Science X-Change

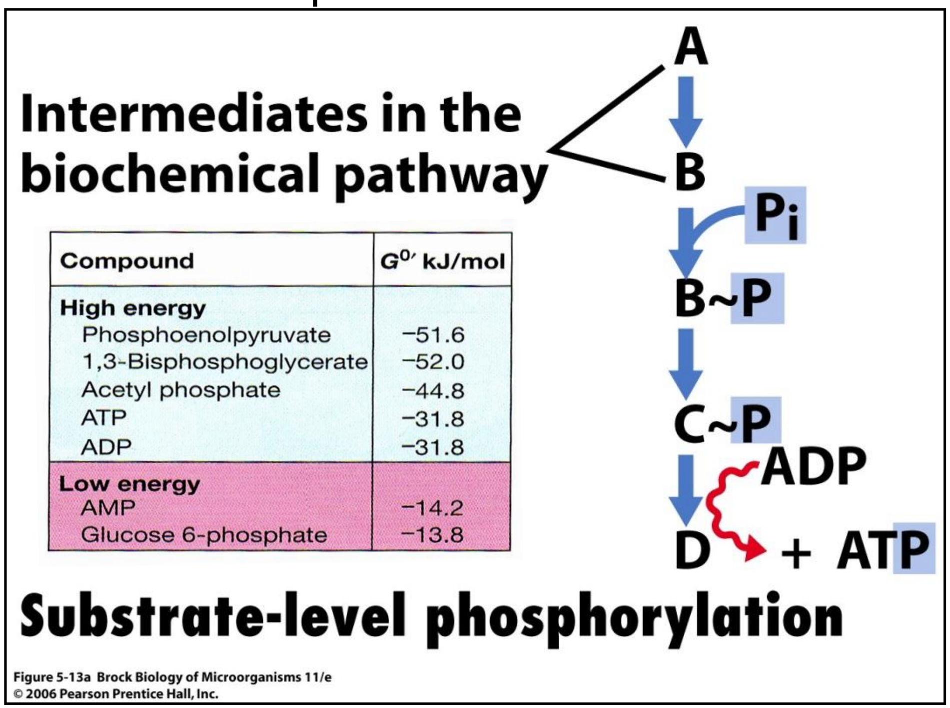
Seminar III

Seminar III

- ATP-Generation via substrate level phosphorylation, electron transport phosphorylation
- CO_2 Fixation
- (Eukaryotic/prokaryotic cell)
- Bacterial cell wall
- Antibiotic resistance

Basic Mechanisms of Energy Conservation

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



Elektron-transport phosphorylation
(Oxidative Phosphorylation)

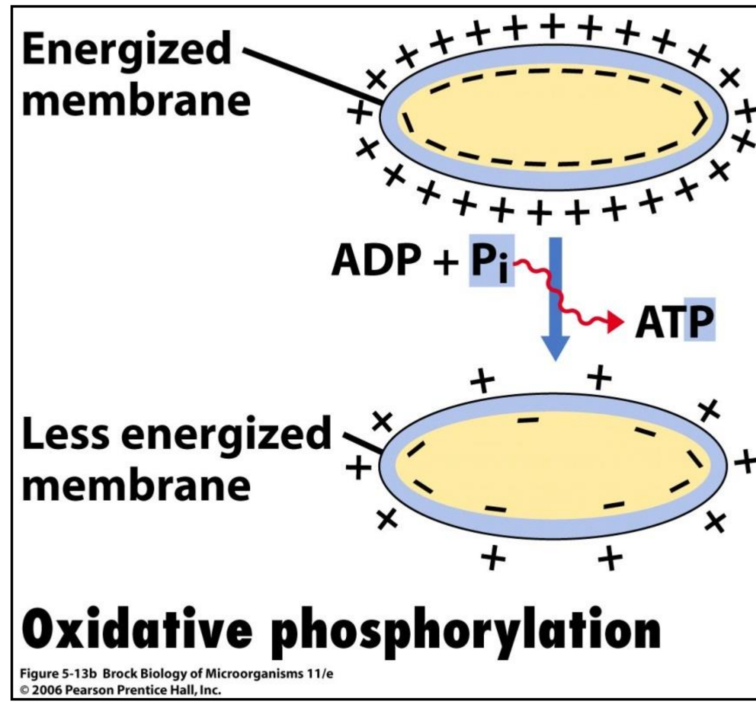
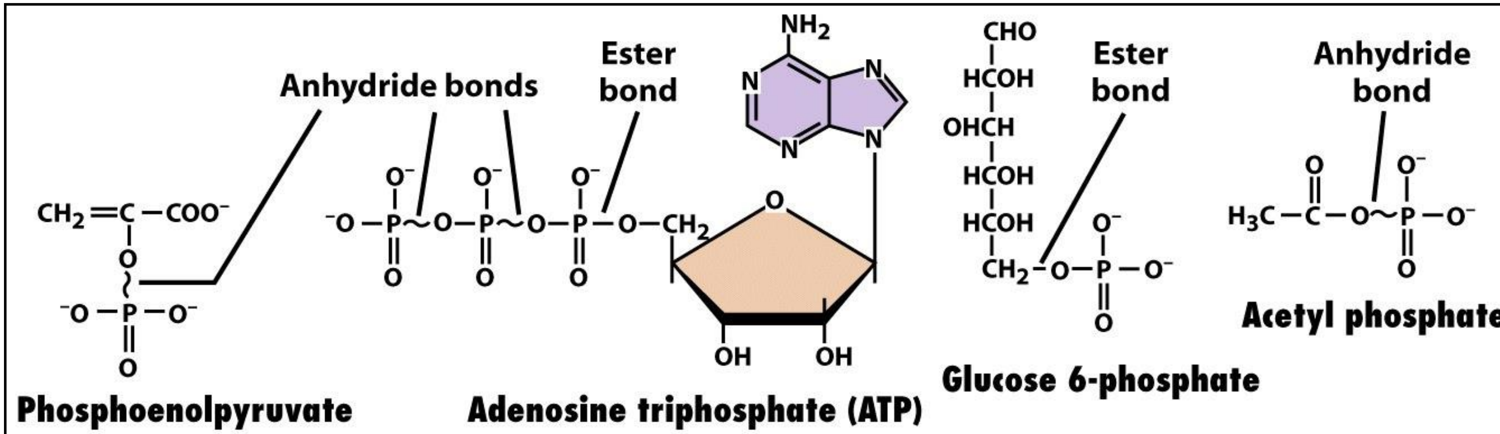
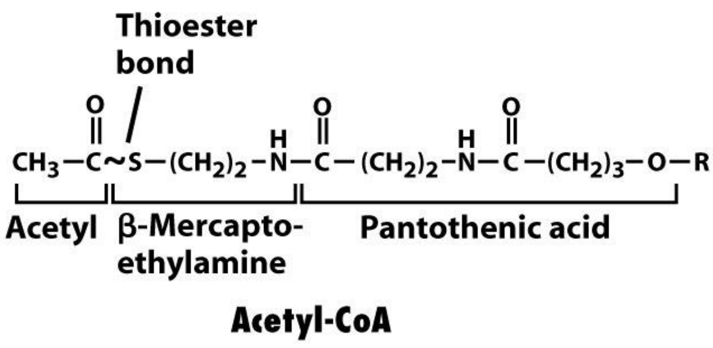


Fig. 5.13 Brock Biology of Microorganisms (11th edition) (Madigan et al.)

Energy-Rich Compounds





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

Figure 5-12 Brock Biology of Microorganisms 11/e

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

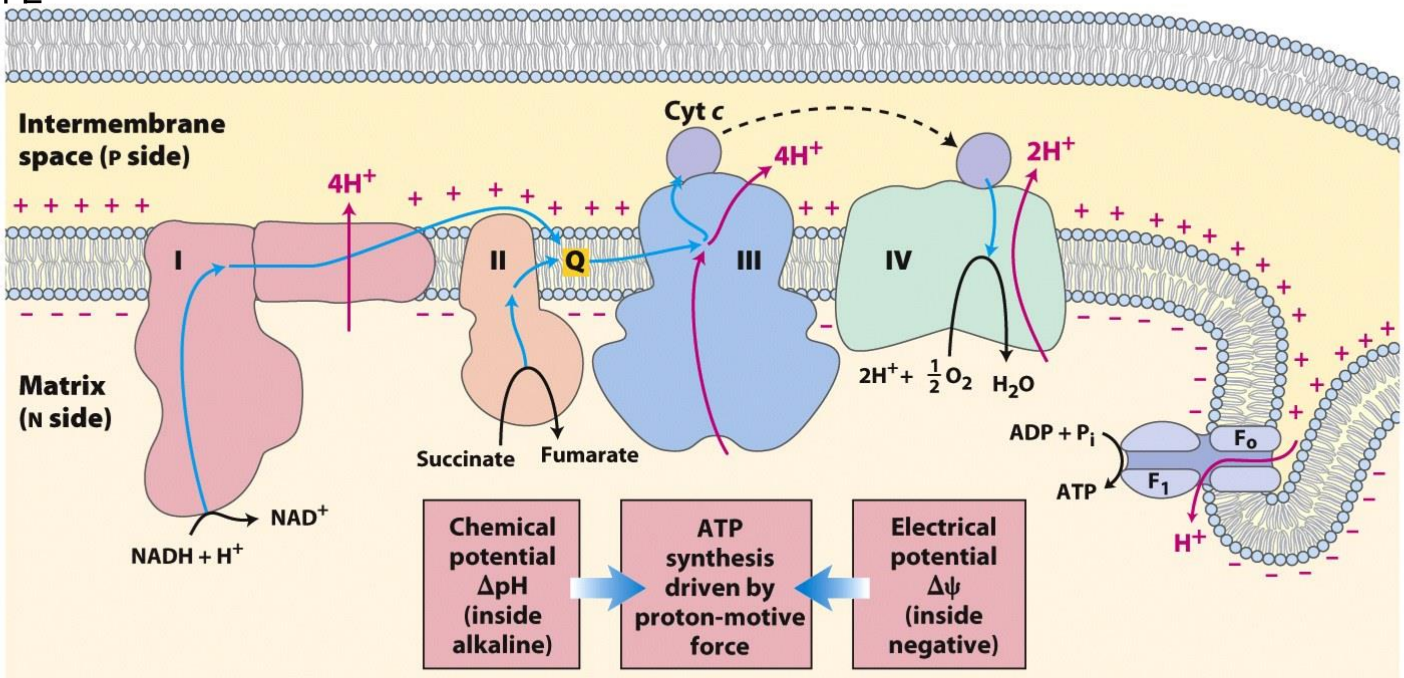


Figure 19-19
Lehninger Principles of Biochemistry, Fifth Edition

PMF Energized Membrane

Proton-motive force (PMF)

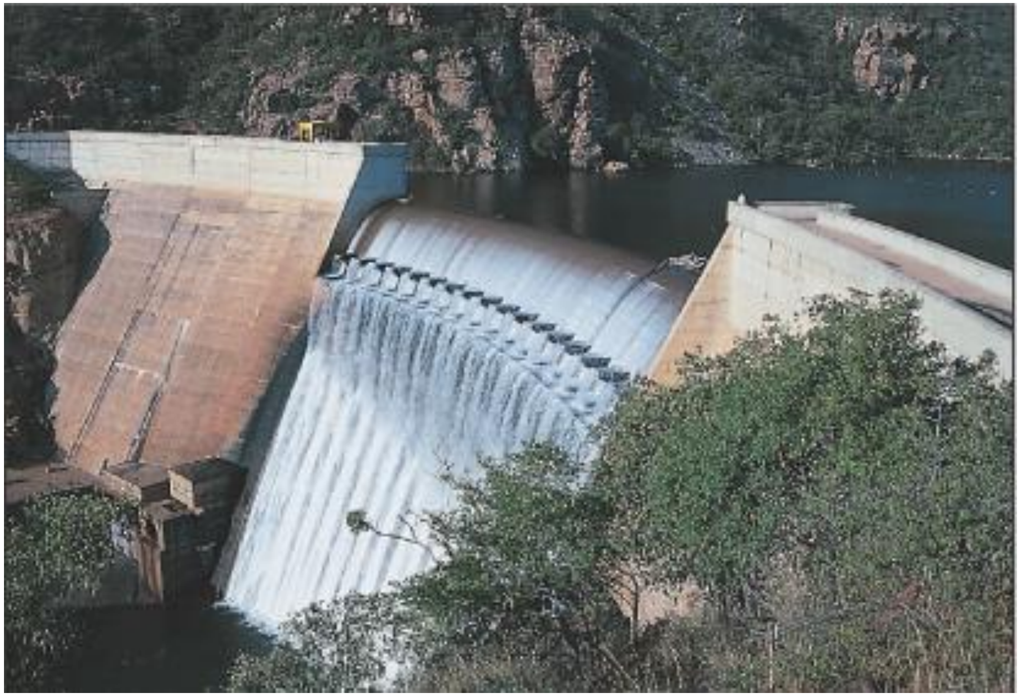


Figure 12-11 Essential Cell Biology, 2/e. (© 2004 Garland Science)

ATP-Synthase/ATPase

-reversibel

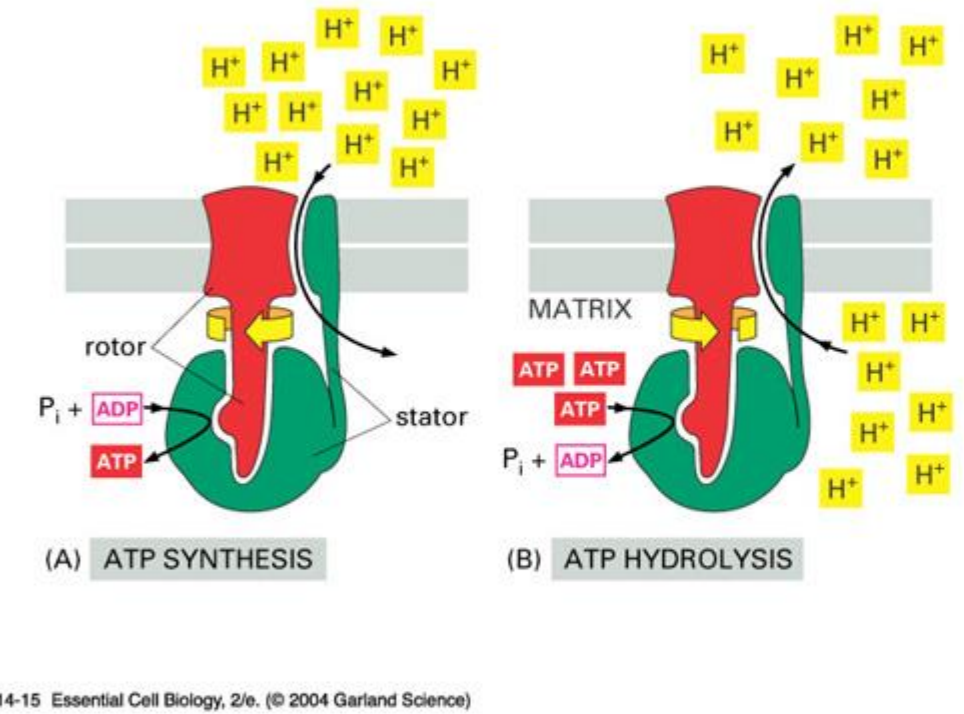
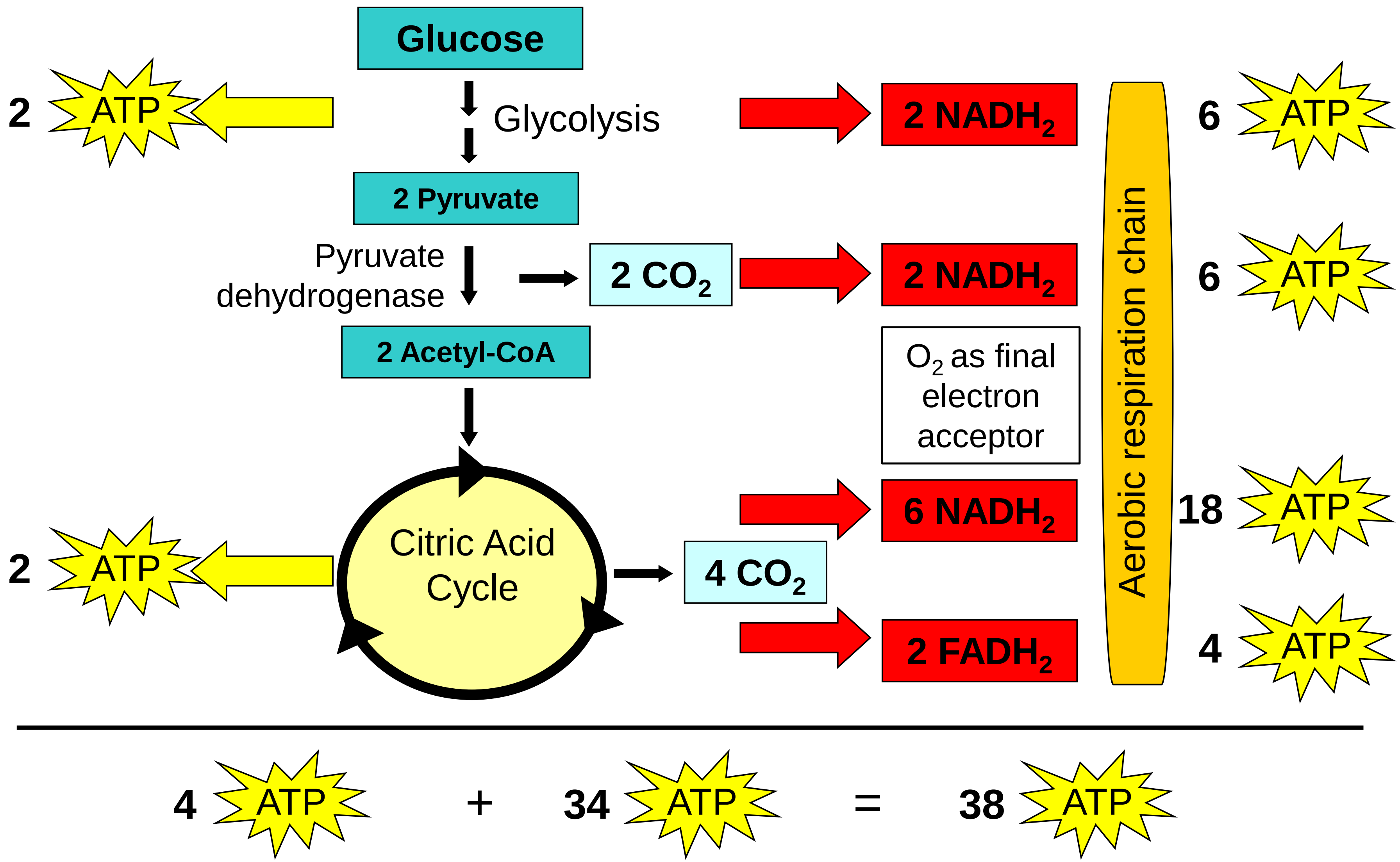


Fig. 14.15 Essential Cell Biology (2nd edition, Alberts, Bray et al.)

Energetics of Carbohydrate Metabolism (Aerobic Respiration)



Energetics Balance Aerobic Respiration

Energetics Balance Sheet for Aerobic Respiration

(1) **Glycolysis:** Glucose + $2NAD^+$ + 2 ATP → 2 $Pyruvate^-$ + 4 ATP + 2 NADH
+ 4 ADP ↓ to CAC; 2 NADH ↓ to Complex I

(a) Substrate-level phosphorylation
2 ADP + Pi → 2 ATP (× 2)
(b) Oxidative phosphorylation
2 NADH → 6 ATP

→ **8 ATP**

(2) **CAC:** $Pyruvate^-$ + $4NAD^+$ + GDP + FAD → 3 CO_2 + 4 NADH + FADH + GTP
4 NADH ↓ to Complex I; FADH ↓ to Complex II

(a) Substrate-level phosphorylation
1 GDP + Pi → 1 GTP
1 GTP + 1 ADP → 1 ATP + 1 GDP
(b) Oxidative phosphorylation
4 NADH → 12 ATP
1 FADH → 2 ATP

→ **15 ATP (×2)**

Einschl. (1 NADH) Pyruvate-Dehydrogenase Komplex

(3) **Sum: Glycolysis plus CAC → 38 ATP per glucose**

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

ATP-Synthese ($\Delta G^{0\prime}$=-31,8 KJ/mol)

Aerobic Respiration „Eucaryotes“

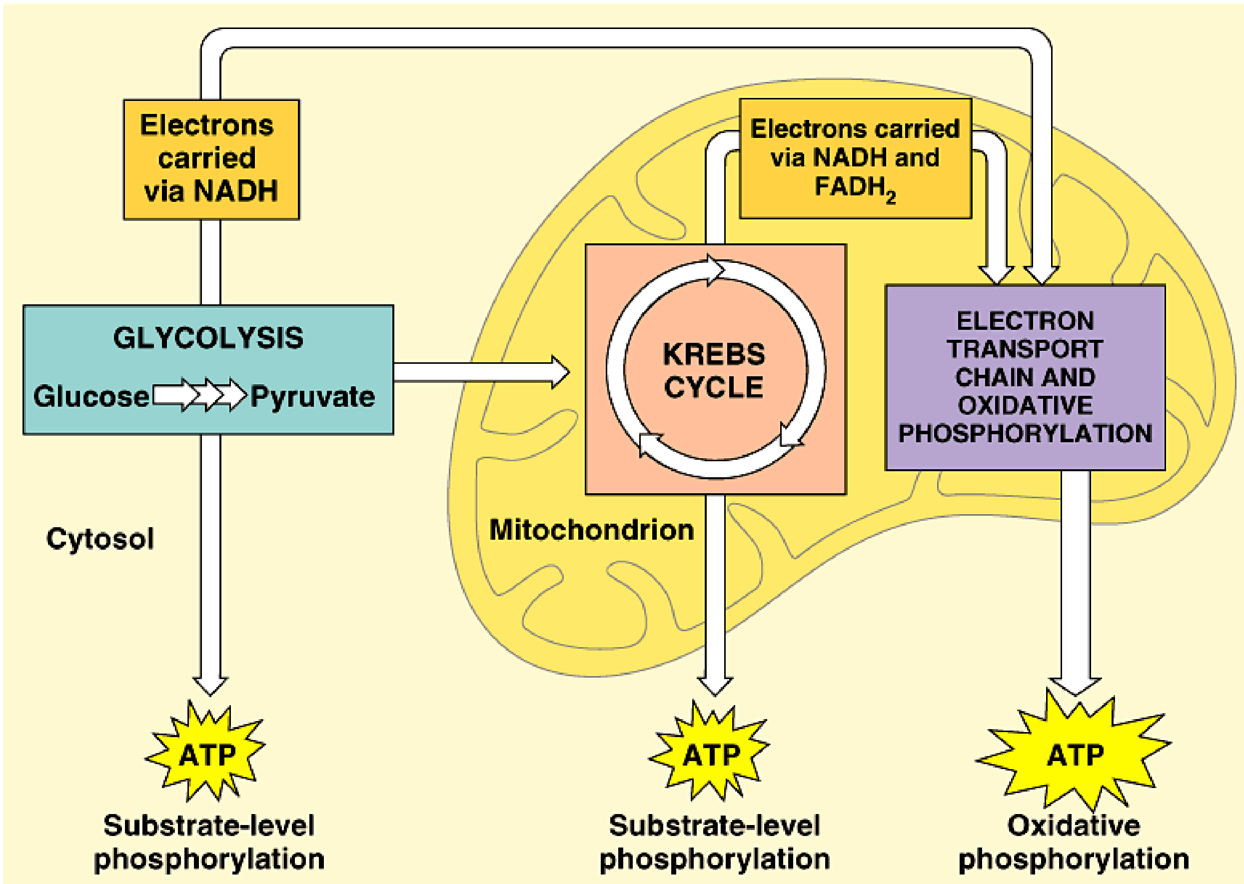


Abb. 9.6 **Die Zellatmung im Überblick.**
Biologie (Campbell)

Regulation

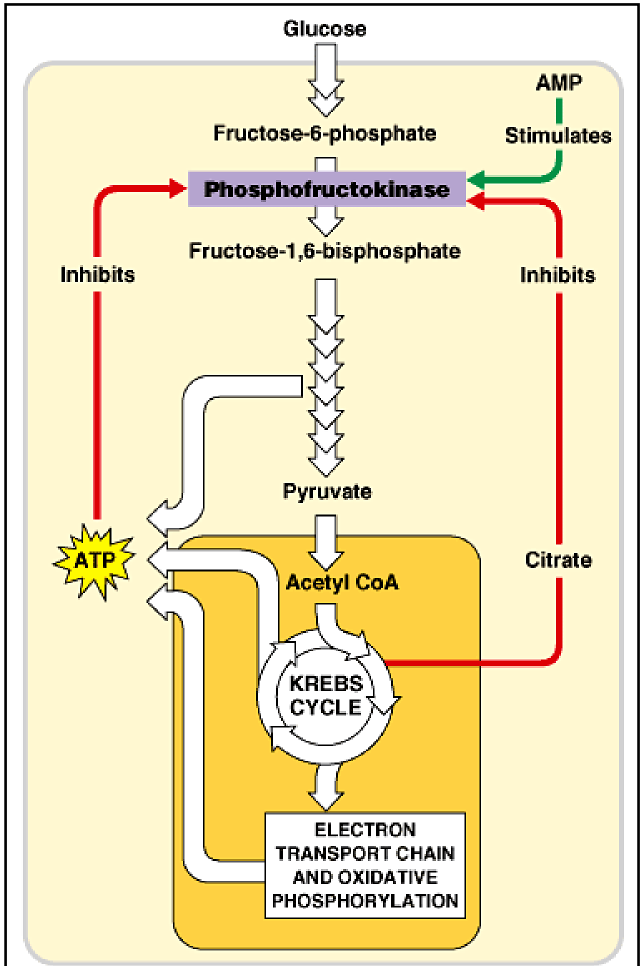


Fig. 9.20 **Die Kontrolle der Zellatmung.**
Biology (6th edition, Campbell & Reece)

Conversion of different Nutrients

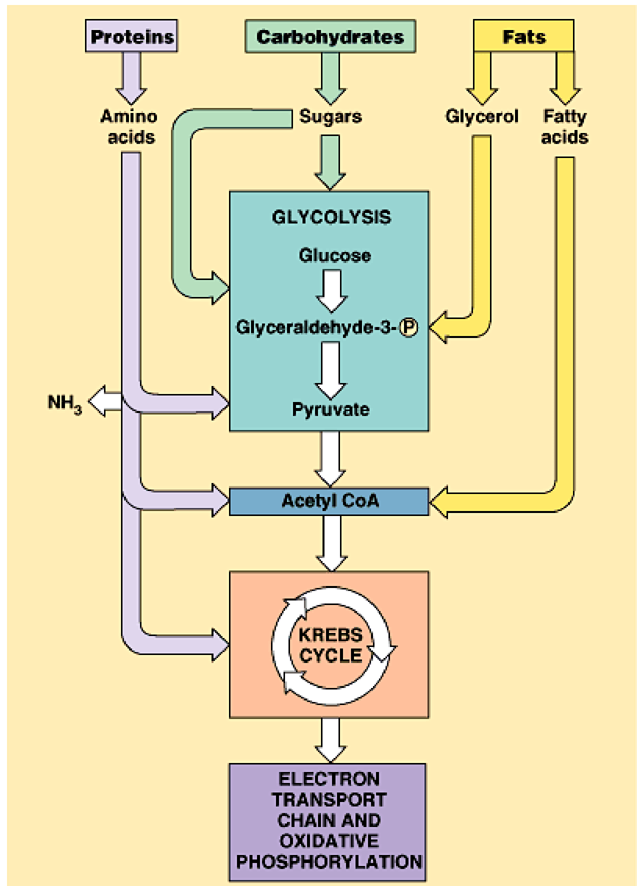


Fig. 9.19 **Catabolism of different nutrients.**
Biology (6th edition, Campbell & Reece)

„Platform Metabolism“
Anabolism

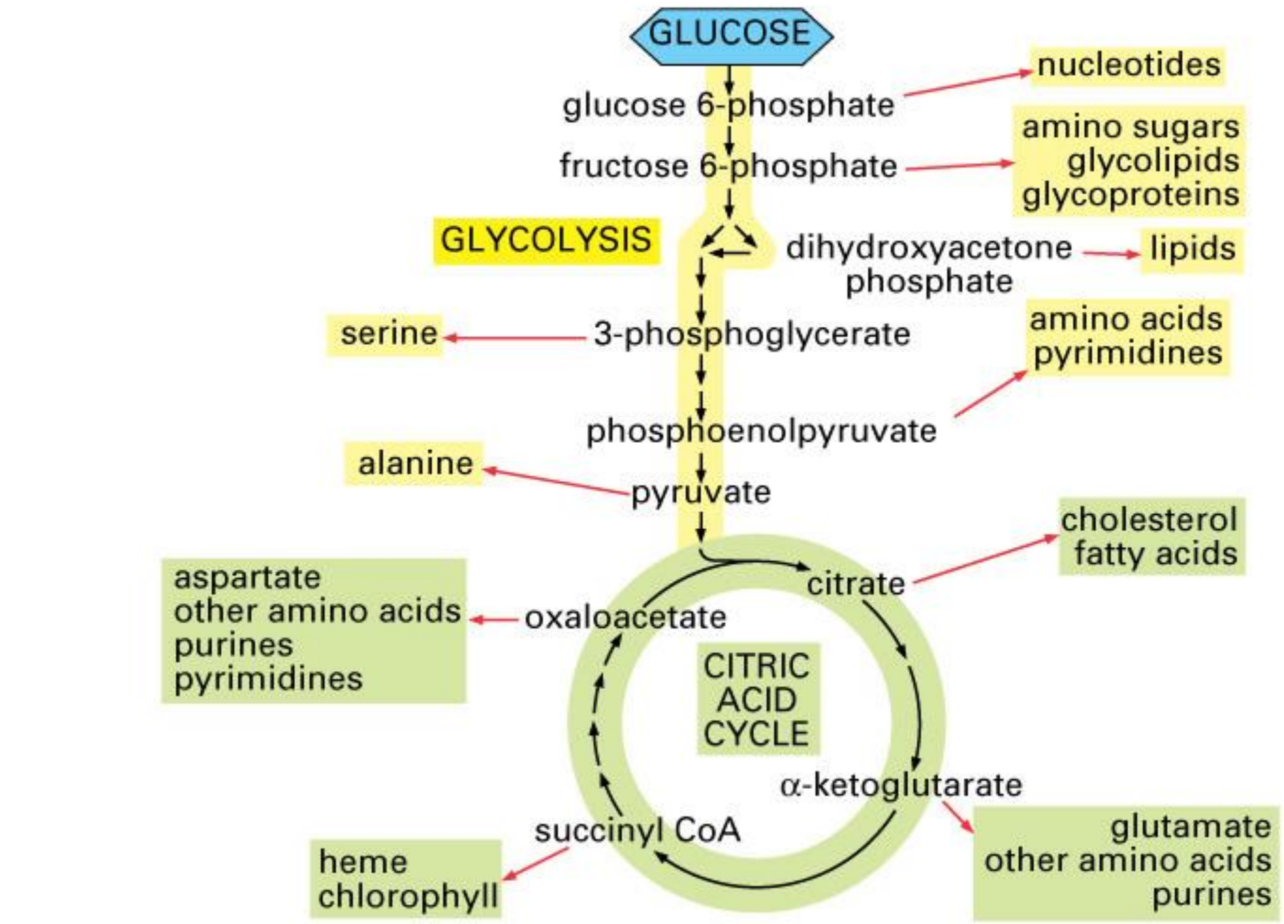


Figure 13-23 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Fermentation

Atmung/Fermentation

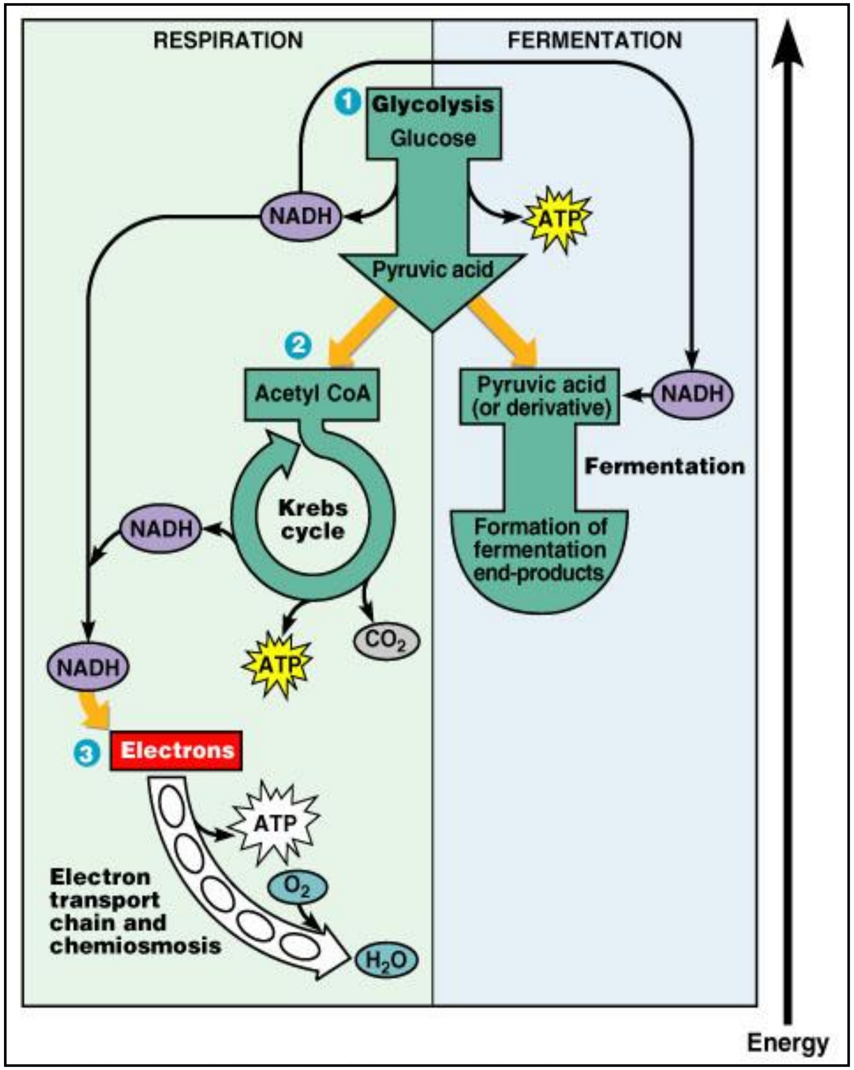
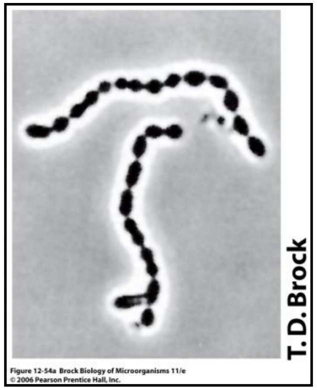
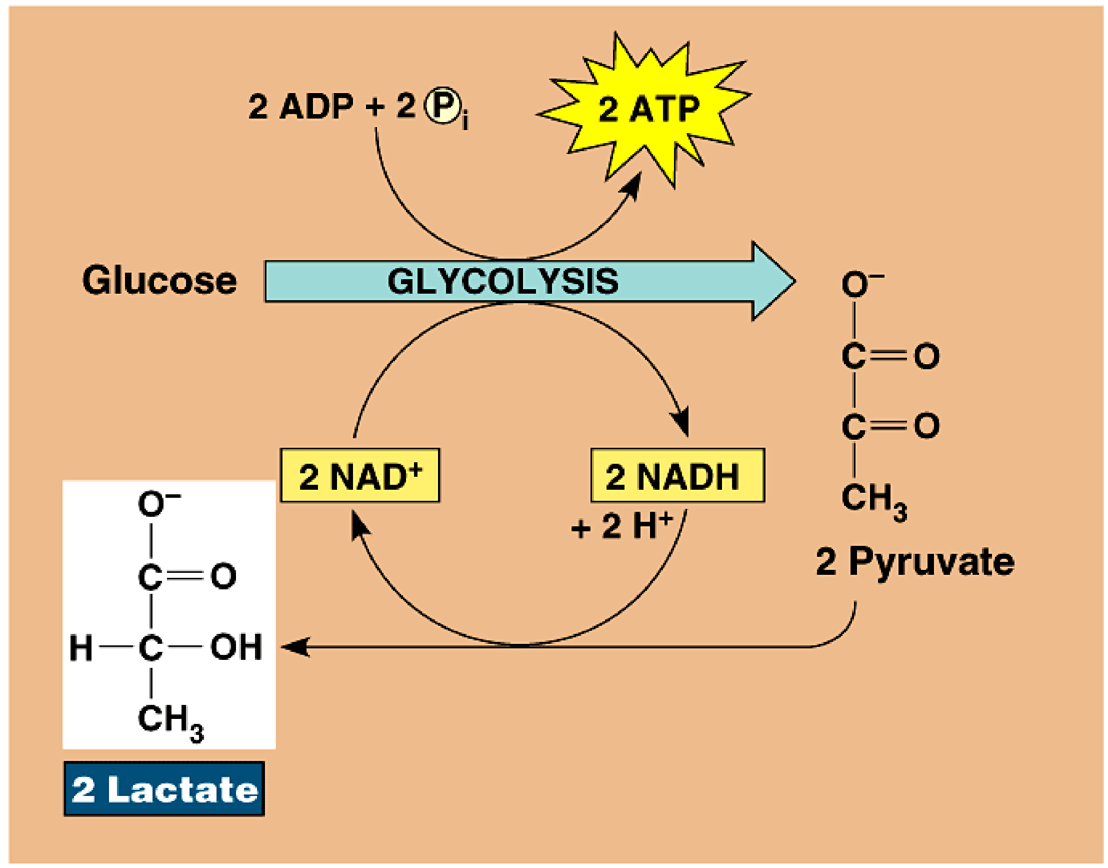


Fig. 5.14 Microbiology: An Introduction (Tortora, Funke, Case)

Lacitc Acid Fermentation



Lactococcus lactis



(b) Lactic acid fermentation

Anaerobic Respiration

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

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

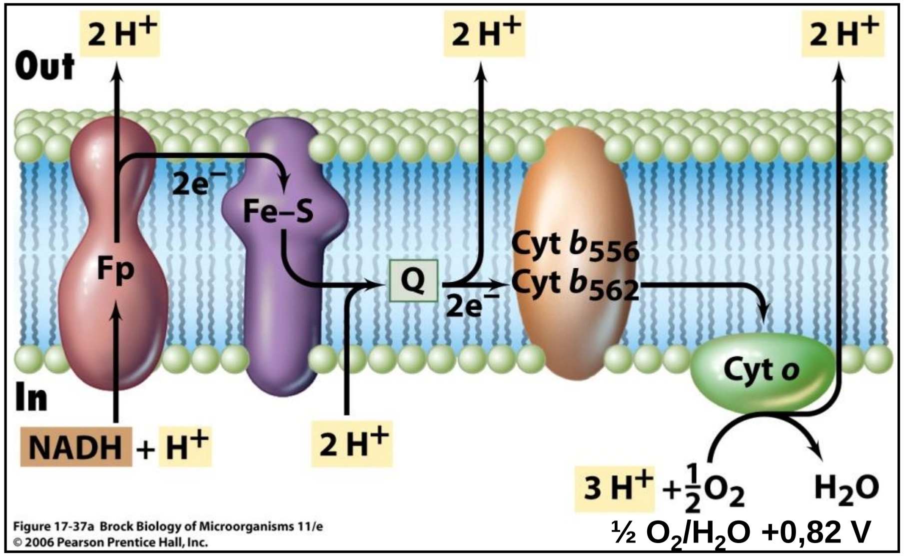
  Inorganic compounds, NO_3^-, SO_4^{2-}, Fe^{3+}, NO_2^-, S^0, CO_2
- **Electron transport chain**:

  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^-)

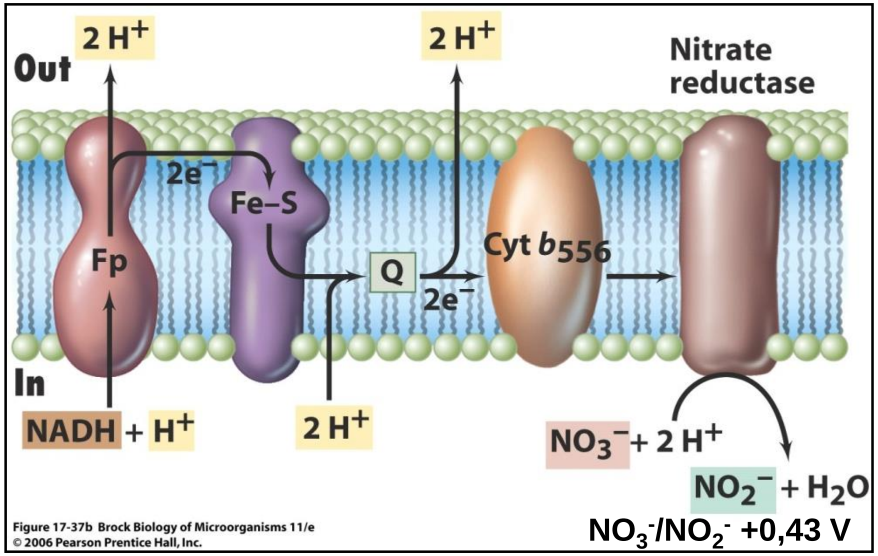


Fig. 17.37 **Vergleich aerobe und Nitrat Atmung.**
Brock Biology of Microorganisms (10th edition) (Madigan et al.)

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)

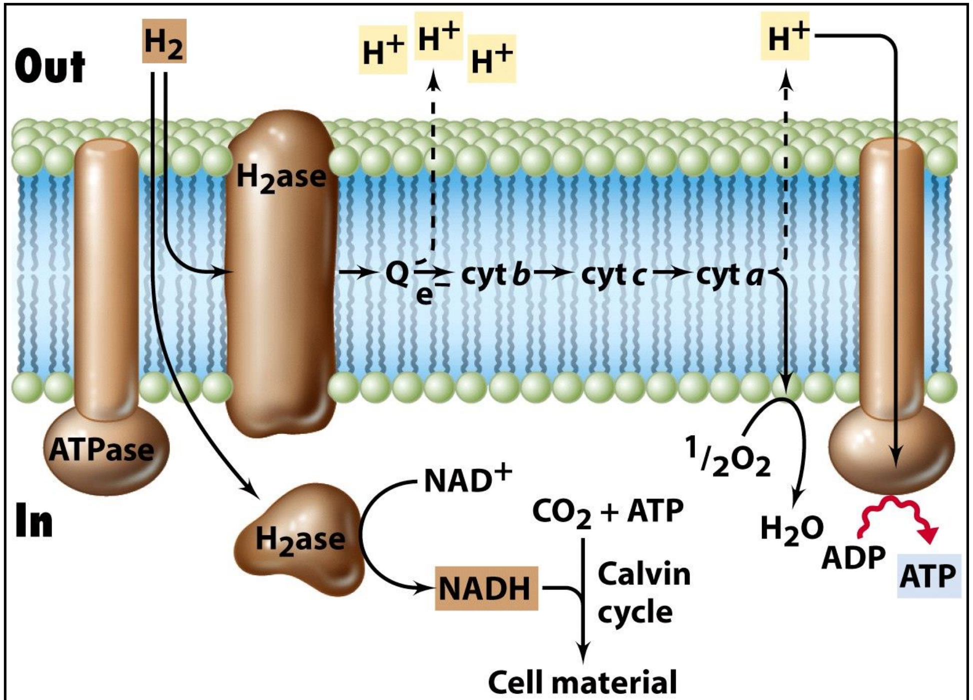


Figure 17-25 Brock Biology of Microorganisms 11/e

Photosynthesis
Light- and Dark- Reaction

Calvin cycle
Melvin Calvin (1940)

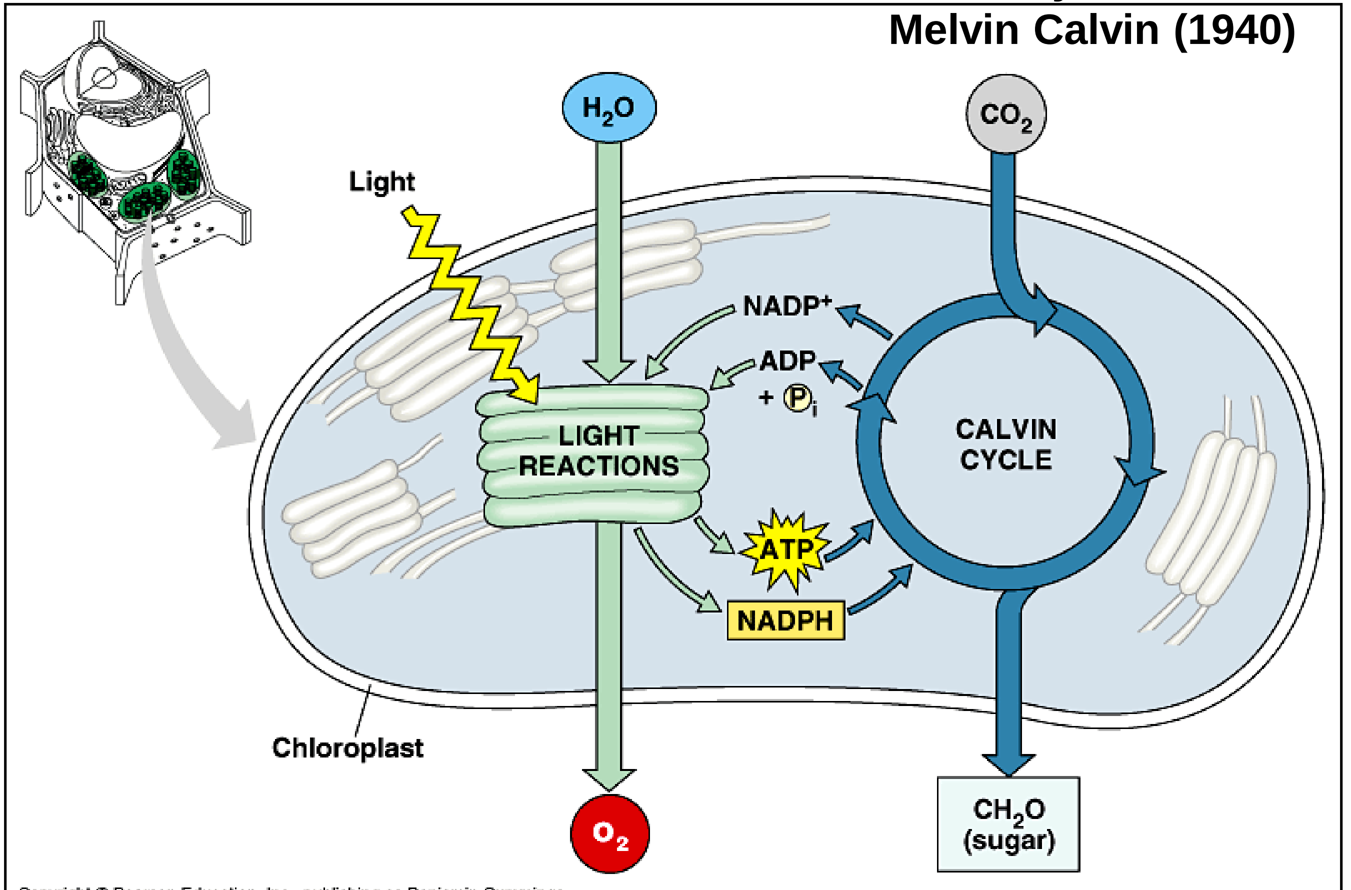


Fig. 10.4 Biology (6th edition, Campbell & Reece)

Non-cyclic Photophosphorylation

P700 absorbs dark red light (700nm)
P 680 absorbs red light (680 nm)

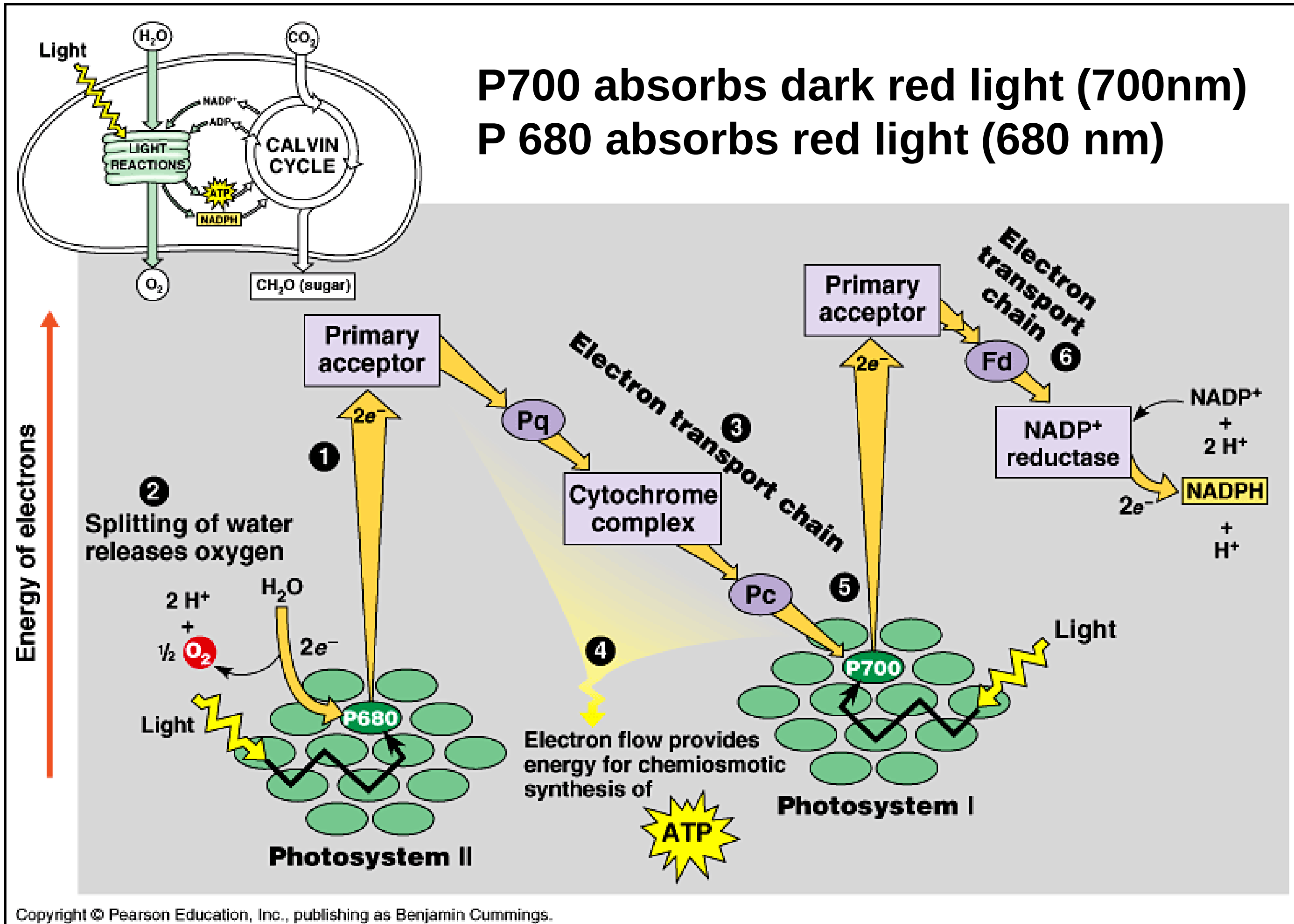


Fig. 10.12 Biology (6th edition, Campbell & Reece)

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

The Light Reaction and Chemiosmosis

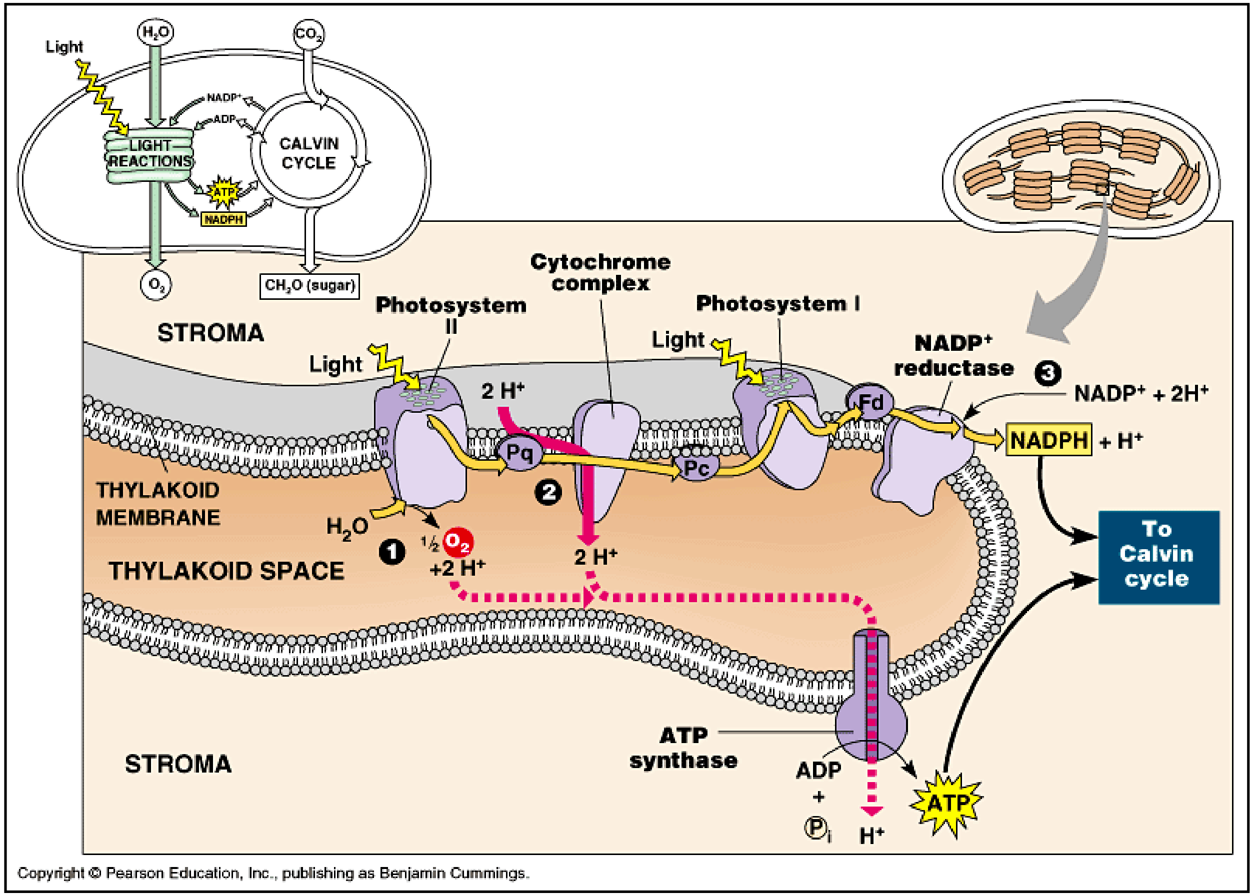


Fig. 10.16 Biology (6th edition, Campbell & Reece)

Comparison of Chemioosmosis in Mitochondrion and Chloroplast

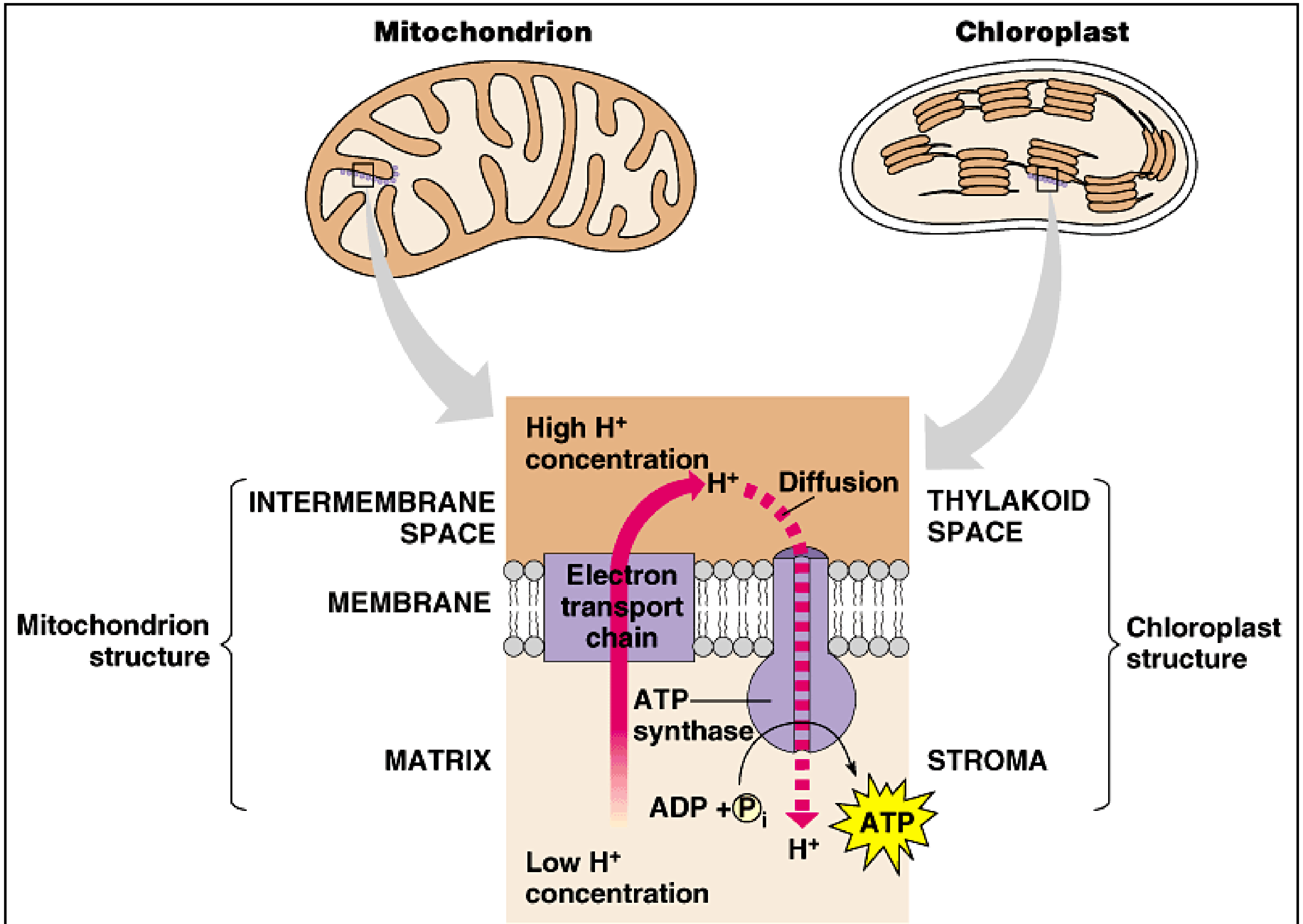


Fig. 10.8 Biology (6th edition, Campbell & Reece)

CO_2 Fixation

CO_2 fixation pathway	ATP requirement/ pyruvate	Relation to O_2	Advantages
Calvin cyle	7 ATP	aerobes	Products = sugars, seperated from other metabolic pathways
Reductive citric acid cycle	2(-3) ATP	anaerobes, microaerobes	Suited for microaerobic conditions, revers: Oxidation of acetyl-CoA
Reductive acetyl-CoA pathway	1 ATP	strict anaerobes	Suited for the assimilation of C1 units
3-hydroxypropionate pathway	7 ATP	aerobe	Suited for mixotrophic assimilation of fermentation products

The Calvin Cycle „Dark-Reaction“

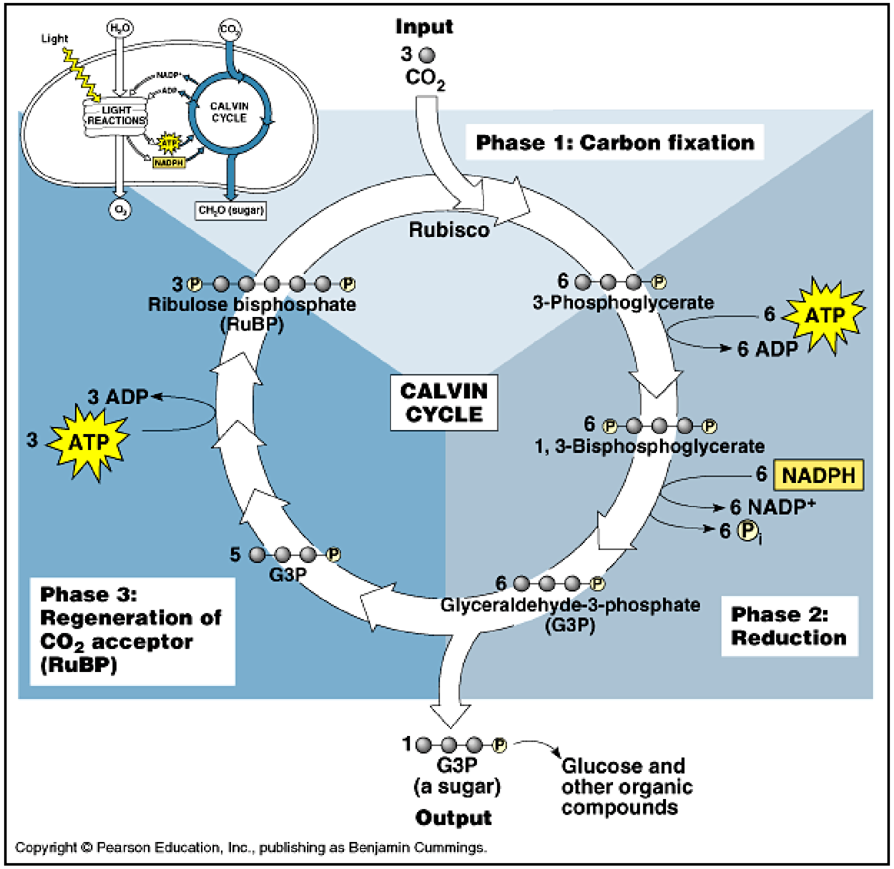


Fig. 10.17 Biology (6th edition, Campbell & Reece)

Key Reactions of the Calvin Cycle
(Reductive Pentose Phosphate Cycle)

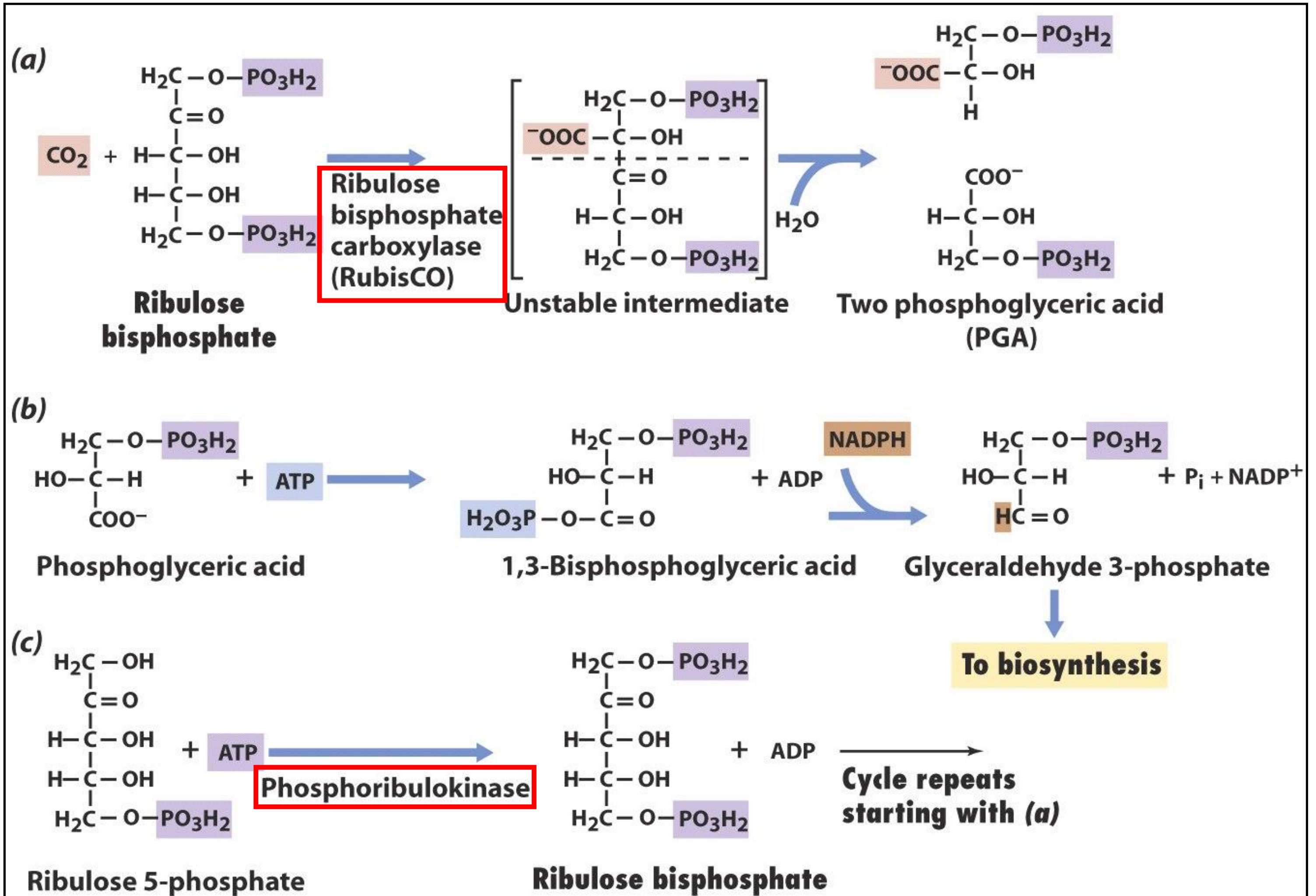


Figure 17-21 Brock Biology of Microorganisms 11/e

Balance of the Calvin Cycle

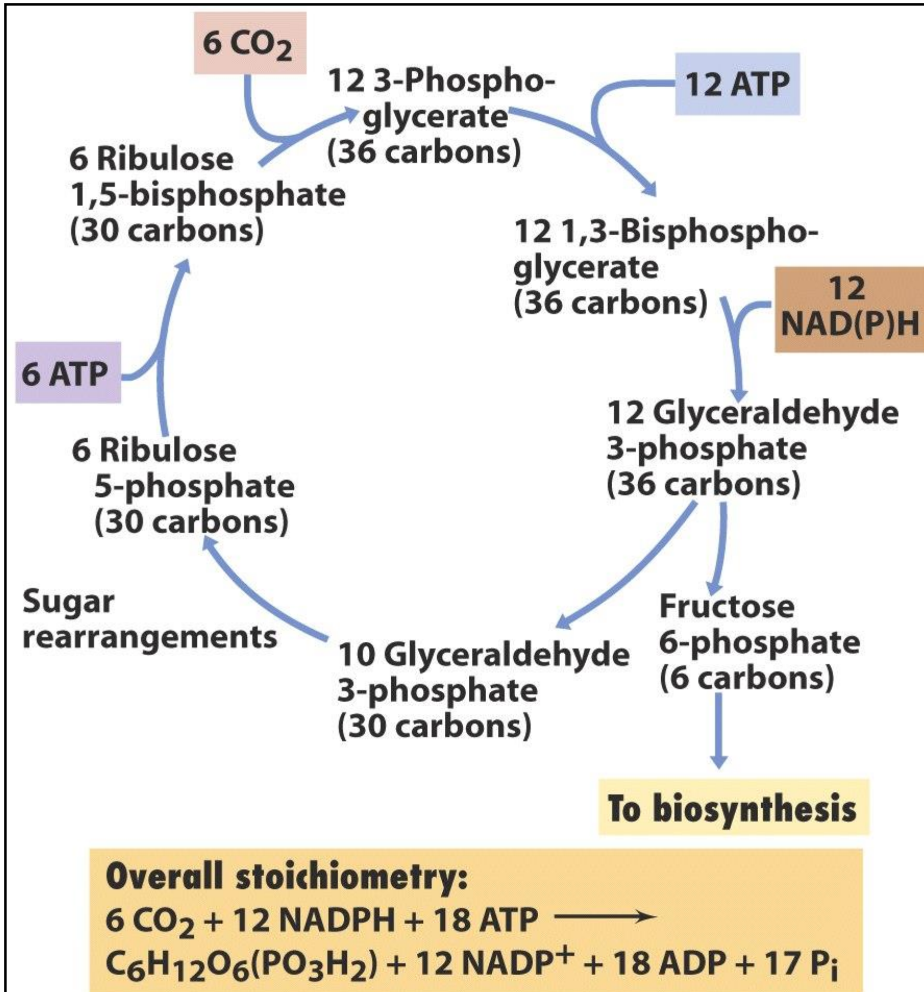


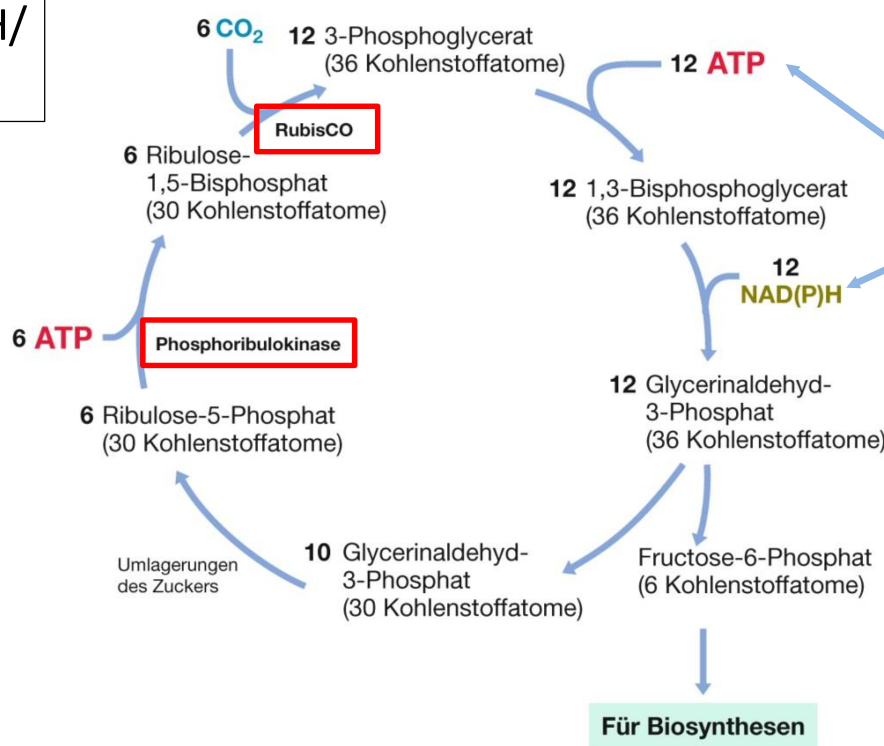
Figure 17-22 Brock Biology of Microorganisms 11/e

Reductive pentose phosphate cycle

(Calvin-Benson cycle)

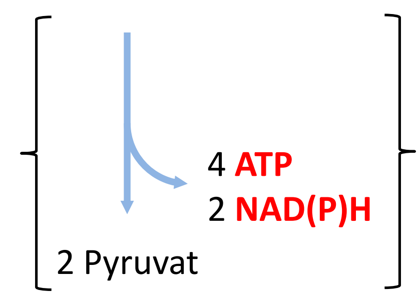
RubisCO = Ribulose-bisphosphate carboxylase/oxygenase

∑ 7ATP +5 NAD(P)H/ pyruvate



From light dependent reactions of photosynthesis

(ETP reactions in chemosynthesis)



- Plants, algae, cyanobacteria, most aerobic and facultativ aerobic Bacteria
- Triosephosphates, 3-phosphoglycerate, sugar phosphates as intermediates

Photosynthesis
Light- and Dark- Reaction

Calvin cycle
Melvin Calvin (1940)

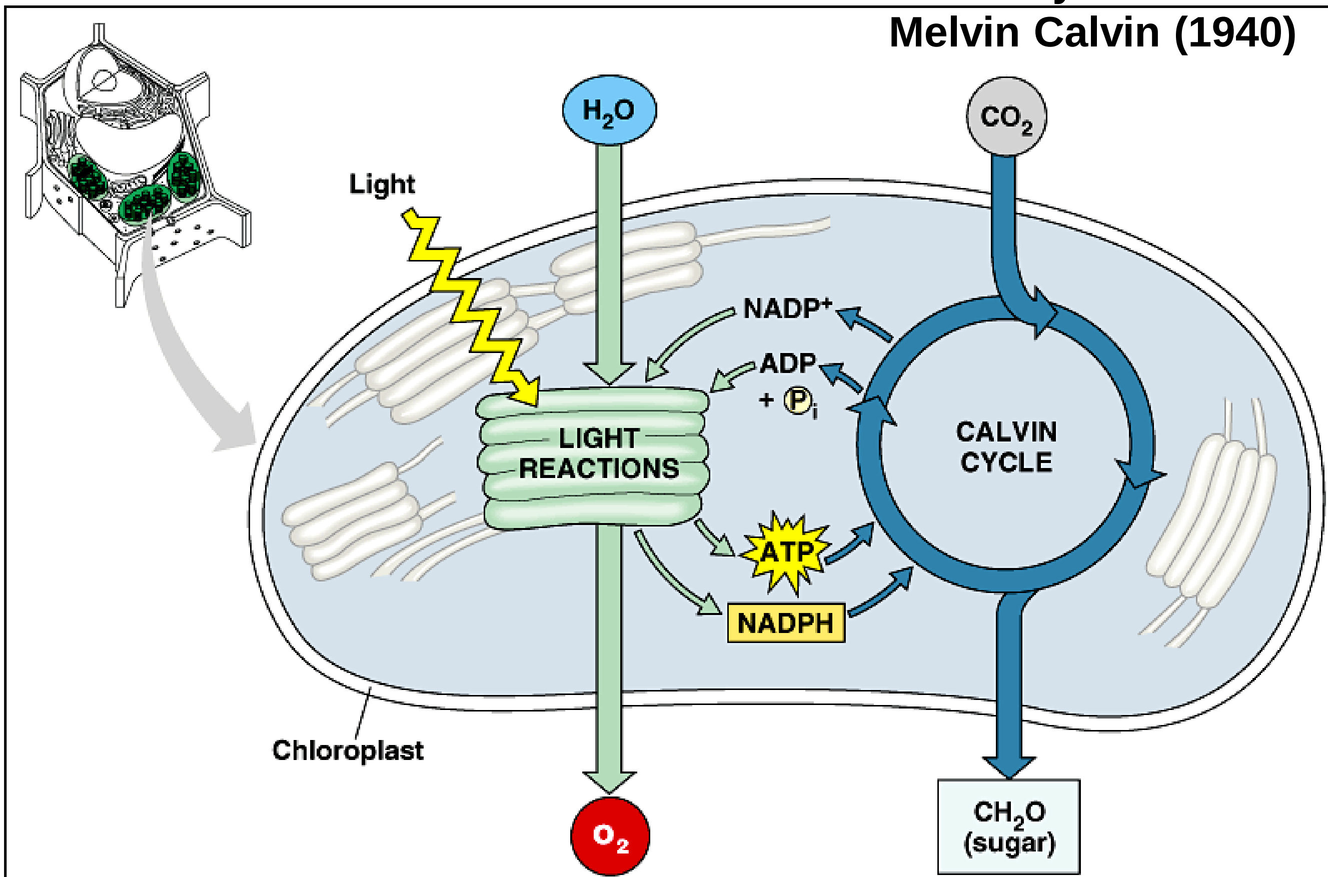


Fig. 10.4 Biology (6th edition, Campbell & Reece)

Pyruvate Dehydrogenase and Oxidative Citric Acid Cycle

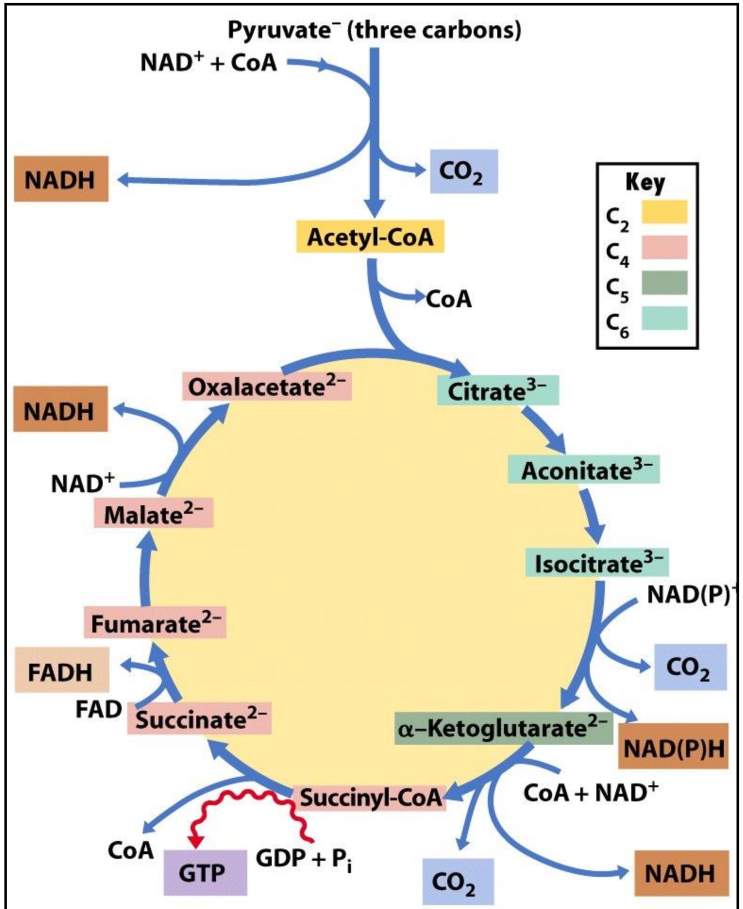


Figure 5-22a Brock Biology of Microorganisms 11/e

Oxidative Citric Acid Cycle

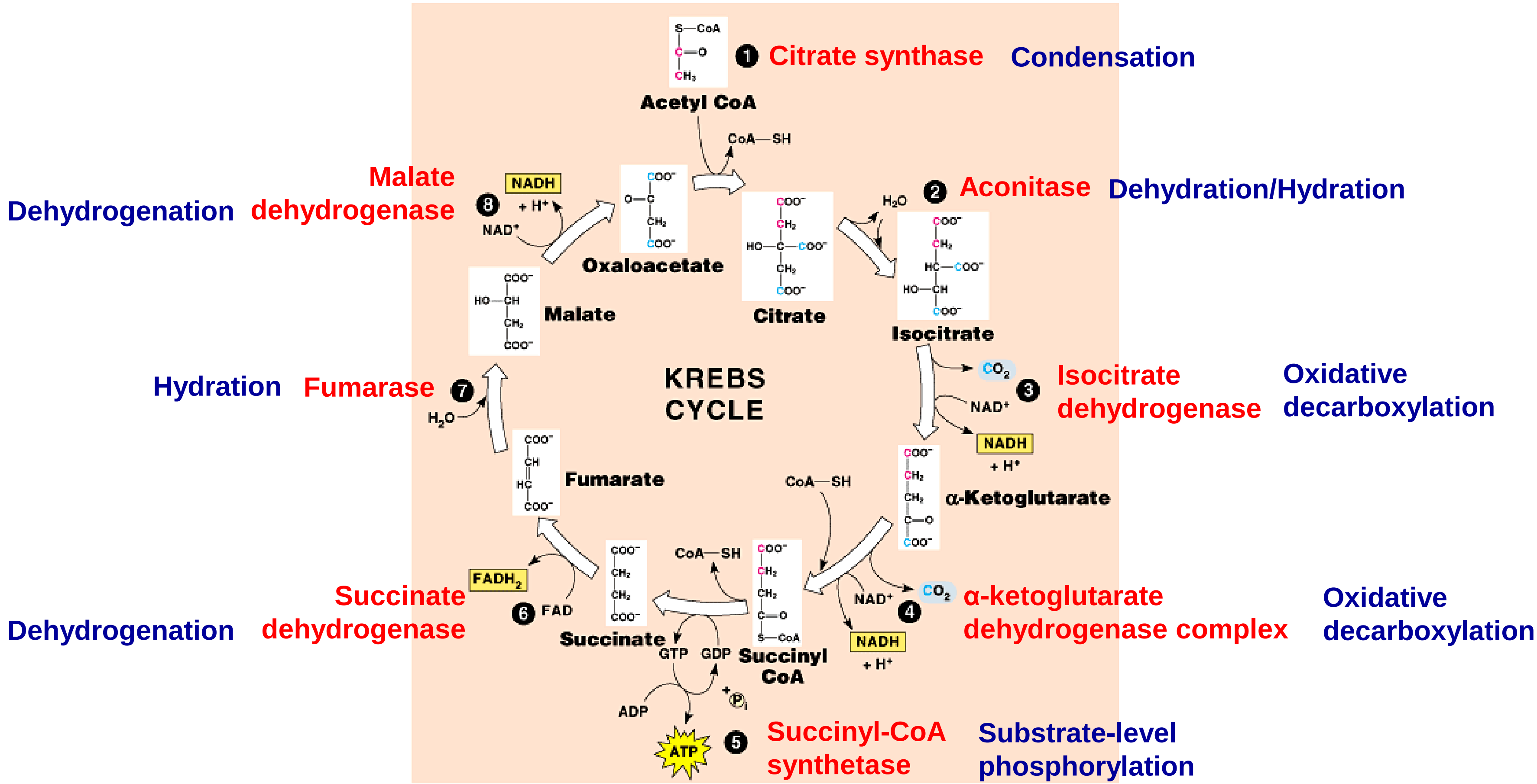


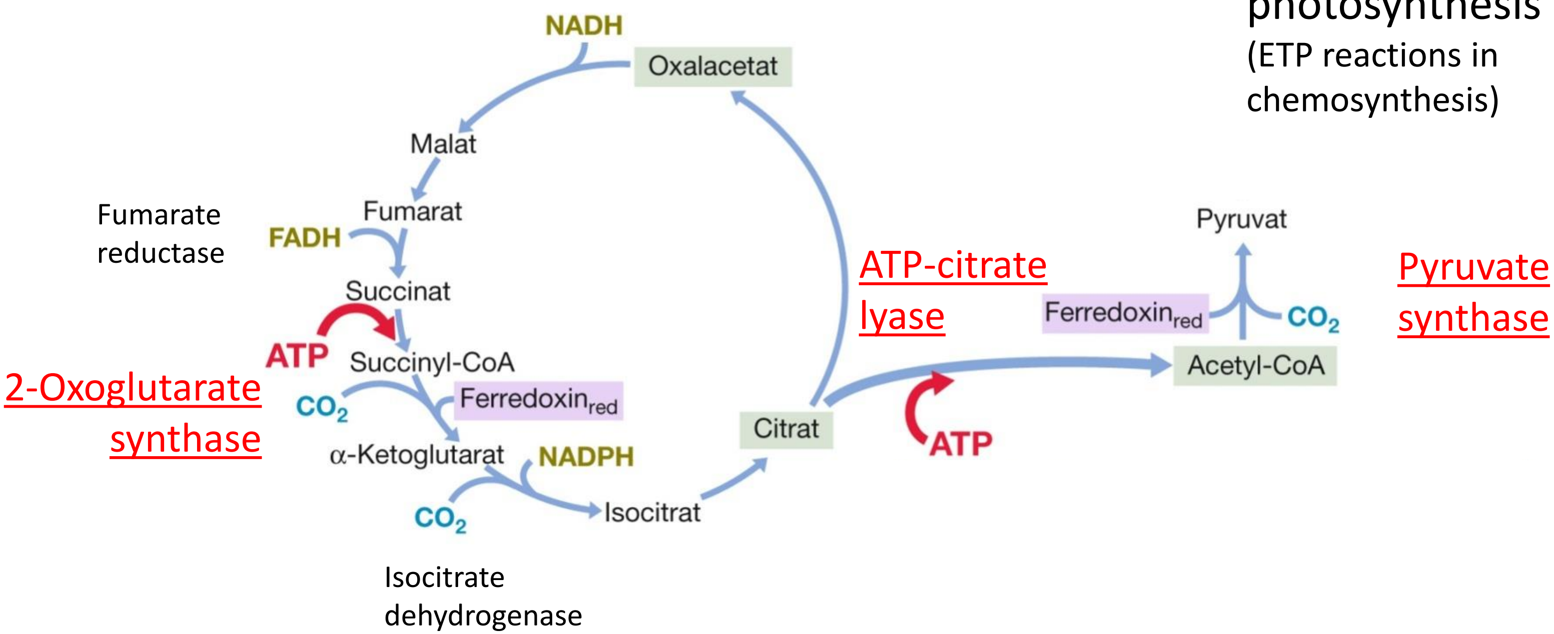
Fig. 9.11 **The citric acid cycle.**
Biology (6th edition, Campbell & Reece)

Reductive Citric Acid Cycle

(Arnon-Buchanan cycle)

∑ 2 (-3) ATP + 3 NAD(P)H + 2 ferredoxin/ pyruvate

ATP and ferredoxin from light dependent reactions of photosynthesis (ETP reactions in chemosynthesis)

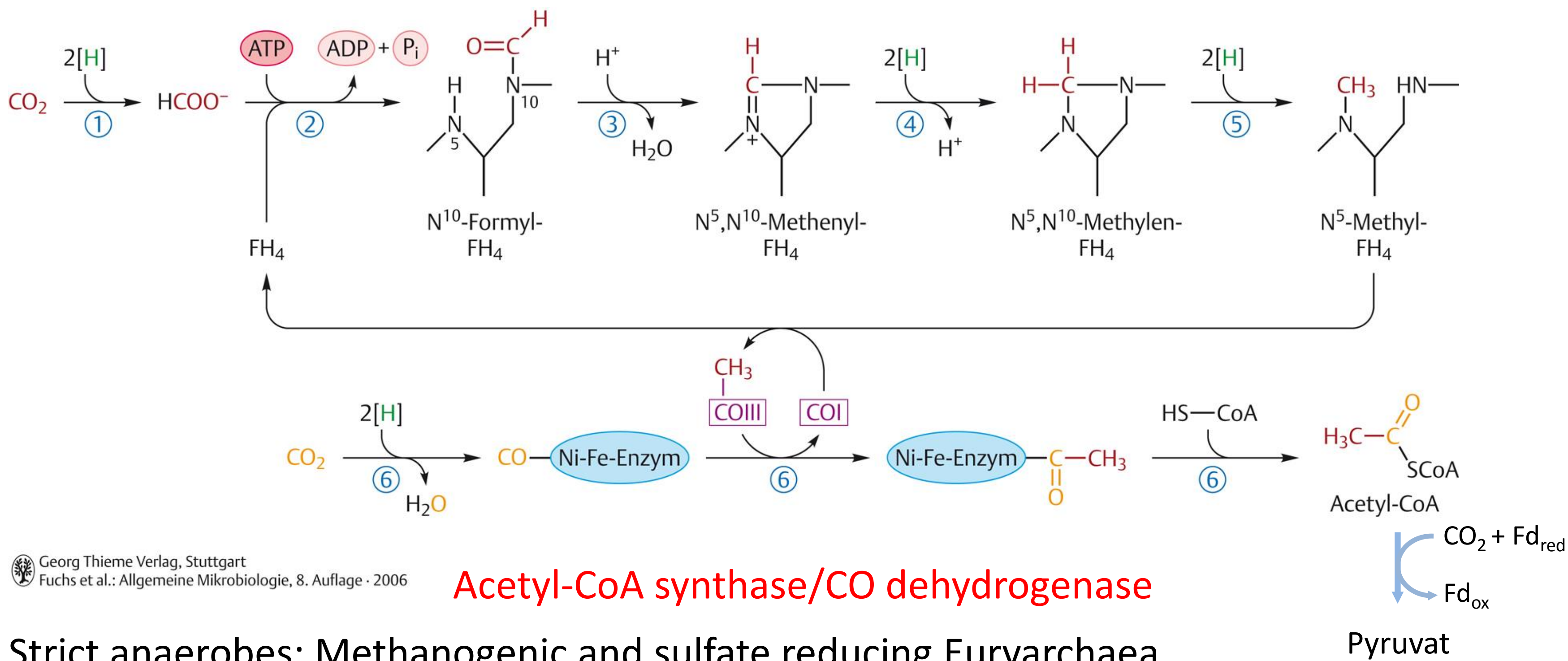


- Anaerobic Green sulfur bacteria (Chlorobiales) and other Proteobacteria, Aquificales (microaerophilic)
- Acetyl-CoA, pyruvate, oxaloacetate, succinyl-CoA, 2-oxoglutarate, (PEP)
- Advantages under anaerobic, microaerophilic conditions

Reductive Acetyl-CoA Pathway

Wood-Ljungdal pathway

$\sum$ ~ 1 ATP + 2 NAD(P)H ($F_{420}H_2$) + 3 ferredoxin/ pyruvate



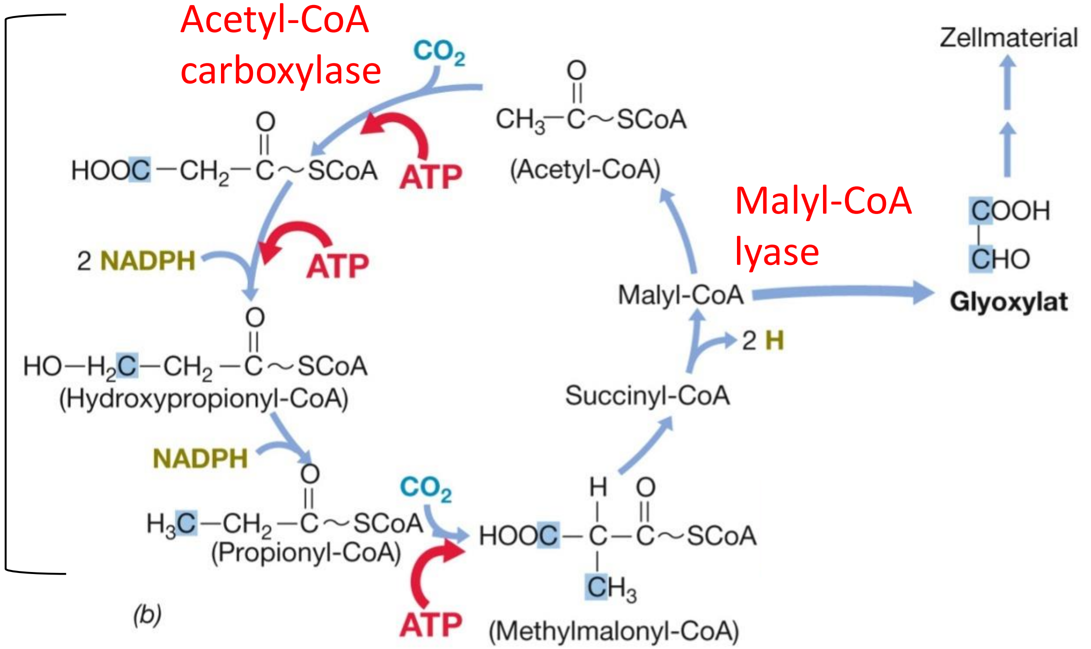
Acetyl-CoA synthase/CO dehydrogenase

- Strict anaerobes: Methanogenic and sulfate reducing Euryarchaea, acetogens, some proteobacteria a.o.
- Acetyl-CoA, pyruvate
- Well suited for the assimilation of C1 units

3-Hydroxypropionate Bi-Cycle

$\sum$ ~ 7 ATP + 6 NAD(P)H (- 1QH_2) / pyruvate

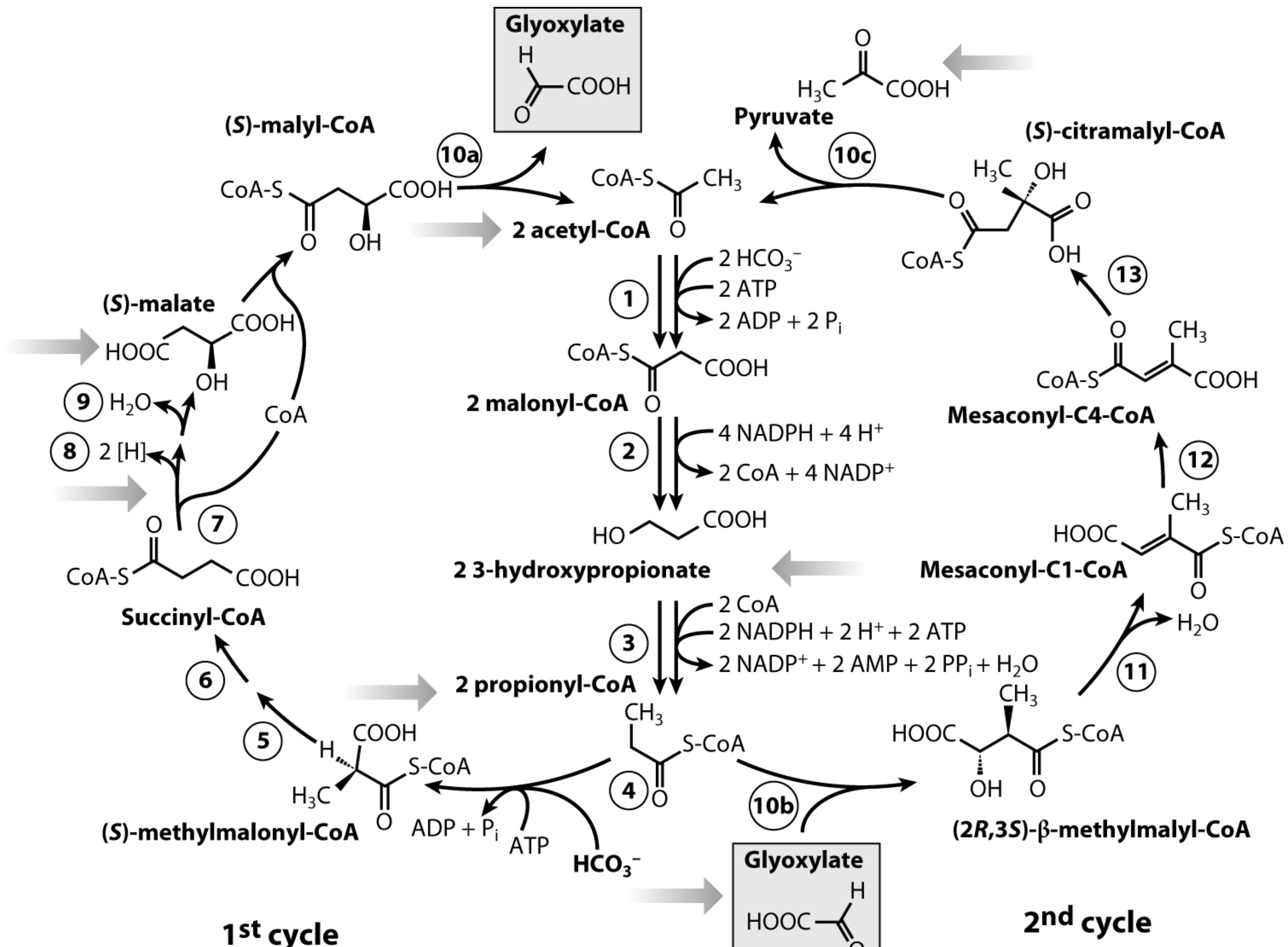
2x



Propionyl-CoA carboxylase

- *Anaerobic Chloroflexaceae*
- Acetyl-CoA, pyruvate, succinyl-CoA
- Suited for mixotrophic assimilation of fermentation products

Hydroxypropionate Bi-Cycle



Fuchs G. 2011.
Annu. Rev. Microbiol. 65:631–58

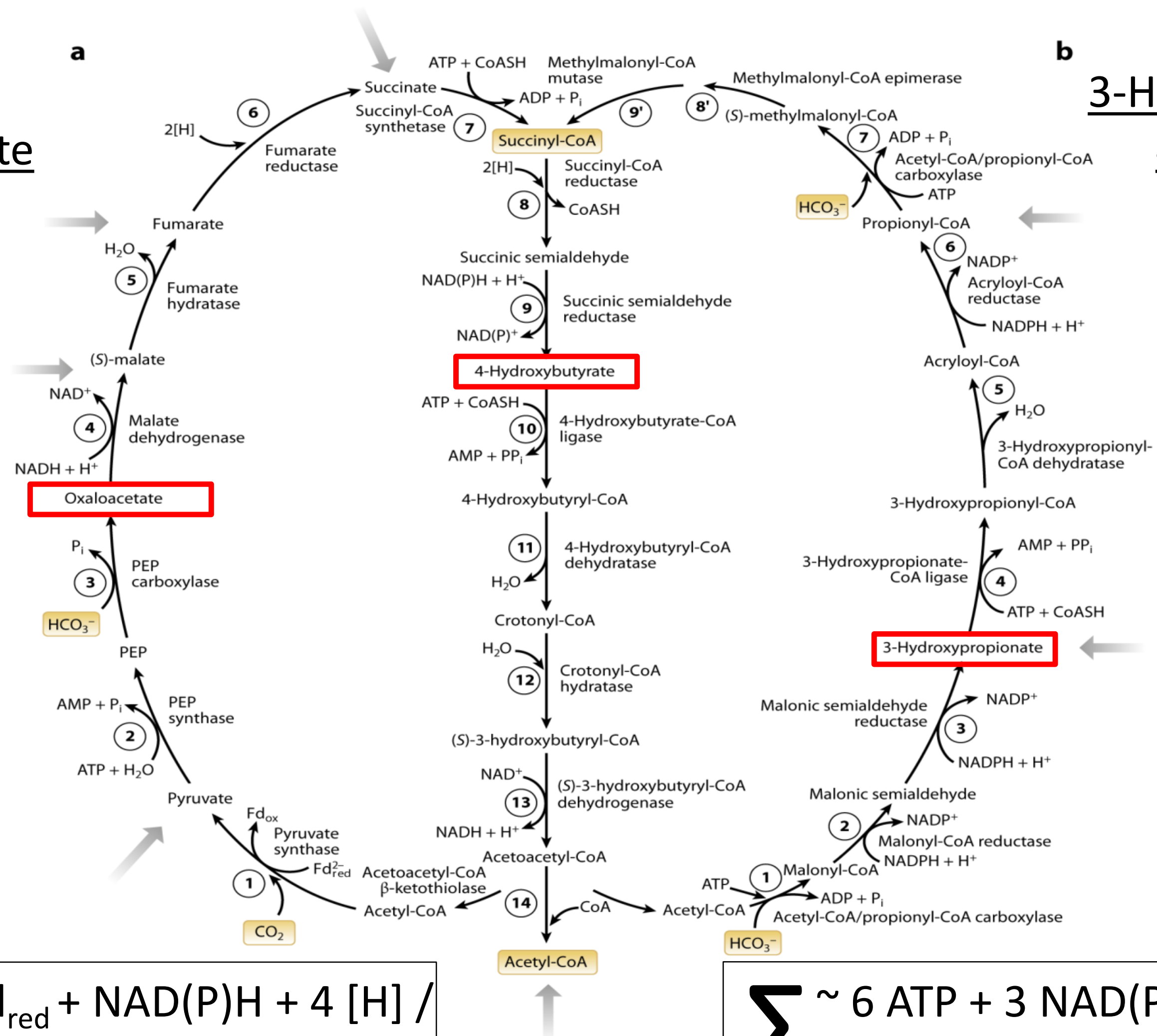
Dicarboxylate/4-Hydroxybutyrate cycle
3-Hydroxypropionate/4-Hydroxybutyrate cycle

Dicarboxylat/ 4-Hydroxybutyrate cycle

Anaerobic Crenarchaeota (Thermoproteales, Desulfurococcales

3-Hydroxypropionate/ 4-Hydroxybutyrate cycle

Aerobic Crenarchaeota (e.g. *Sulfolobus*) and Thaumarchaeota (Thermoproteales, Desulfurococcales



$\sum$ ~ 5 ATP + 2 Fd_{red} + NAD(P)H + 4 [H] / pyruvate

$\sum$ ~ 6 ATP + 3 NAD(P)H + 4 [H] / pyruvate

Fuchs G. 2011.
Annu. Rev. Microbiol. 65:631–58

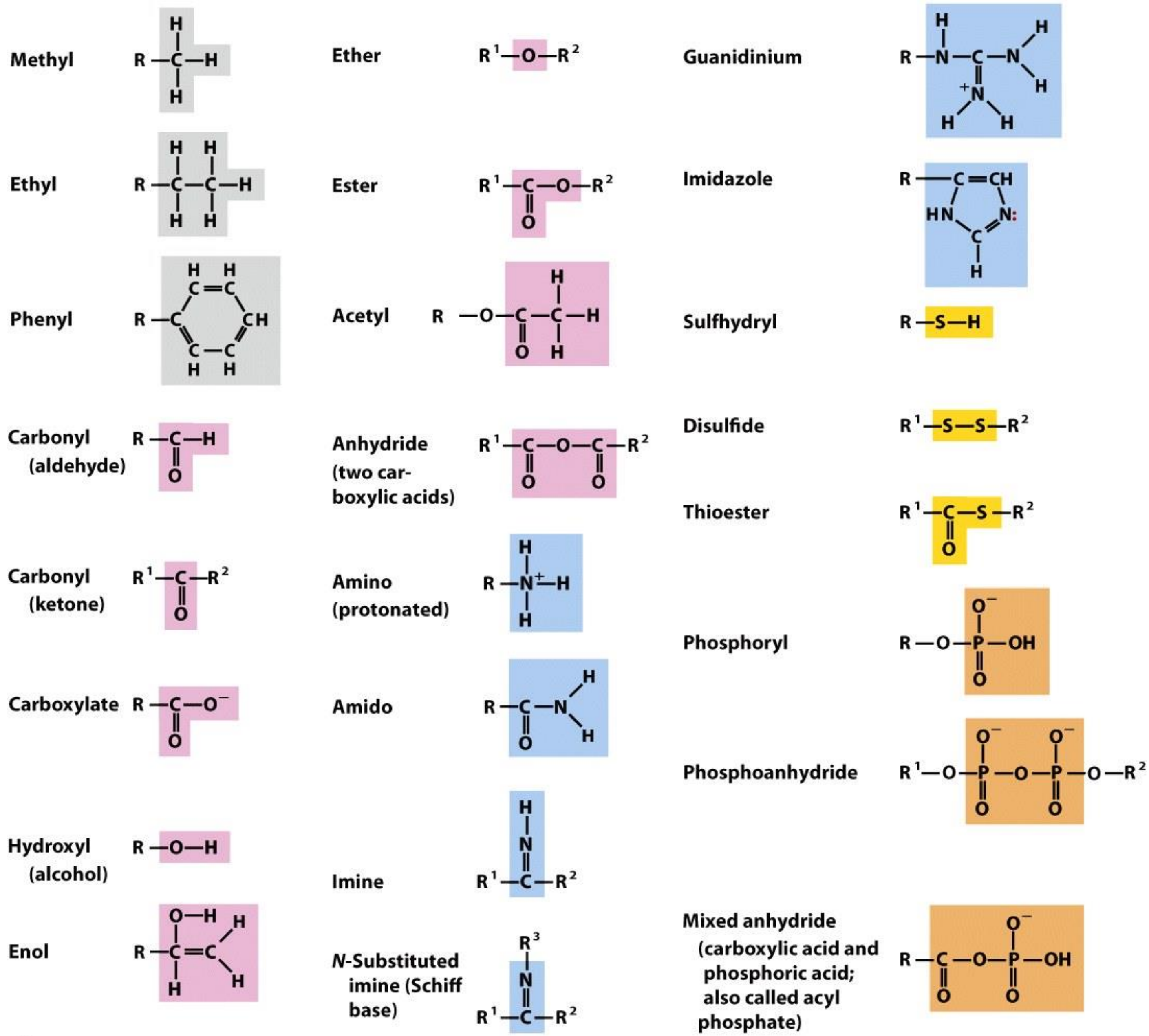


Figure 1-15

Lehninger Principles of Biochemistry, Fifth Edition

TABLE 1.1 SI units commonly used in biochemistry

Physical quantity	*SI unit*	*Symbol*
Length	meter	m
Mass	gram	g
Amount	mole	mol
Volume	liter[a]	L
Energy	joule	J
Electric potential	volt	V
Time	second	s
Temperature	kelvin[b]	K

[d]1 liter = centimeter.

[b]273K = 0°C

Table 1-1 Principles of Biochemistry, 4/e

TABLE 1.2 Prefixes commonly used with SI units

Prefix	Symbol	Multiplication factor
giga-	G	10^9
mega-	M	10^6
kilo-	k	10^3
deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
micro-	μ	10^{-6}
nano-	n	10^{-9}
pico-	p	10^{-12}
femto-	f	10^{-15}

Table 1-2 Principles of Biochemistry, 4/e

Das griechische Alphabet

A	α	alpha	I	ι	iota	P	ρ	rho
B	β	beta	K	κ	kappa	Σ	σ	sigma
Γ	γ	gamma	Λ	λ	lambda	T	τ	tau
Δ	δ	delta	M	μ	m	Υ	υ	psilon
E	ϵ	epsilon	N	ν	n	Φ	ϕ	phi
Z	ζ	zeta	Ξ	ξ	xi	X	χ	chi
H	η	eta	O	o	omicron	Ψ	ψ	psi
Θ	θ	theta	Π	π	pi	Ω	ω	omega

Seminar III

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

Prokaryotes & Eukaryotes

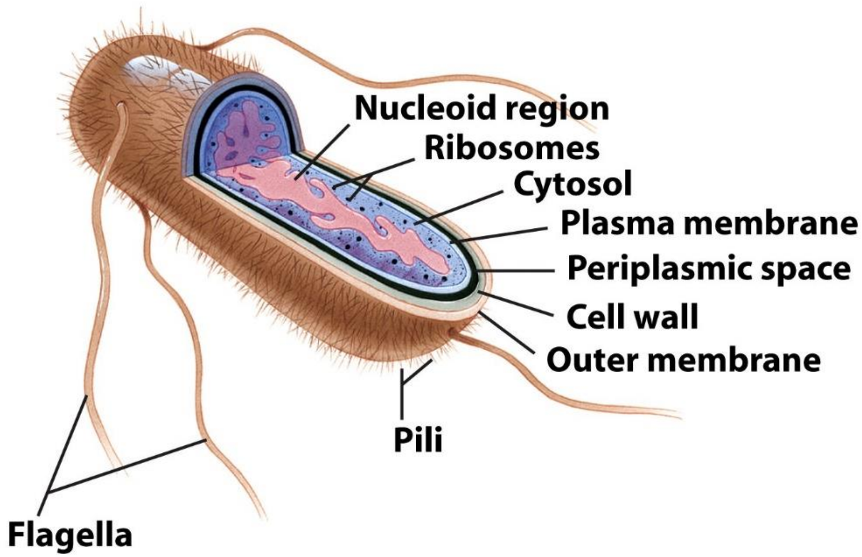


Figure 1-14 Principles of Biochemistry, 4/e

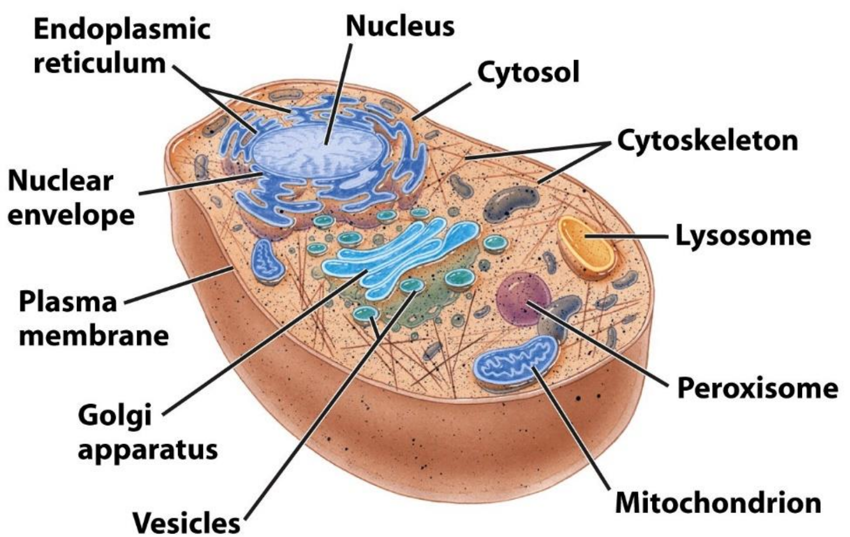


Figure 1-15a Principles of Biochemistry, 4/e

Murein: Cell wall (Bacteria)

- Gram positive cell wall

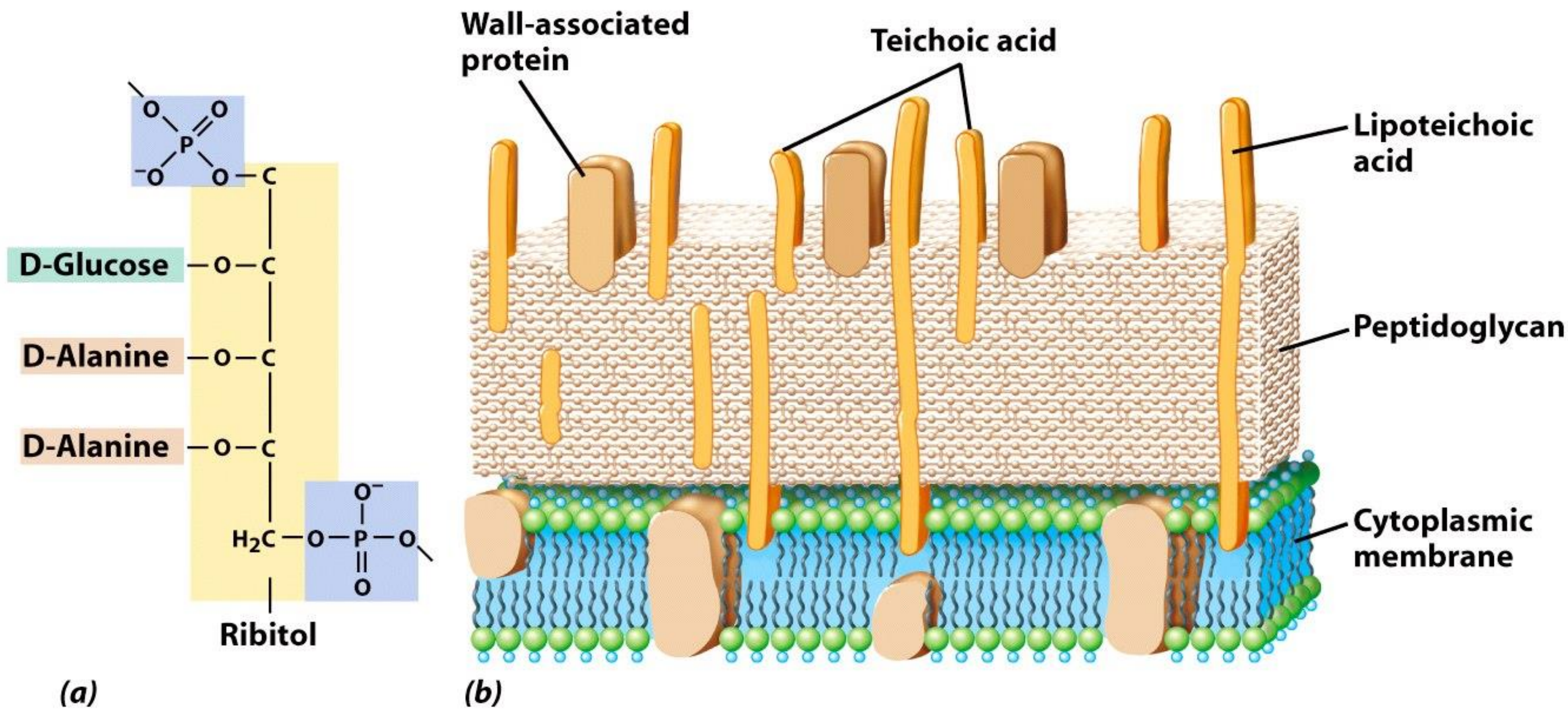


Figure 4-31 Brock Biology of Microorganisms 11/e

Murein: Cell wall (Bacteria)

- Gram negative cell wall

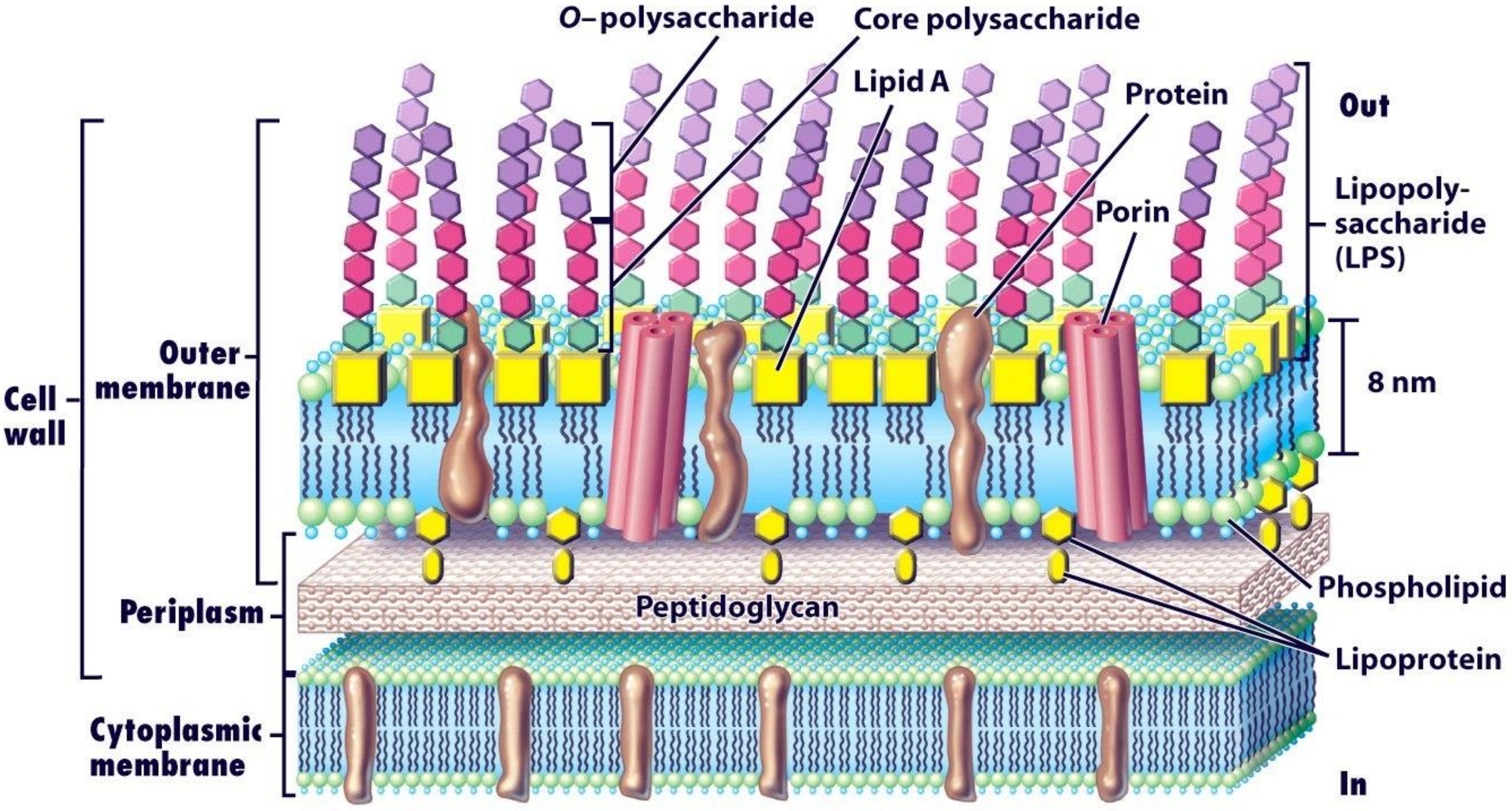


Figure 4-35a Brock Biology of Microorganisms 11/e

Glycoconjugate

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

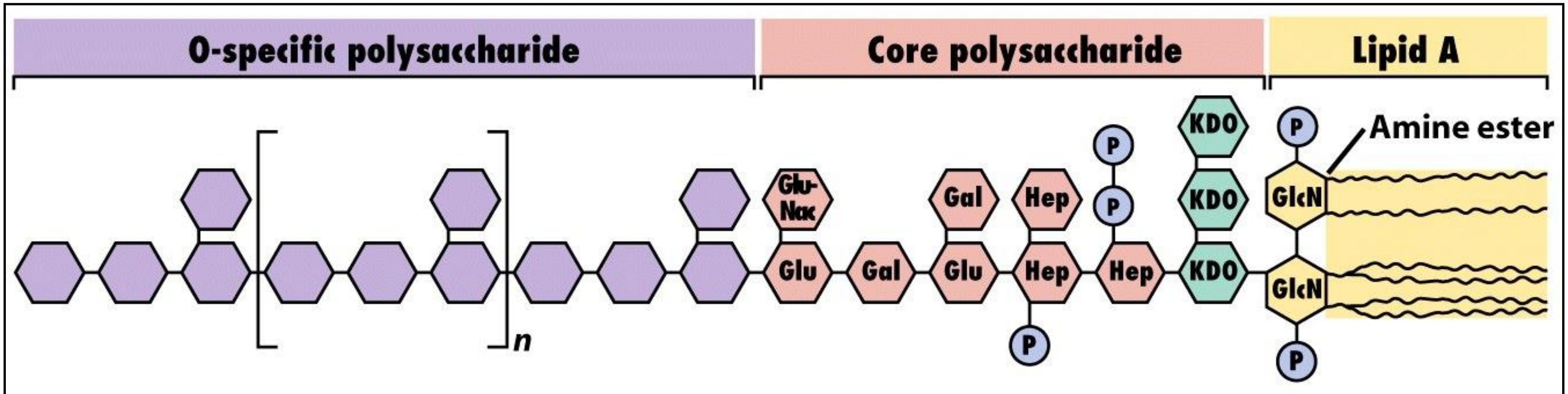


Figure 4-34 Brock Biology of Microorganisms 11/e

N-acetylglucosamine

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

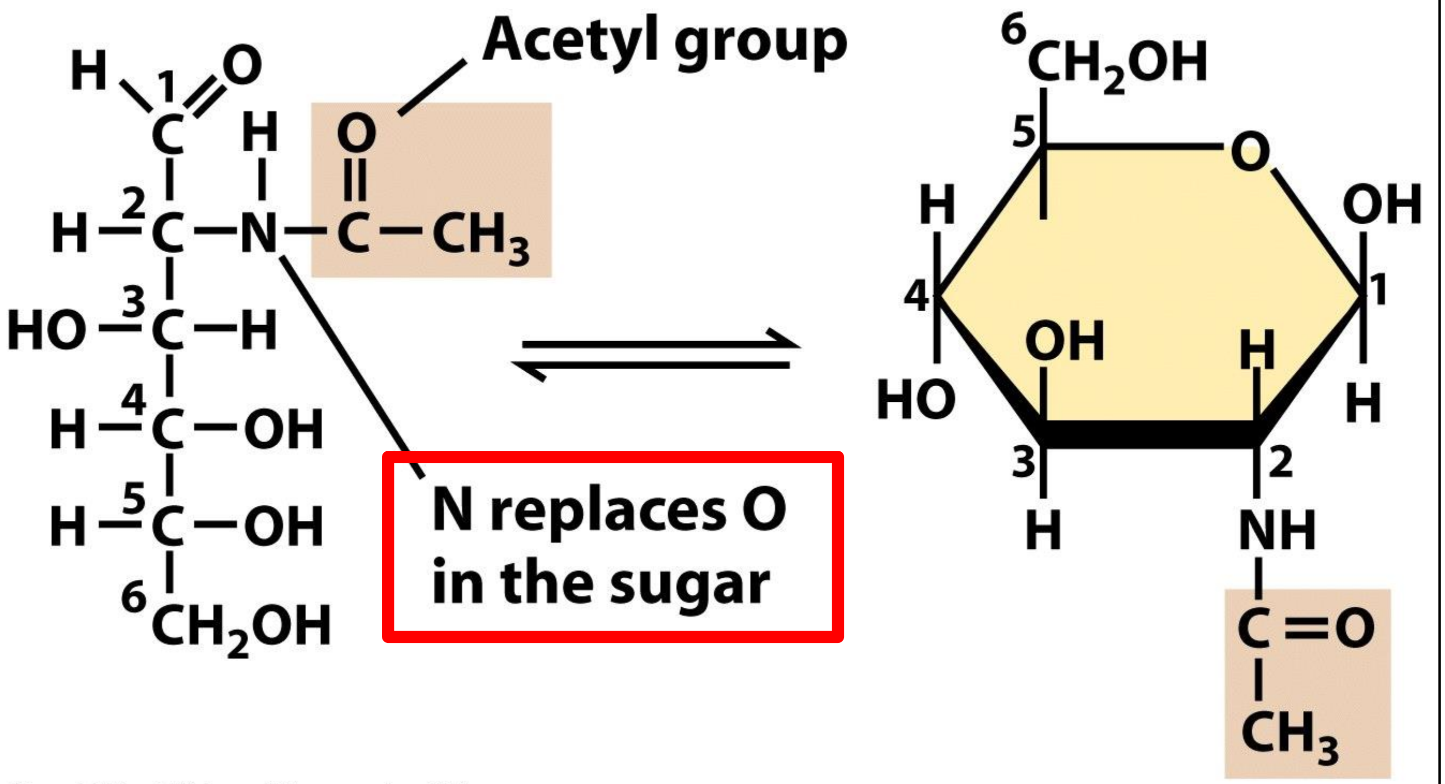
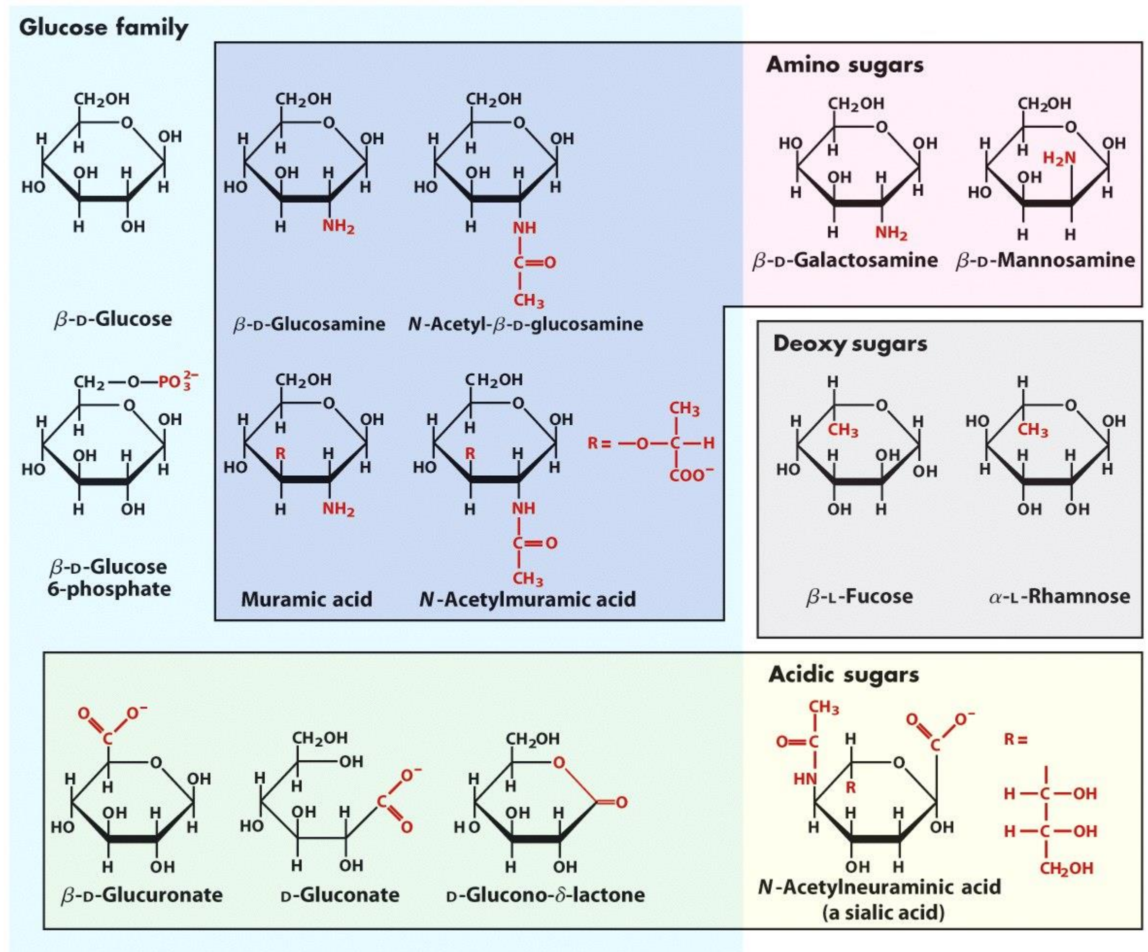


Figure 3-5 Brock Biology of Microorganisms 11/e

Hexose/Zuckerderivate

- Hydroxylgruppen in der Ausgangsverbindung sind durch andere Substituenten ersetzt . Aminogruppe (z.B. Glucosamin)
  - Aminogruppe kondensiert mit Essigsäure (N-Acetylglucosamin)
  - Milchsäure verbunden mit C-4 Atom N-Acetyl-muraminsäure
  - Substitution einer Hydroxylgruppe durch Hydrogen (z.B. Fucose)
  - Oxidation einer Aldehyd-gruppe zur Aldonsäure (z.B. Gluconsäure)
  - C-6 Oxidation Uronsäure (z.B. Glucuronsäure)
  - Sialinsäure C-9 Zucker



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

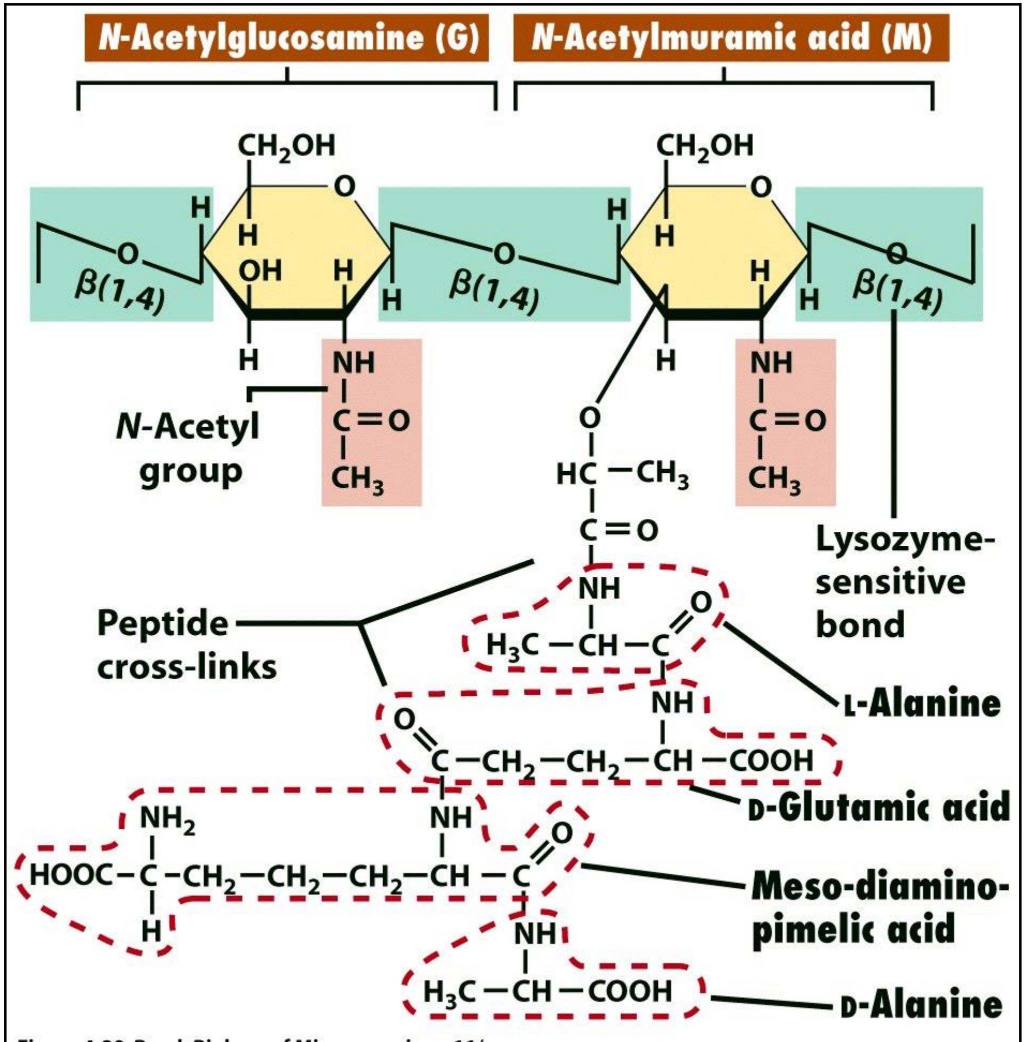
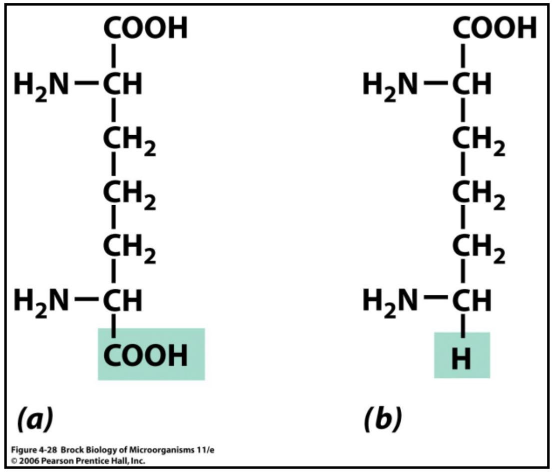
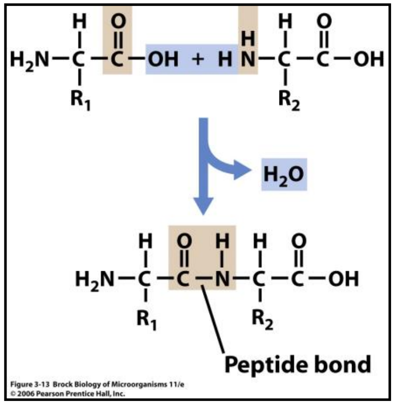


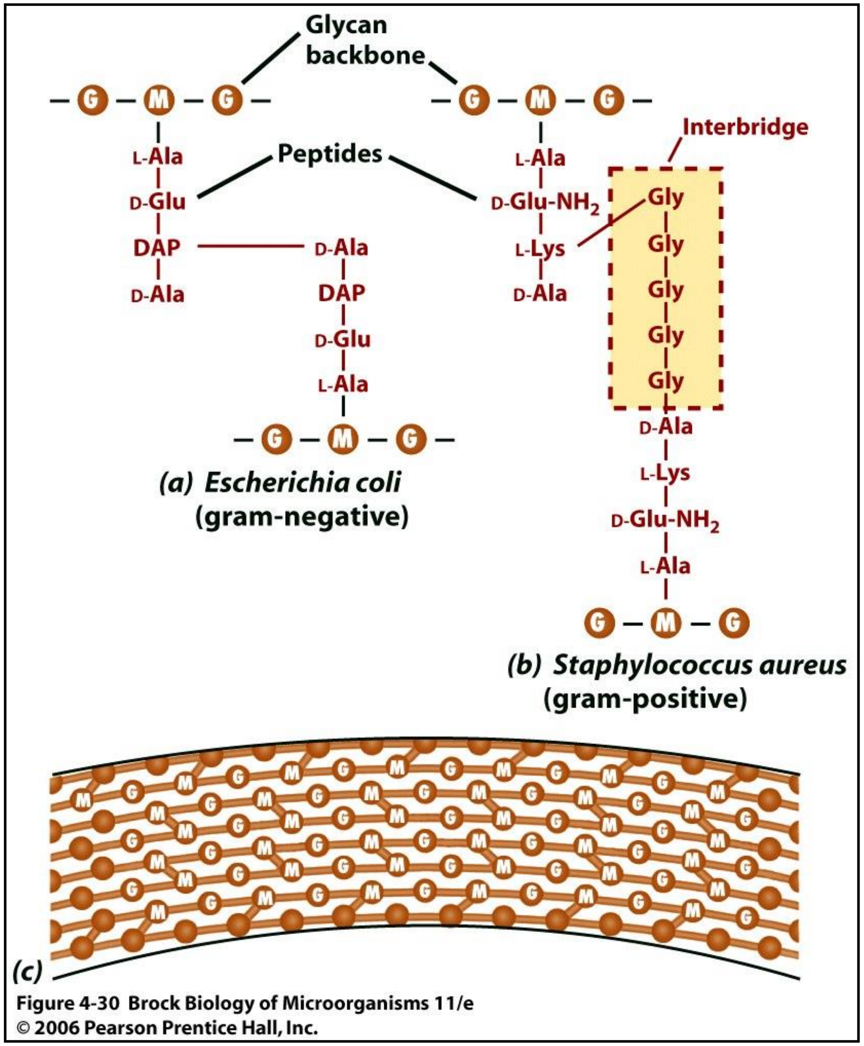
Figure 4-29 Brock Biology of Microorganisms 11/e

Murein: Cell wall (Bacteria)



(a) Diaminopimelinsäure
(b) Lysin





Murein: Cell wall (Bacteria)

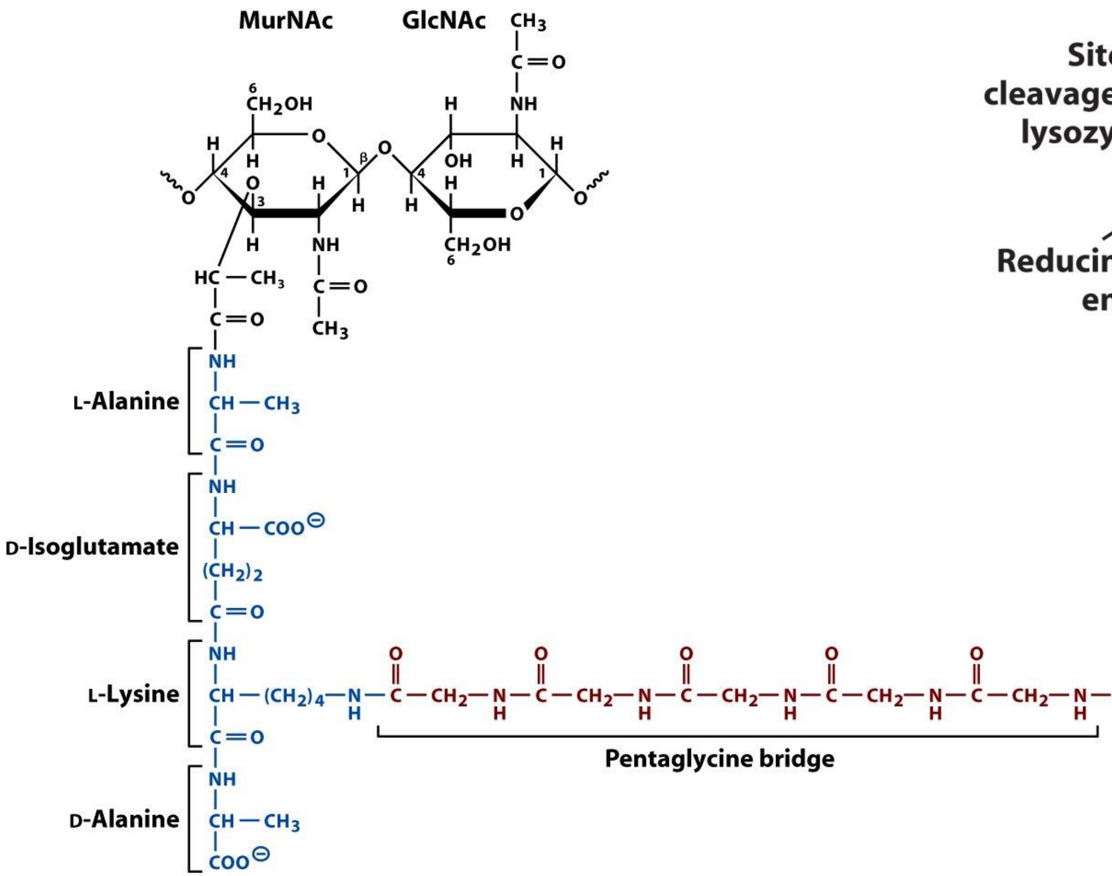


Figure 8-31a Principles of Biochemistry, 4/e

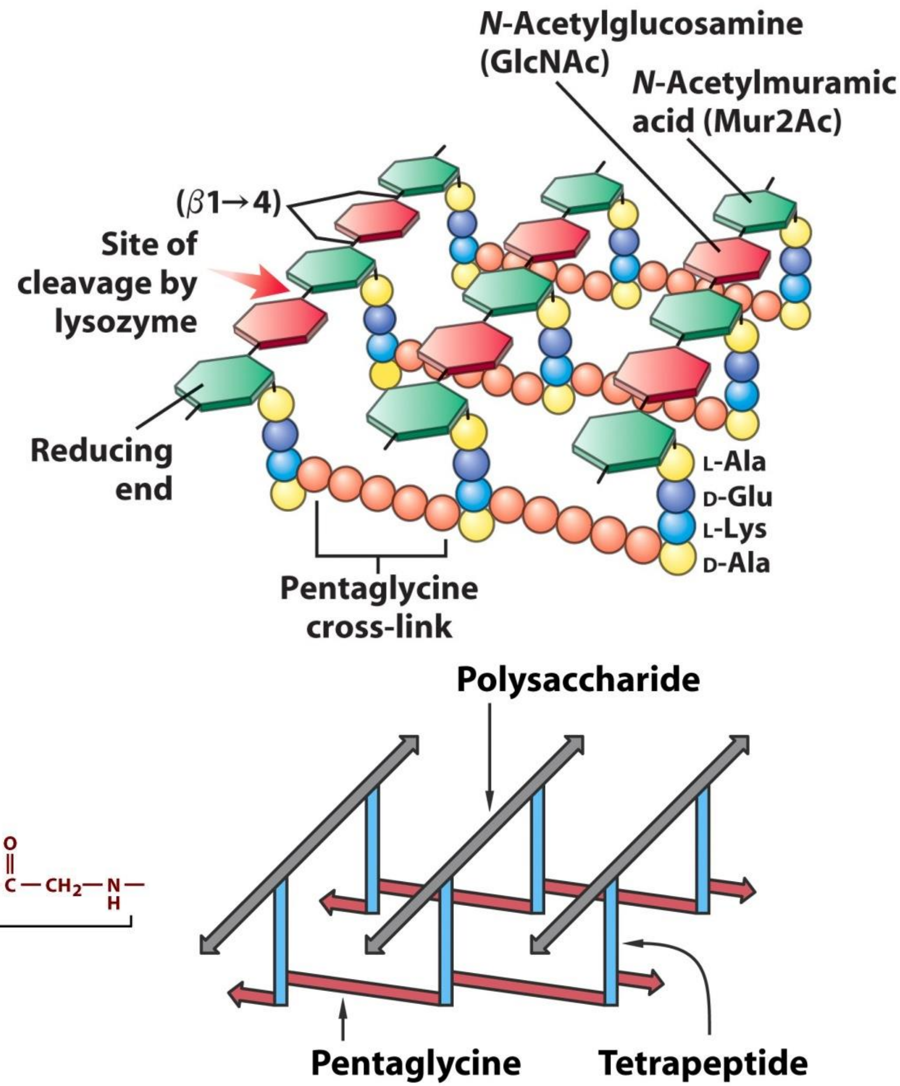


Figure 8-31b Principles of Biochemistry, 4/e

Mode of Action of Some Major Antimicrobial Agents

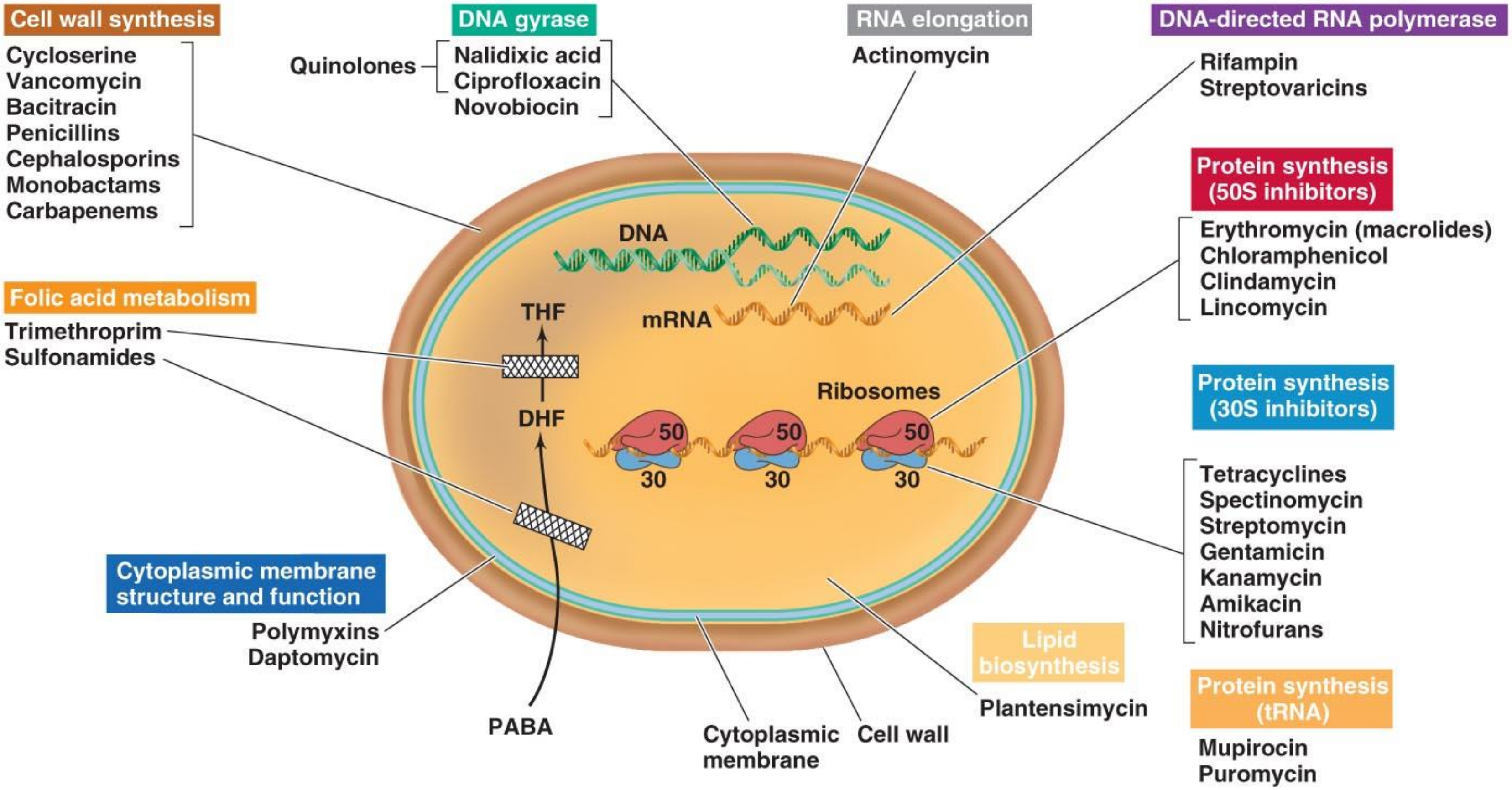


Figure 27.12

Antimicrobial Spectrum of Activity

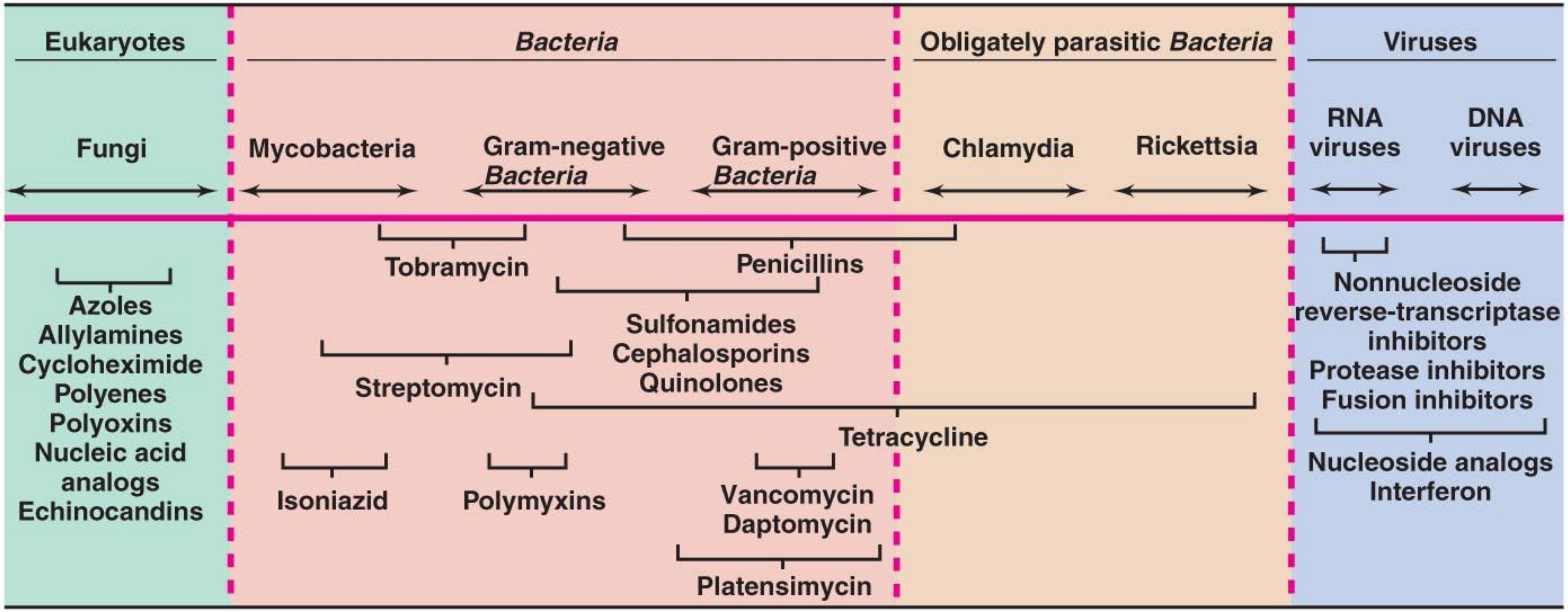
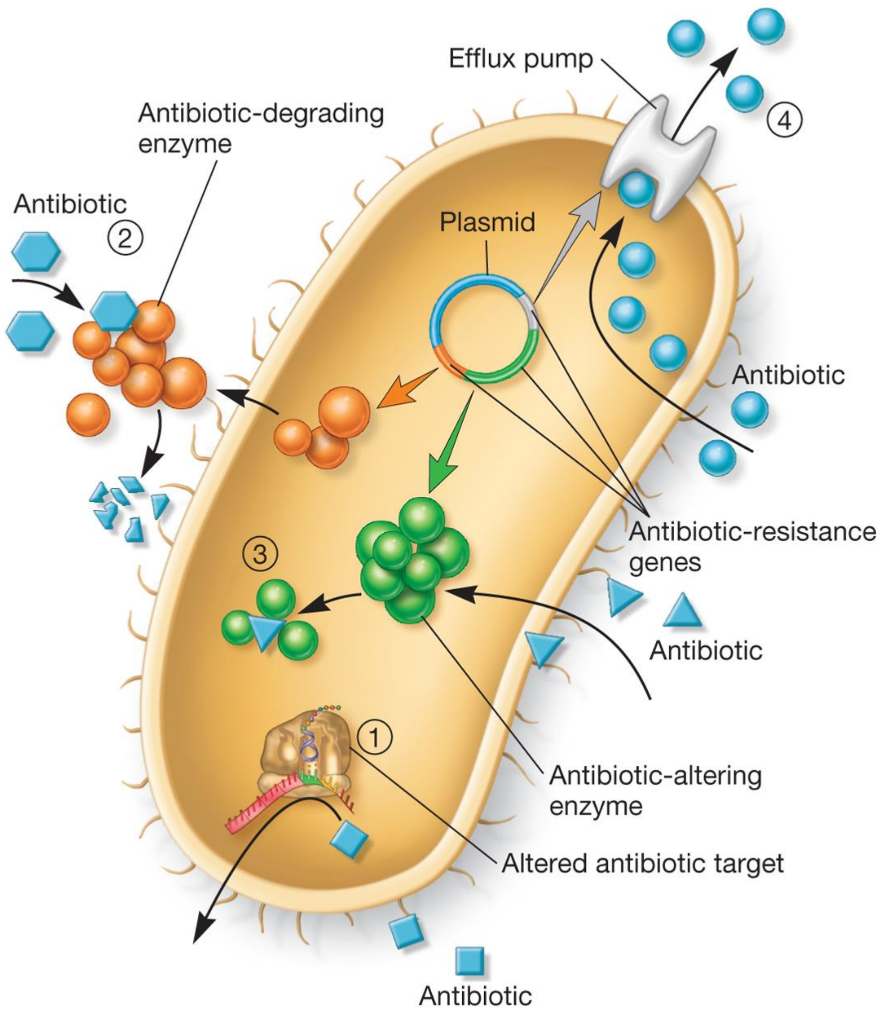


Figure 27.13

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

Antimicrobial Drug Resistance

- At least six reasons that microbes are naturally resistant to certain antibiotics
  - Organism lacks structure the antibiotic inhibits
  - Organism is impermeable to antibiotic
  - Organism can inactivate the antibiotic
  - Organism may modify the target of the antibiotic
  - Organism may develop a resistant biochemical pathway
  - Organism may be able to pump out the antibiotic (efflux)

Sites at Which Antibiotics are Attacked by Enzymes

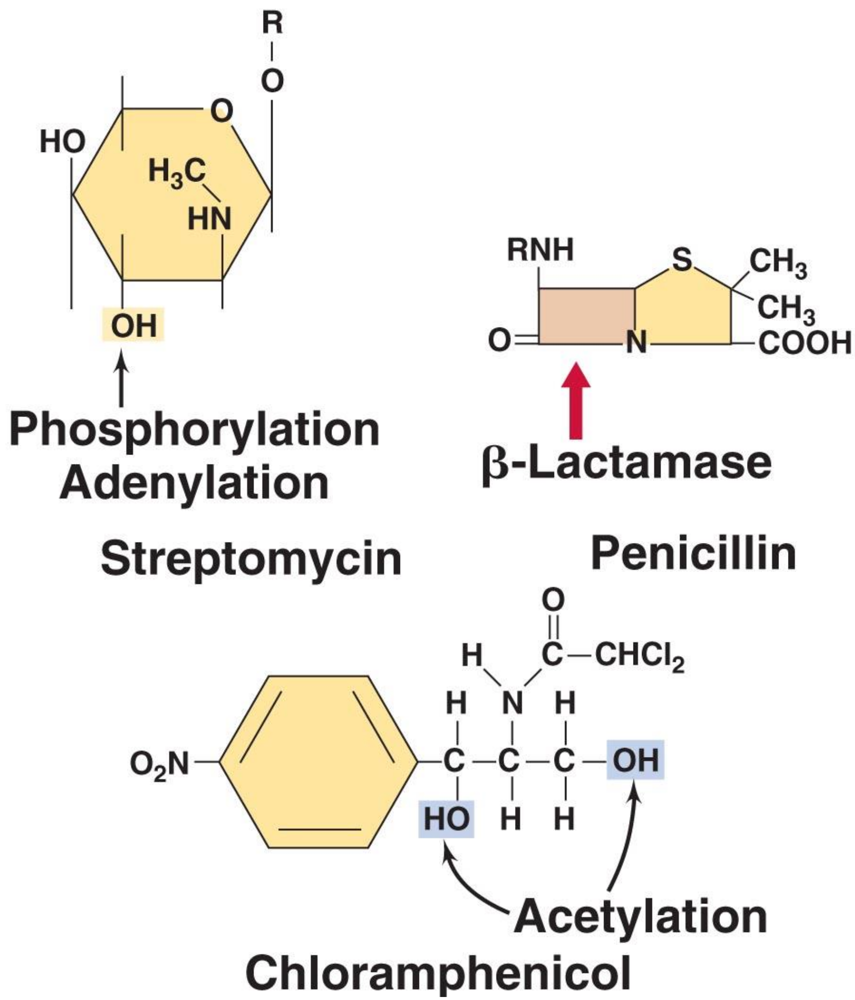


Figure 27.27

Mechanisms of Bacterial Resistance to Antibiotics

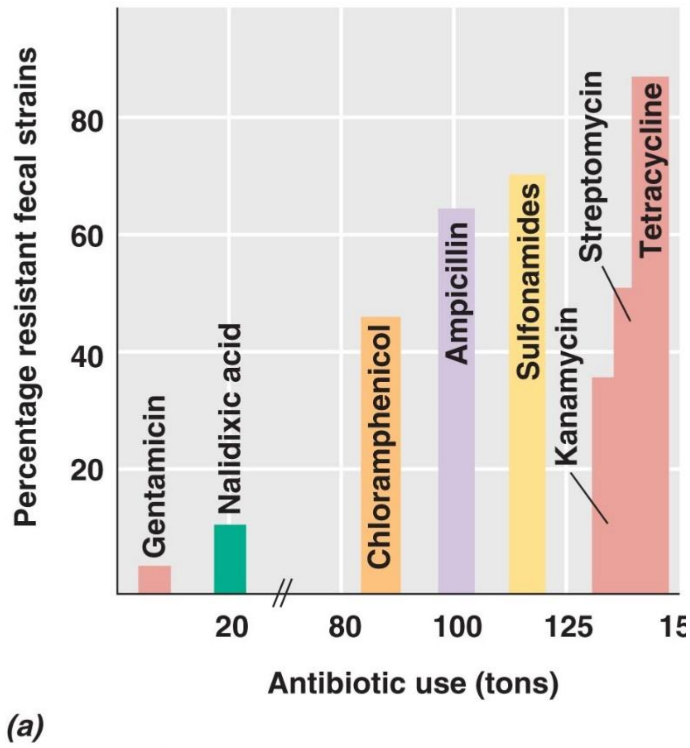
Table 27.7 **Mechanisms of bacterial resistance to antibiotics**

Resistance mechanism	*Antibiotic example*	*Genetic basis of resistance*	*Mechanism present in:*
Reduced permeability	Penicillins	Chromosomal	*Pseudomonas aeruginosa* Enteric *Bacteria*
Inactivation of antibiotic (for example, penicillinase; modifying enzymes such as methylases, acetylases, phosphorylases, and others)	Penicillins	Plasmid and chromosomal	*Staphylococcus aureus* Enteric *Bacteria* *Neisseria gonorrhoeae*
	Chloramphenicol	Plasmid and chromosomal	*Staphylococcus aureus* Enteric *Bacteria*
	Aminoglycosides	Plasmid	*Staphylococcus aureus*
Alteration of target (for example, RNA polymerase, rifamycin; ribosome, erythromycin, and streptomycin; DNA gyrase, quinolones)	Erythromycin	Chromosomal	*Staphylococcus aureus*
	Rifamycin		Enteric *Bacteria*
	Streptomycin		Enteric *Bacteria*
	Norfloxacin		Enteric *Bacteria* *Staphylococcus aureus*
Development of resistant biochemical pathway	Sulfonamides	Chromosomal	Enteric *Bacteria* *Staphylococcus aureus*
Efflux (pumping out of cell)	Tetracyclines	Plasmid	Enteric *Bacteria*
	Chloramphenicol	Chromosomal	*Staphylococcus aureus* *Bacillus subtilis*
	Erythromycin	Chromosomal	*Staphylococcus* spp.

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



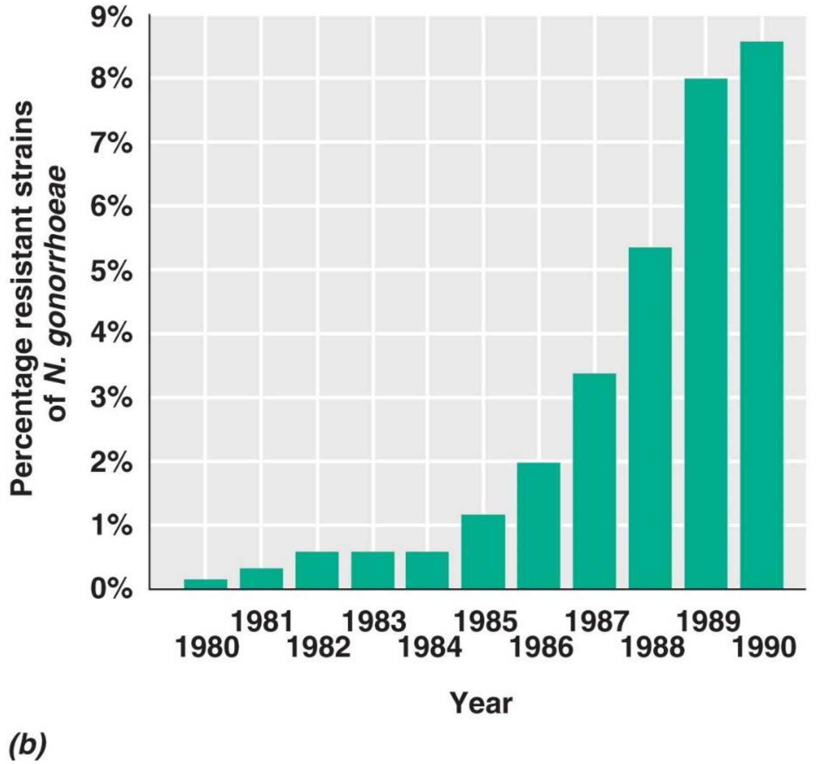


Figure 27.28

Figure 27.28