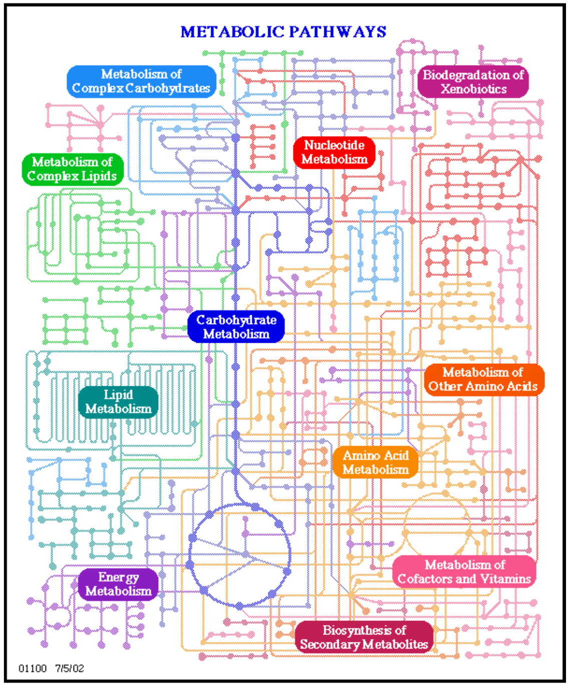
Science X-Change

Seminar II

# Seminar II

- ATP-Generation via substrate level phosphorylation, electron transport phosphorylation
- (Eukaryotic/prokaryotic cell)
- Bacterial cell wall
- Antibiotic resistance

# Principles of Metabolism
# -Energy generation-



# Energy Change in Exergonic und Endergonic Reactions

- **Change of free energy (∆G Gibbs free energy (enthalpie)) indicates if a reaction runs spontaneous or not.**
- **$\Delta G^{0\prime}$:** standard conditions, pH 7, 25°C, all reaction compounds at 1M
- Reaction runs spontaneous, **$\Delta G<0$ (exergonic reaction)**
- Reaction can not run spontaneous **$\Delta G>0$ (endergonic reaction)**

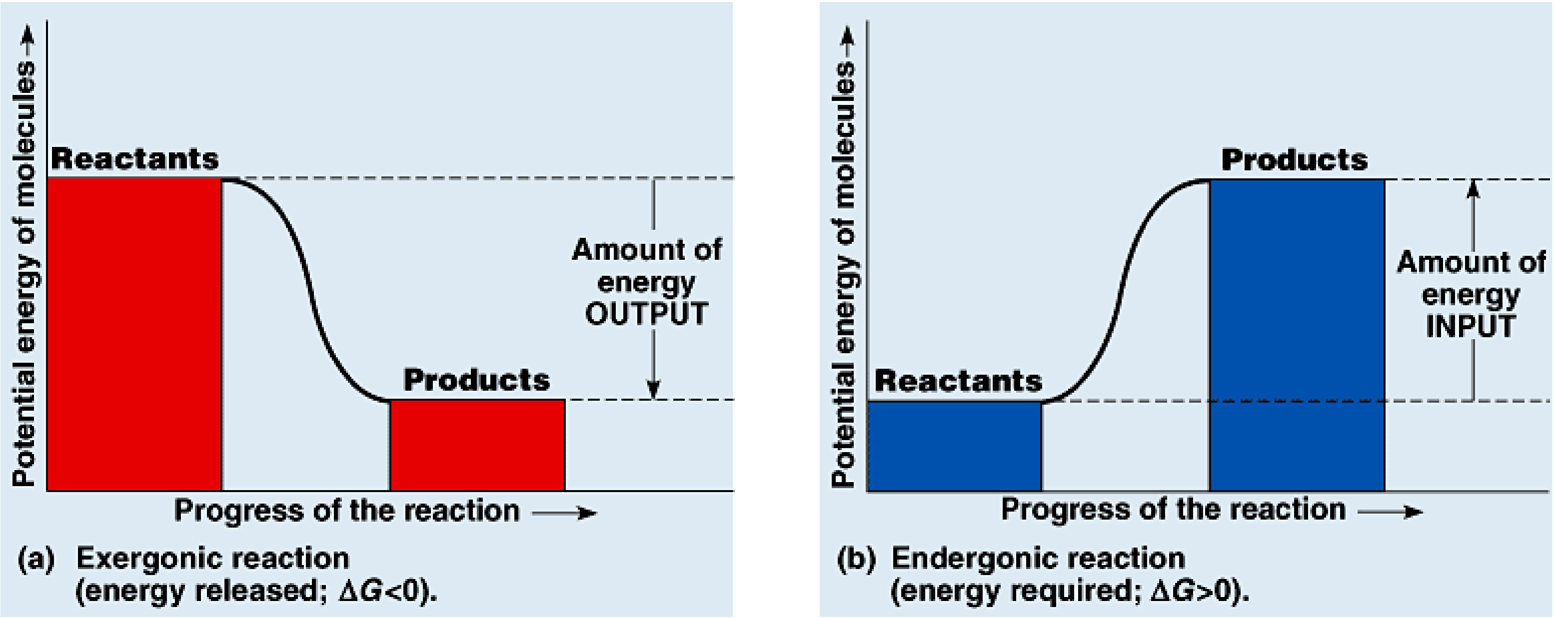





Fig. 6.5 Biology (6th edition, Campbell & Reece)

# Chemical Principles

## Example Cellular Respiration

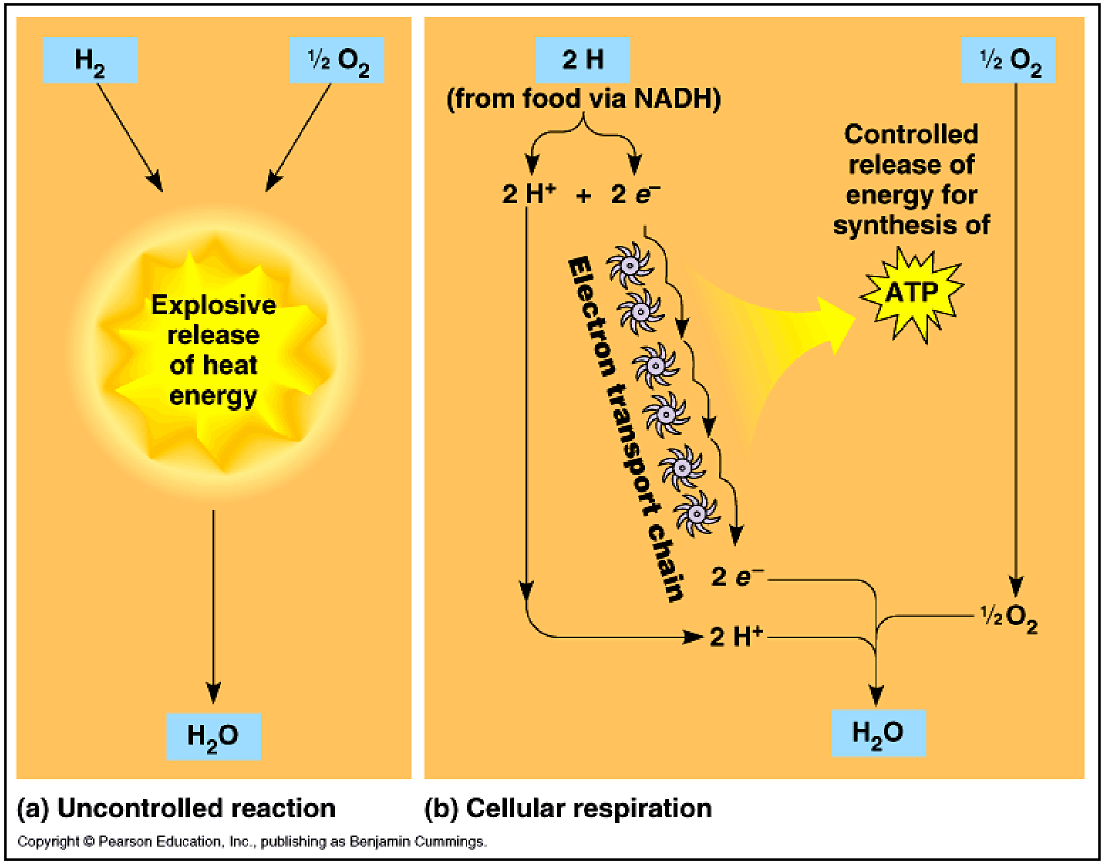



Fig. 9.5 Biology (6th edition, Campbell & Reece)

# Electron Transfer in Metabolism

**Oxidation-Reduction „Redox“-reactionen**
**Oxidation: donation/release of electrons**
**Reduktion: acception/uptake of electrons**

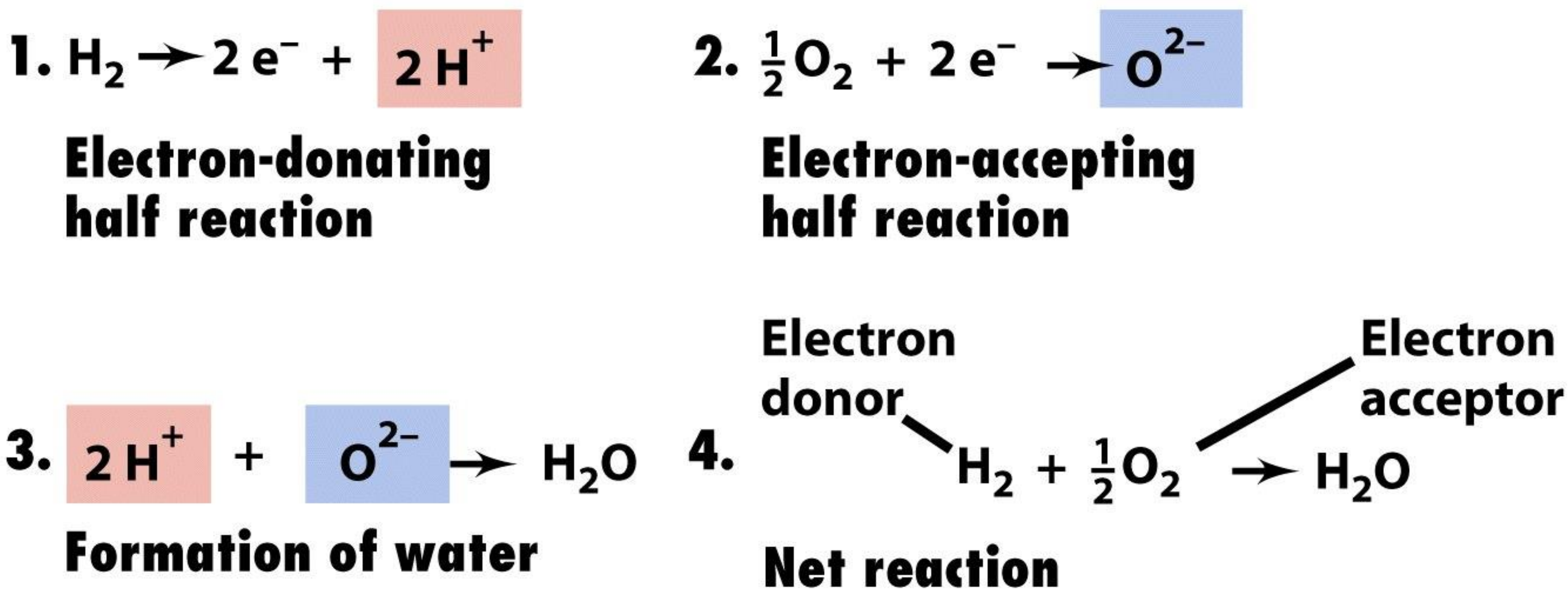



Figure 5-8 Brock Biology of Microorganisms 11/e

# Redoxreaktionen & Redoxpotential

$H_2 + ½\ O_2 \rightarrow H_2O$

$H_2 \rightarrow 2\ e^- + 2\ H^+$
Electron-donor

$½\ O_2 + 2\ e^- \rightarrow O^{2-}$
Electron-acceptor

**Reduction (Redox) potential**: Substrates vary in their tendency to be oxidized or reduced, wich is expressed as reduction potential ($E_0$') in volts (V). The free energy ($\Delta G^{0'}$) of the redox reaction is proportional to the difference of the reduction potential ($E_0$', standard conditions) of both half reactions.

$$\Delta G^{0'} = -n \cdot F \cdot \Delta E_0' = -n \cdot 96{,}5 \cdot \Delta E_0' \text{ (kJ/mol)}$$

n = number of transferred electrons
F = Faraday constant

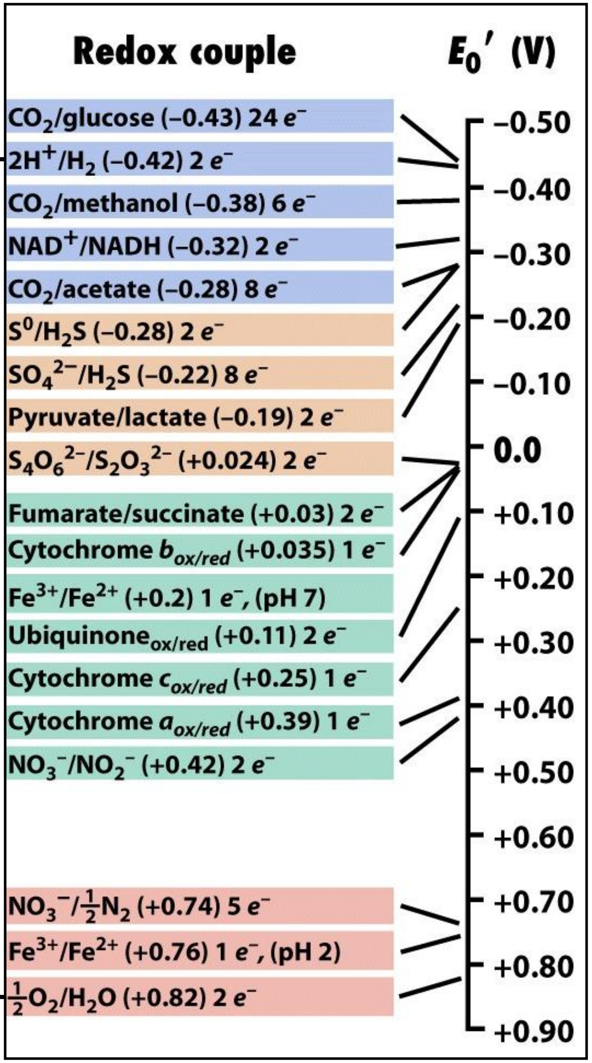
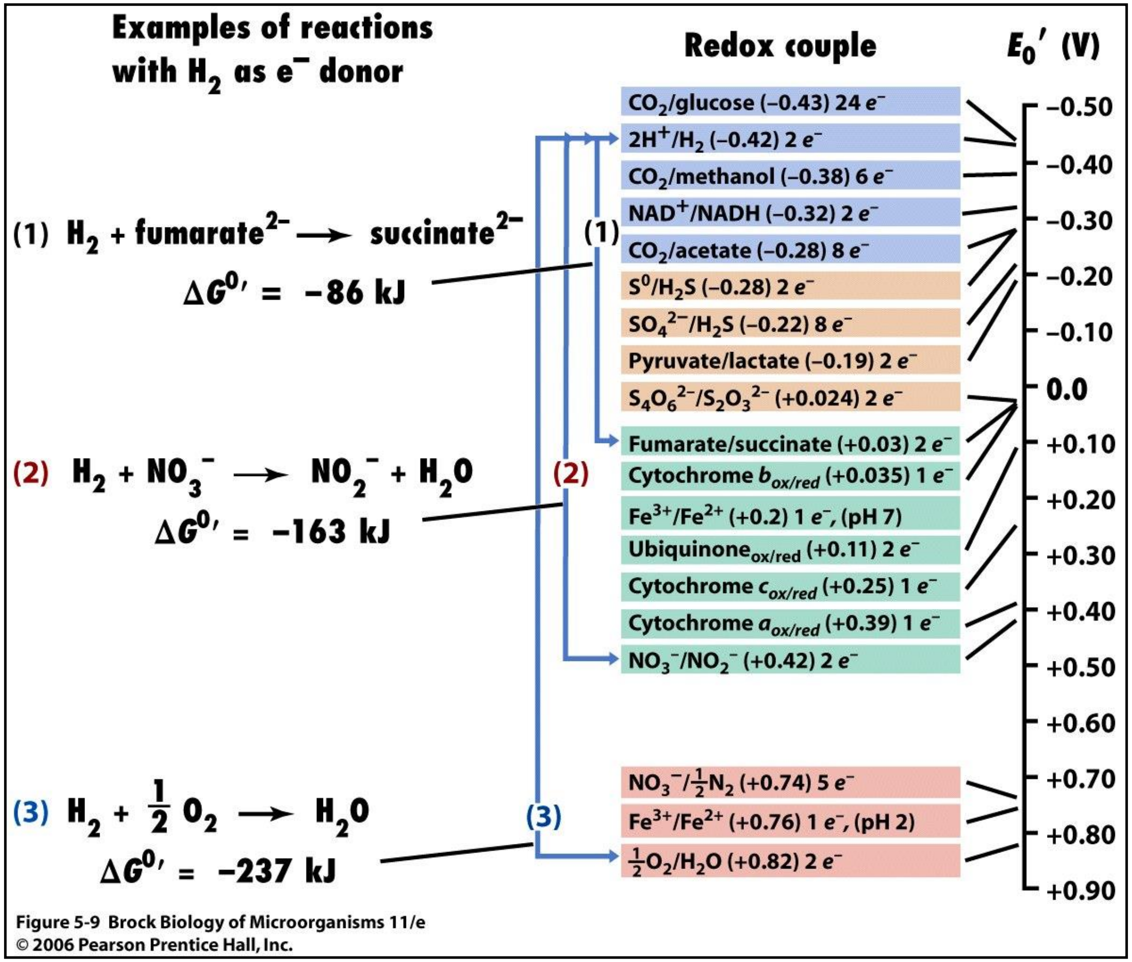



Fig. 5.8, 5.9 Brock Biology of Microorganisms (10th edition) (Madigan et al.)

# The Electronen Tower

$\Delta G^{0'}$ of ATP synthesis or hydrolysis = 32 kJ/mol




Redoxpairs arranged from the strongest reductants (neg. reduction potential, at the top) to the strongest oxidants (positive reduction potential, at the bottom).

# Electronen Carriers

**Nicotinamide adenine dinucleotide**
**(NAD(P)$^+$/NAD(P)H + H$^+$)**
**Free „carrier" (coenzyme)**

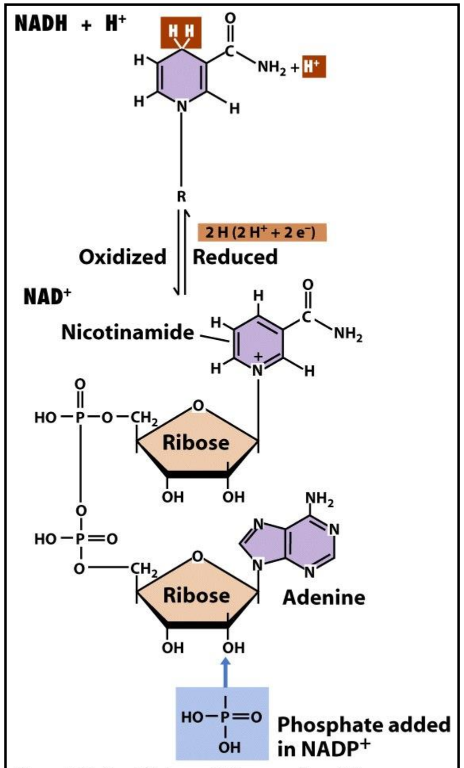
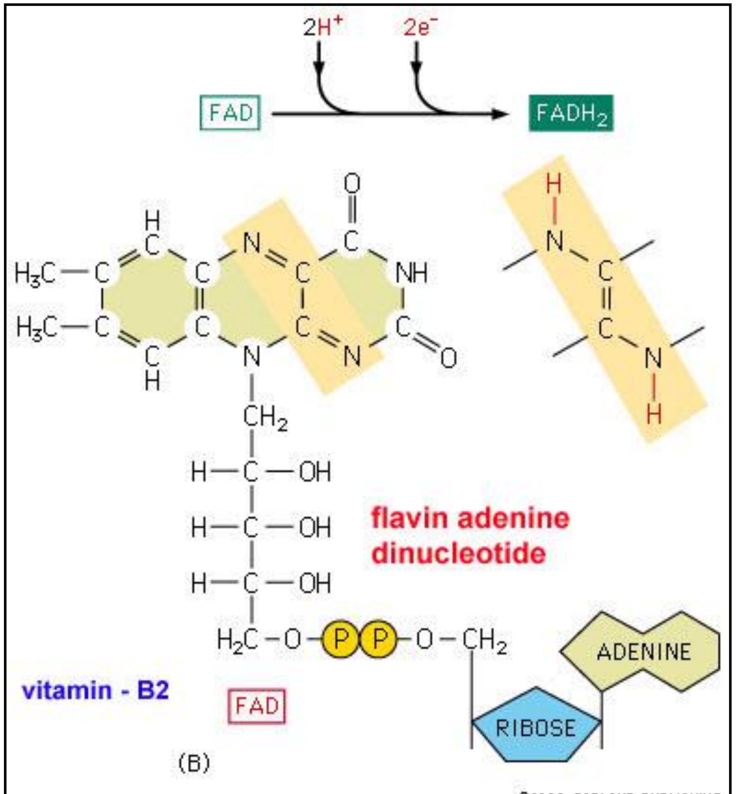



Figure 5-10 Brock Biology of Microorganisms 11/e


**Flavin adenine dinucleotide (FAD) (FAD$^+$/FADH$_2$)**
**Bound „Carrier" (prostethic group, e.g. succinate dehydrogenase)**





**Glyceraldehyde-3-phosphate dehydrogenase:**
Glyceraldehyde-3-phosphate + NAD$^+$ + P$_i$ ↔1,3-Diphosphoglycerate + NADH + H$^+$

# Energy Currency of all Cells „ATP“

$\Delta G^{0'}$ of ATP synthesis or hydrolysis = 32 kJ/mol

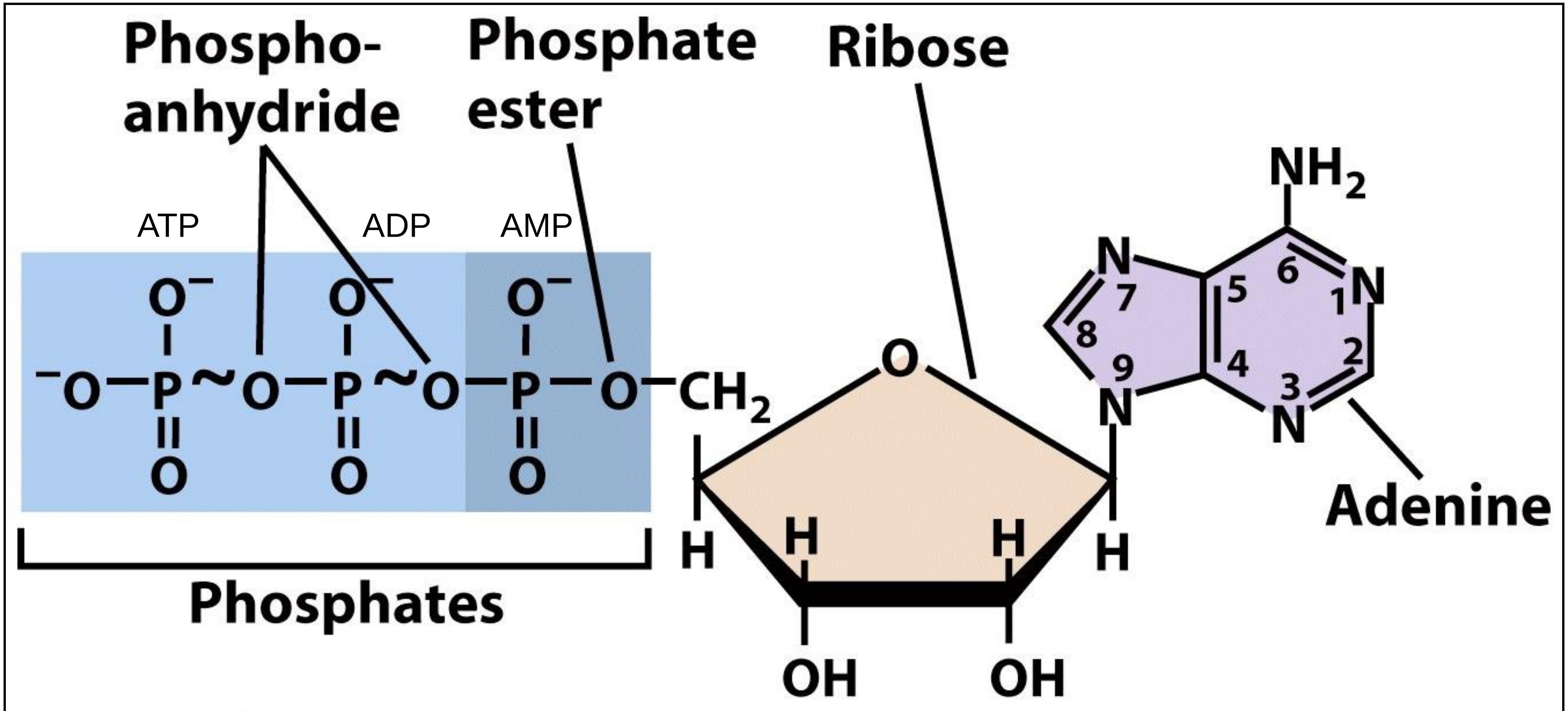
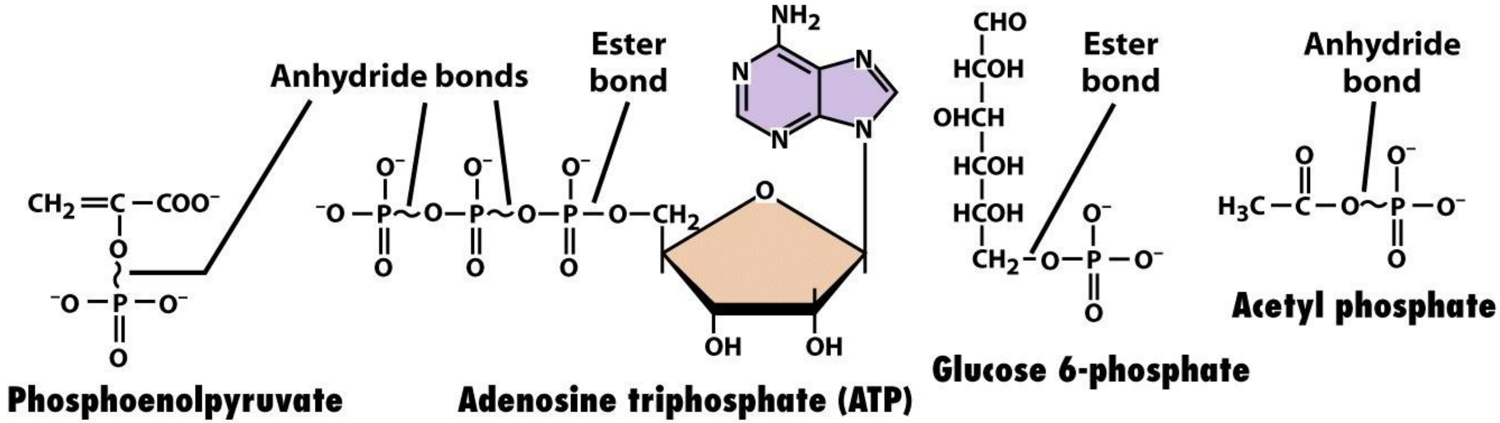
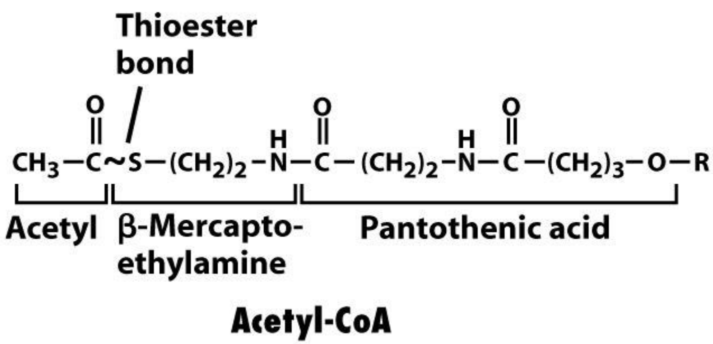



Figure 3-10 Brock Biology of Microorganisms 11/e

# Energy-Rich Compounds



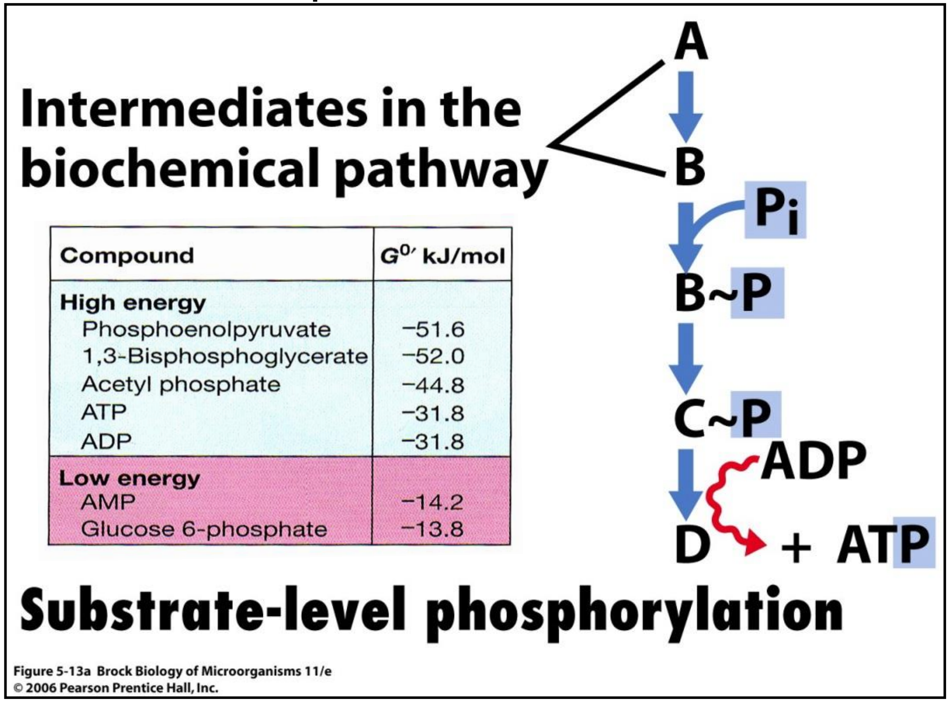

| Compound | $G^{0\prime}$ kJ/mol |
|---|---|
| $\Delta G^{0\prime} > 30$kJ | |
| Phosphoenolpyruvate | −51.6 |
| 1,3-Bisphosphoglycerate | −52.0 |
| Acetyl phosphate | −44.8 |
| ATP | −31.8 |
| ADP | −31.8 |
| Acetyl CoA | −31 |
| $\Delta G^{0\prime} < 30$kJ | |
| AMP | −14.2 |
| Glucose 6-phosphate | −13.8 |

Figure 5-12 Brock Biology of Microorganisms 11/e

# Basic Mechanisms of Energy Conservation

**Substrate-level phosphorylation**
Formation of energy-rich intermediates produces ATP

**Elektron-transport phosphorylation**
(Oxidative Phosphorylation)




| Compound | $G^{0\prime}$ kJ/mol |
|---|---|
| **High energy** | |
| Phosphoenolpyruvate | −51.6 |
| 1,3-Bisphosphoglycerate | −52.0 |
| Acetyl phosphate | −44.8 |
| ATP | −31.8 |
| ADP | −31.8 |
| **Low energy** | |
| AMP | −14.2 |
| Glucose 6-phosphate | −13.8 |

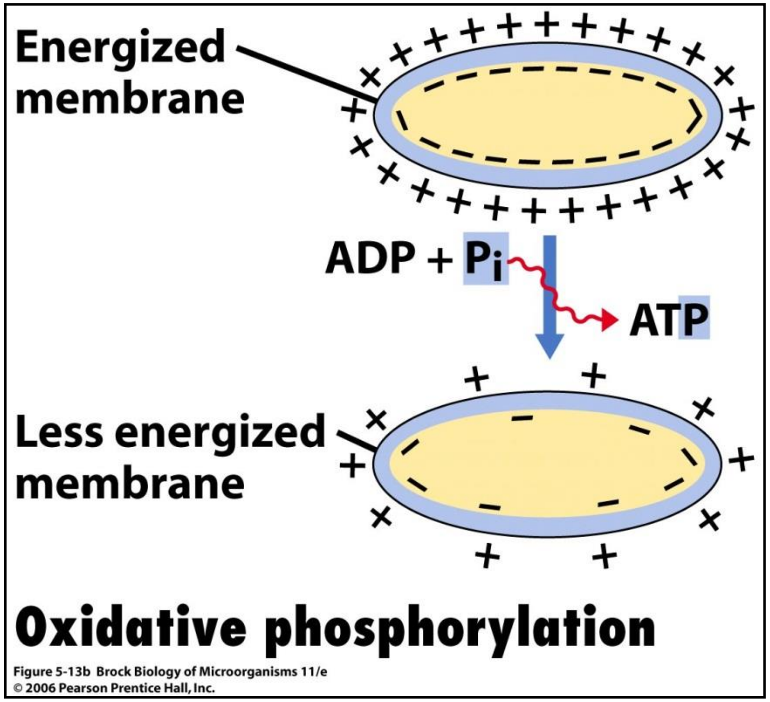



Fig. 5.13 Brock Biology of Microorganisms (11th edition) (Madigan et al.)

# EMP-Weg (Glycolysis)

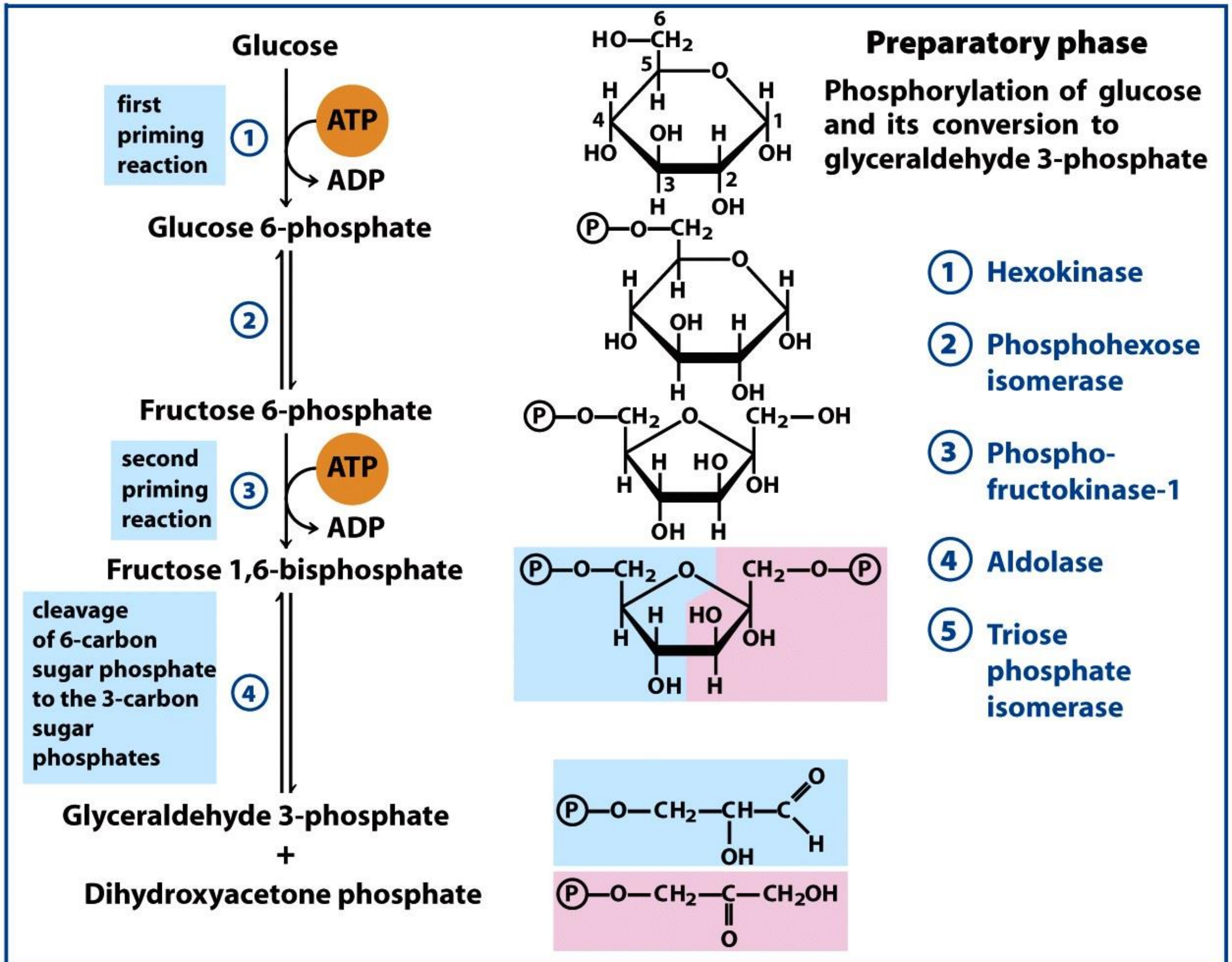



Figure 14-2a
*Lehninger Principles of Biochemistry, Fifth Edition*

# EMP-Weg (Glycolysis)

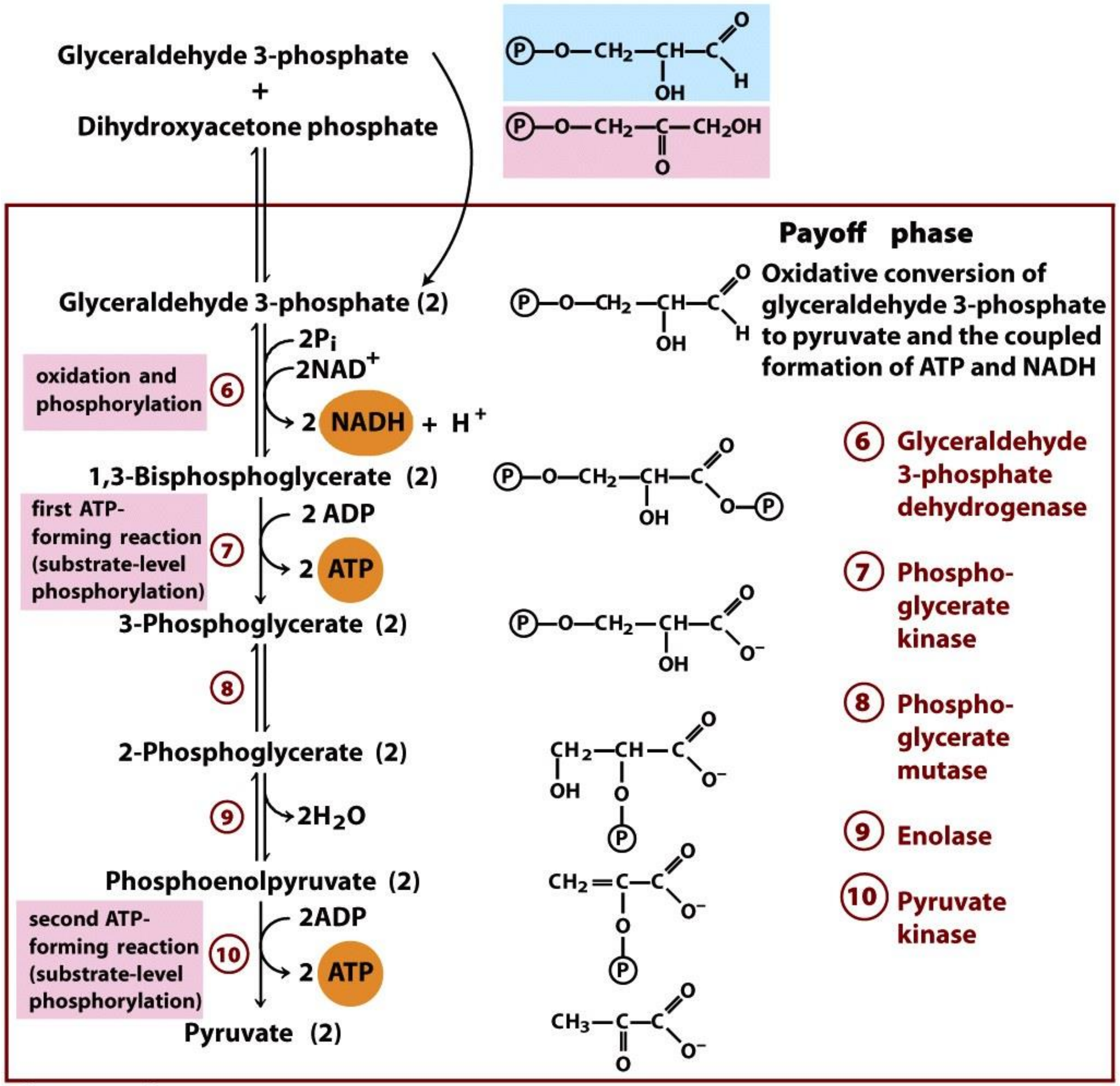
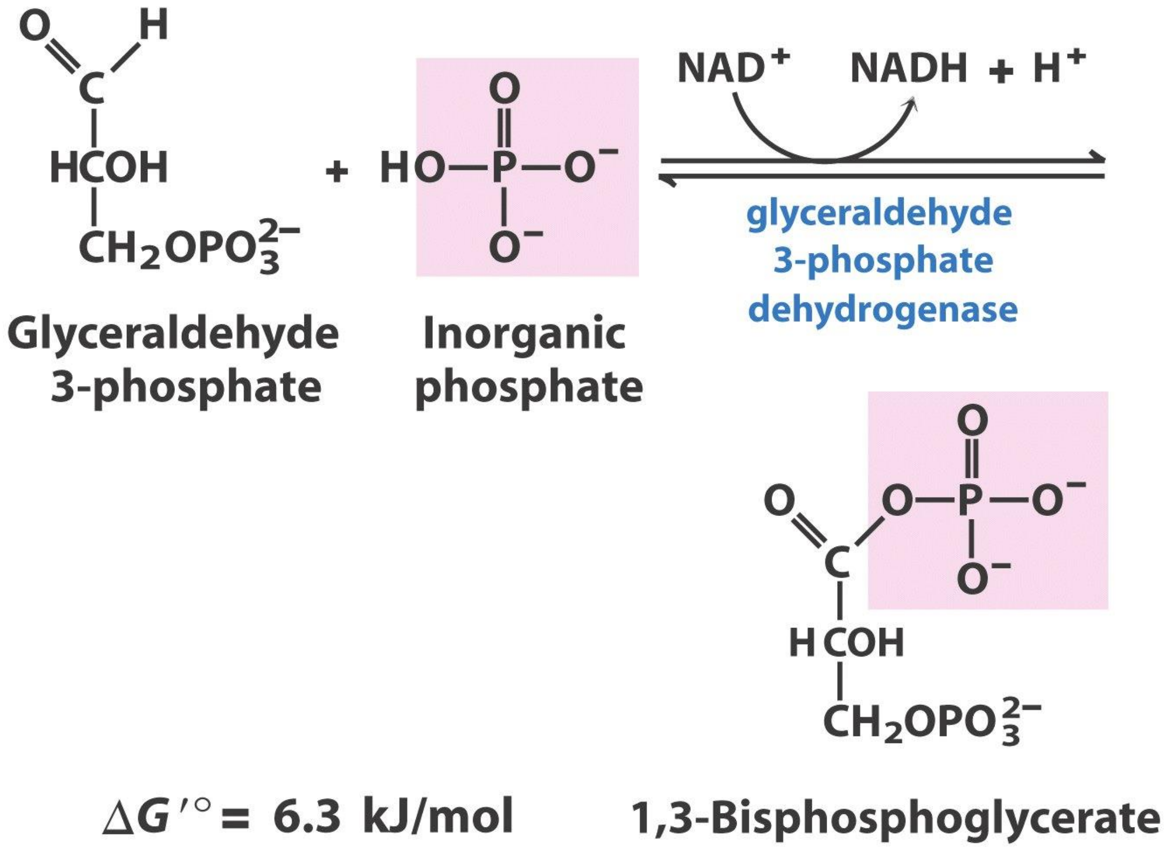



**Figure 14-2b**

*Lehninger Principles of Biochemistry, Fifth Edition*

# Glyceraldehyde-3-phosphate dehydrogenase

- Which compound is oxidized/reduced?



# Energetics of Glycolysis

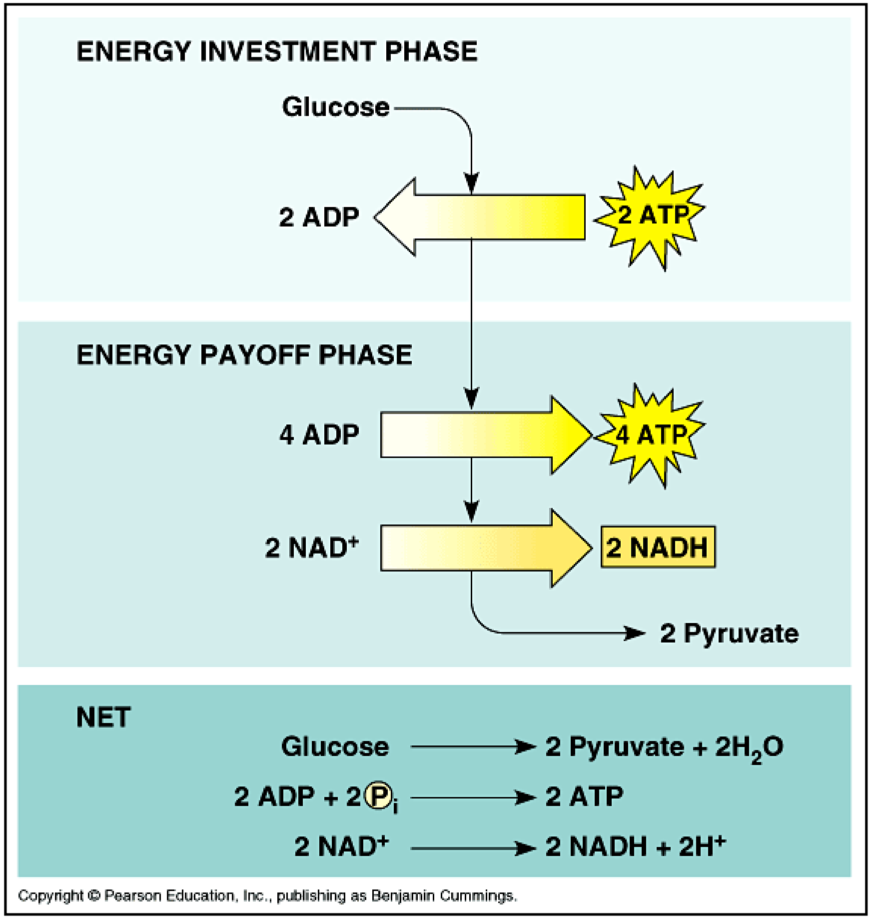



Fig. 9.8 **Die Glycolyse im Überblick.**
Biology (6th edition, Campbell & Reece)

# Pyruvat Dehydrogenase and Citric Acid Cycle

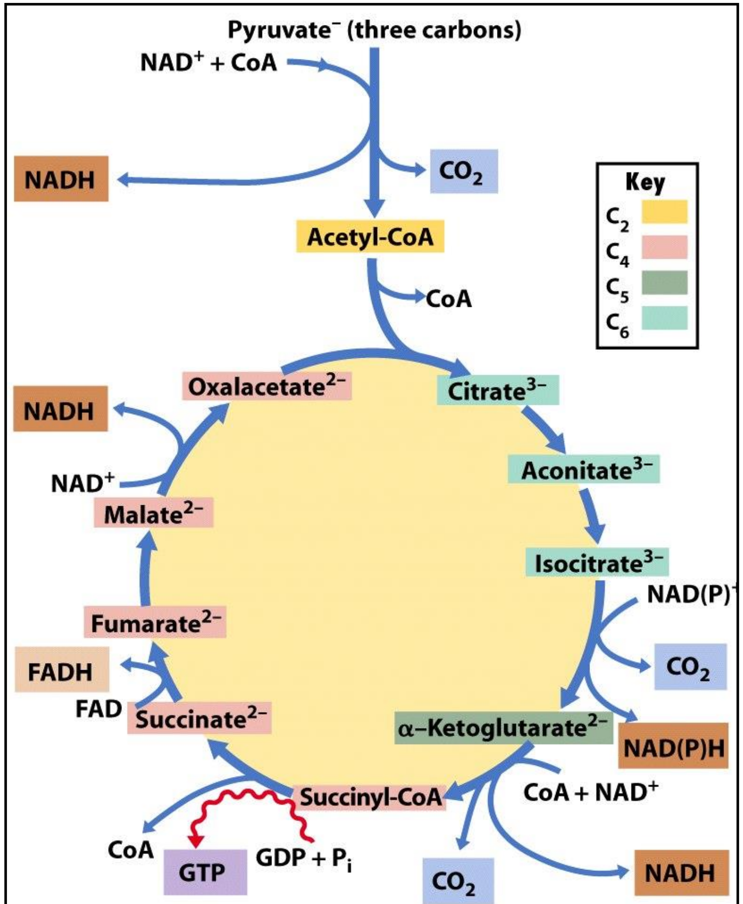
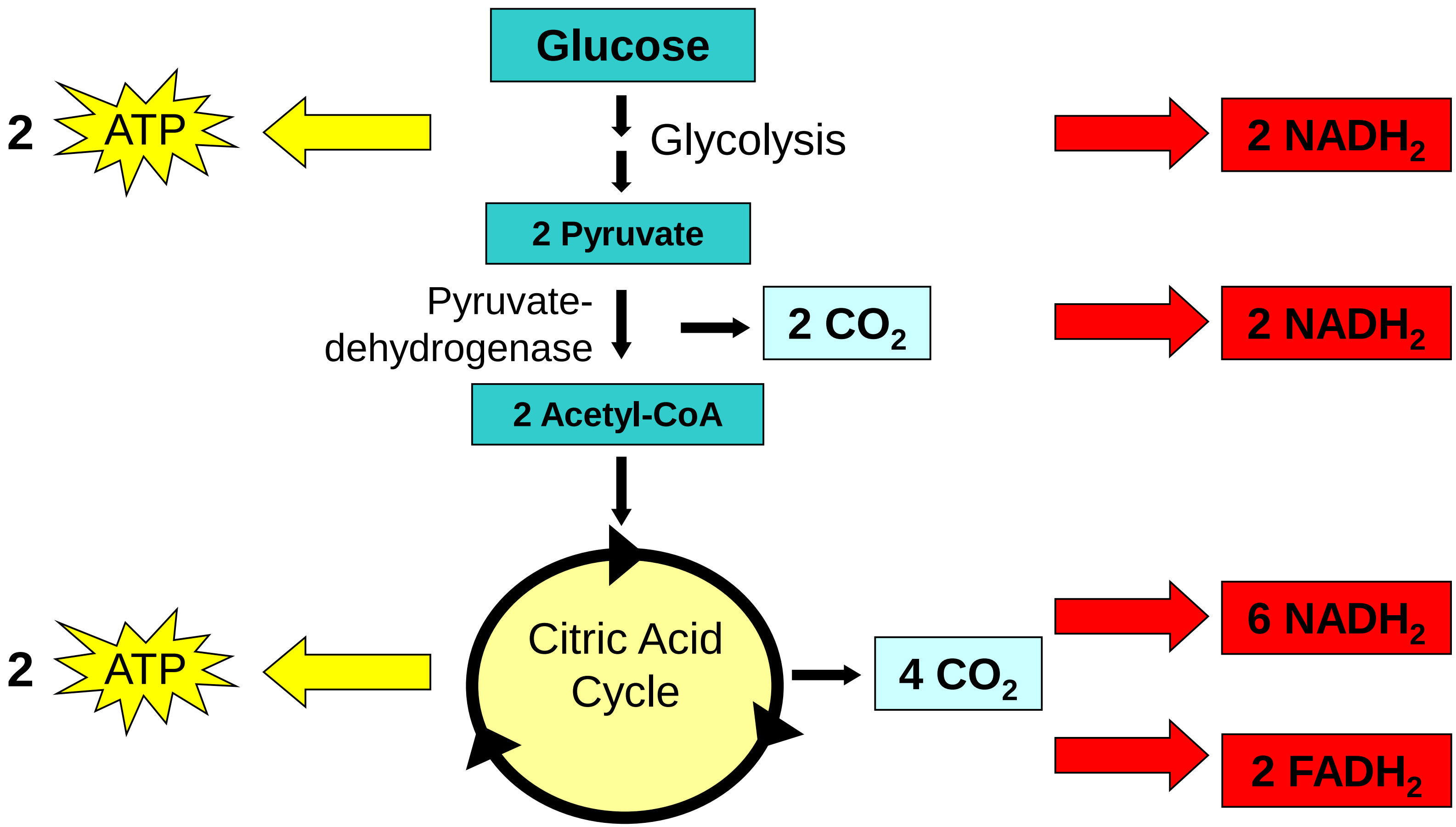



Figure 5-22a Brock Biology of Microorganisms 11/e

# Energetics of Carbohydrate Metabolism




$$C_6H_{12}O_6 + 6\ H_2O + 4\ ADP + 4\ P_i \rightarrow 6\ CO_2 + 24\ [H] + 4\ ATP$$

# Electron Transport Chain

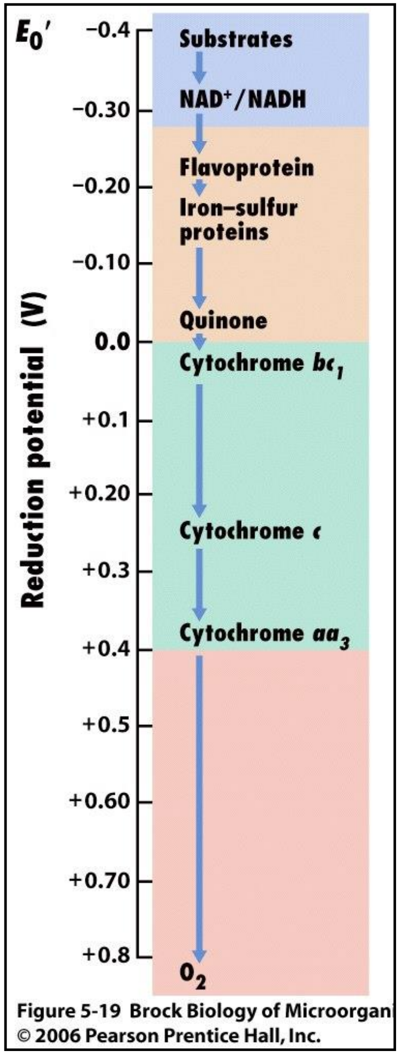



Fig. 5.19 Brock Biology of Microorganisms (10th edition) (Madigan et al.)

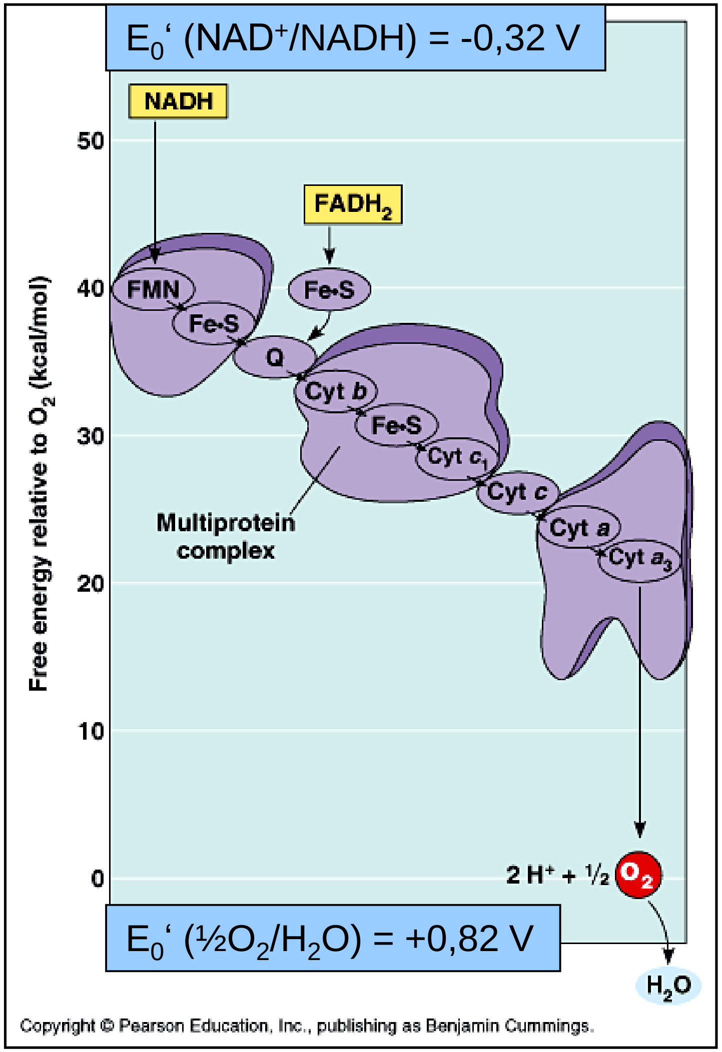


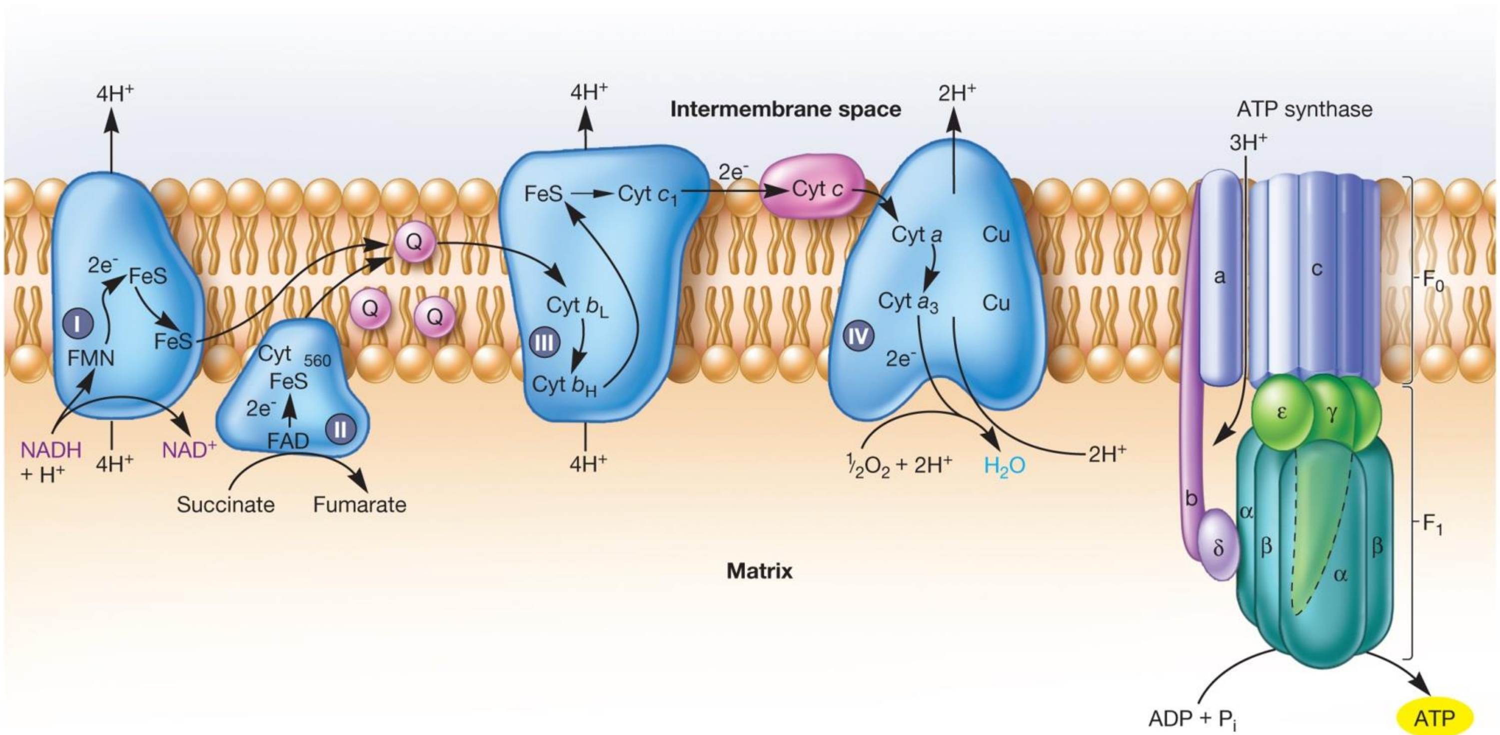

Fig. 9.13 Biology (6th edition, Campbell & Reece)

- The mitochondrial or bacterial electron transport chain (ETC) = a series of $e^-$ carriers, operating together to transfer $e^-$ from NADH and $FADH_2$ to a terminal $e^-$ acceptor, $O_2$
- $E^-$ flow from carriers with more negative reduction potentials ($E_0$) to carriers with more positive $E_0$

# Elektron Transport Chain

- In eukaryotes the e$^-$ transport chain carriers are in the inner mitochondrial membrane, connected by coenzyme Q and cytochrome c
- E$^-$ transfer accompanied by proton movement across inner mitochondrial membrane (**proton pumps**)





# Chemiosmotic Model

- In this simple representation of the chemiosmotic theory applied to mitochondria, electrons from NADH and other oxidizable substrates pass through a chain of carriers arranged asymmetrically in the inner membrane.
- Electron flow is accompanied by proton transfer across the membrane, producing both a chemical gradient (ΔpH ) and an electrical gradient (Δψ).
- The inner mitochondrial membrane is impermeable to protons; protons can reenter the matrix only through proton-specific channels ($F_o$). The **proton-motive force (PMF)** that drives protons back into the matrix provides the energy for ATP synthesis, catalyzed by the $F_1$ complex associated with F

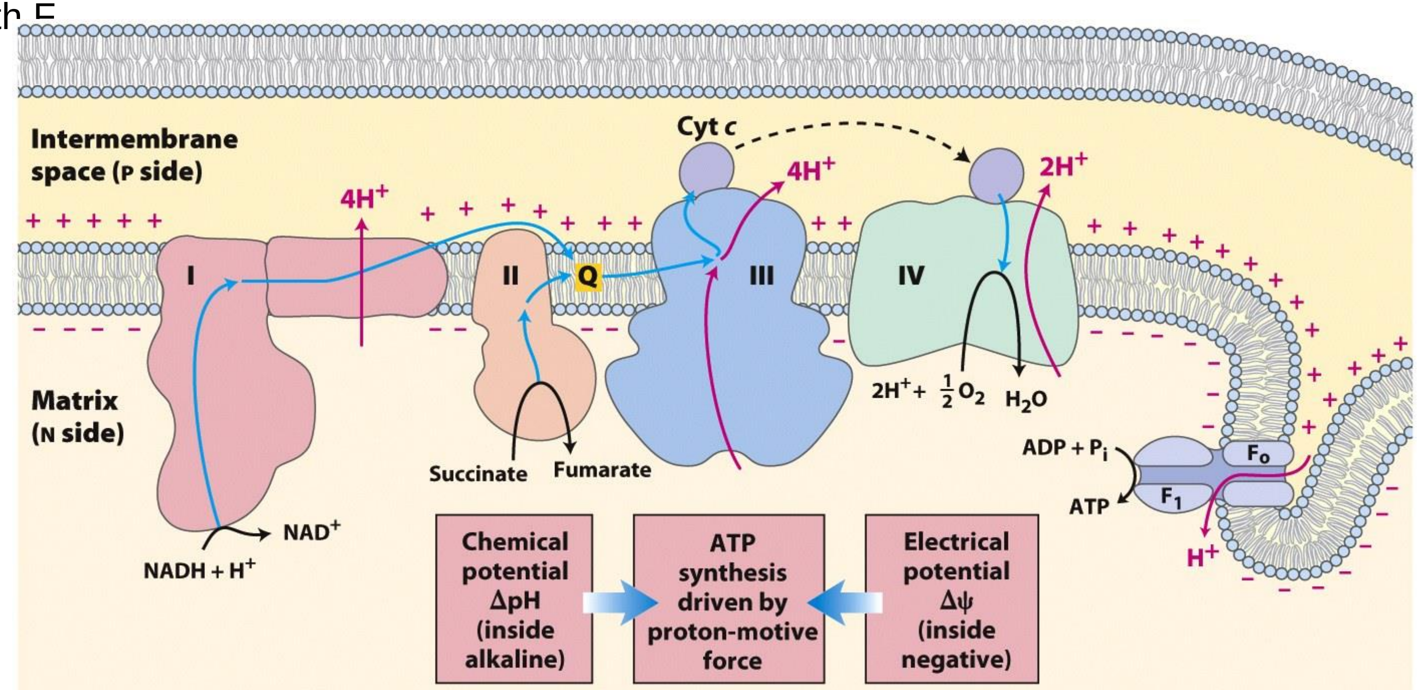



**Figure 19-19**
*Lehninger Principles of Biochemistry, Fifth Edition*

# ATP-Synthase/ATPase

-reversibel

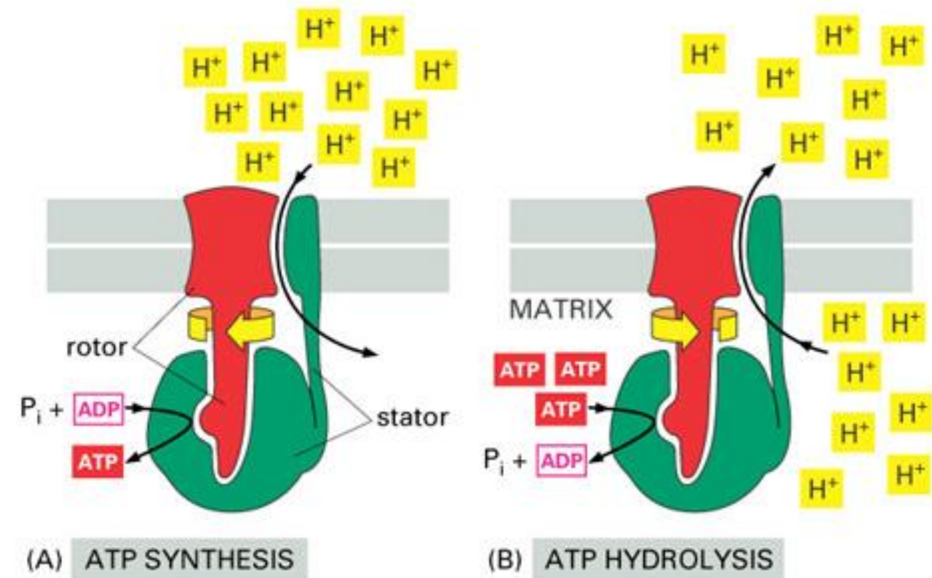
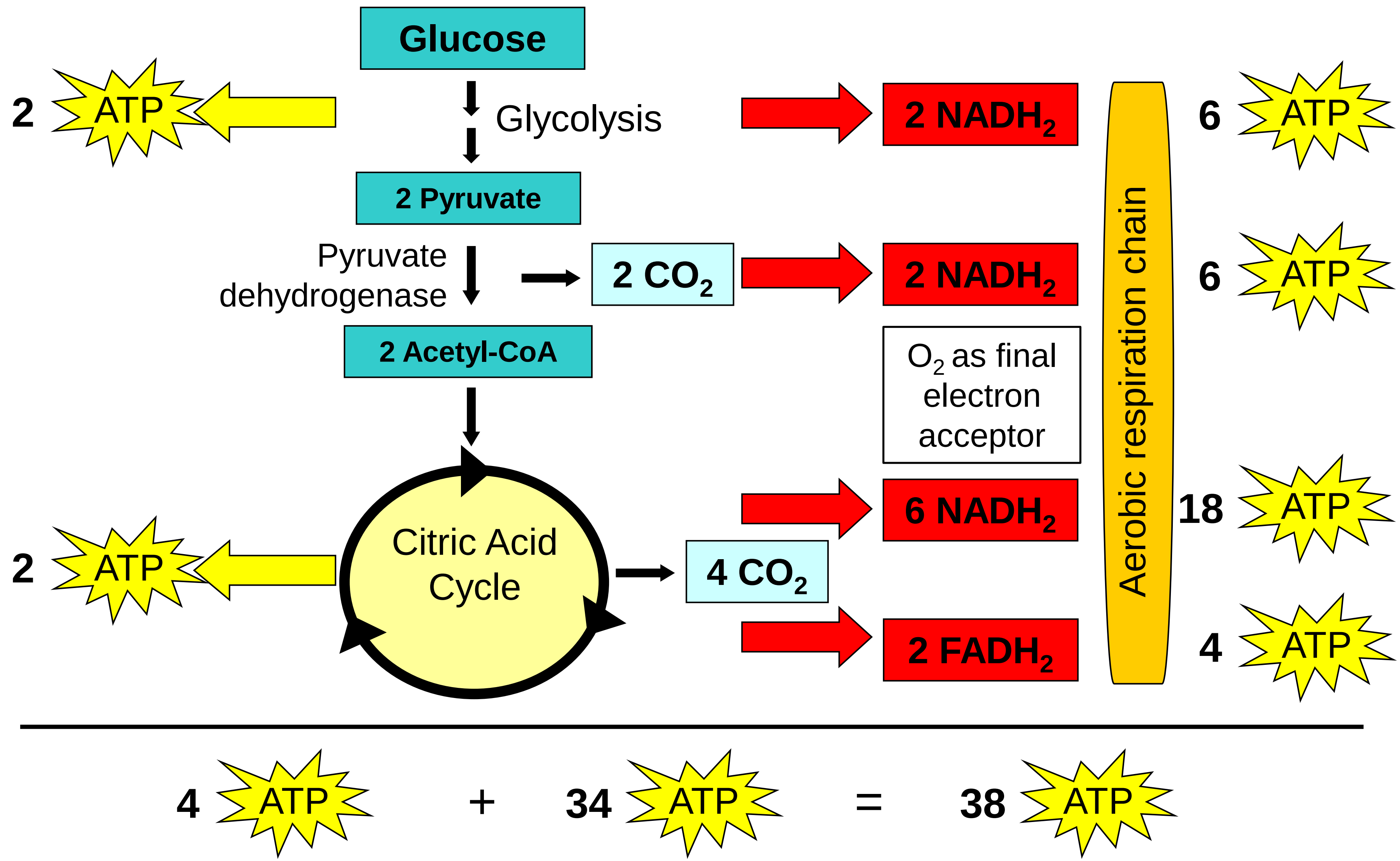



Figure 14-15 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Fig. 14.15 Essential Cell Biology (2nd edition, Alberts, Bray et al.)

# Energetics of Carbohydrate Metabolism (Aerobic Respiration)



# PMF Energized Membrane

**Proton-motive force (PMF)**

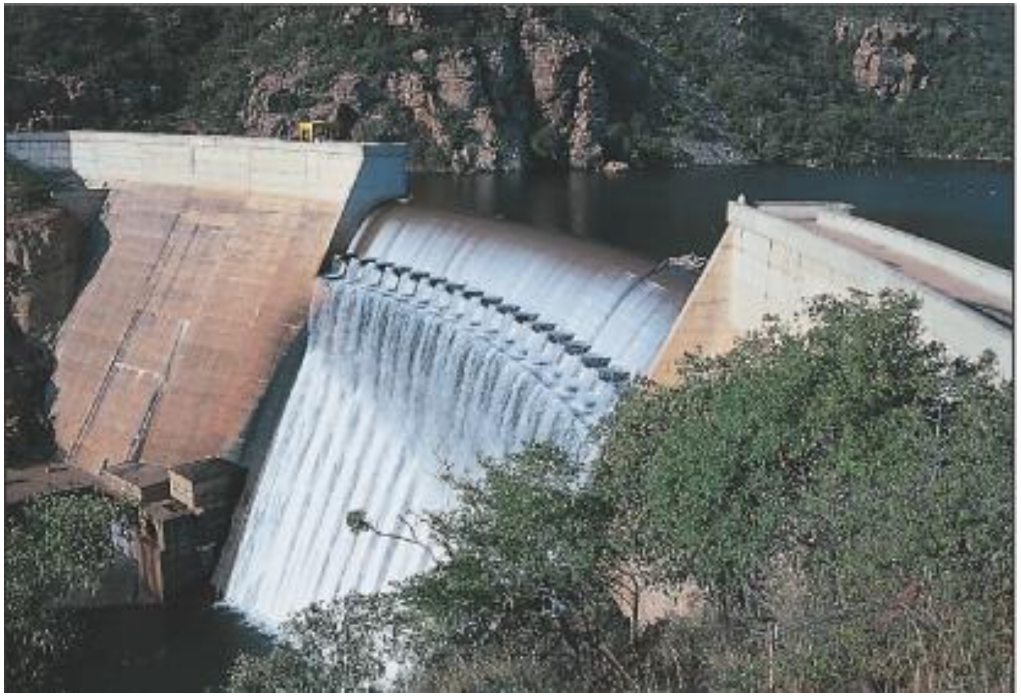


Figure 12-11 Essential Cell Biology, 2/e. (© 2004 Garland Science)

# Fermentation


# Atmung/Fermentation

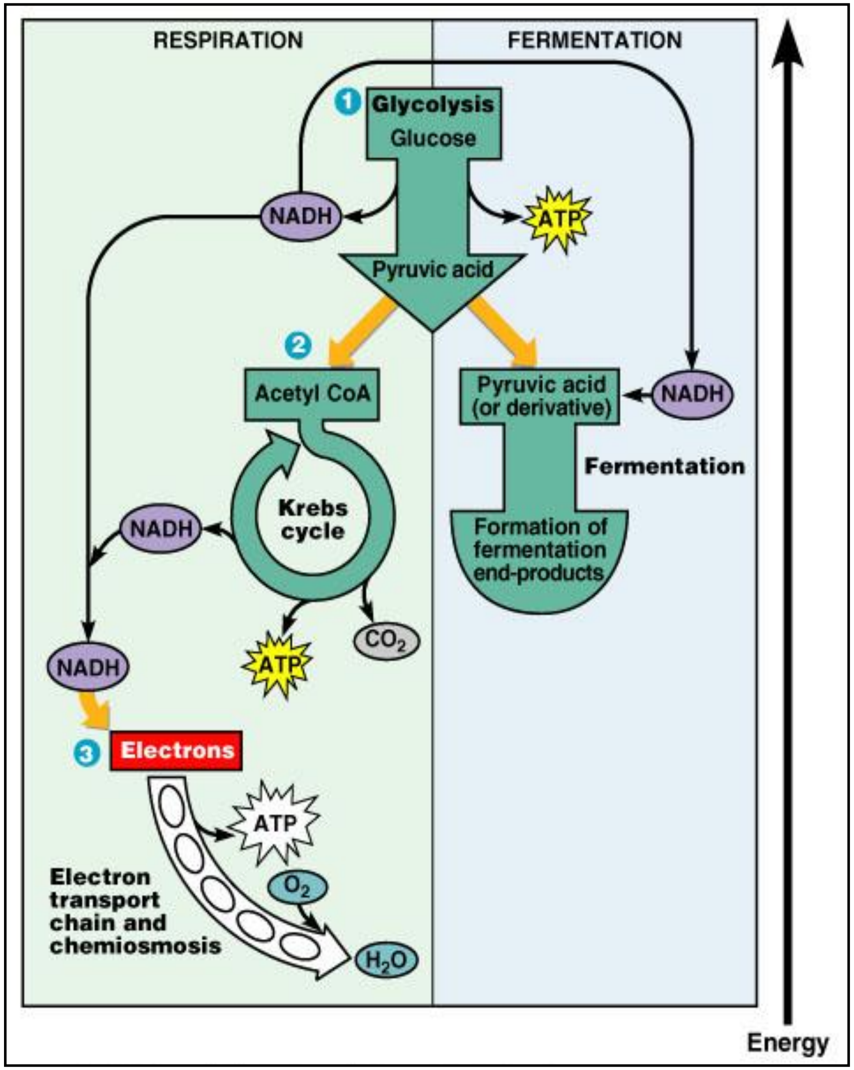
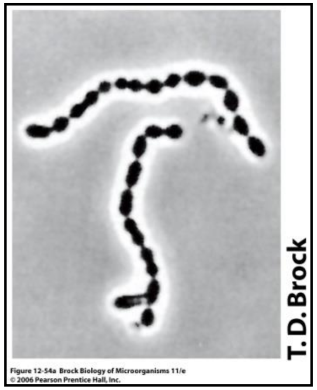
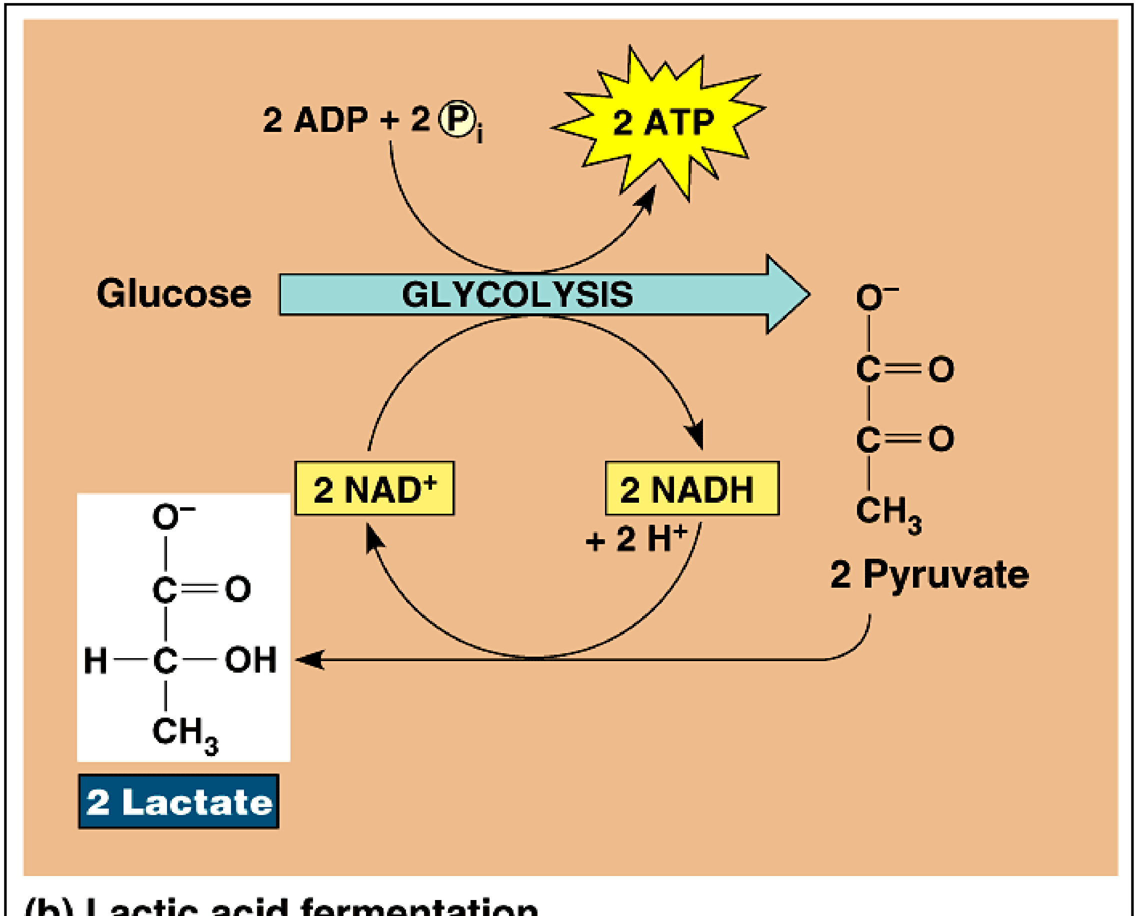



Fig. 5.14 Microbiology: An Introduction (Tortora, Funke, Case)

# Lacitc Acid Fermentation




***Lactococcus lactis***



# Anaerobic Respiration

- **Alternative electron acceptors in absence of oxygen**
- **Energy source**:

  mostly organic compounds (chemoorganotrophic org.); but also inorganic compounds (chemolithotrophic org.)
- **Electron acceptors**:

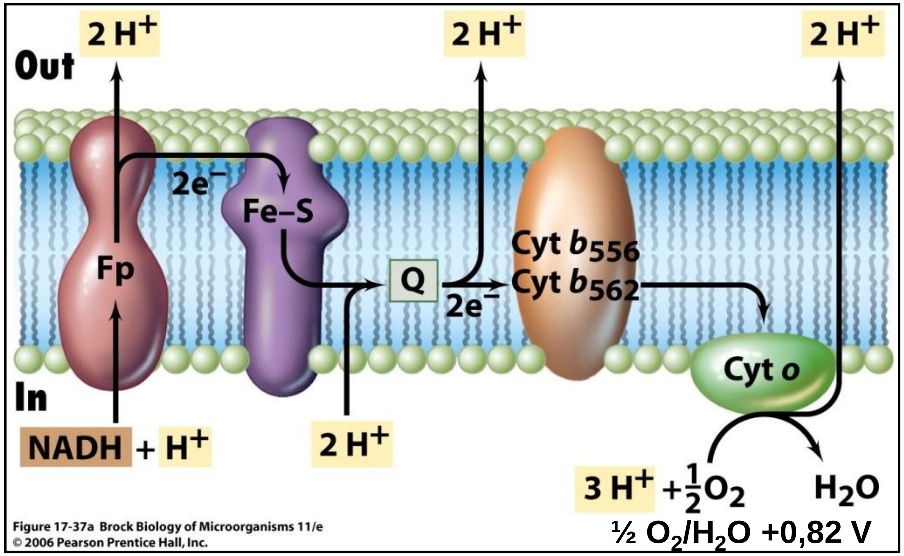
  Inorganic compounds, $NO_3^-$, $SO_4^{2-}$, $Fe^{3+}$, $NO_2^-$, $S^0$, $CO_2$
- **Electron transport chain**:

  analogue to the aerobic chain (Cytochrome, Quinone, Fe-S Proteine)
- **Facultative aerobes/anaerobes** with aerobic and anaerobic respiration;
- **Obligate anaerobes** only anaerobic respiration

# Nitrate Reduction (*E. coli*)

- **Enterobacteriaceae** (e.g. *E. coli*)
- **facultative anaerobic** Bacteria (anaerobic fermentation)
- only **reduction of nitrate to nitrite** (nitrate reductase A)

**aerob**




**anaerob ($NO_3^-$)**

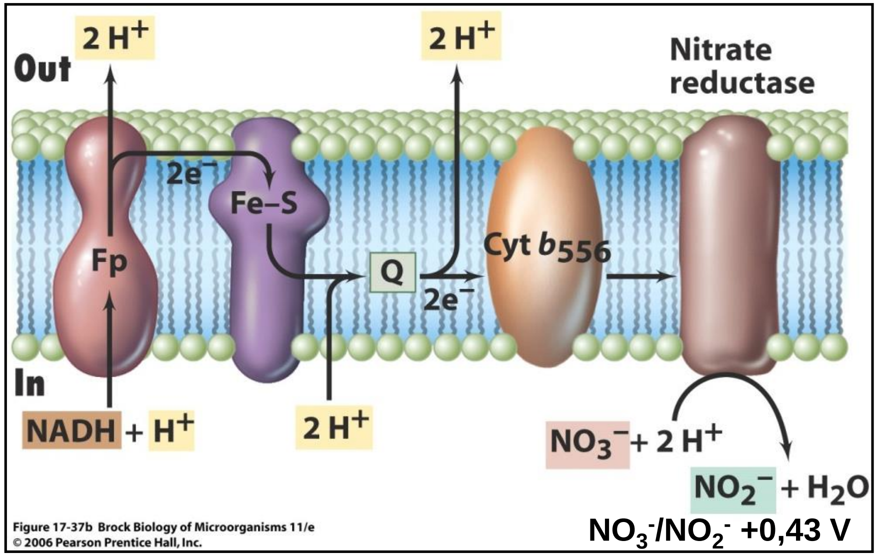



Fig. 17.37 **Vergleich aerobe und Nitrat Atmung.**
Brock Biology of Microorganisms (10th edition) (Madigan et al.)

# Knallgas-Bacteria

- Biologic knallgas-reaktion „Oxidation of hydrogen“

$H_2 + ½ O_2 \rightarrow H_2O$ $\Delta G^{0'}$=-237 kJ

„Hydrogenase“

- Different Bacteria:
  - $G^-$: *Pseudomonas, Alcaligenes, Paracoccus,*
  - $G^+$: *Nocardia, Mycobacterium, Bacillus*
- Hydrogenase (membrane-bound) „Electron transport“; some organisms in addition soluble hydrorgenase „direct reduction of $NAD^+$“
- Chemolithoautotrophe „$CO_2$ fixation via calvin cycle“
- Chemoorganotrophic growth (Calvin cycle and hydrogenase repressed)

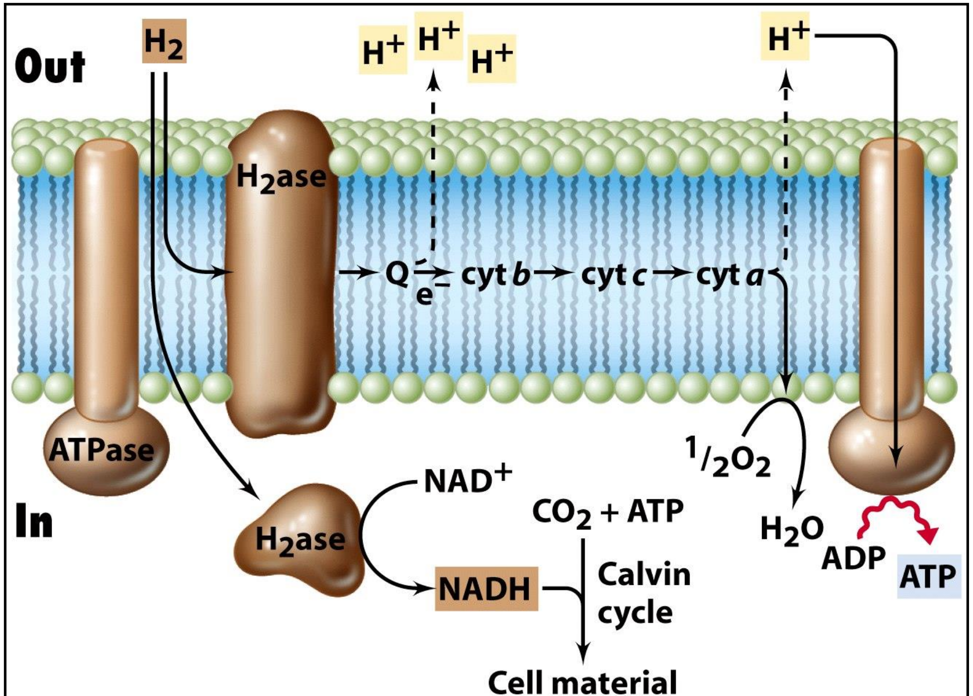



Figure 17-25 Brock Biology of Microorganisms 11/e

# Photosynthesis
# Light- and dark-reaction

**Calvin cycle**
**Melvin Calvin (1940)**

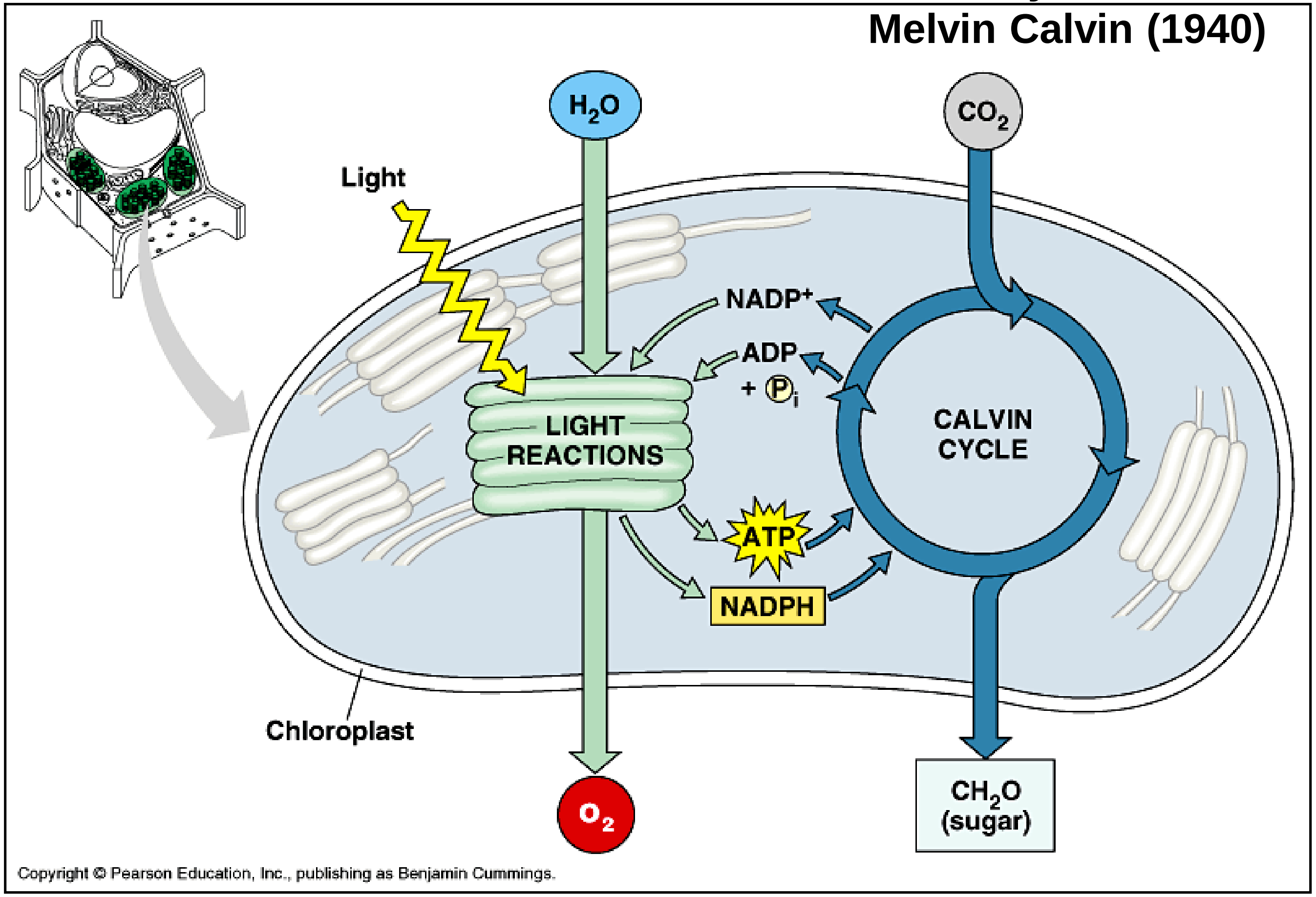



**Fig. 10.4** Biology (6th edition, Campbell & Reece)

# Non-cyclic Photophosphorylation

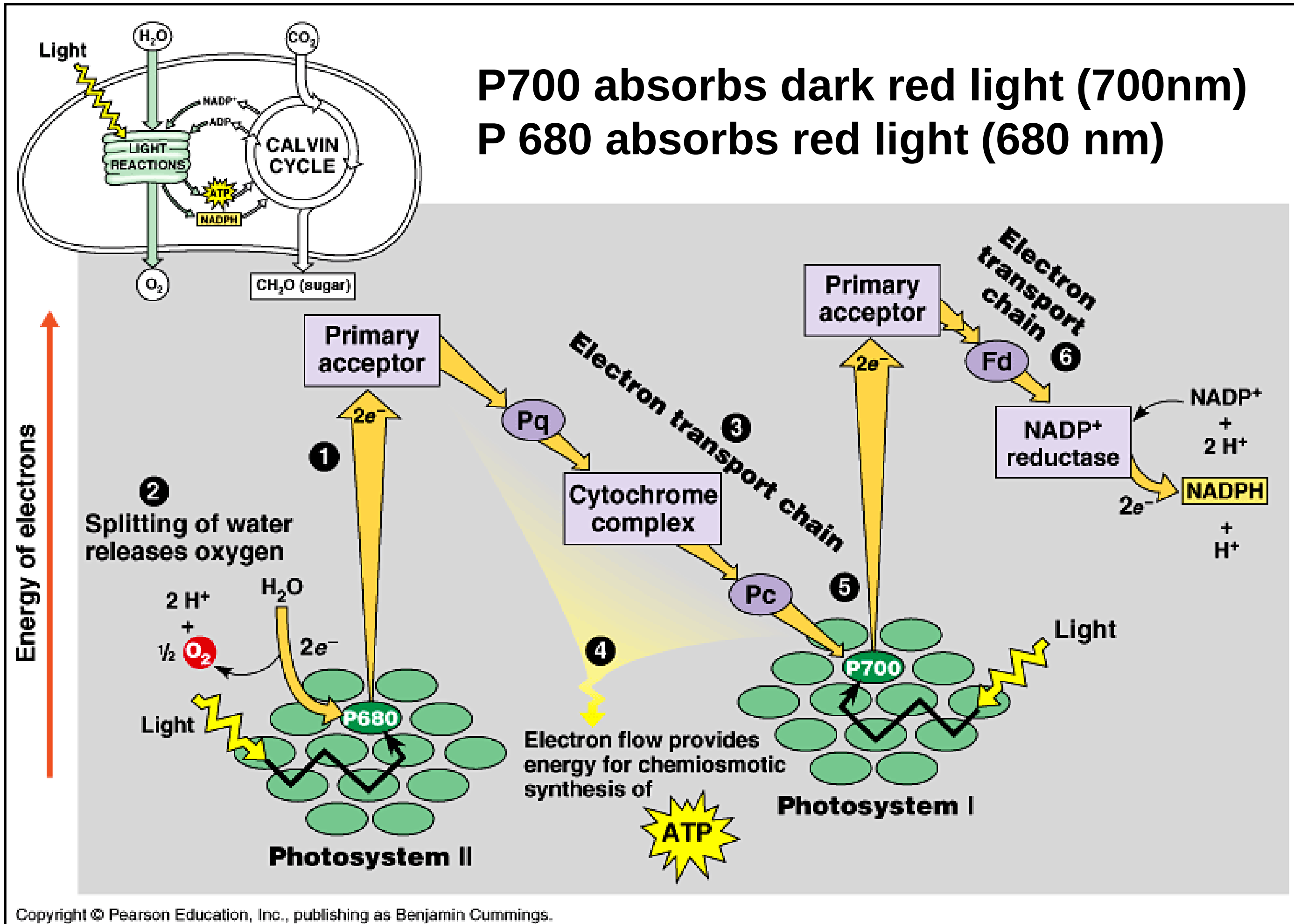





**Fig. 10.12** Biology (6th edition, Campbell & Reece)

**Plastoquinone (Pq), Cytochrome $b_6$-f-complex (proton pump), Plastocyanin (Pc, $Cu^{2+}$-Protein)**

# The Light Reaction and Chemiosmosis

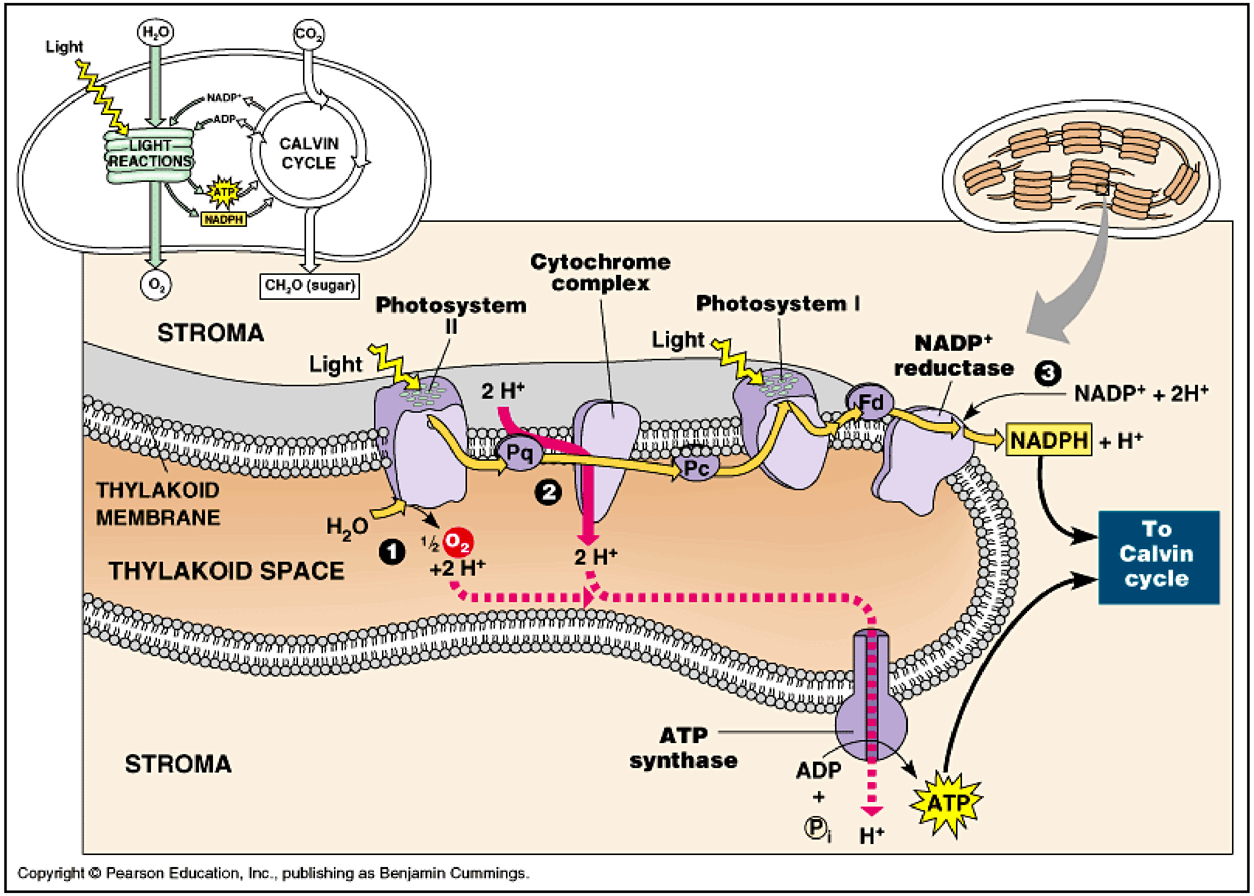





**Fig. 10.16** Biology (6th edition, Campbell & Reece)

# Comparison of Chemioosmosisin Mitochondrien und Chloroplasten

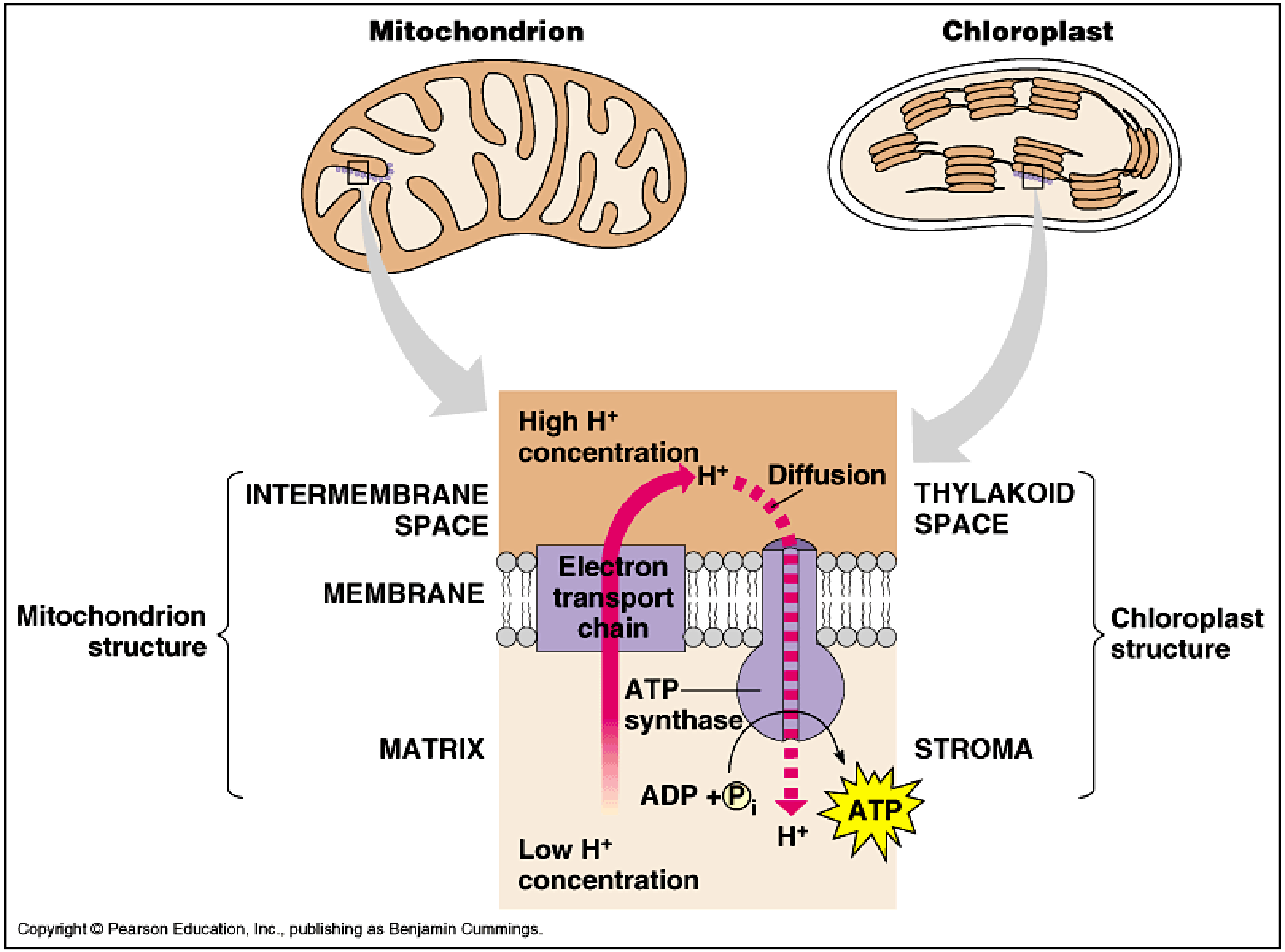



**Fig. 10.8** Biology (6th edition, Campbell & Reece)

# Seminar II

- ATP-Generation via substrate level phosphorylation, electron transport phosphorylation
- (Eukaryotic/prokaryotic cell)
- Bacterial cell wall
- Antibiotic resistance

# Prokaryotes & Eukaryotes

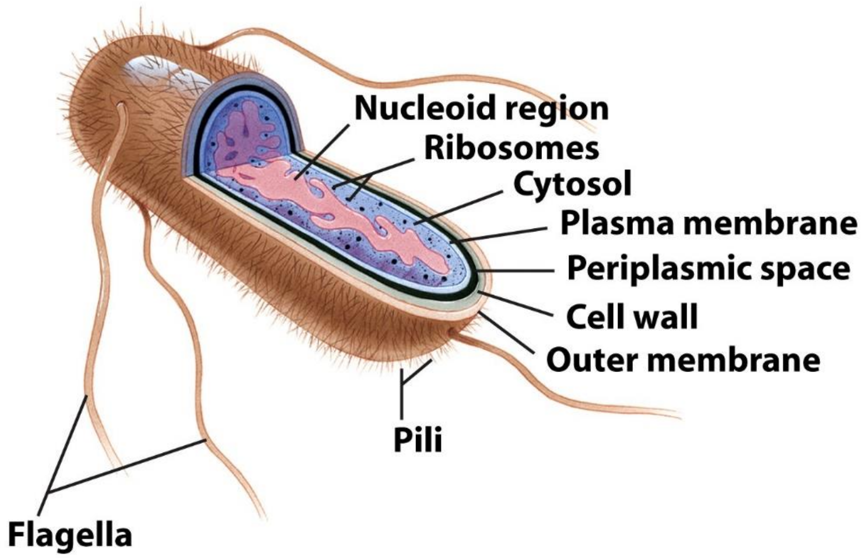



Figure 1-14 Principles of Biochemistry, 4/e

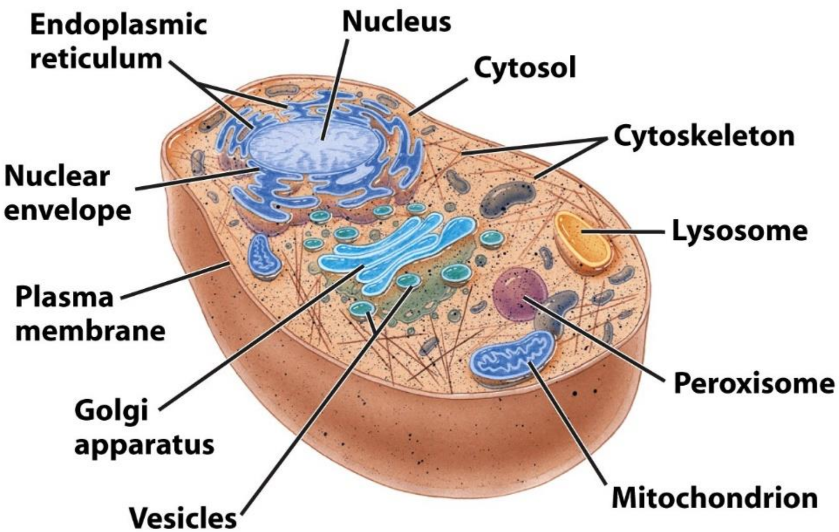




Figure 1-15a Principles of Biochemistry, 4/e

# Murein: Cell wall (Bacteria)

- Gram positive cell wall

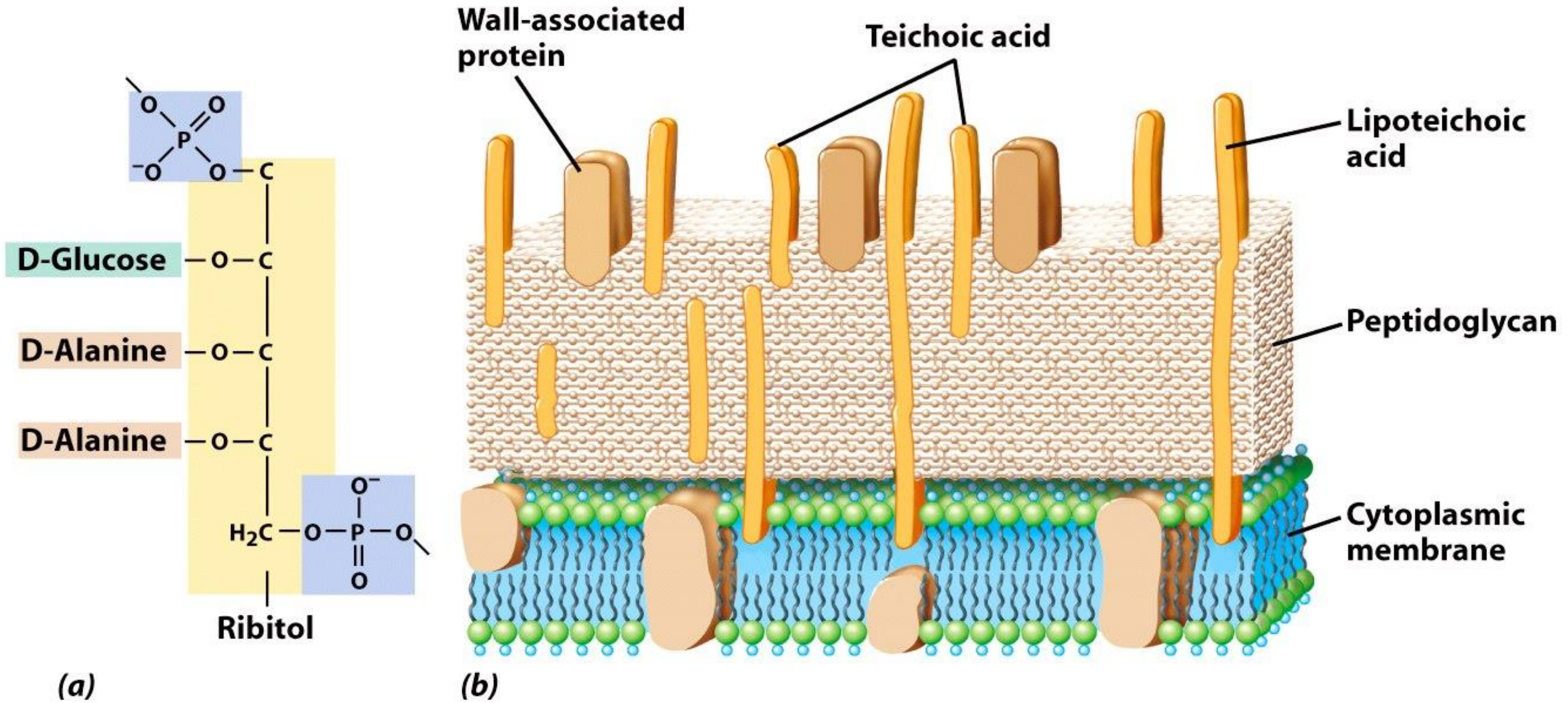



Figure 4-31 Brock Biology of Microorganisms 11/e

# Murein: Cell wall (Bacteria)

- Gram negative cell wall

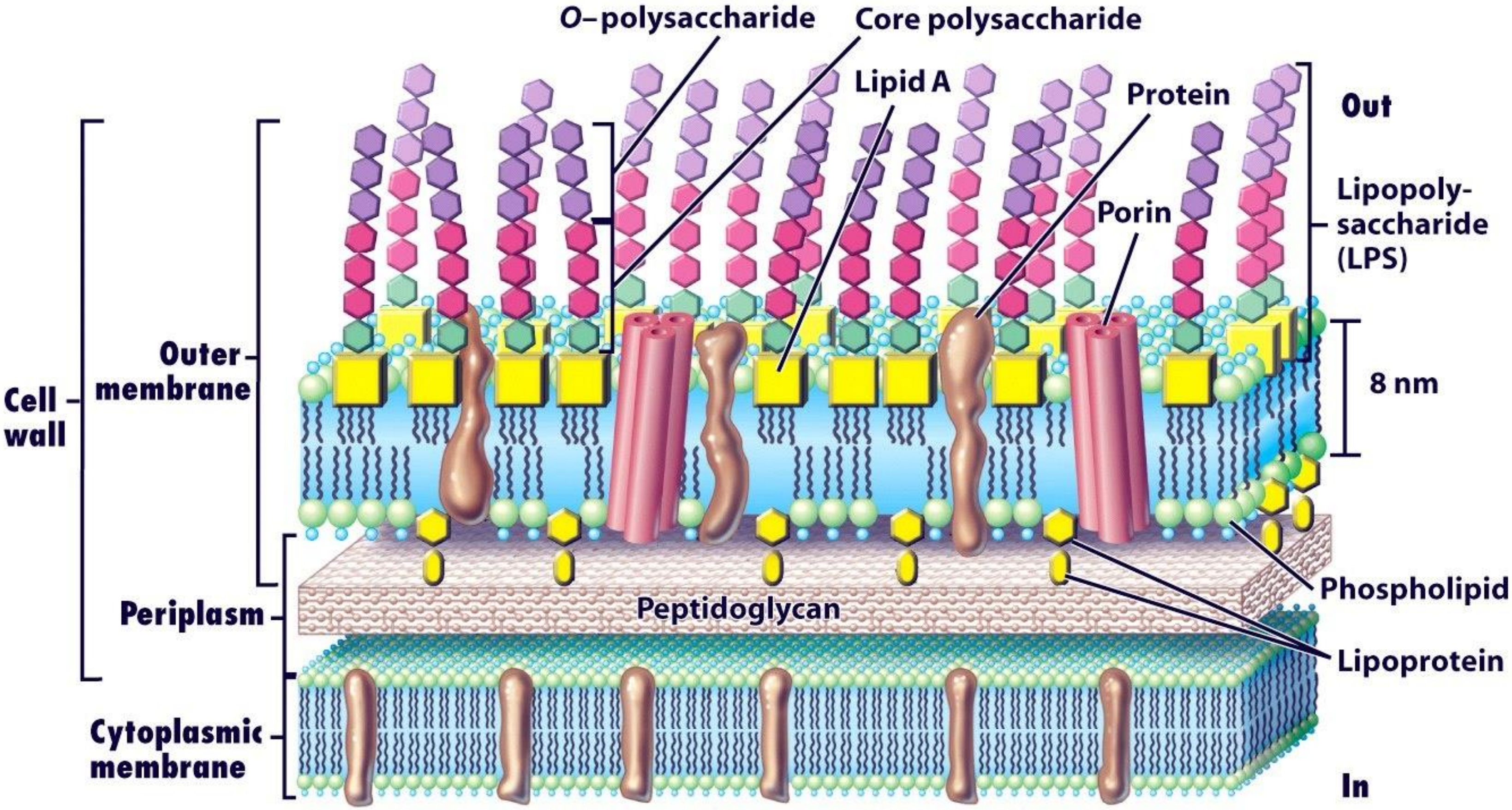



Figure 4-35a Brock Biology of Microorganisms 11/e

# N-acetylglucosamine

- N-acetylglucosamine, a sugar derivative, basic building block for **chitin** and **murein**.

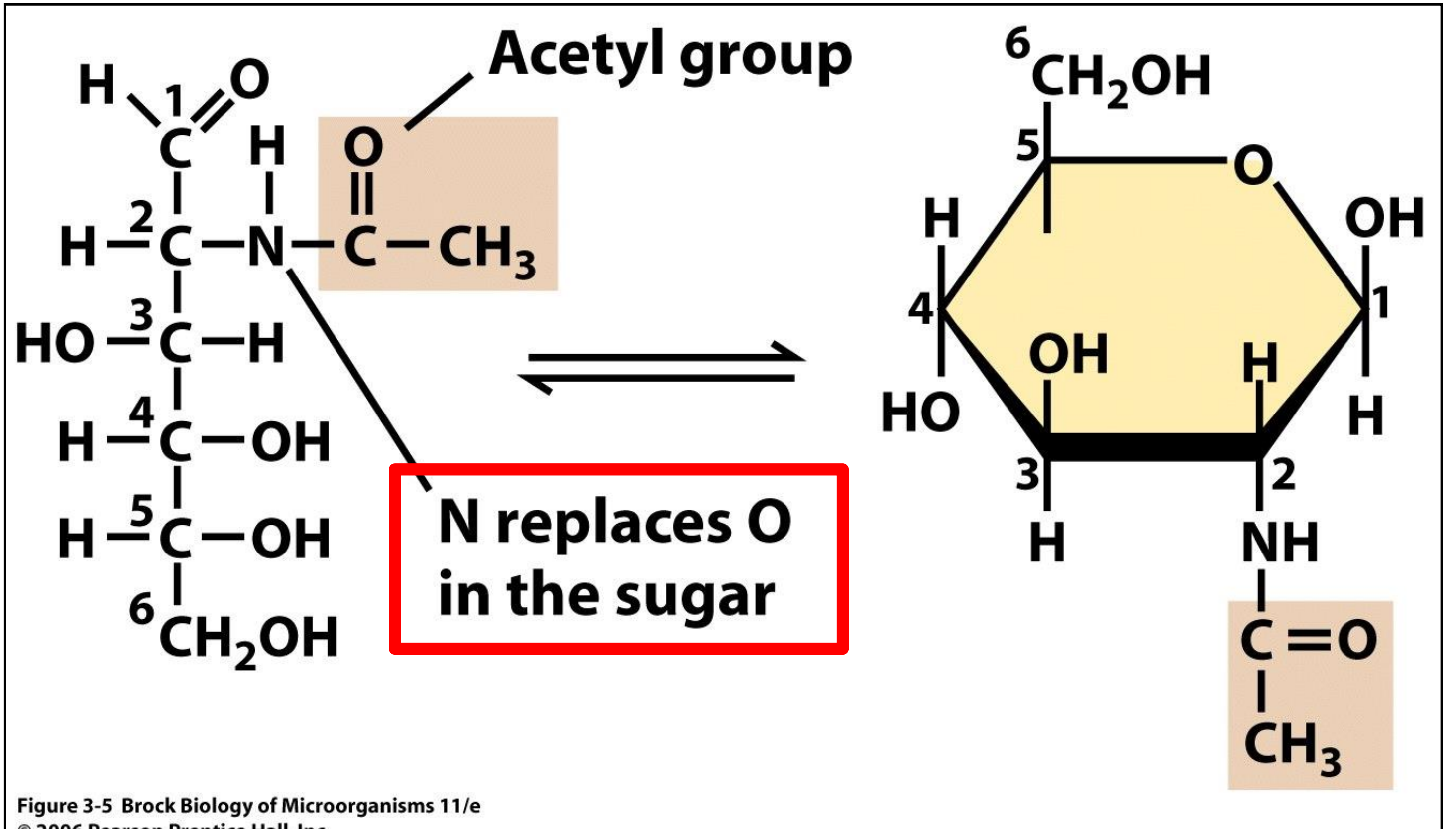



Figure 3-5 Brock Biology of Microorganisms 11/e

# Murein: Cell wall (Bacteria)

- Structure of the polysaccharide in bacterial cell wall **peptidoglycan**.
- The glycan is a polymer of alternating **GlcNAc** and ***N*-acetylmuramic acid** (MurNAc, Lactic acid linked to C-4 atom) residues.
- Alternating **peptide chains of D- und L-amino acids**
- Linkage of the L-alanine amino group (amide linkage) with the lactylcarboxylgroup of a MurNac residue

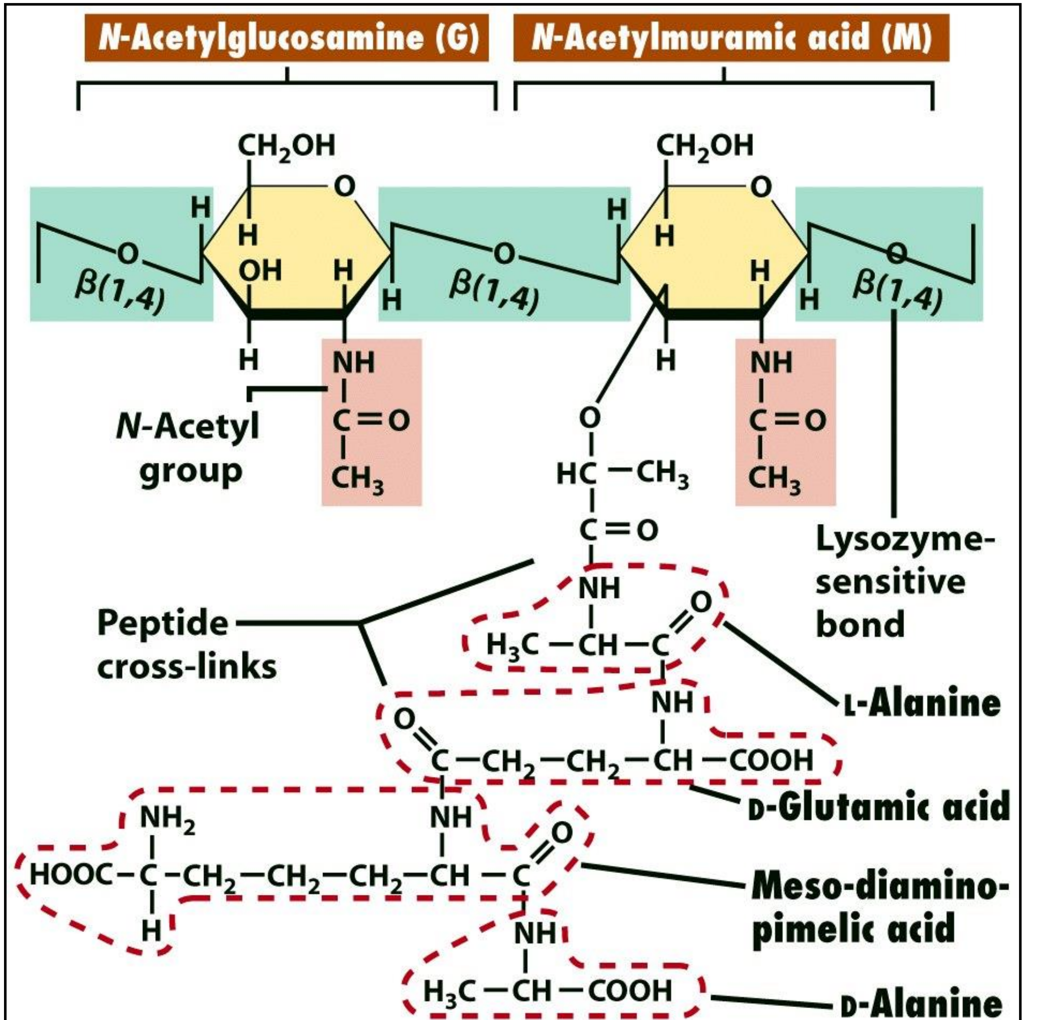
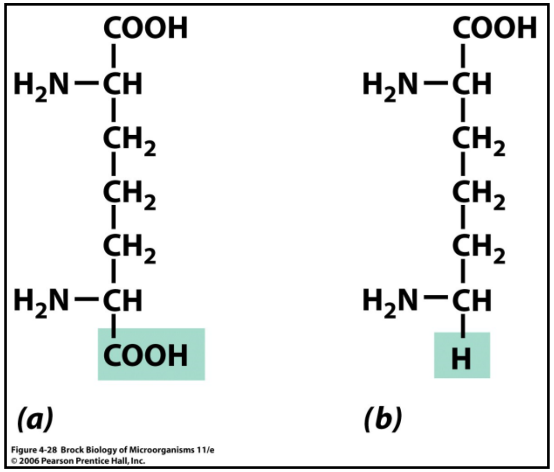
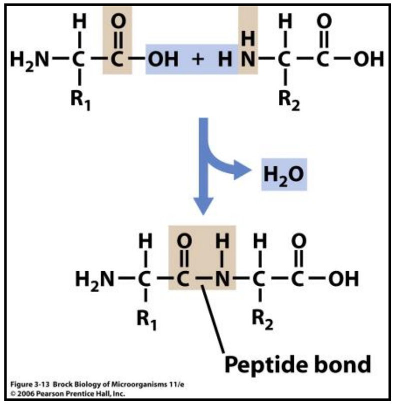


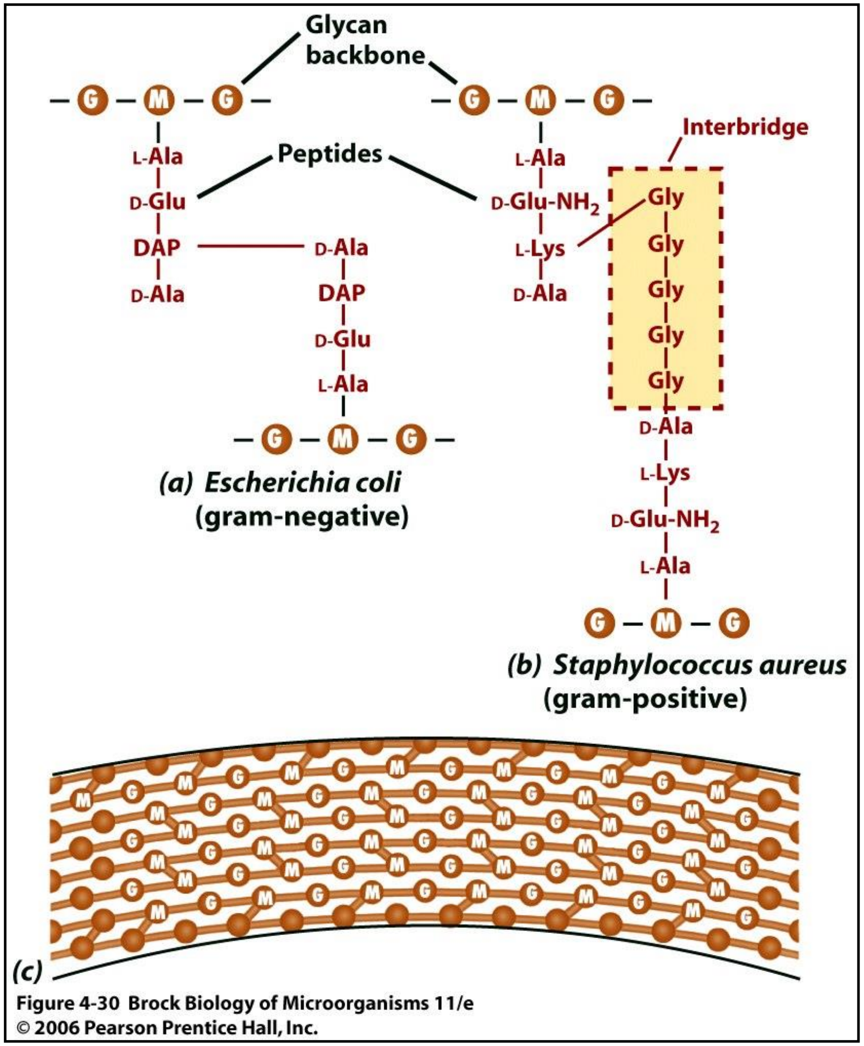

Figure 4-29 Brock Biology of Microorganisms 11/e

# Murein: Cell wall (Bacteria)




**(a) Diaminopimelinsäure**
**(b) Lysin**



# Murein: Cell wall (Bacteria)

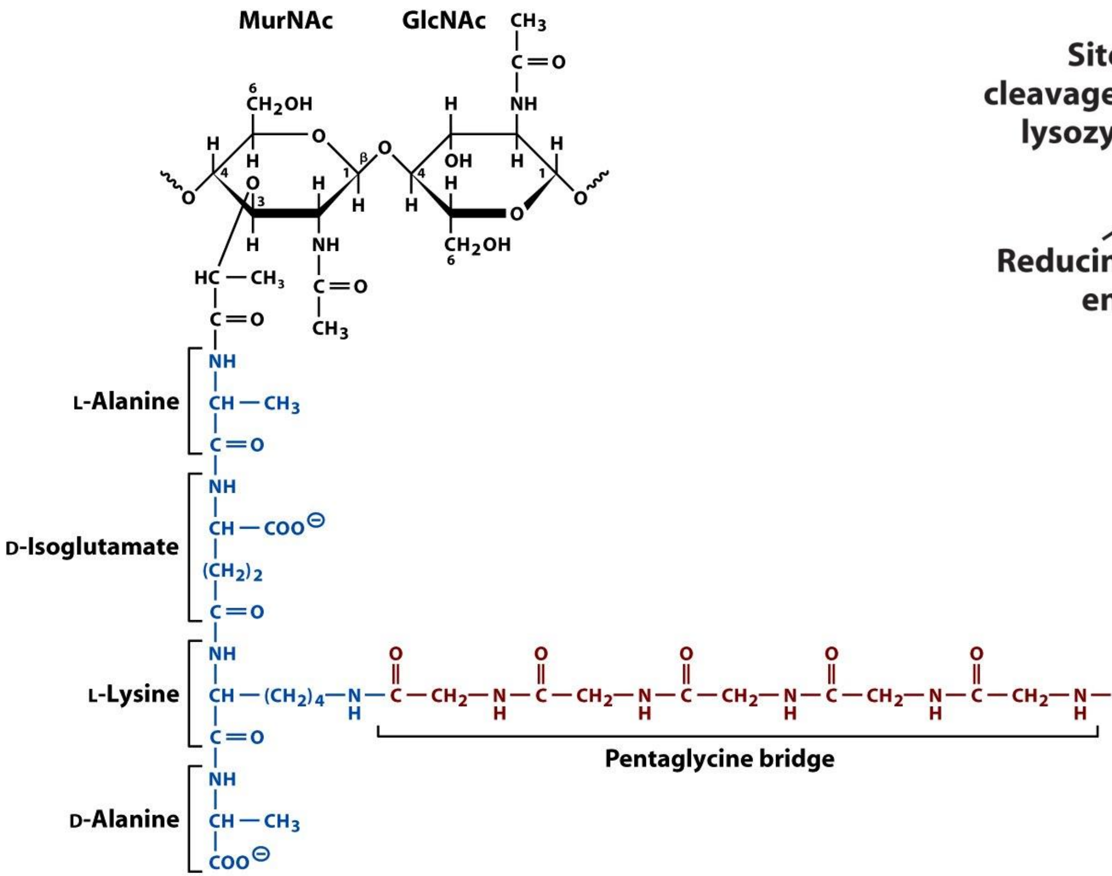



Figure 8-31a Principles of Biochemistry, 4/e

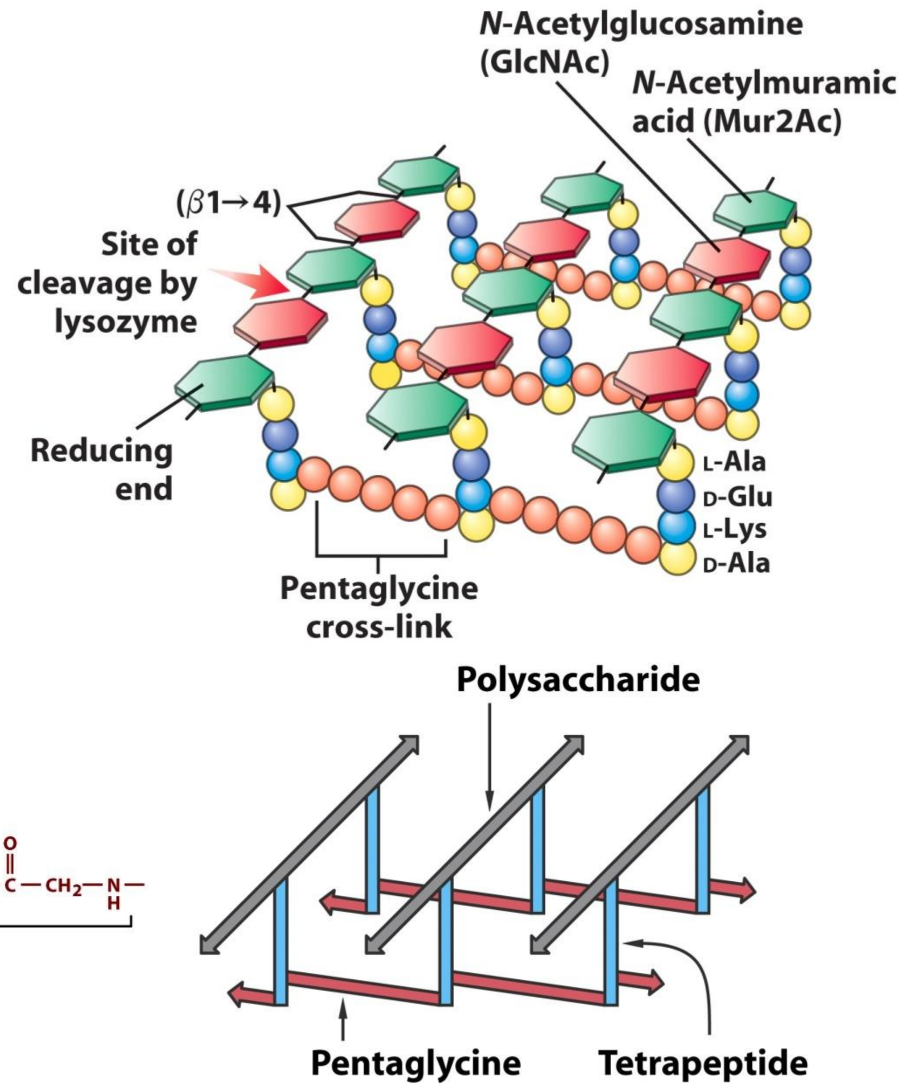




Figure 8-31b Principles of Biochemistry, 4/e

# Glycoconjugate

- Glycolipids
  - Lipopolysaccharide (Gram negative Bacteria, outer membrane)

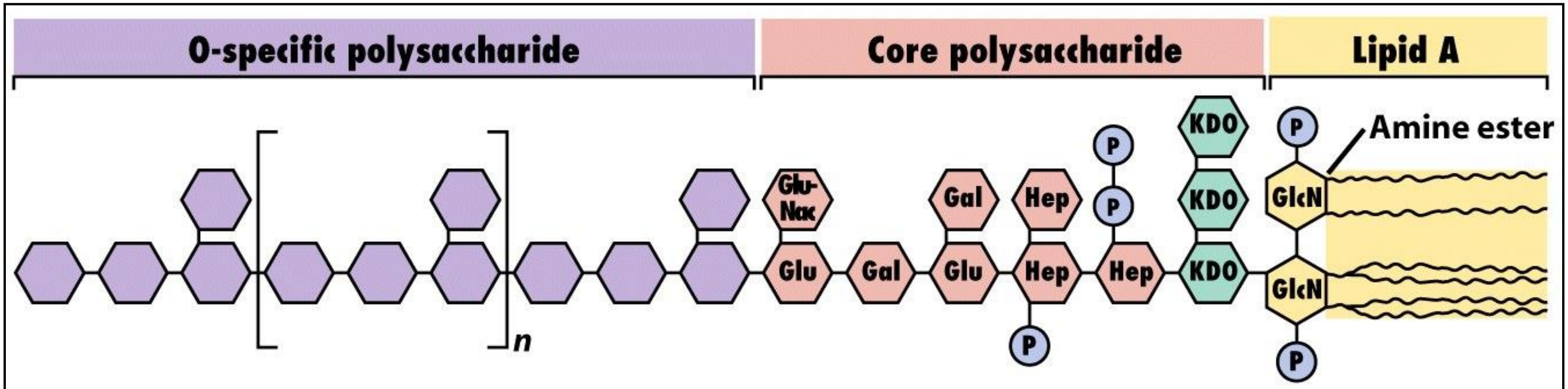



Figure 4-34 Brock Biology of Microorganisms 11/e

# Mode of Action of Some Major Antimicrobial Agents

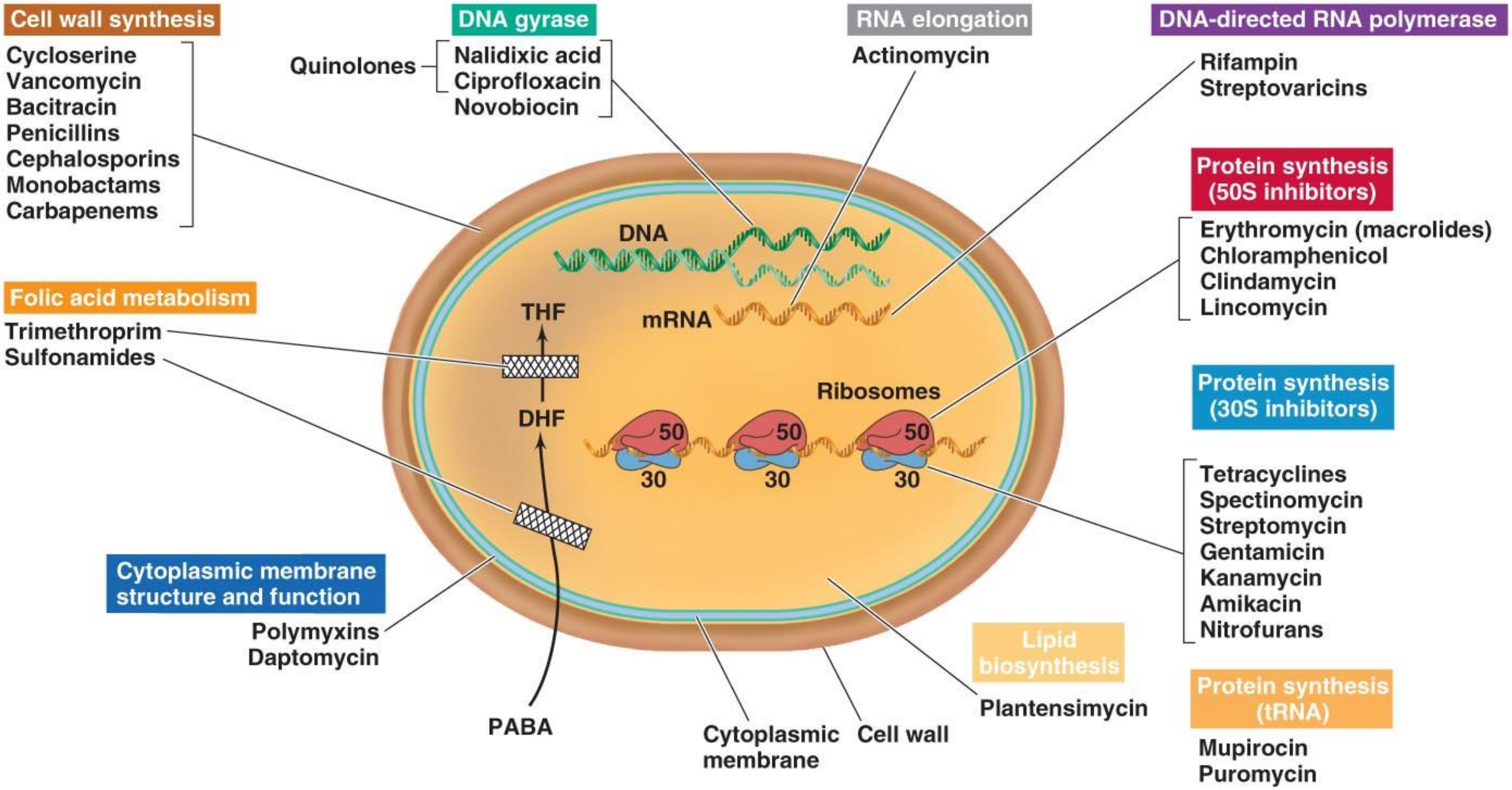



Figure 27.12

# Antimicrobial Spectrum of Activity

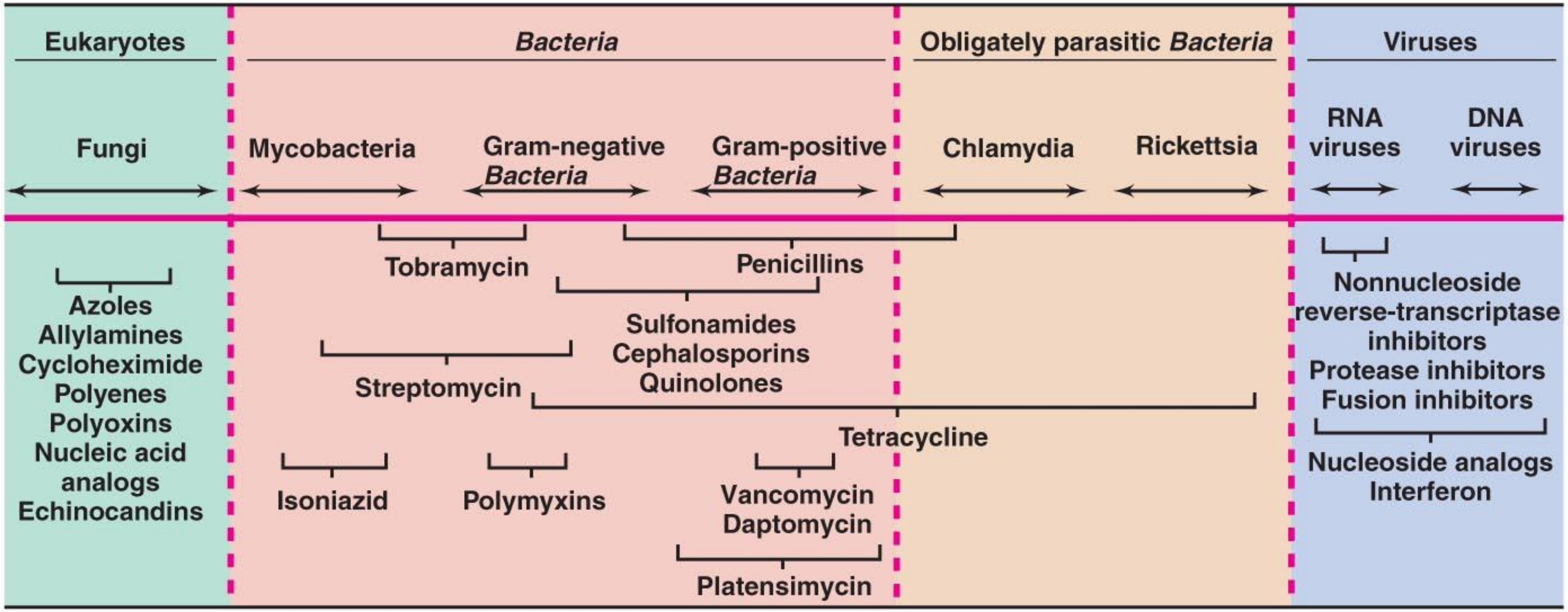


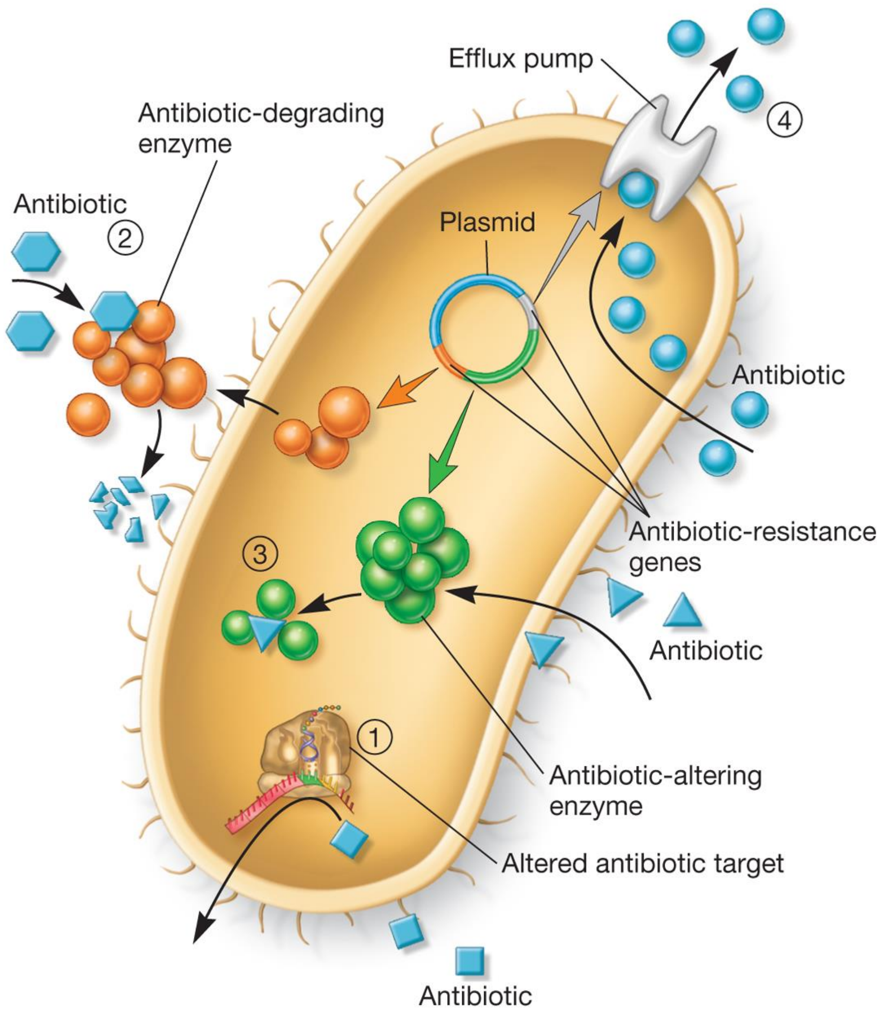

Figure 27.13

# Antimicrobial Drug Resistance

- *Antimicrobial drug resistance*
  - The acquired ability of a microbe to resist the effects of a chemotherapeutic agent to which it is normally sensitive

# Mechanisms of Drug Resistance






- Prevent entrance of drug
- Drug efflux (pump drug out of cell)
- Inactivation of drug
  - chemical modification of drug by pathogen
- Modification of target enzyme or organelle
- Use of alternative pathways or increased production of target metabolite

# Sites at Which Antibiotics are Attacked by Enzymes

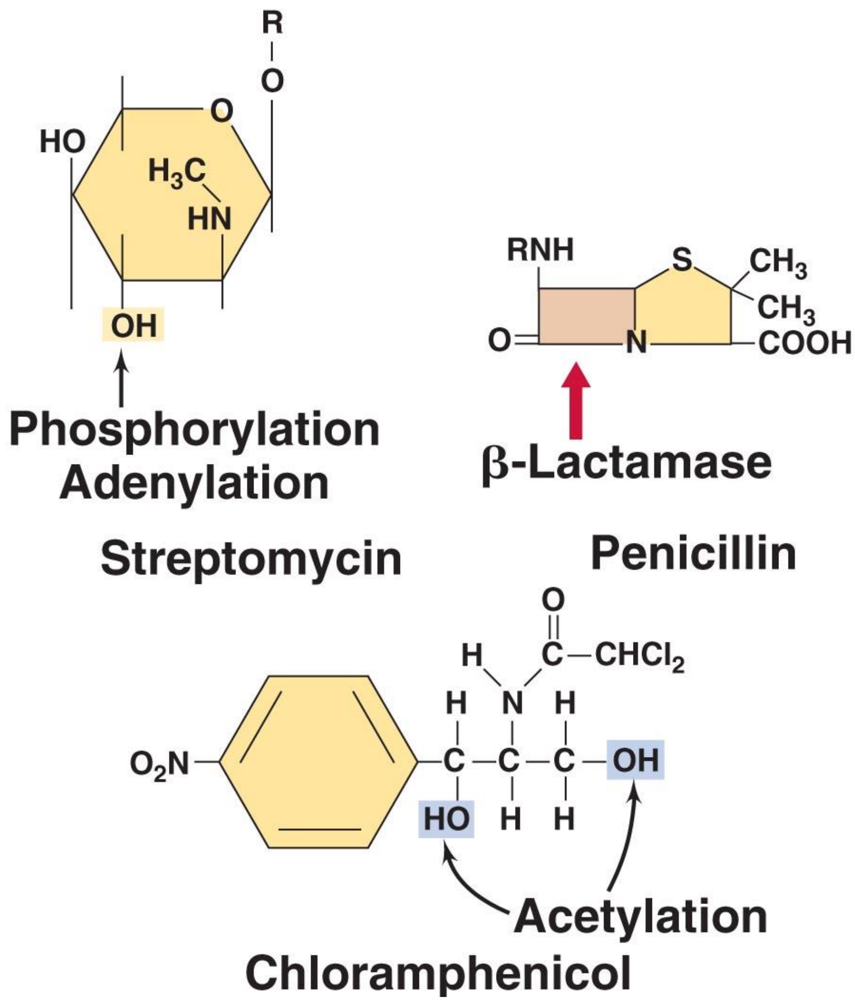
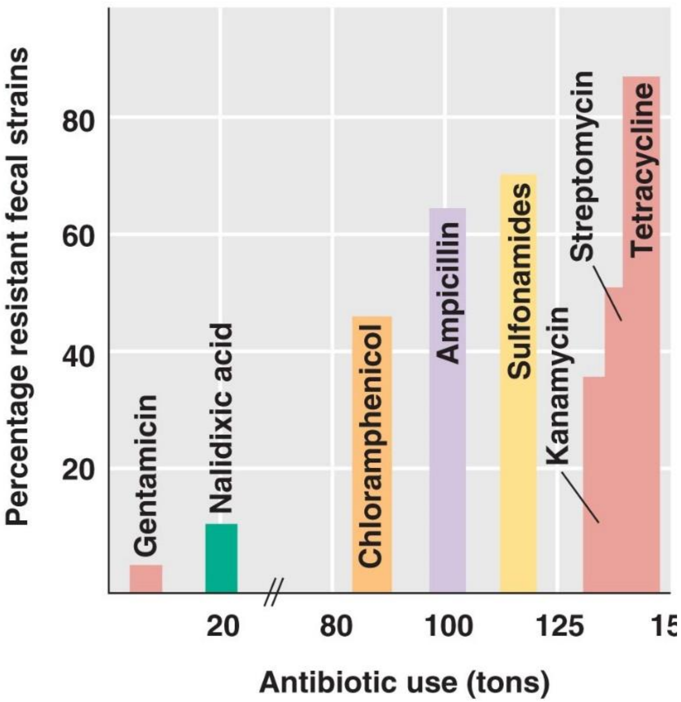



Figure 27.27

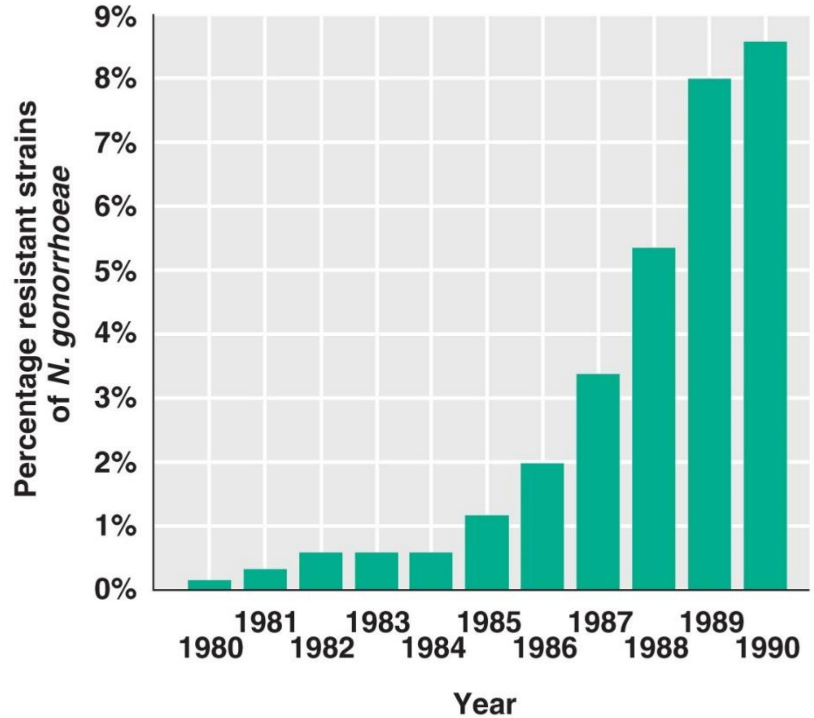
# Antimicrobial Drug Resistance

- Most drug-resistant bacteria isolated from patients contain drug-resistance genes located on **R plasmids**
- The use of antibiotics in **medicine, veterinary,** and **agriculture** select for the **spread of R plasmids**
  - Many examples of **overuse** of antibiotics
  - Used far more often than necessary (i.e., antibiotics used in agriculture as supplements to animal feed)

# Patterns of Drug Resistance in Pathogens




*(a)*




*(b)*

Figure 27.28

Figure 27.28