An Overview of Metabolism

- metabolism
  - total of all chemical reactions occurring in cell
- catabolism
  - breakdown of larger, more complex molecules into smaller, simpler ones
  - energy is released and some is trapped and made available for work
- anabolism
  - synthesis of complex molecules from simpler ones with the input of energy

Sources of energy

electrons released during oxidation of chemical energy sources must be accepted by an electron acceptor

microorganisms vary in terms of the acceptors they use

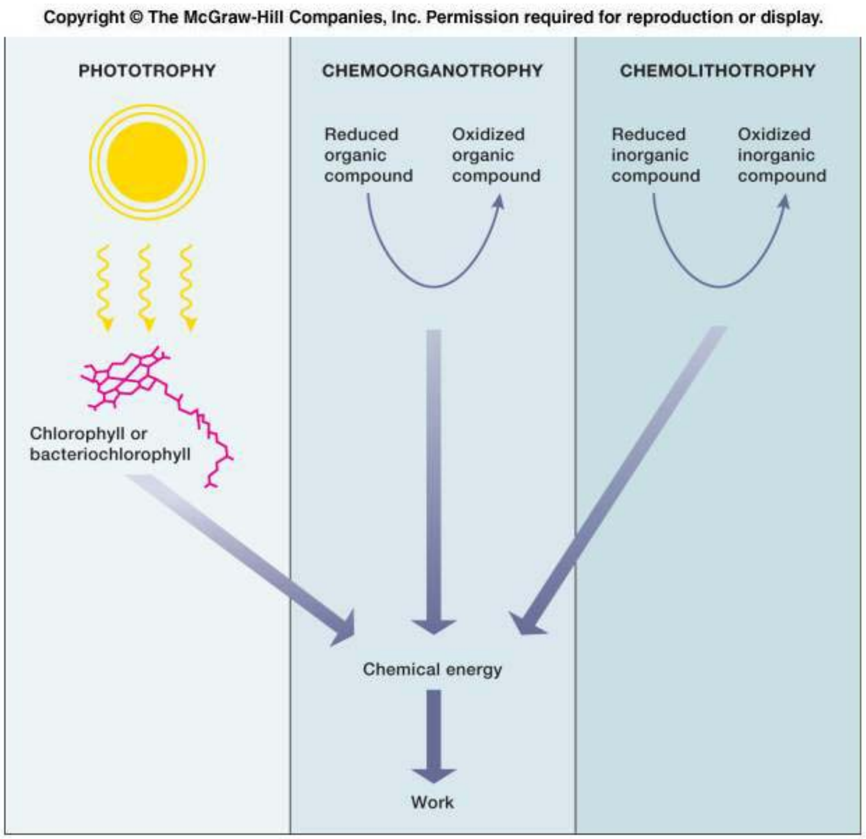

Figure 9.1

Electron acceptors for chemotrophic processes

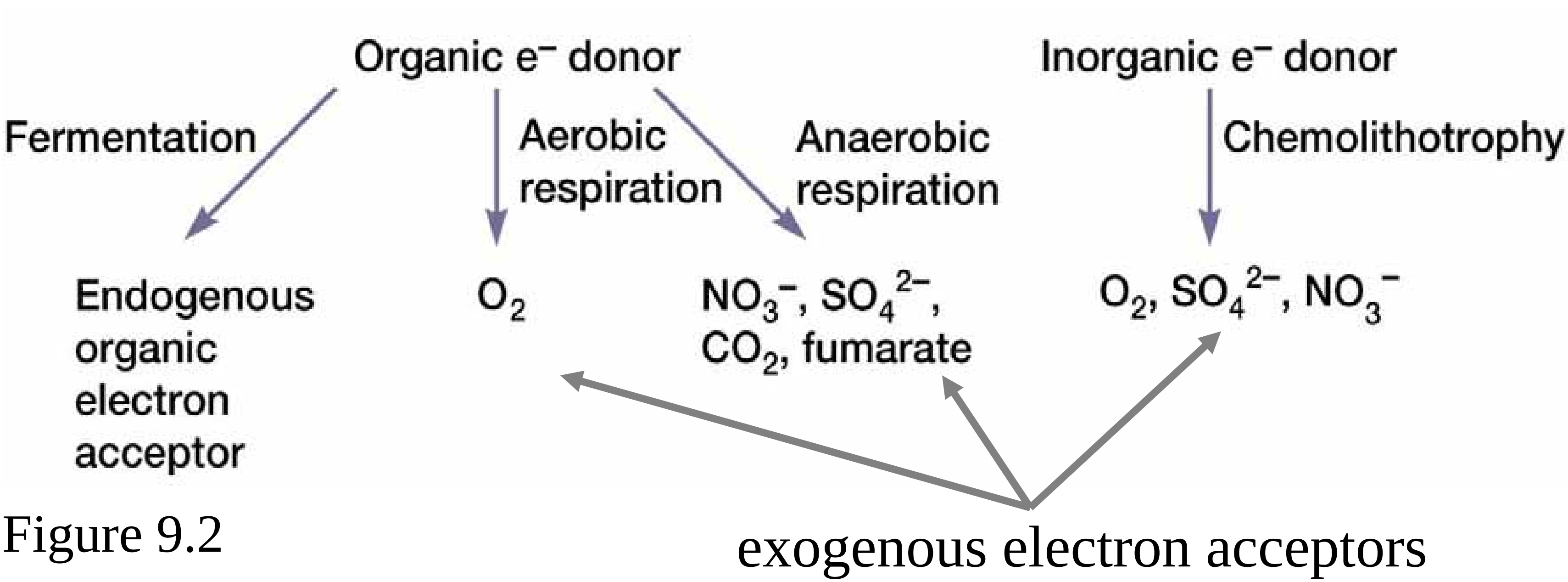

Figure 9.2

Chemoorganotrophic metabolism

- fermentation
  - energy source oxidized and degraded using endogenous electron acceptor
  - often occurs under anaerobic conditions
  - limited energy made available

Chemoorganotrophic metabolism

- aerobic respiration
  - energy source degraded using oxygen as exogenous electron acceptor
  - yields large amount of energy, primarily by electron transport activity

Chemoorganotrophic metabolism

- anaerobic respiration
  - energy source oxidized and degraded using molecules other than oxygen as exogenous electron acceptors
  - can yield large amount of energy (depending on reduction potential of energy source and electron acceptor), primarily by electron transport activity

Overview of aerobic catabolism

- three-stage process
  - large molecules (polymers) $\rightarrow$ small molecules (monomers)
  - initial oxidation and degradation to pyruvate
  - oxidation and degradation of pyruvate by the tricarboxylic acid cycle (TCA cycle)

many different energy sources are funneled into common degradative pathways

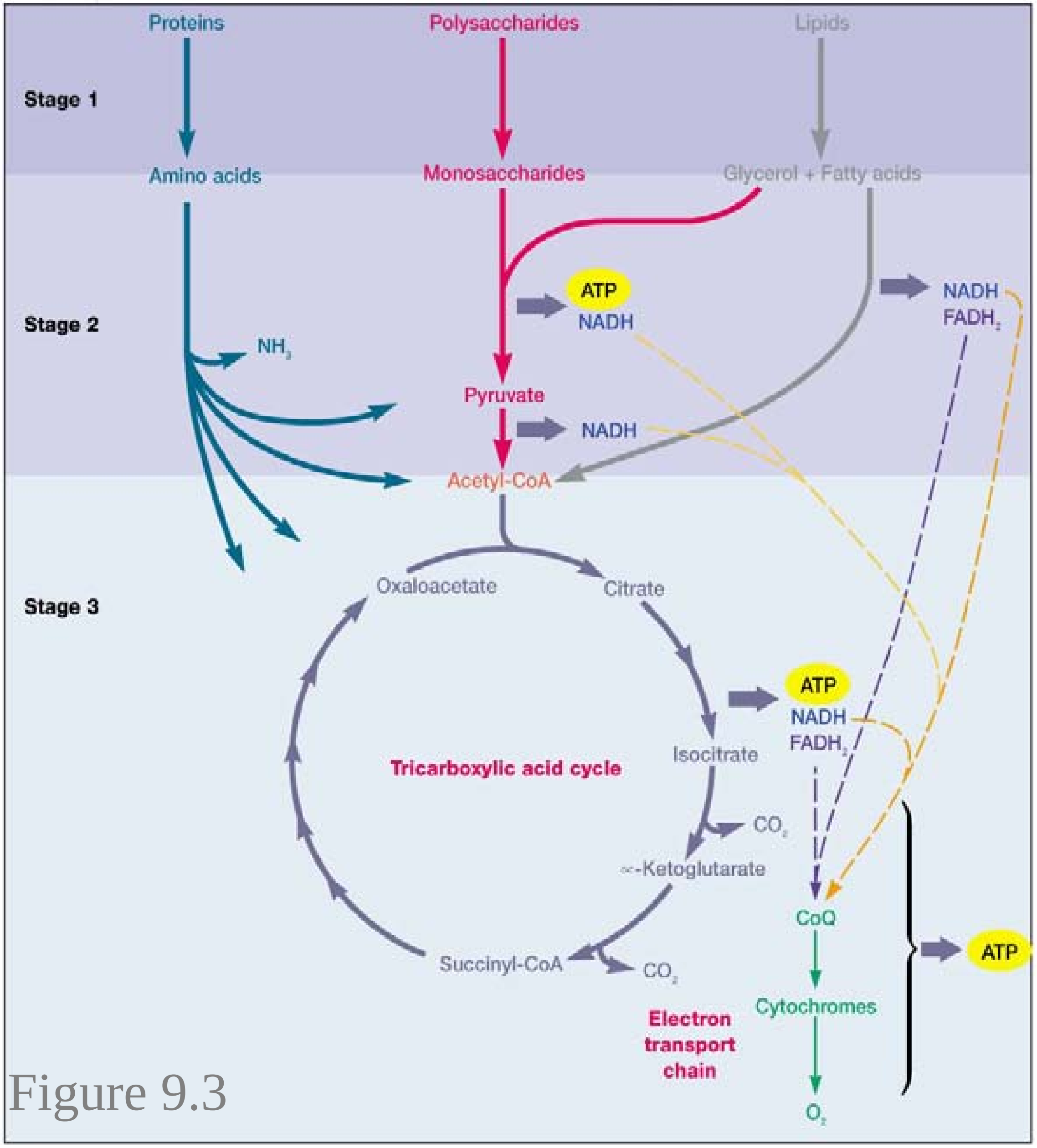

Figure 9.3

ATP made primarily by oxidative phosphory-lation

Two functions of organic energy sources

- oxidized to release energy
- supply carbon and building blocks for anabolism
  - amphibolic pathways
    - function both as catabolic and anabolic pathways

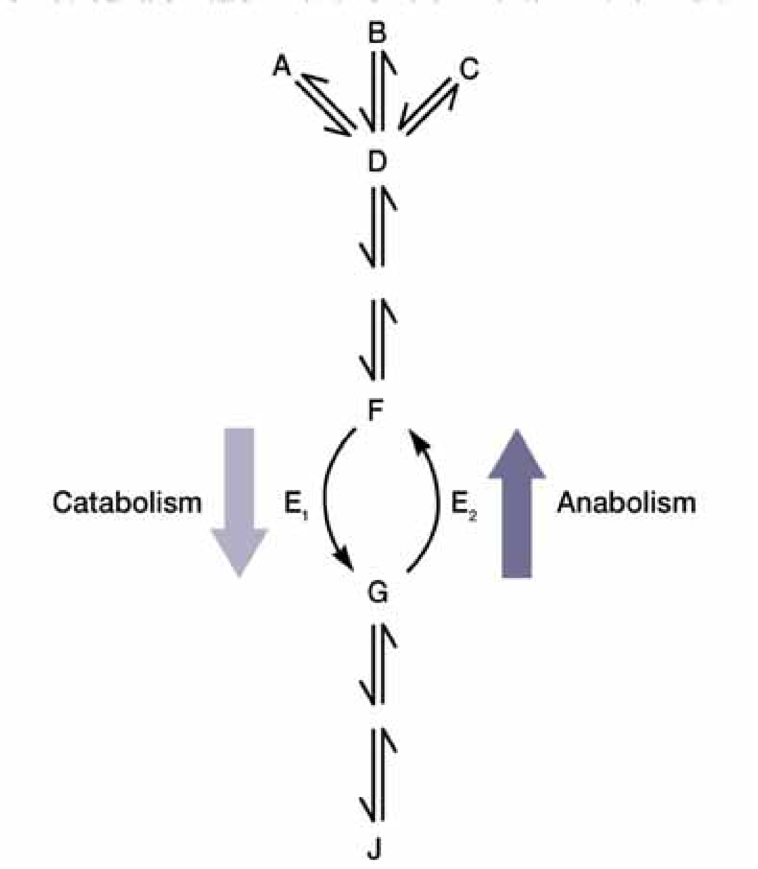

Figure 9.4

The Breakdown of Glucose to Pyruvate

- Three common routes
  - glycolysis
  - pentose phosphate pathway
  - Entner-Doudoroff pathway

The Glycolytic Pathway

- also called Embden-Meyerhof pathway
- occurs in cytoplasmic matrix of both procaryotes and eucaryotes

addition of phosphates "primes the pump"

oxidation step – generates NADH

high-energy molecules – used to synthesize ATP by substrate-level phosphorylation

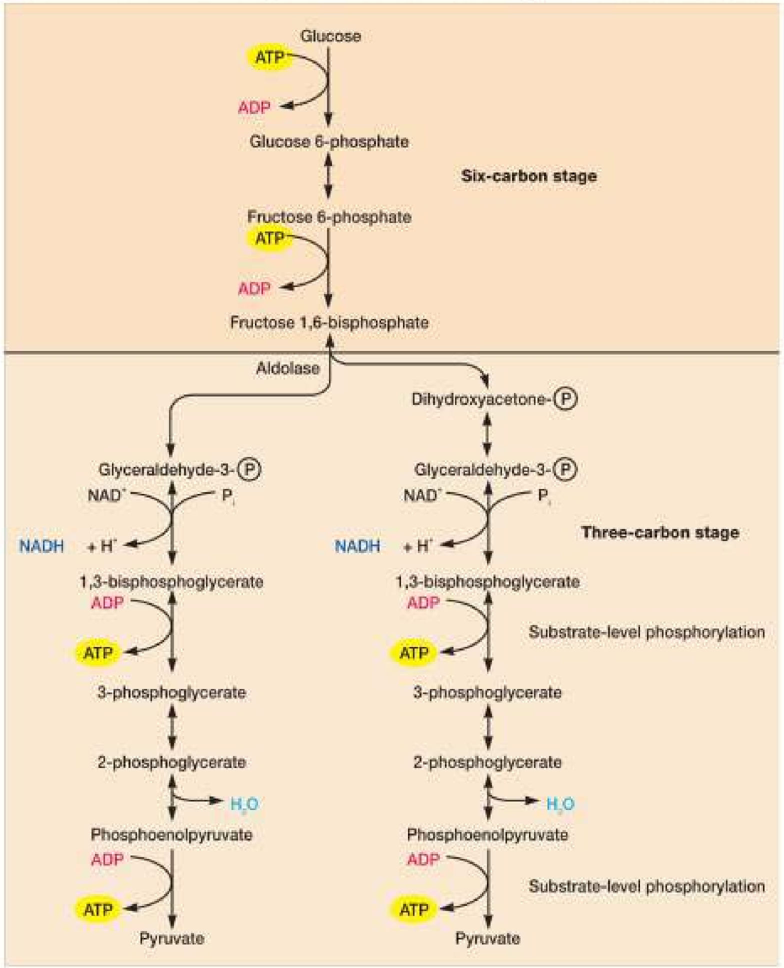

Figure 9.5

Summary of glycolysis

$$\text{glucose} + 2\text{ADP} + 2\text{P}_i + 2\text{NAD}^+$$

$$\downarrow$$

$$2\ \text{pyruvate} + 2\text{ATP} + 2\text{NADH} + 2\text{H}^+$$

The Pentose Phosphate Pathway

- also called hexose monophosphate pathway
- can operate at same time as glycolytic or Entner-Doudoroff pathways
- can operate aerobically or anaerobically
- an amphibolic pathway

oxidation steps

produce NADPH, which is needed for biosynthesis

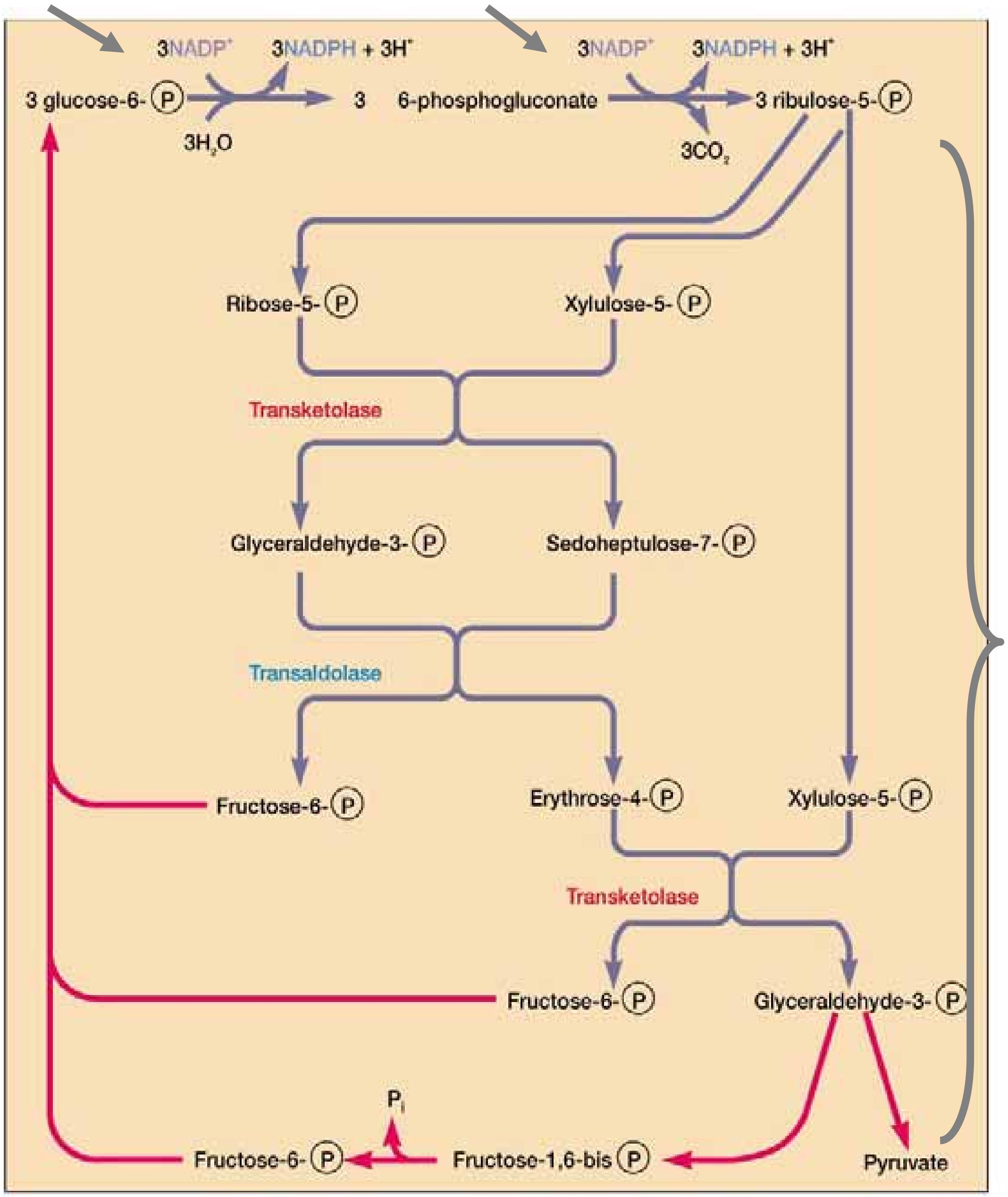

Figure 9.6

sugar trans-formation reactions

produce sugars needed for biosynthesis

sugars can also be further degraded

Fermentations

- oxidation of NADH produced by glycolysis
- pyruvate or derivative used as endogenous electron acceptor
- ATP formed by substrate-level phosphorylation

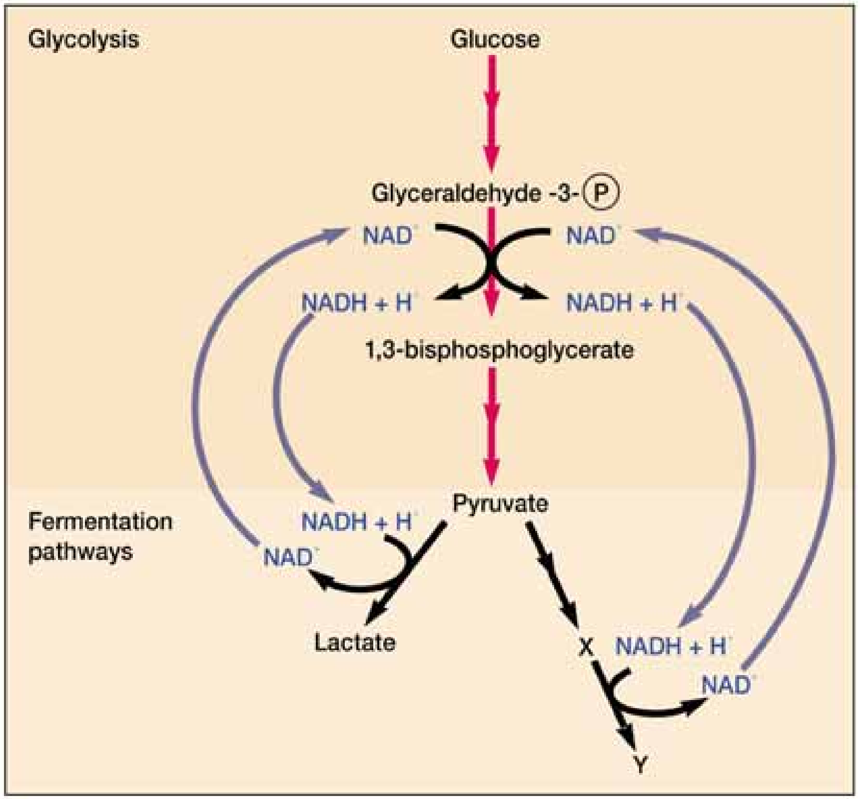

Figure 9.9

Inhibitors of ATP synthesis

- blockers
  - inhibit flow of electrons through ETC
- uncouplers
  - allow electron flow, but disconnect it from oxidative phosphorylation
  - many allow movement of ions, including protons, across membrane without activating ATP synthase
    - destroys pH and ion gradients
  - some may bind ATP synthase and inhibit its activity directly

The Yield of ATP in Glycolysis and Aerobic Respiration

- aerobic respiration provides much more ATP than fermentation
- Pasteur effect
  - decrease in rate of sugar metabolism when microbe shifted from anaerobic to aerobic conditions
  - occurs because aerobic process generates greater ATP per sugar molecule

Anaerobic Respiration

- uses electron carriers other than O_2
- generally yields less energy because E_0 of electron acceptor is less positive than E_0 of O_2

Table 9.3 Some Electron Acceptors Used in Respiration

	Electron Acceptor	Reduced Products	Examples of Microorganisms
Aerobic	O_2	H_2O	All aerobic bacteria, fungi, protozoa, and algae
Anaerobic	NO_3^-	NO_2^-	Enteric bacteria
	NO_3^-	NO_2^-, N_2O, N_2	*Pseudomonas, Bacillus,* and *Paracoccus*
	SO_4^{2-}	H_2S	*Desulfovibrio* and *Desulfotomaculum*
	CO_2	CH_4	All methanogens
	S^0	H_2S	*Desulfuromonas* and *Thermoproteus*
	Fe^{3+}	Fe^{2+}	*Pseudomonas, Bacillus,* and *Geobacter*
	$HAsO_4^{2-}$	$HAsO_2$	*Bacillus, Desulfotomaculum, Sulfurospirillum*
	SeO_4^{2-}	Se, $HSeO_3^-$	*Aeromonas, Bacillus, Thauera*
	Fumarate	Succinate	*Wolinella*

Photosynthesis

- light reactions
  - energy from light trapped and converted to chemical energy
- dark reactions
  - chemical energy used to reduce CO_2 and synthesize cell constituents (discussed in Chapter 10)