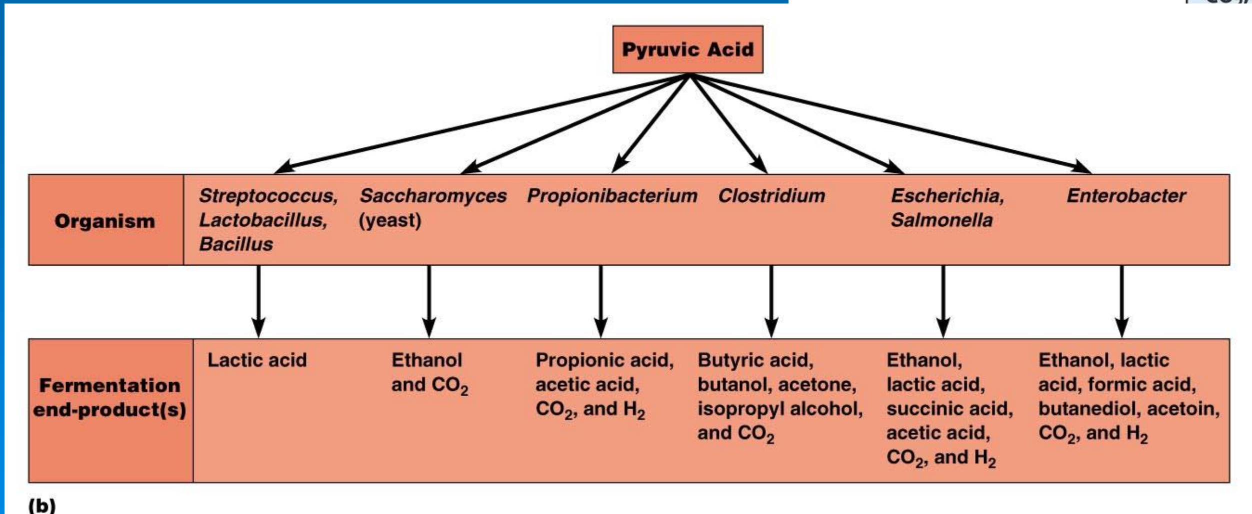
****Lactic acid fermentation**
Homolactic
OR
Heterolactic
****Alcoholic fermentation**
Additional fermentation pathways



(a) Lactic acid fermentation
(b) Alcohol fermentation

Fermentative microbes





See Figure 5.18 and Table 5.4

Comparison of catabolic efficiency

Table 5.5 Aerobic Respiration, Anaerobic Respiration, and Fermentation Compared

Energy-Producing Process	Growth Conditions	Final Hydrogen (Electron) Acceptor	Type of Phosphorylation Used to Generate ATP	ATP Molecules Produced per Glucose Molecule
Aerobic Respiration	Aerobic	Molecular oxygen (O_2)	Substrate-level and oxidative	36 (eukaryotes) 38 (prokaryotes)
Anaerobic Respiration	Anaerobic	Usually an inorganic substance (such as NO_3^-, SO_4^{2-}, or CO_3^{2-}) but not molecular oxygen (O_2)	Substrate-level and oxidative	Variable (fewer than 38 but more than 2)
Fermentation	Aerobic or anaerobic	An organic molecule	Substrate-level	2

Reminder: other organic molecules can be used for ATP production

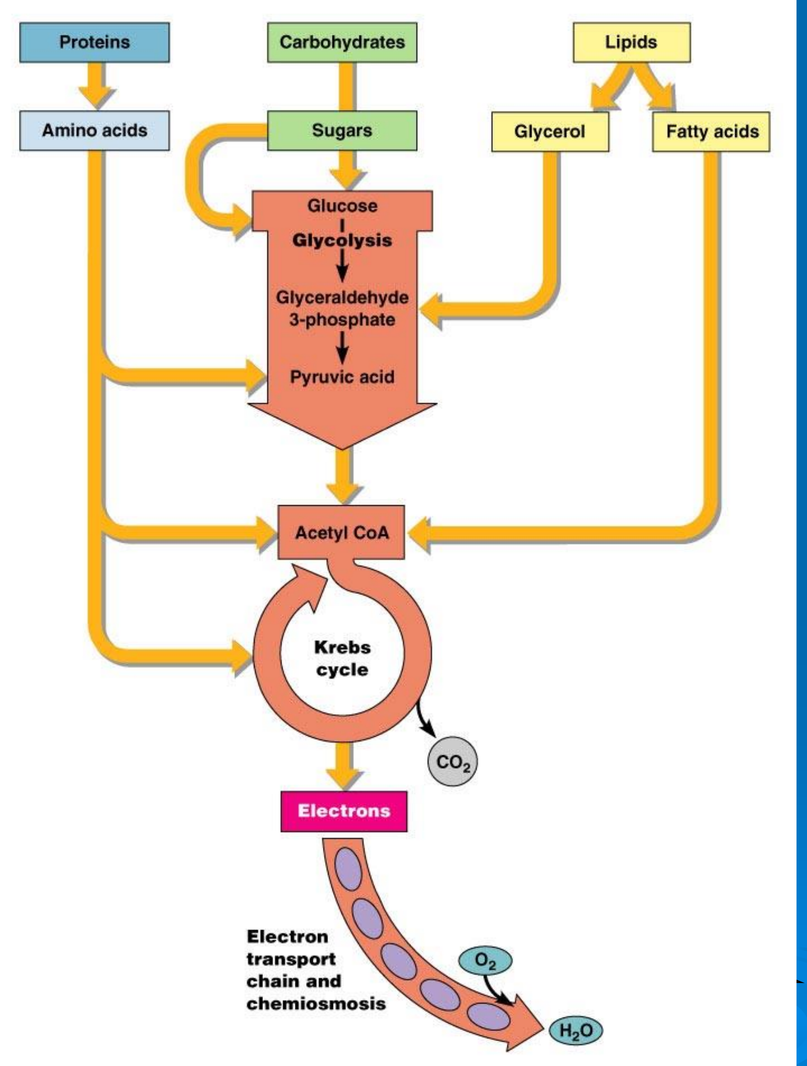
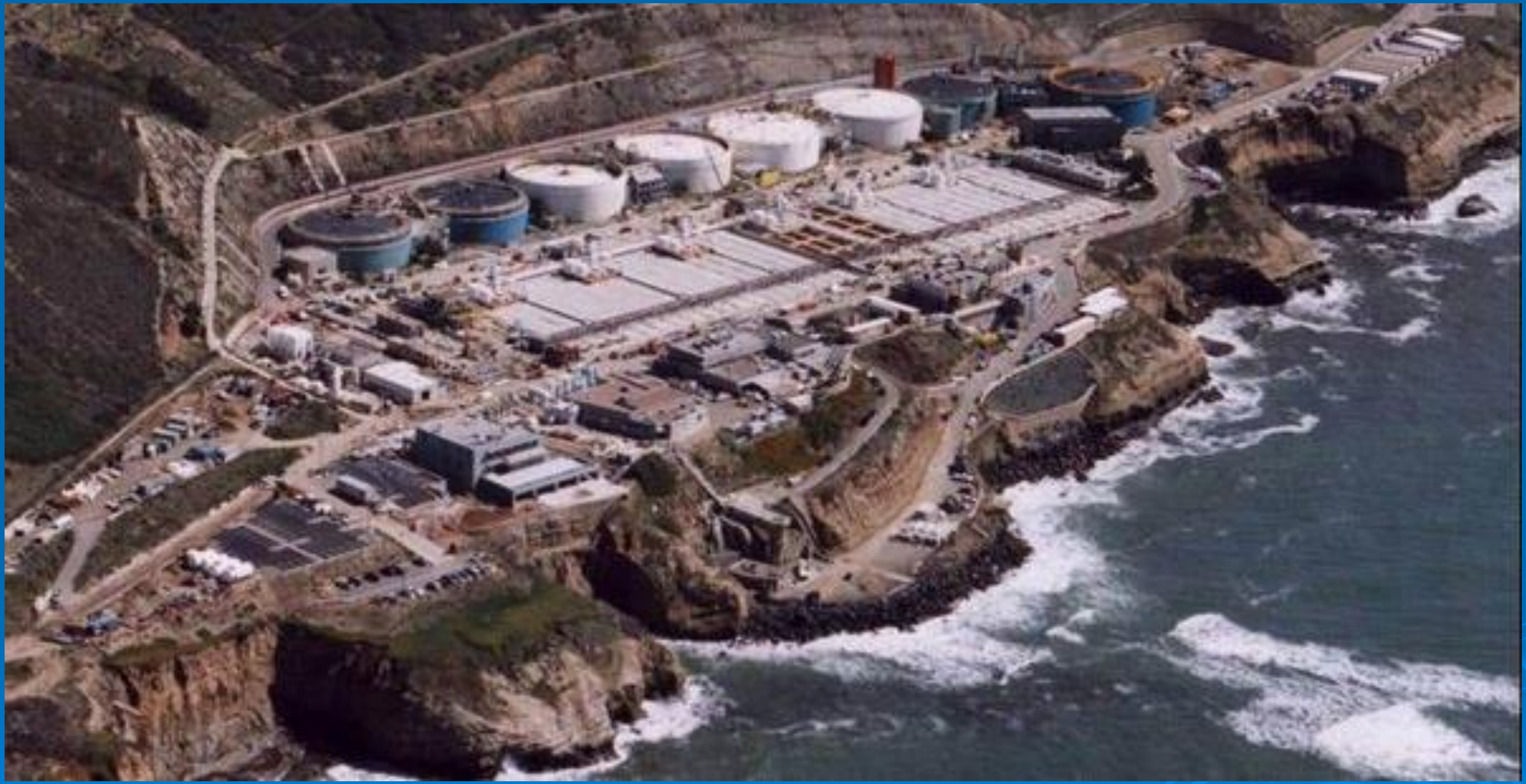


Figure 5.21

What good are alternative metabolisms to us?



Pt. Loma Wastewater Treatment Plant

http://www.sandiego.gov/mwwd/facilities/ptloma.shtml

How does it happen?

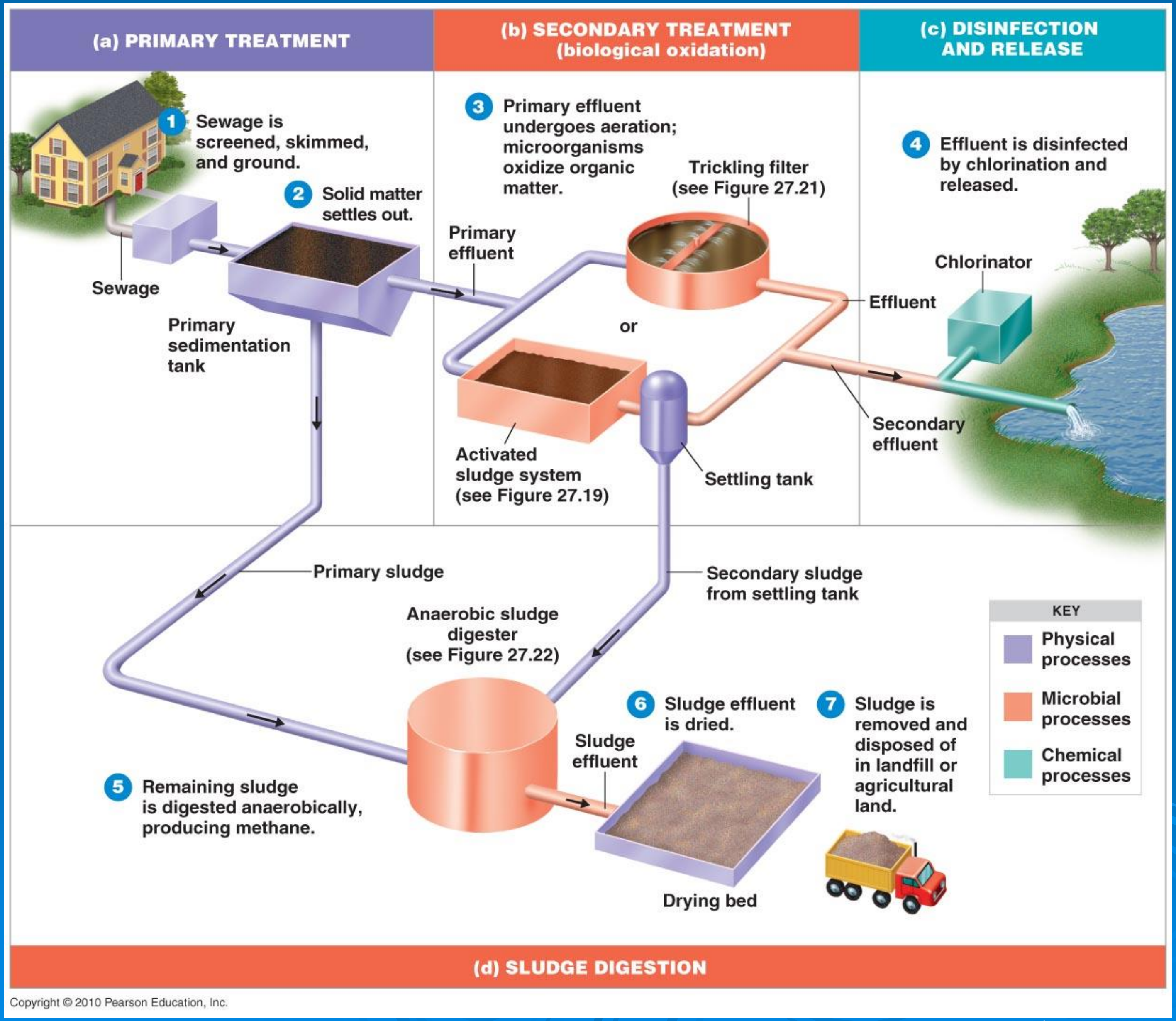
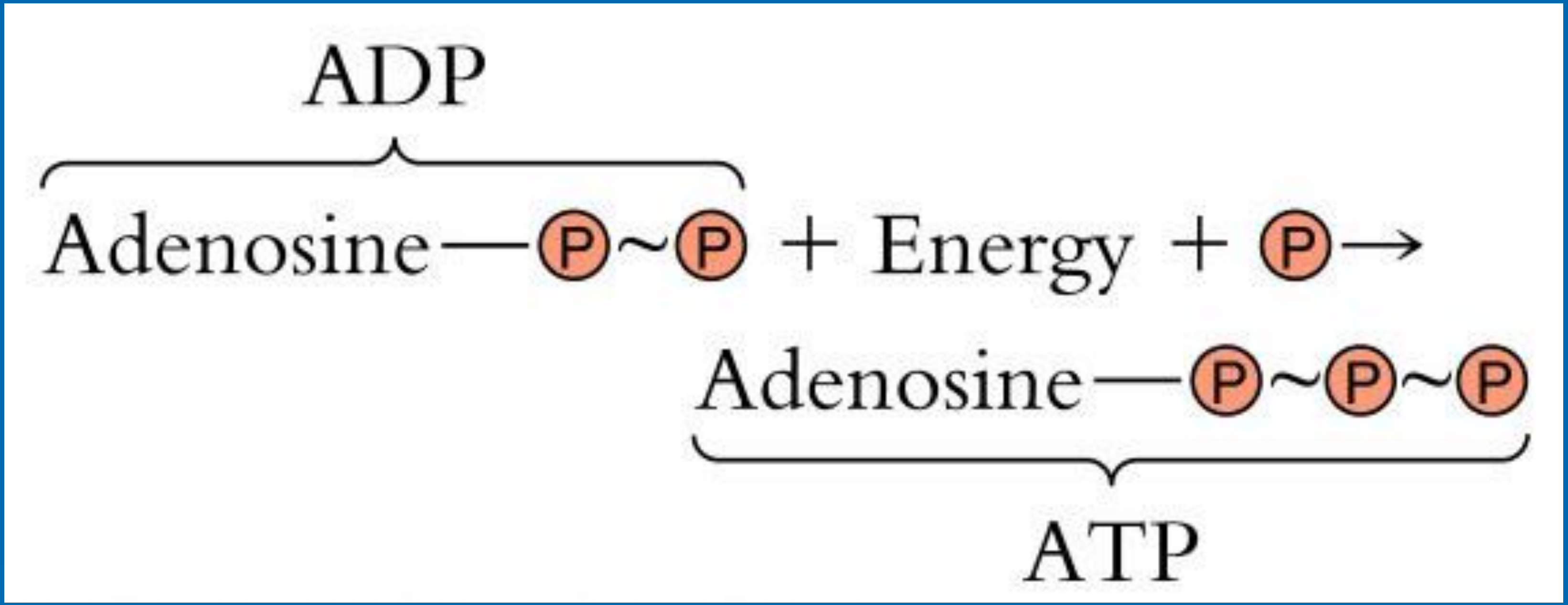


Figure 27.18

Phosphorylation reactions or HOW WE MAKE ATP



1. Substrate level phosphorylation
2. Oxidative phosphorylation
3. **Photophosphorylation**

3. Photophosphorylation

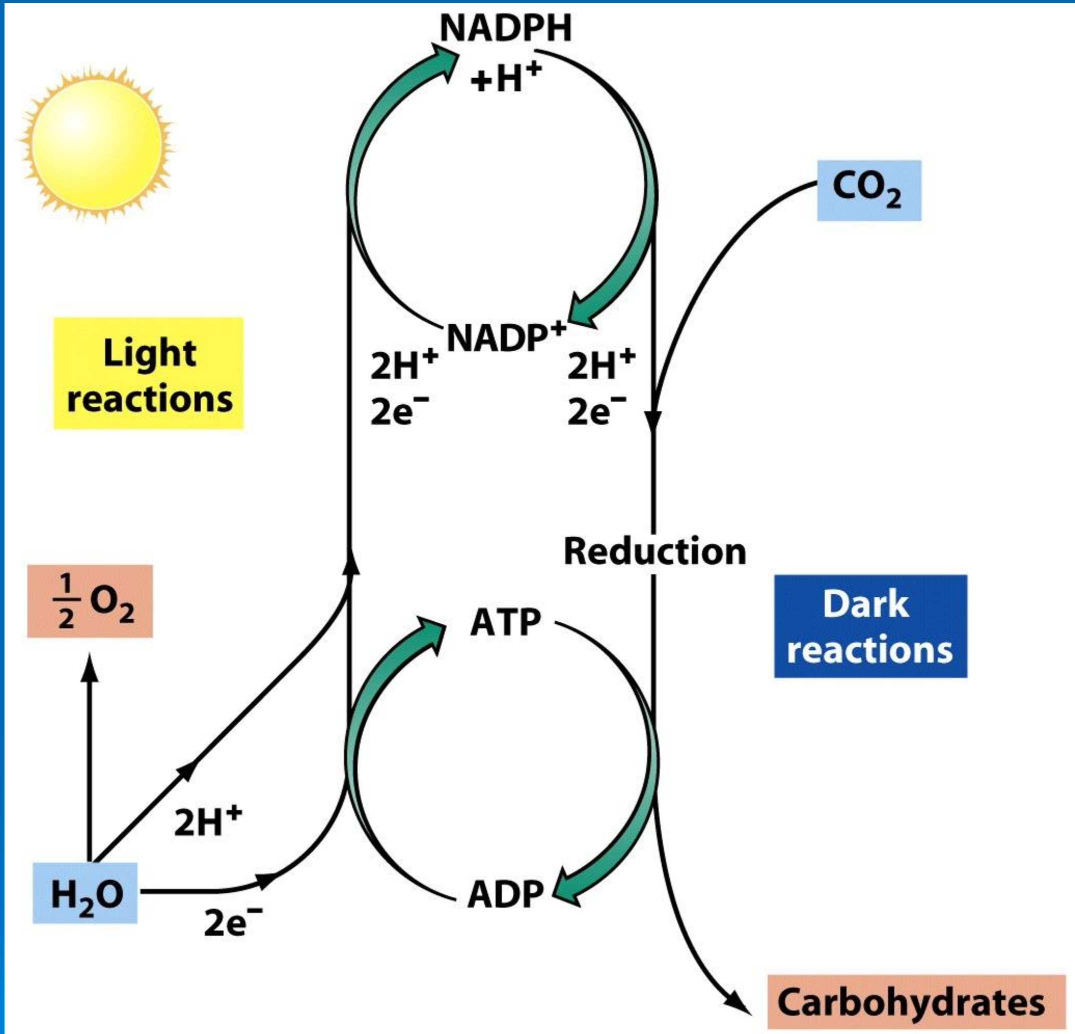


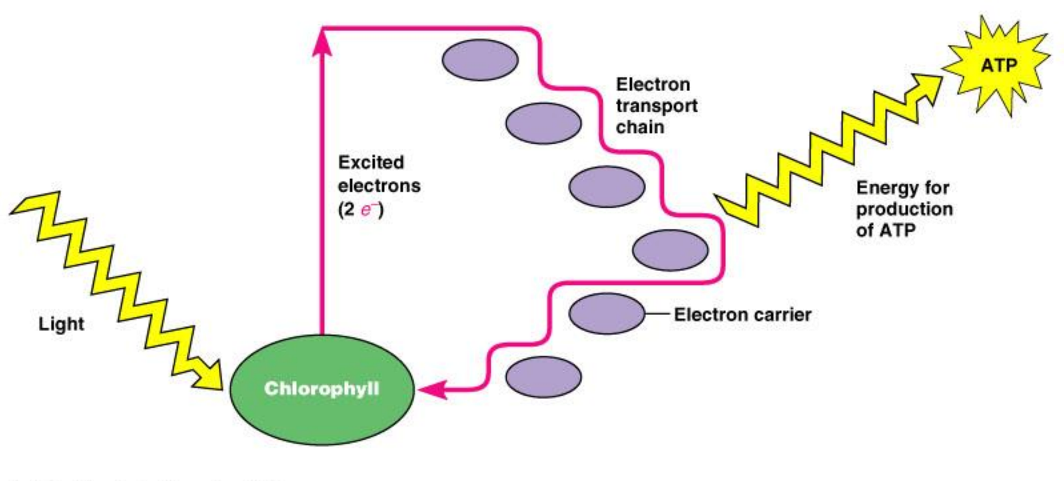
Figure 5-26 Microbiology, 6/e

Photo reactions of photosynthesis

Photo reactions: cyclic and non-cyclic photophosphorylation

Cyclic outcomes

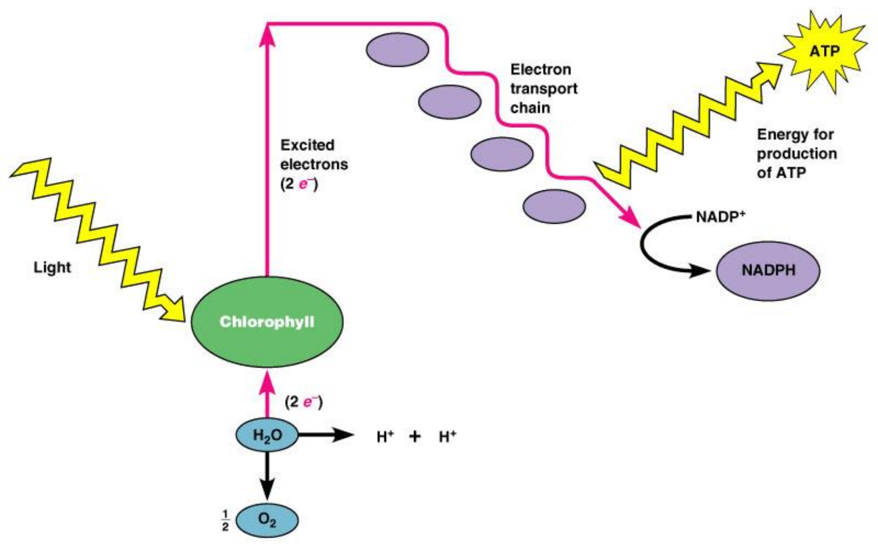
e- thru ETC produce ATP
e- recycle back to chloropyll



(a) Cyclic photophosphorylation

Non-cyclic outcomes

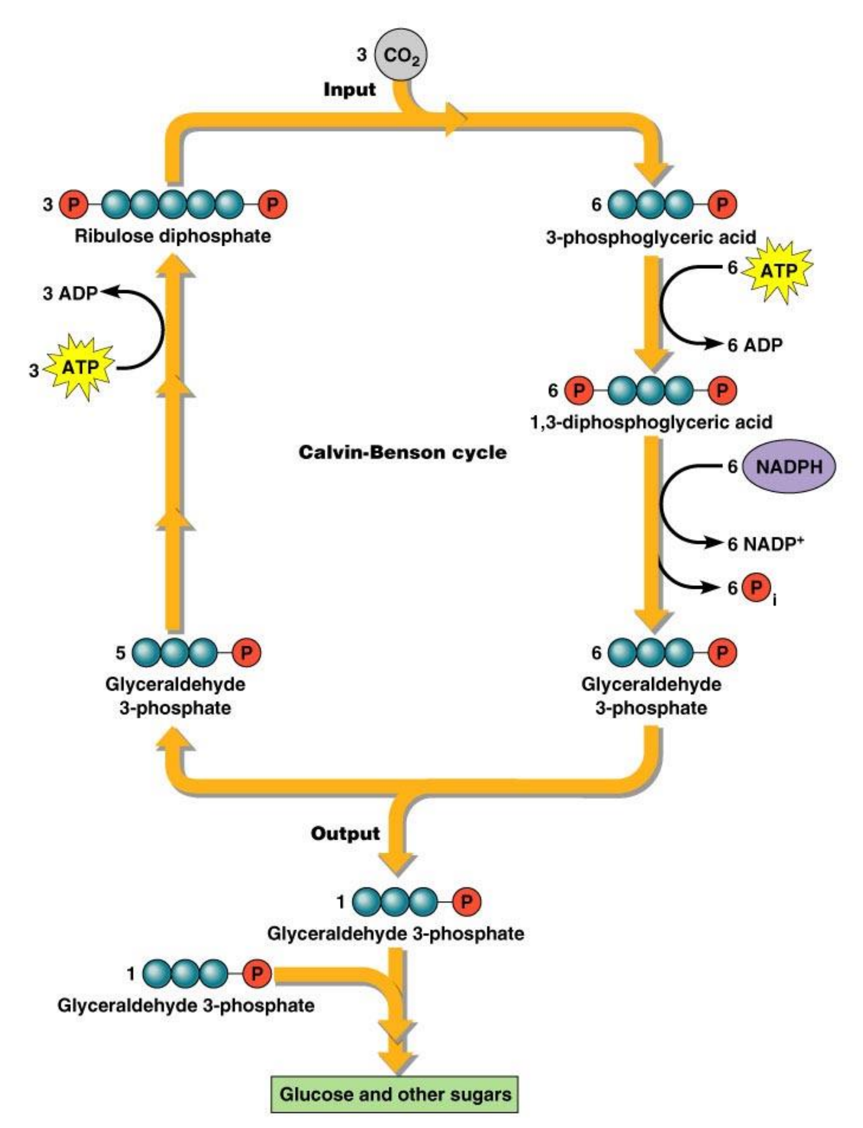
e- thru ETC produce ATP
Terminal acceptor is NADP+
Photoylsis recycles e- to clorophyll:
$H_2O \rightarrow 2H^+ + ½O_2 + 2e-$



(b) Noncyclic photophosphorylation

Figure 5.24

What is the ATP and NADPH used for?



Synthesis reactions

Figure 5.26

Varieties of photosynthesis

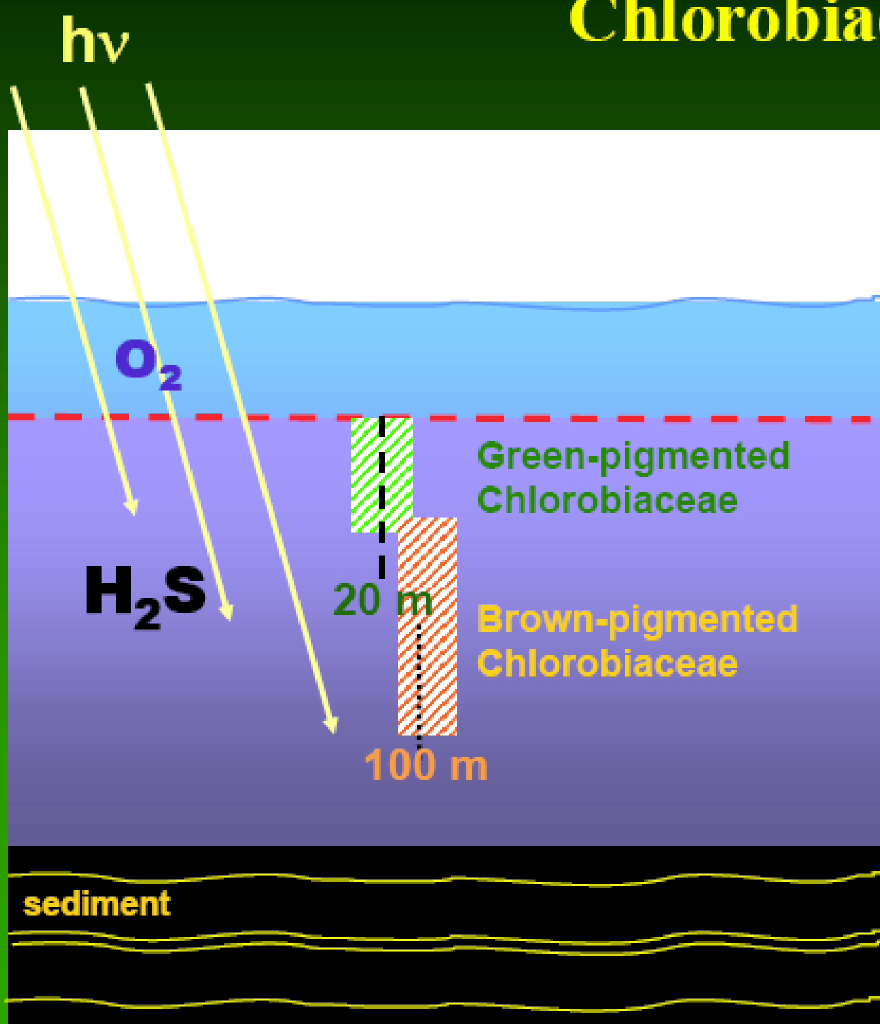
Table 5.6 Photosynthesis Compared in Selected Eukaryotes and Prokaryotes

Characteristic	*Eukaryotes*	*Prokaryotes*		
	Algae, Plants	**Cyanobacteria**	**Green Bacteria**	**Purple Bacteria**
Substance That Reduces CO_2	H atoms of H_2O	H atoms of H_2O	Sulfur, sulfur compounds, H_2 gas	Sulfur, sulfur compounds, H_2 gas
Oxygen Production	Oxygenic	Oxygenic (and anoxygenic)	Anoxygenic	Anoxygenic
Type of Chlorophyll	Chlorophyll *a*	Chlorophyll *a*	Bacteriochlorophyll *a*	Bacteriochlorophyll *a* or *b*
Site of Photosynthesis	Chloroplasts with thylakoids	Thylakoids	Chlorosomes	Chromatophores
Environment	Aerobic	Aerobic (and anaerobic)	Anaerobic	Anaerobic

Example of anoxygenic photosynthesis

Green sulfur bacteria

Chlorobiaceae



Anoxygenic photosynthesis

$$H_2S + CO_2 \xrightarrow{h\nu} SO_4^{2-} + C_{org}$$

- requires reduced sulfur
- requires light
- strictly anaerobic

Biomarkers of Chlorobiaceae

chlorobactane

isorenieratane

Summons et al., 1987; JJ Brocks et al 2005

Nutritional classification of organisms

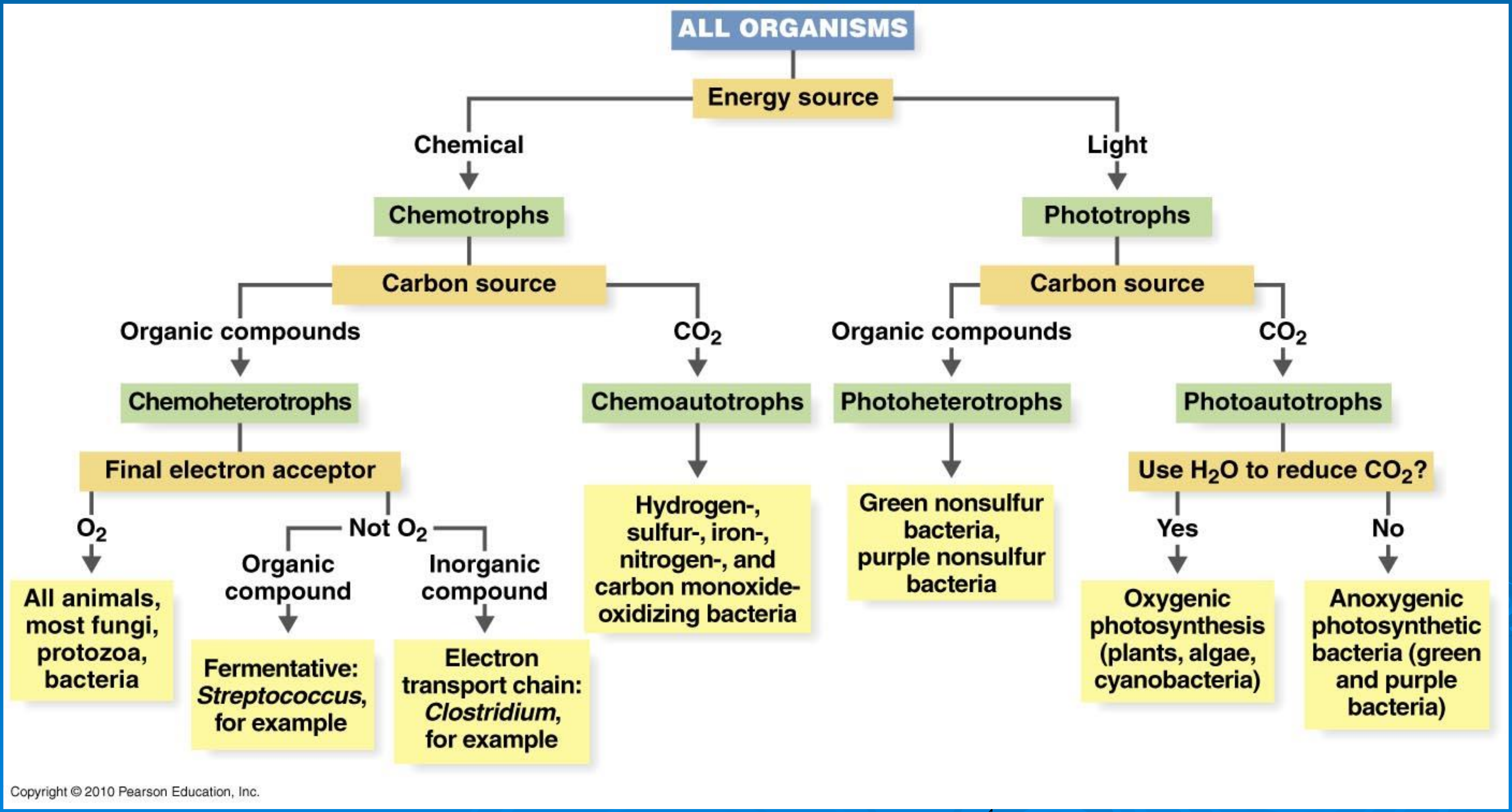


Figure 5.28

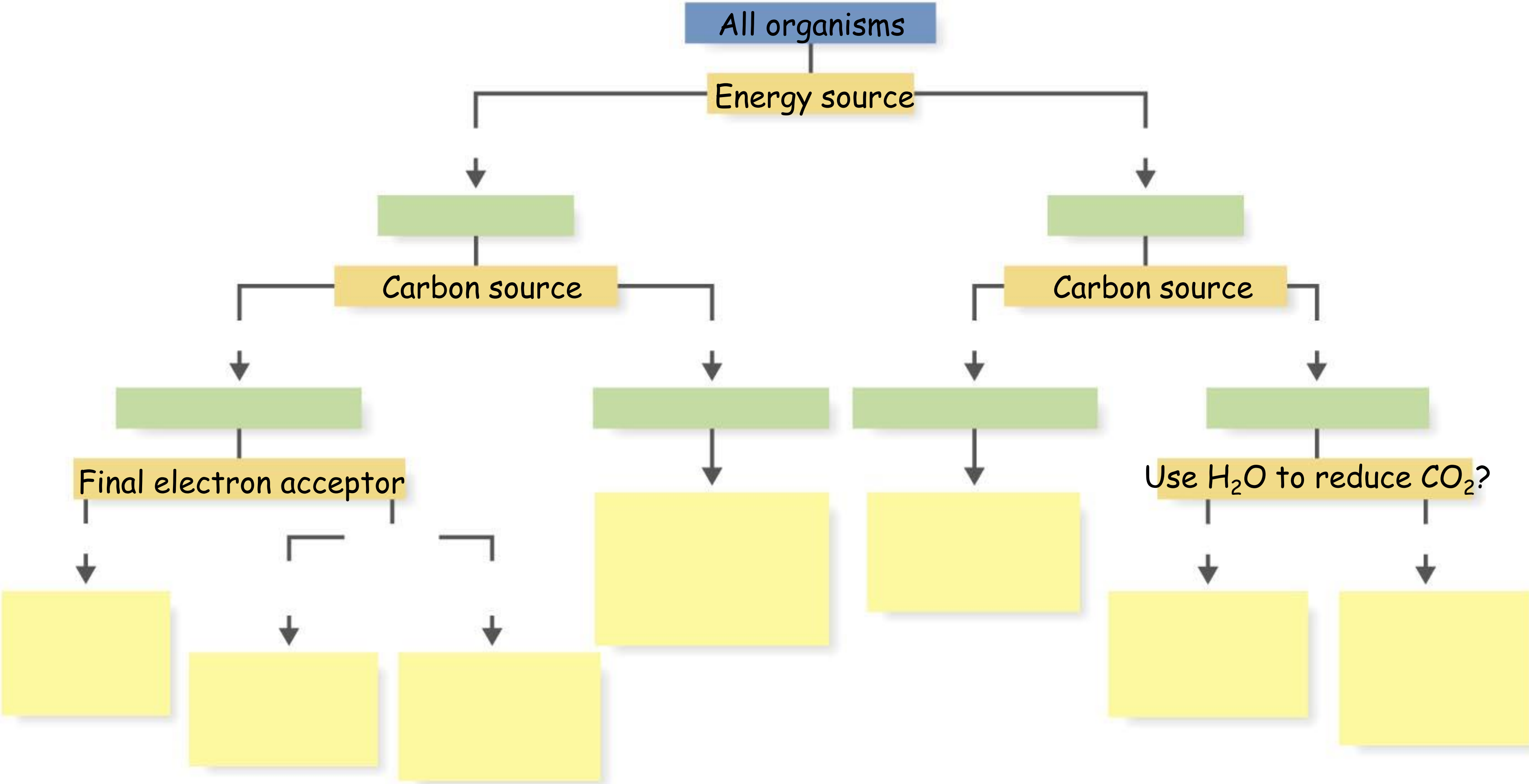
Independent Study

1. Test yourself on the energy and carbon needs of microbes. Use the blank flowchart in the following slide and fill in the appropriate nutritional categories. Once you have done this, use the flowchart to answer question #2.

2. Determine carbon source, energy course, and type of metabolism (i.e. aerobic or anaerobic respiration, fermentation, oxygenic or oxygenic photosythesis) for the following organisms:

    a. *Pseudomonas*, an aerobic chemoheterotroph
    b. Clostridium, an anaerobic chemoheterotroph
    c. *Spirulina*, an oxygenic photoautotroph
    d. *Ectothiorhodopsin*, an anoxygenic photoautotroph
    e. *Nitrosomonas*, a nitrogen oxidizing chemoautotroph

3. Study for Exam 1


All organisms
Energy source
Carbon source
Carbon source
Final electron acceptor
Use H2O to reduce CO2?