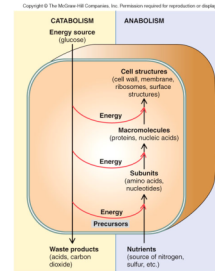


Chapter 6

Metabolism

Principles of Metabolism

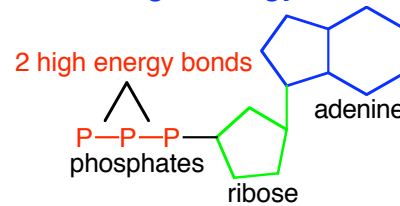
- ✓ Catabolism
 - Degradative reactions
 - Reactions produce energy from the break down of larger molecules
- ✓ Anabolism
 - Reactions involved in the synthesis of cell components
 - Anabolic reactions require energy
 - ↳ Anabolic reactions utilize the energy produced from catabolic reactions



Types of energy

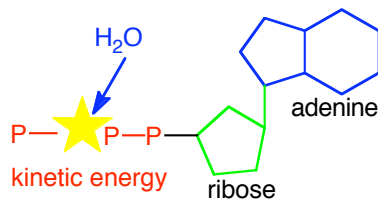
- ✓ Potential energy
 - Stored energy
- ✓ Kinetic energy
 - Energy of movement

ATP has 2 high energy bonds

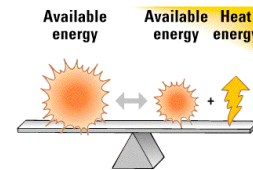


- ATP is created 3 ways
 - Substrate phosphorylation - uses chemical energy
 - Oxidative phosphorylation - uses chemical energy to form a proton motive force
 - Photophosphorylation - uses light energy to form a proton motive force

Breaking bonds releases energy

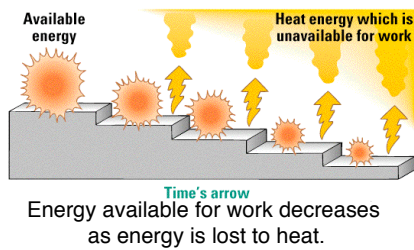


First Law of Thermodynamics



Conservation of energy:
energy is neither gained nor lost, it is only transformed.

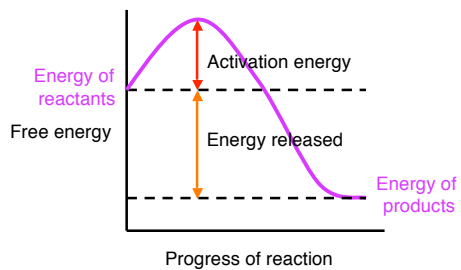
Second Law of Thermodynamics



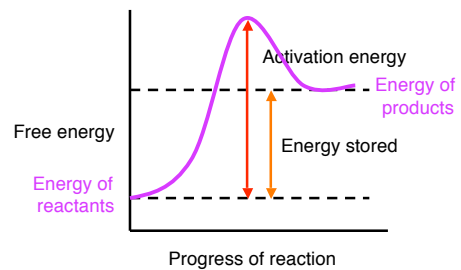
Reactions

- ✓ Exergonic
 - Energy-releasing reactions.
- ✓ Endergonic
 - Energy-storing reactions.
- ✓ Coupled reactions
 - Exergonic reactions often provide the energy for endergonic reactions.
 - Enzymes mediate the coupling.

Exergonic reactions



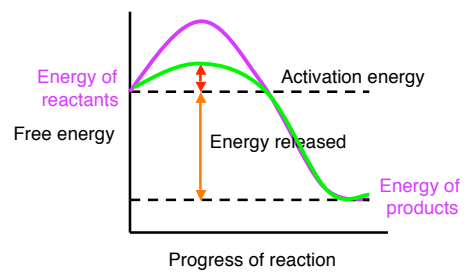
Endergonic reactions



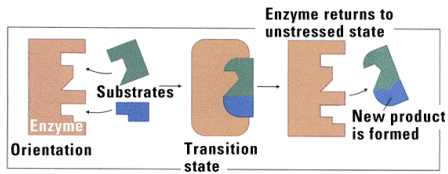
Enzymes...

- ✓ Are biochemical catalysts.
- ✓ Speed up reactions.
- ✓ Are not used up by the reaction they catalyze.
- ✓ Lower the activation energy of the reaction.
- ✓ Are usually proteins.
- ✓ Are usually influenced by pH, temperature, and the concentration of the substrate.
- ✓ Influenced by inhibitors

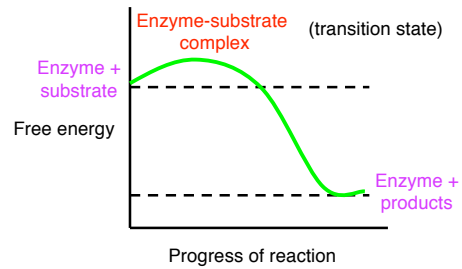
Enzymes lower the activation energy



Biological reactants are called substrates



Enzymes form a complex with the substrate



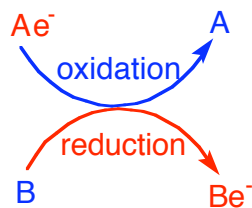
Enzymes can be inhibited

- ✓ Competitive inhibitors.
 - Compete with the substrate for the active site of the enzyme.
 - Often are steric in nature.
- ✓ Noncompetitive inhibitors.
 - Bind to another site on the enzyme and deactivate the active site.
 - ◻ (allosteric)
- ✓ Feedback inhibition

Oxidation-Reduction Reactions

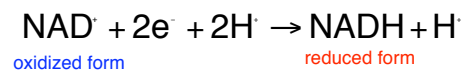
- ✓ Loss of electrons is **OXIDATION**.
 - Loss of energy
 - Loss of hydrogen
- ✓ Gain of electrons is **REDUCTION**.
 - Gain of energy
 - Gain of hydrogen

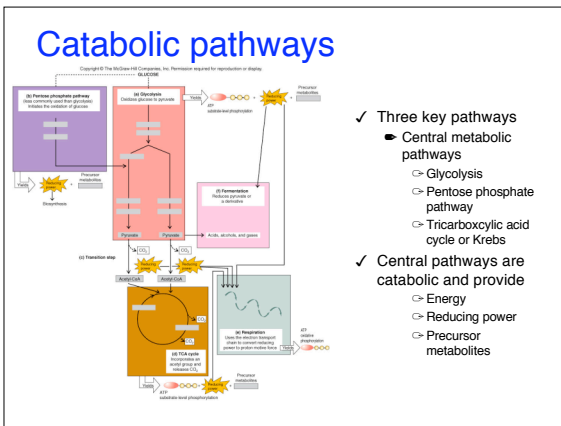
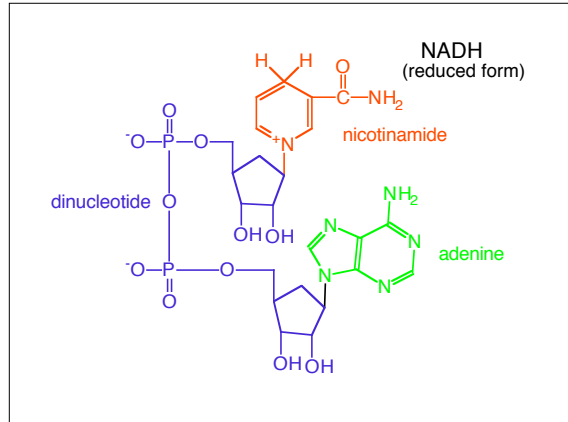
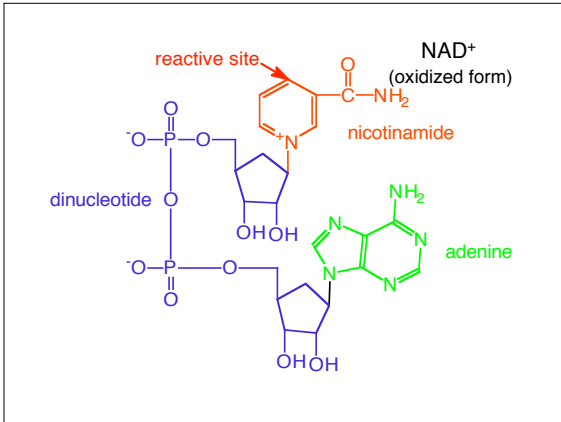
Oxidation-reduction reactions are coupled



Common electron acceptors

- ✓ Nicotinamide adenine dinucleotide (NAD⁺)
- ✓ Flavin adenine dinucleotide (FAD⁺)
- ✓ Nicotinamide adenine dinucleotide phosphate (NADP⁺)





Carbon source

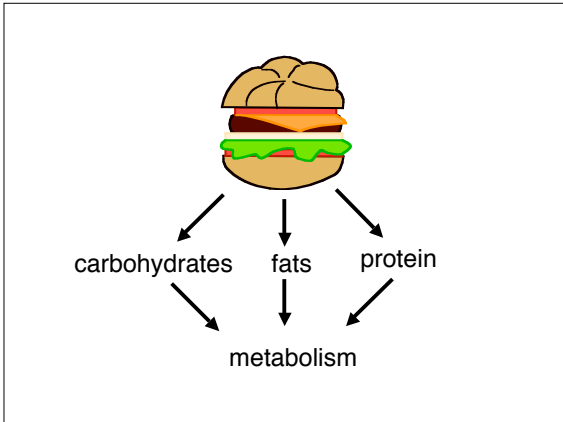
- ✓ Autotrophs
- ✓ Use inorganic C, mainly CO₂, as a C source.
- ✓ Heterotrophs
- ✓ Use organic C as a C source

Energy source

- ✓ Phototrophs
- ✓ Use light as an energy source.
- ✓ Chemotrophs
- ✓ Use organic or inorganic compounds as energy sources.

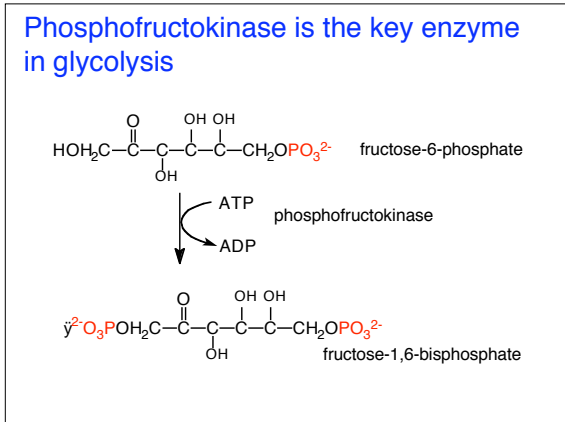
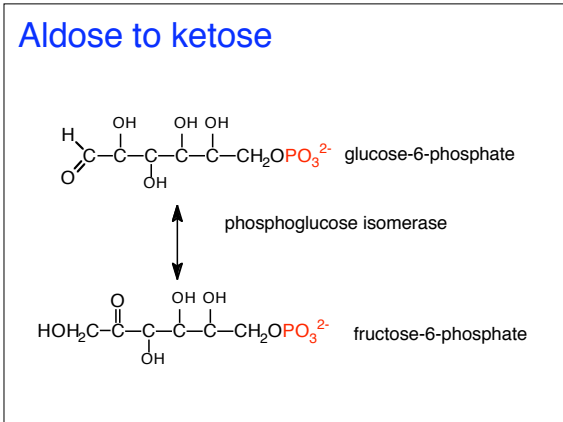
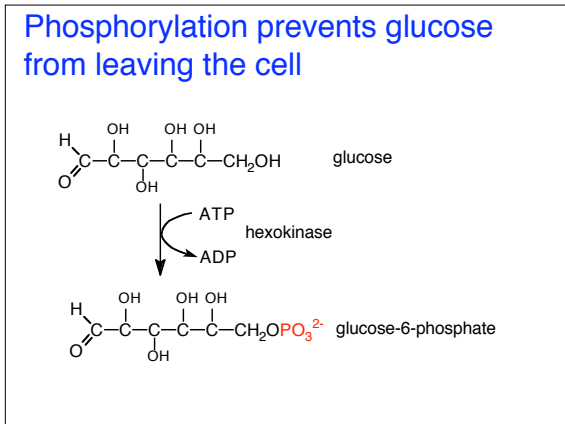
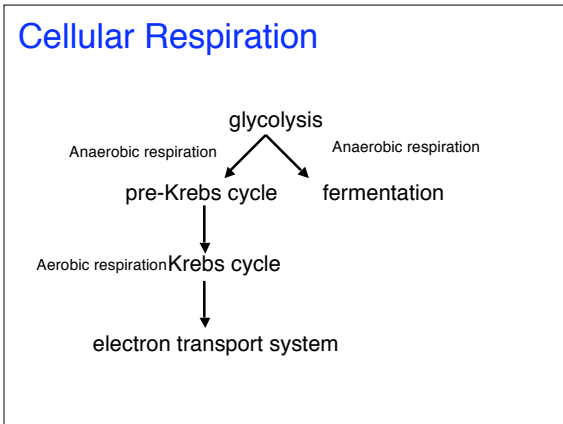
Carbon and Energy Sources

	carbon source	energy source
chemoautotrophs	CO ₂	inorganic molecules
chemoheterotrophs	organic molecules	organic molecules
photoautotrophs	CO ₂	light
photoheterotrophs	organic molecules	light

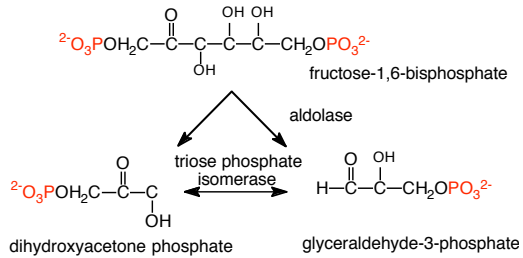


Catabolic Pathways

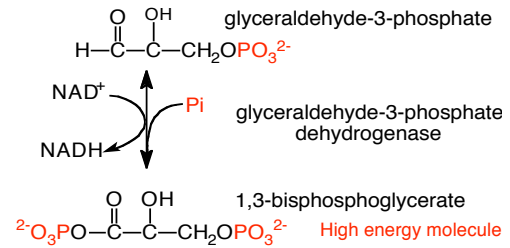
- ✓ Glycolysis
 - a.k.a Embden-Meyerhoff pathway
 - Oxidizes glucose to two molecules of pyruvate
- ✓ Pentose phosphate pathway (PPP)
 - Breaks down glucose
 - Produces molecules for biosynthesis
 - Works in conjunction with glucose degrading pathways
- ✓ Tricarboxylic acid cycle (TCA) or Krebs
 - Before entering cycle, pyruvate enters transition step
 - Pyruvate formed in glycolysis and PPP
 - Cycle turns twice to complete oxidation of one glucose molecule
- ✓ Respiration vs. fermentation
 - Respiration uses reducing power to generate ATP
 - NADH and FADH₂ transfer electrons to produce proton motive force
 - Allows for recycling of electron carriers
 - Electrons join with terminal electron acceptor
 - Oxygen in aerobic respiration
 - Anaerobic respiration uses another inorganic molecule
 - Fermentation is partial oxidation of glucose
 - Produces very little ATP
 - Uses pyruvate or derivative as terminal electron acceptor
 - Other organisms may use other organic molecules as terminal electron acceptor



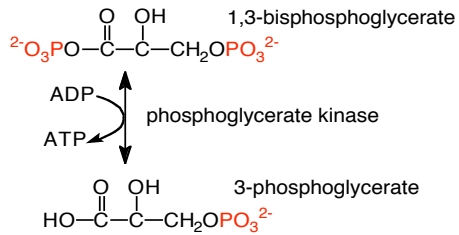
Sugar-splitting



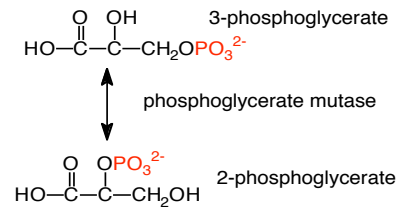
Energy transfer



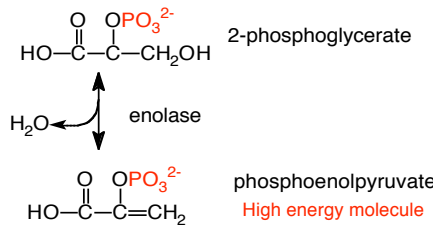
Forming ATP



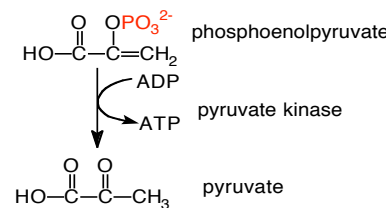
Rearrangement



Dehydration increases the potential for transfer of phosphate to ADP



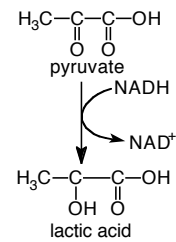
Transfer of P to ADP is irreversible



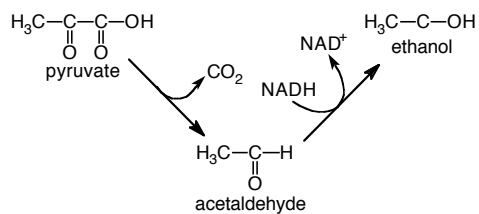
Fermentation

- ✓ Anaerobic process
 - Formation of 2 ATP (net) in glycolysis.
 - Regeneration of NAD^+

Lactic acid fermentation



Alcoholic fermentation



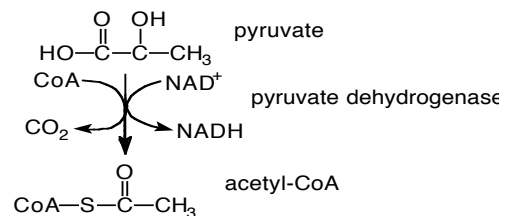
Other fermentations

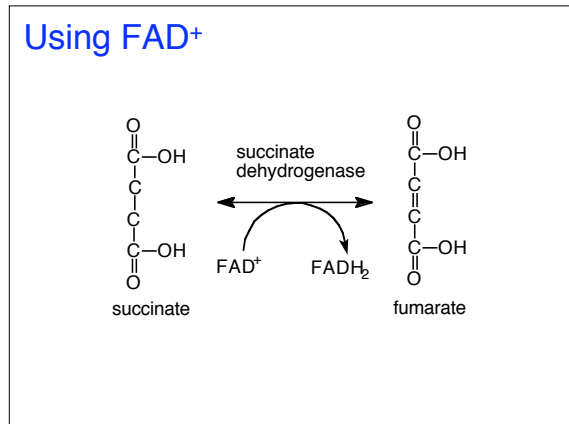
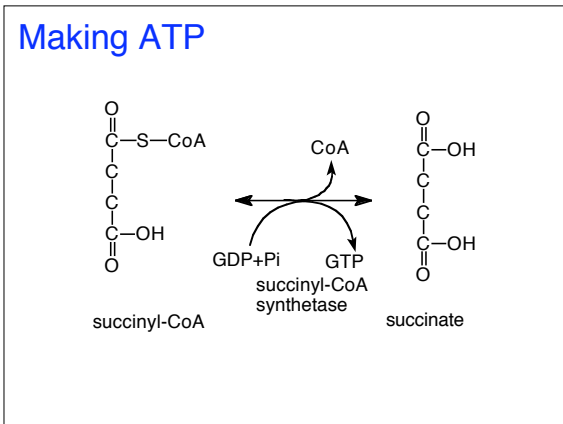
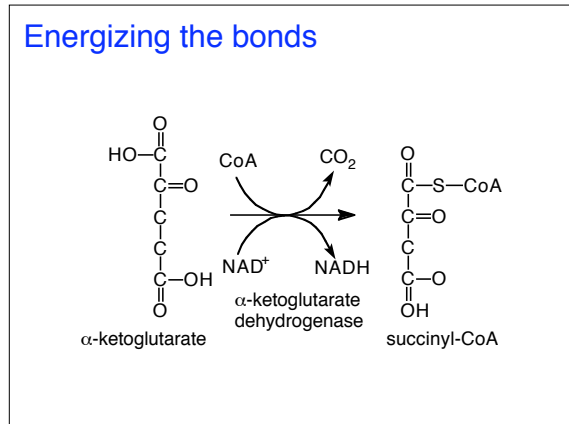
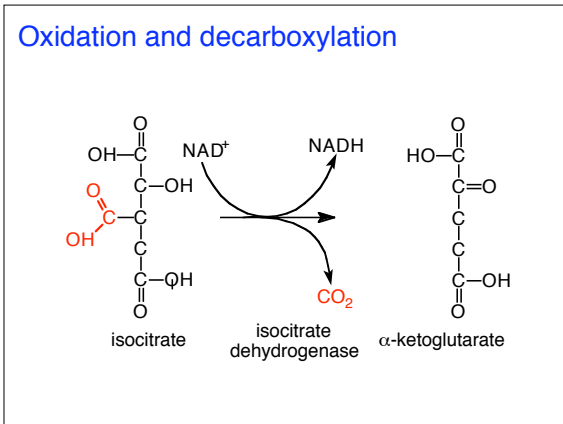
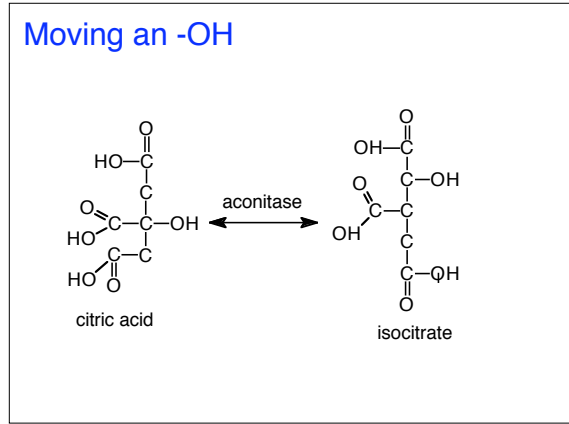
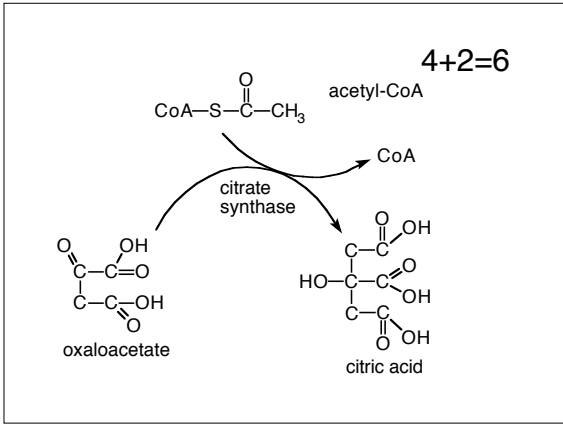
- ✓ Mixed acid fermentation
 - Acetic acid, succinic acid, ethanol, CO_2 , H_2 .
- ✓ Propionic fermentation
 - Propionic acid, acetic acid, CO_2
- ✓ Butanediol fermentation
 - Butanediol,
- ✓ Butyric-butylic fermentation
 - Butanol, isopropanol, acetone, CO_2

Krebs cycle

- ✓ A sequence of reactions by which acetyl (2C) groups are oxidized to CO_2 .
- ✓ Hydrogen groups are removed and electrons are transferred to NAD^+ and FAD^+ .

CoA activates the carbons from pyruvate





Energy summary

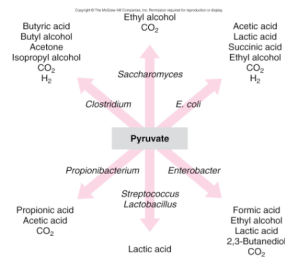
- | | | |
|--------------------|---------|----------------------|
| ✓ Glycolysis | • 4ATP | • 2NADH |
| ✓ Pre-Kreb's cycle | • 2NADH | |
| ✓ Kreb's cycle | • 6NADH | • 2FADH ₂ |
| | • 2GTP | |
-
- | | |
|--------------------|----------|
| ✓ Glycolysis | • 7 ATP |
| ✓ Pre-Kreb's cycle | • 5 ATP |
| ✓ Kreb's cycle | • 20 ATP |
- Total = 32 ATP

Anaerobic Respiration

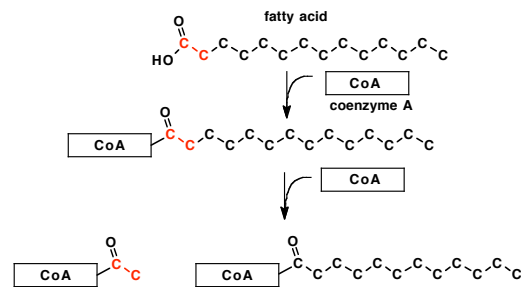
- ✓ Alternate terminal electron acceptors are used in the ETS.
 - Nitrate, sulfate, iron
- ✓ Not as much energy is produced as when oxygen is used (aerobic respiration).

Fermentation

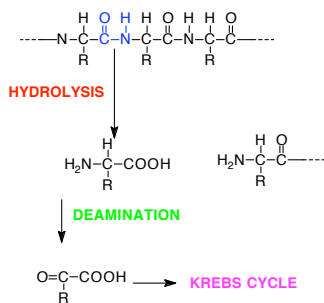
- ✓ Reduction of pyruvate.
- ✓ Anaerobic process.
- ✓ Regenerates NAD⁺
- ✓ Produces very little energy (2ATPs)
- ✓ Produces lactic acid, ethyl alcohol, CO₂, H₂, acetic acid, succinic acid, propionic acid, butyric acid etc.



Fat metabolism



Protein metabolism



Respiration (review)

Producing energy for the cell

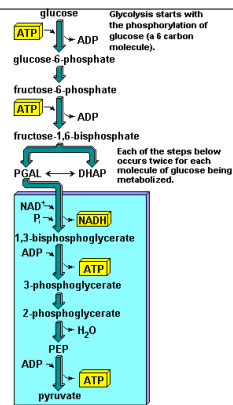
The mitochondria is the site for oxidative phosphorylation in eukaryotes- the cell membrane is the site in prokaryotes



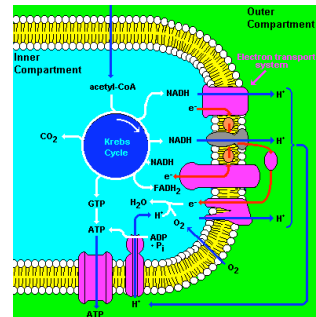
Types of respiration

- ✓ Aerobic respiration
 - O_2 is the electron acceptor
- ✓ Anaerobic respiration
 - An acceptor other than O_2 is used
 - eg. NO_3^- , NO_2^- , SO_4^{2-} and elemental S and several metal ions such as Fe^{3+} , and fumarate
- ✓ Lithotrophic respiration
 - Inorganic molecules are used to produce energy
 - eg. H_2S
 - Oxidation of H_2S takes place in the periplasm
 - NADH is not used to shuttle the electrons

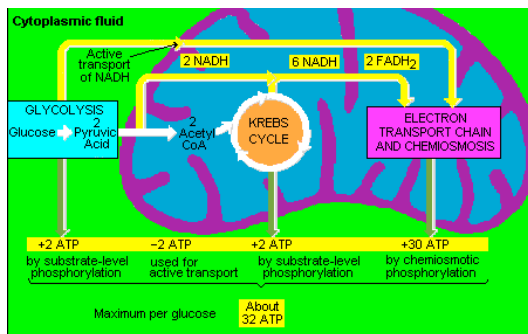
Glycolysis



Electron transport chain



Total energy obtained from one glucose molecule



Photosynthesis

- ✓ Light-capturing pigments
- ✓ Photosystems
- ✓ Photophosphorylation

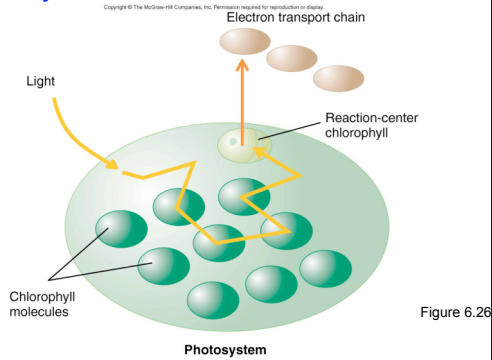
Light-capturing pigments

- ✓ Chlorophylls
- ✓ Bacteriochlorophylls
- ✓ Carotenoids
- ✓ Phycobilins

Photosystems

- ✓ Reaction center pigments
- ✓ Accessory pigments (antennae pigments)

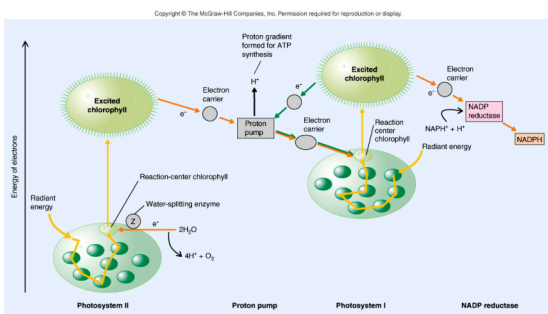
Photosystem



Photophosphorylation

- ✓ Tandem photosystems – cyanobacteria and plants
- ✓ Single photosystem – purple and green bacteria

Photosystem I and II



Photosynthetic mechanisms

Table 6.9 Comparison of the Photosynthetic Mechanisms Used by Different Organisms

	Oxygenic Photosynthesis		Anoxygenic Photosynthesis	
	Plants, Algae	Cyanobacteria	Purple Photosynthetic Bacteria	Green Photosynthetic Bacteria
Location of the photosystem	In membranes of thylakoids, which are within the stroma of chloroplasts.	In membranes of thylakoids, located within the cell.	Within the cytoplasmic membrane; extensive invaginations in that membrane effectively increase the surface area.	Primarily within the cytoplasmic membrane; chlorosomes attached to the inner surface of the membrane contain the accessory pigments.
Type of photosystem	Photosystem I and photosystem II		Similar to photosystem II	Similar to photosystem I
Primary light harvesting pigment	Chlorophyll <i>a</i>		Bacteriochlorophylls	
Mechanism for generating reducing power	Non-cyclic photophosphorylation using both photosystems		Reversed electron transport	Non-cyclic use of the photosystem
Source of electrons for reducing power	H_2O		Varies among the organisms in the group; may include H_2S , H_2 , or organic compounds.	
CO_2 fixation	Calvin-Benson cycle		Reverse TCA cycle	Reversed TCA cycle
Accessory pigments	Carotenoids	Carotenoids, phycobilins	Carotenoids	Carotenoids

Table 6.9

Carbon fixation

- ✓ Calvin cycle
- ✓ Reversed TCA cycle

Calvin Cycle

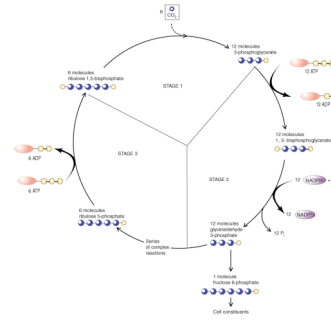


Figure 6.28