Biochemistry (BA 2)
Building Blocks (Lecture 3)

Bettina Siebers (MEB)

Links

- Links Biochemie Vorlesung
- http://www.uni-due.de/water-science/1721b_11.php (BA2)
- kiya

Glycoconjugates

- Proteoglycans
- Glycoproteins
- Glycolipids

Glycoconjugates

- Polysaccharides and oligosaccharides are also **information carriers**
- Some provide **communication** between cells and their extracellular surroundings.
  - Label for transport & localization (e.g. organelles)
  - Label for destruction (malformed protein)
  - Recognition sites for extracellular molecules (growth factors) or parasites (bacteria or viruses)
- Eukaryotic cells (gycocalyx)
  - Cell-cell recognition and adhesion
  - Cell migration
  - Blood clotting
  - Immune response
  - Wound healing etc.

Proteoglucans

- Proteoglycan aggregate of the exttracellular matrix.

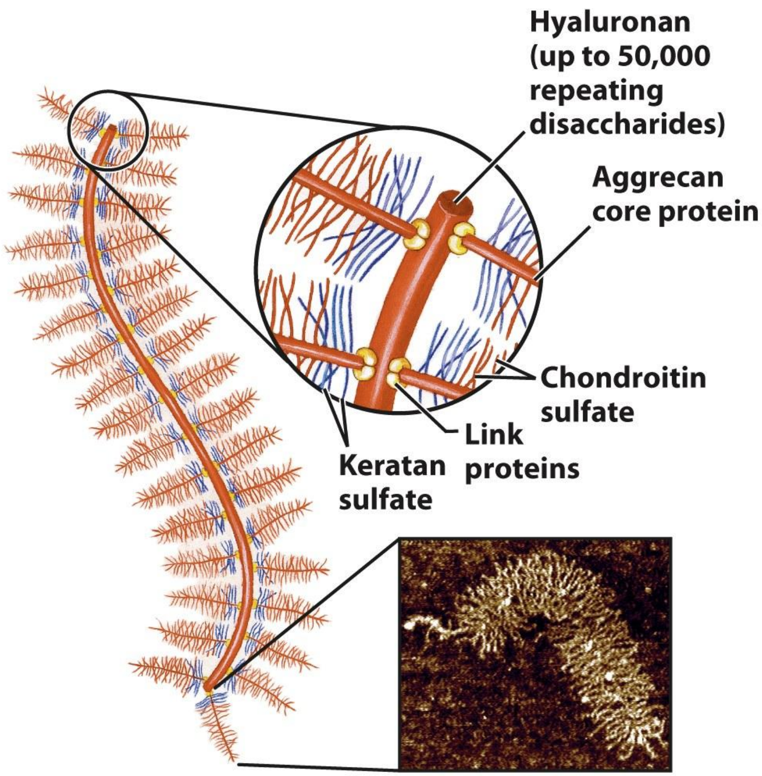

Figure 7-27
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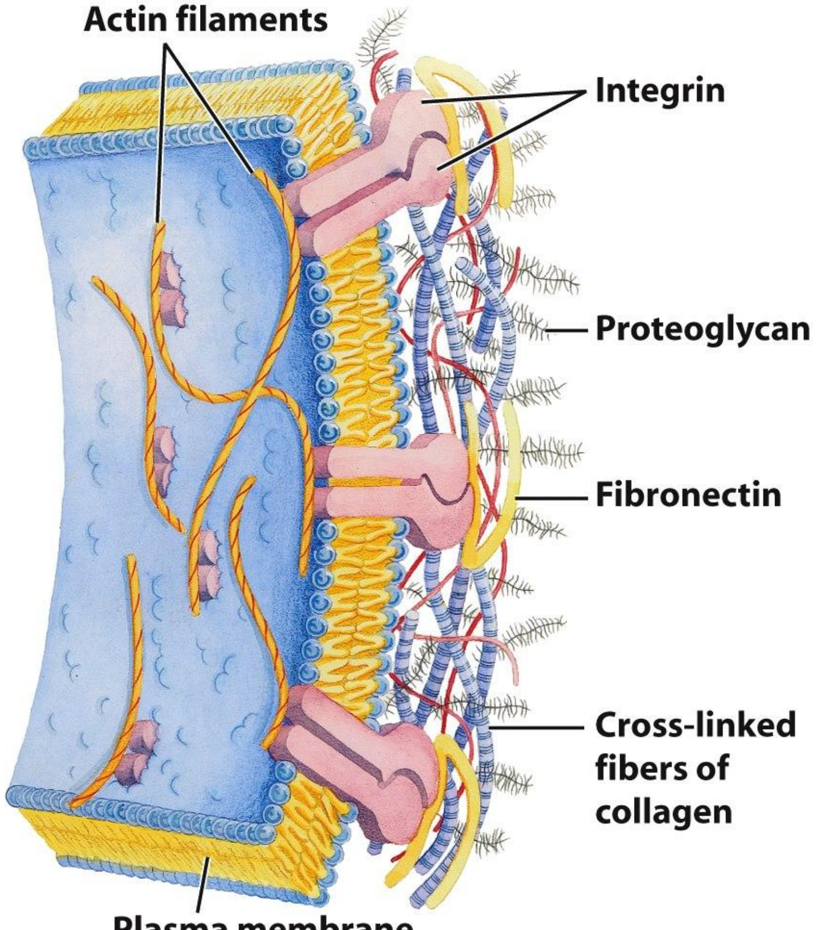
AFM



Glycocoproteins

- *O*-Glycosidic and *N*-glycosidic linkages.
- (a) ***N*-Acetylgalactosamine–serine** linkage, the major ***O*-glycosidic linkage** found in glycoproteins.
- (b) ***N*-Acetylglucosamine–asparagine** linkage, which characterizes ***N*-linked** glycoproteins.
- The *O*-glycosidic linkage is α whereas the *N*-glycosidic linkage is β.

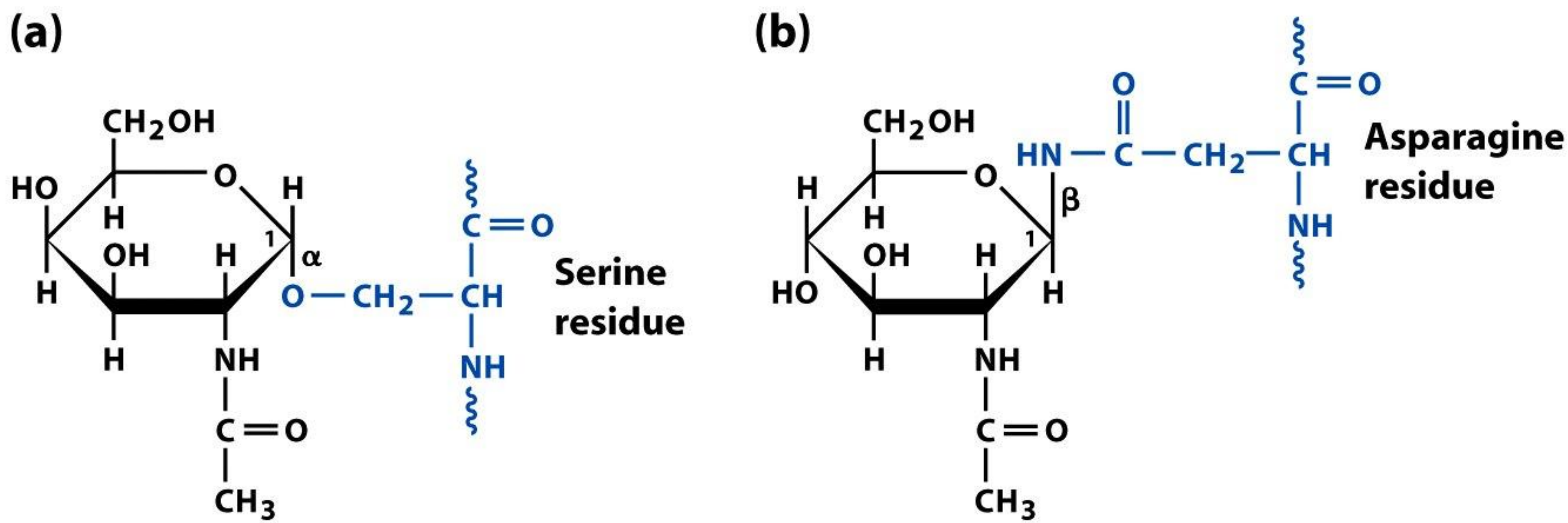


Figure 8-33 Principles of Biochemistry, 4/e

Glycoconjugates

- Glycolipids
  - Bacterial Lipopolysaccharides (gram negative outer membrane)

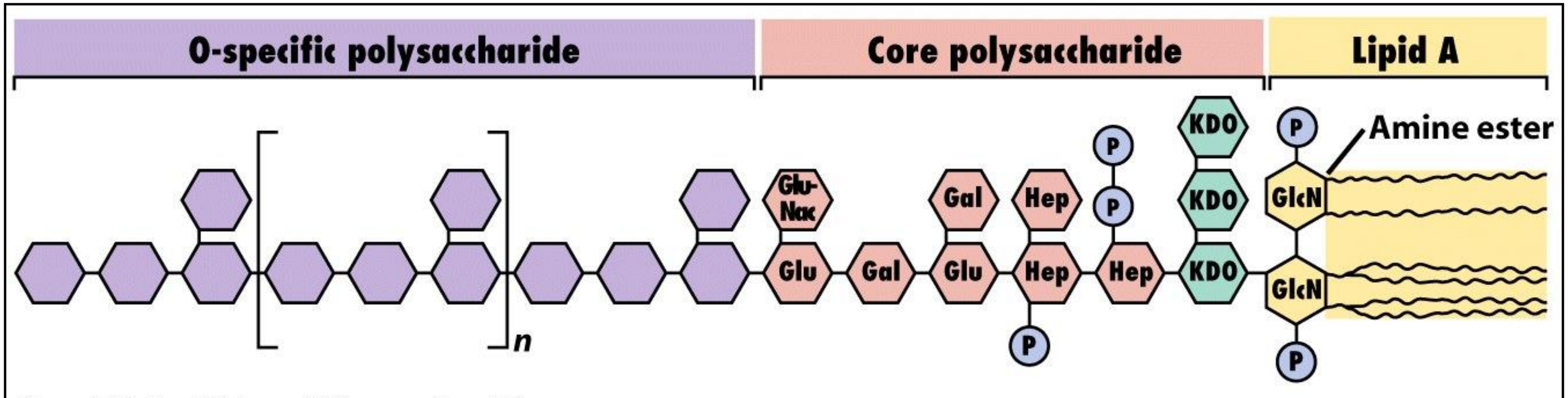


Figure 4-34 Brock Biology of Microorganisms 11/e

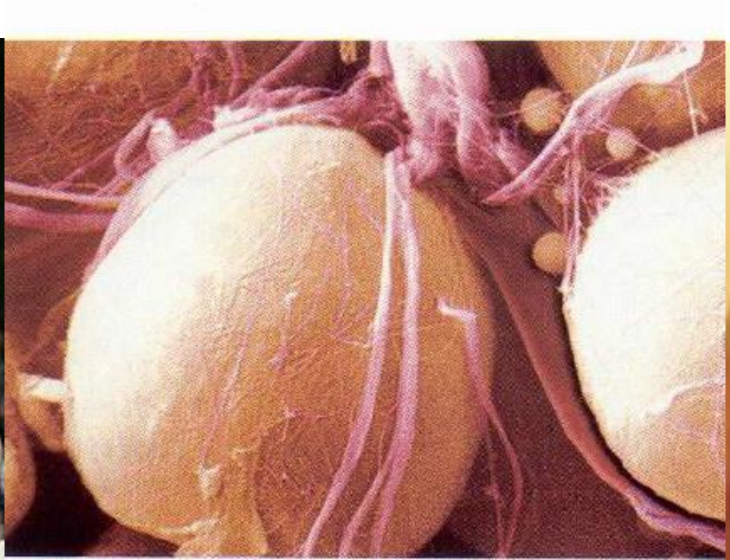
Sugars and Blood Groups

- Blood groups:
  - A; A antigen
  - B; B antigen
  - AB, A & B antigen
  - 0; only H antigen

- Blood group determined by 1 gene
  - (Chromosome 9, several allels of the gene)
  - Original A enzyme (glycosyltransferase)
  - Mutation B enzyme (only one amino acid substitution !)
  - Non-functional enzyme (deletion !) blood group 0

Biomolecules

Lipids



Lipids

- **Lipids** are **amphipathic**—they have both hydrophobic (**nonpolar**) and hydrophilic (**polar**) properties.
- Biological lipids are a chemically **diverse** group of compounds
- Common and defining feature - **insolubility in water**
- ***Glycerol bonded to fatty acids and other groups such as phosphate by an ester or ether linkage***

Lipids

- They play crucial roles:
  - Storage lipids; depots for excess carbon
  - Structural lipids in membrane
  - Lipids as signals, cofactors and pigments

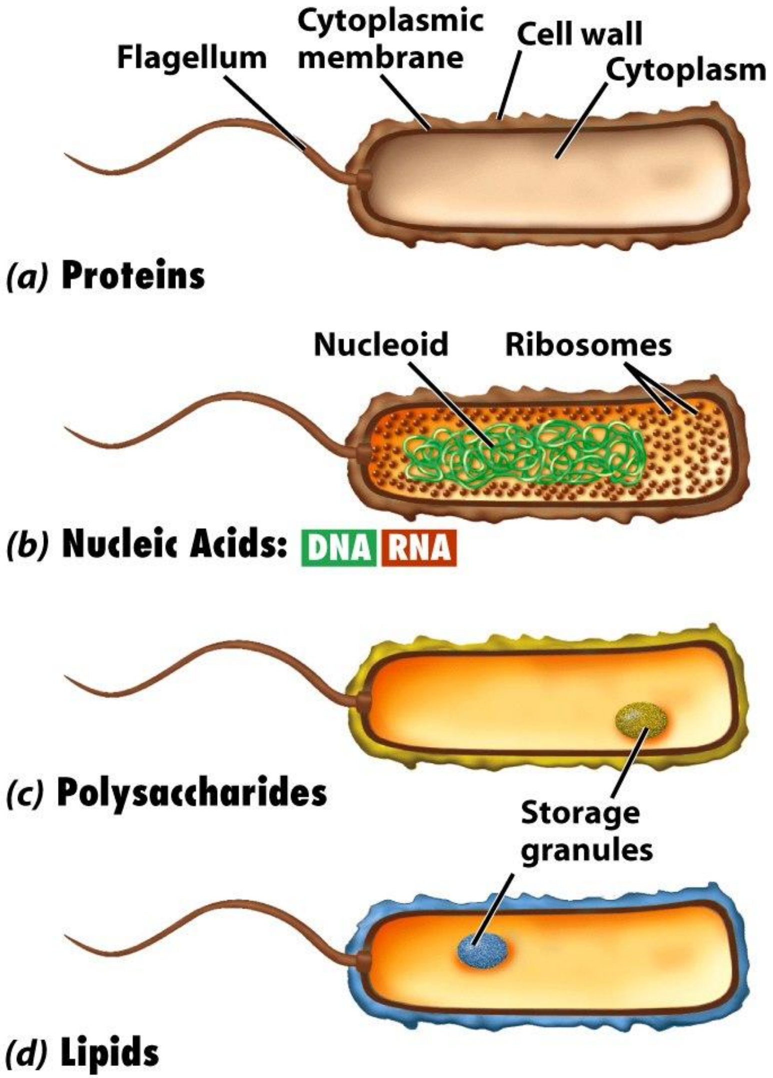
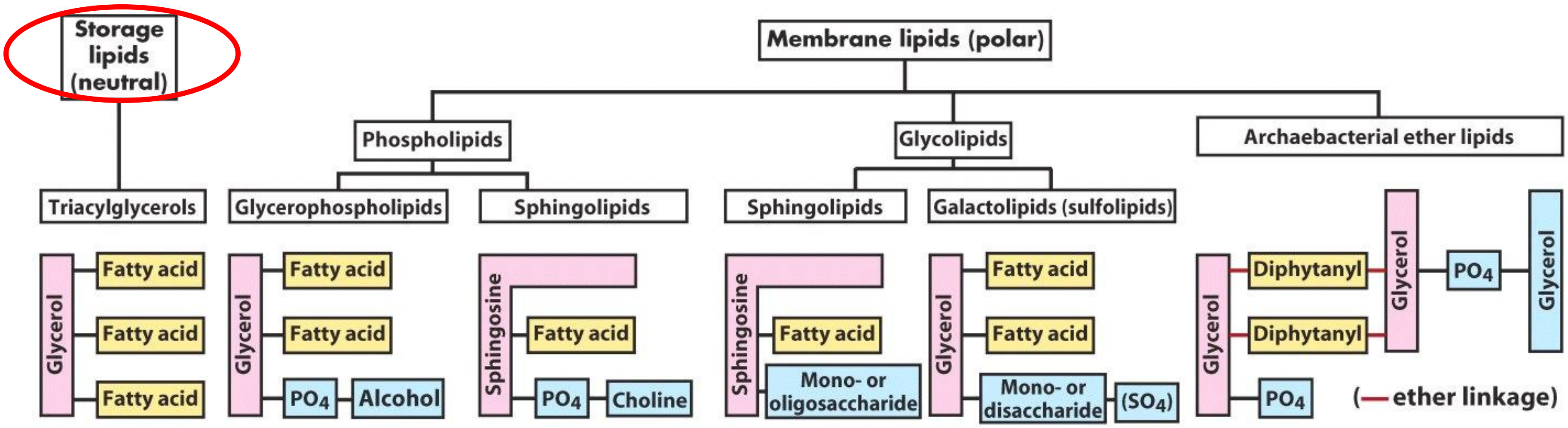


Figure 3-3 Brock Biology of Microorganisms 11/e

Major Classes of Lipids



Storage Lipids

- Simple lipids (triglycerides)

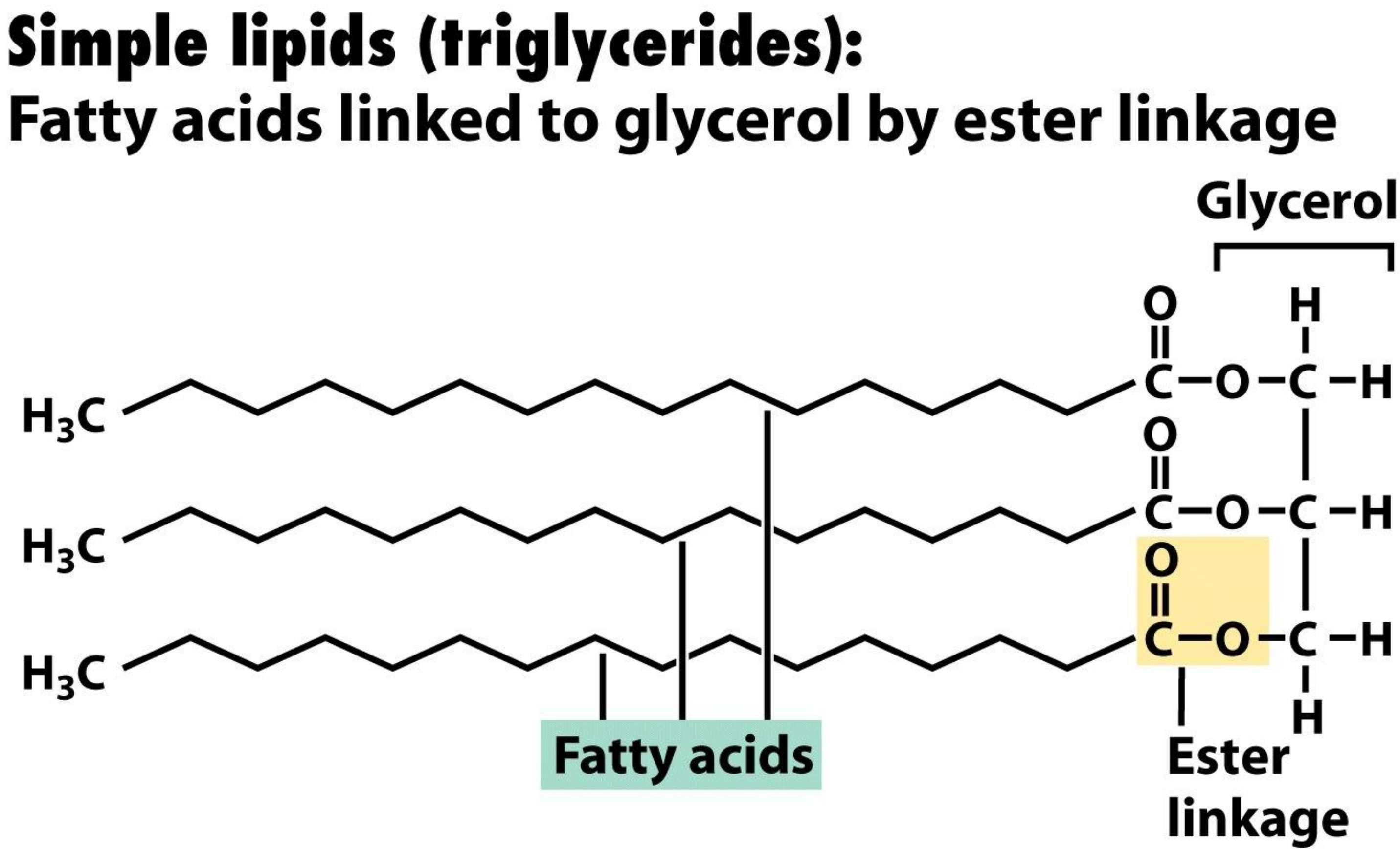
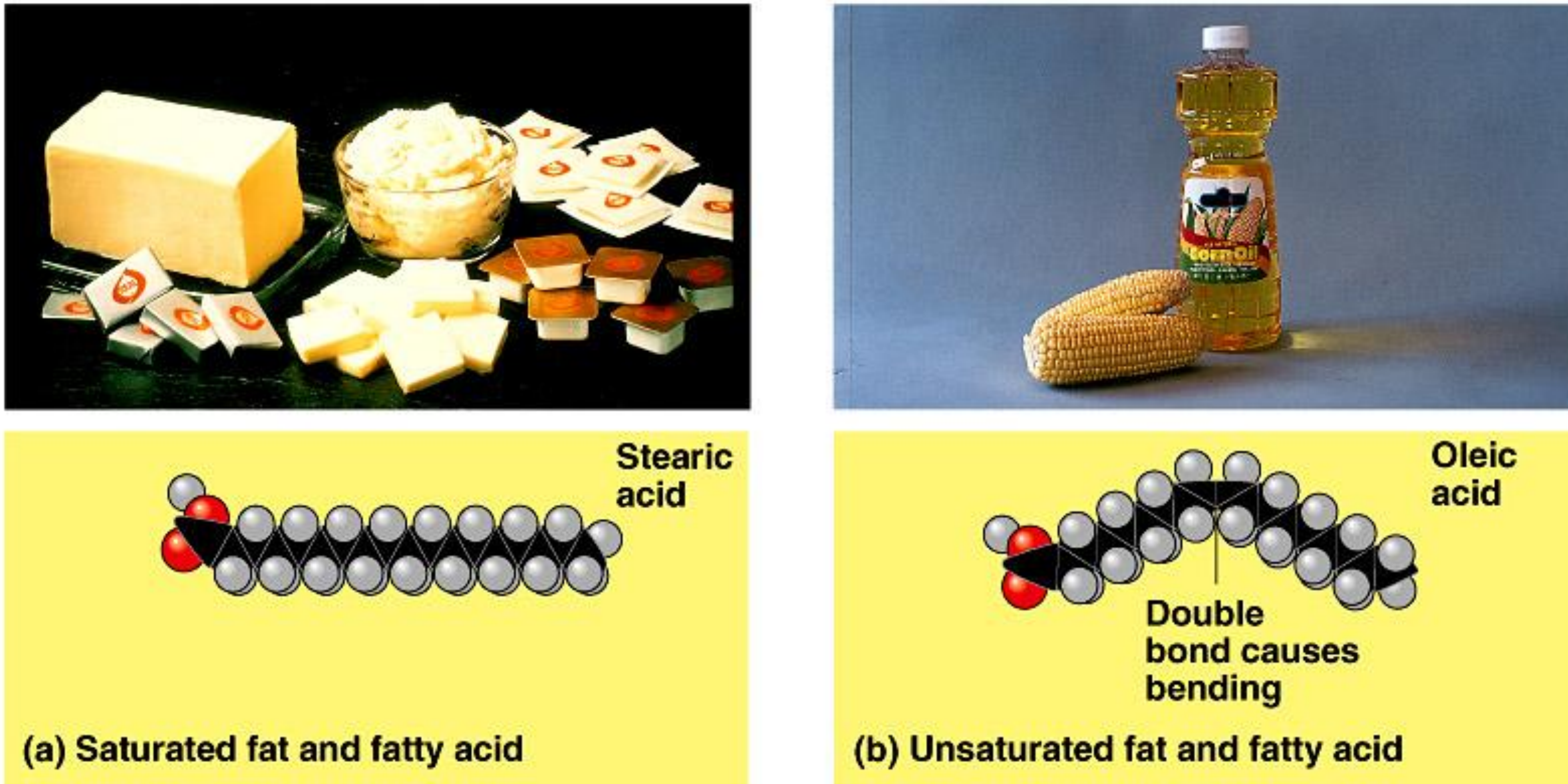


Figure 3-7 part 2 Brock Biology of Microorganisms 11/e

Examples of Fatty Acids

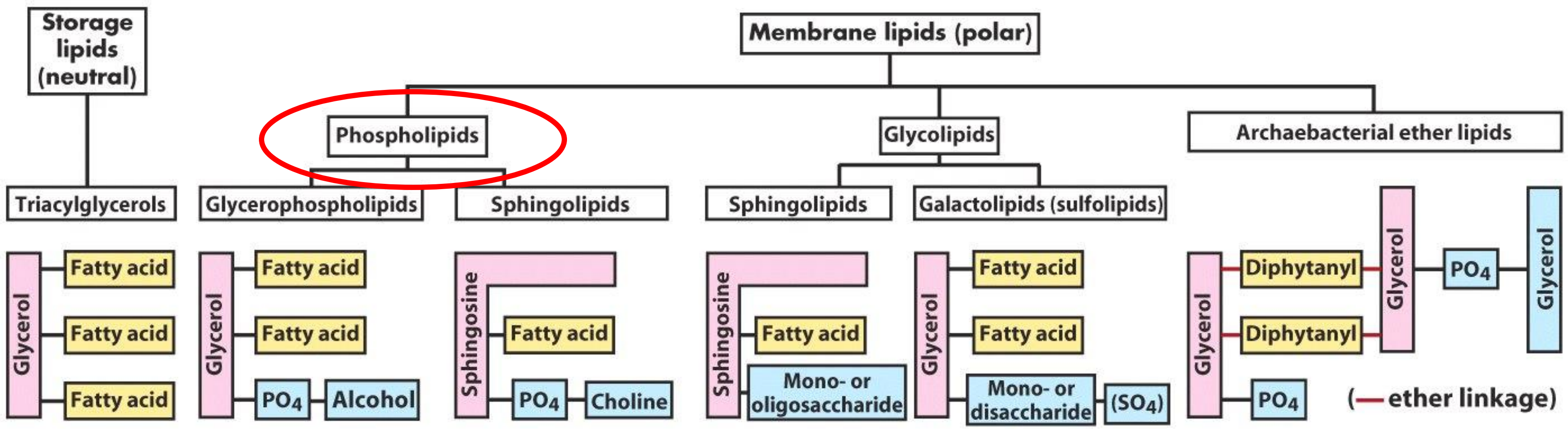


(a) Saturated fat and fatty acid. At room temperature, the molecules of a saturated fat are packed closely together, forming a solid.

(b) Unsaturated fat and fatty acid. At room temperature, the molecules of an unsaturated fat cannot pack together closely enough to solidify because of the kinks in their fatty acid tails.

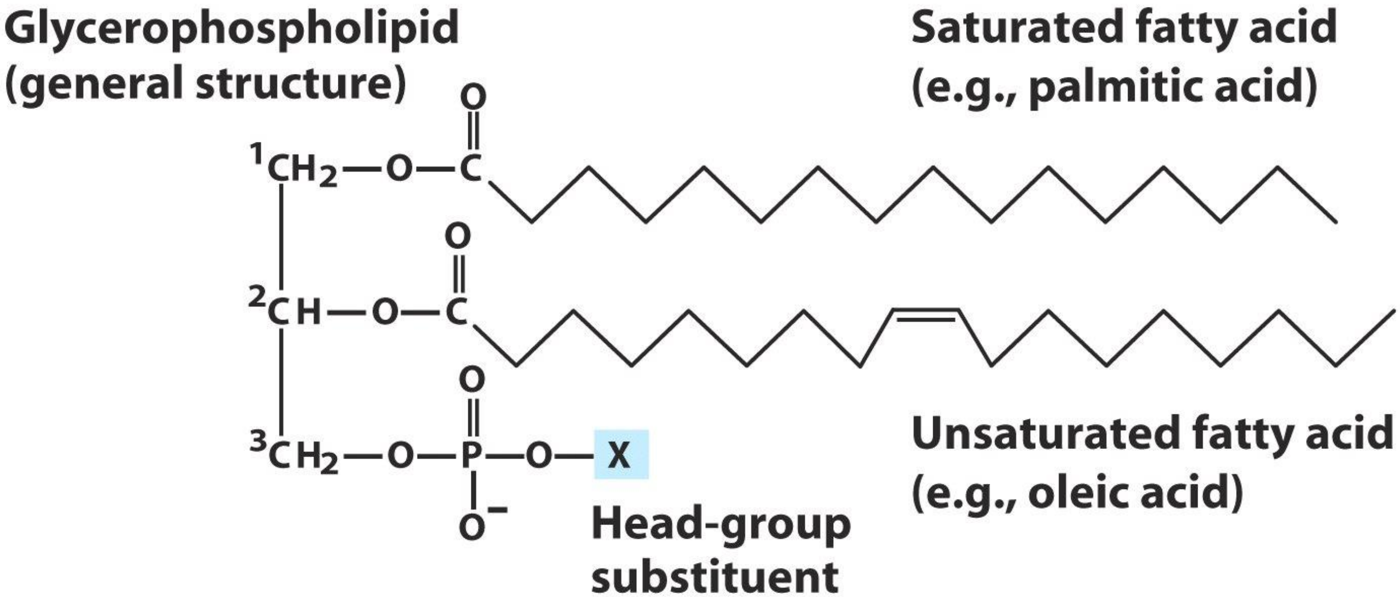
FIGURE 5.11 Examples of saturated and unsaturated fats and fatty acids.

Major Classes of Lipids



Glycerophospholipids

- **Diacylglycerols** linked to **head-group alcohols** through **a phosphodiester** bond.
- **Phosphatidic acid**, a phosphomonoester, is the parent compound.
- Derivatives (x), named for the headgroup alcohol with prefix „phosphatidyl-x“



Structural Lipids in Membranes

- Functional groups derived from **esterified alcohols** are shown in **blue**.
- Since each of these lipids can contain many combinations of fatty acyl groups, the **general name refers to a family of compounds**, not to a single molecule.

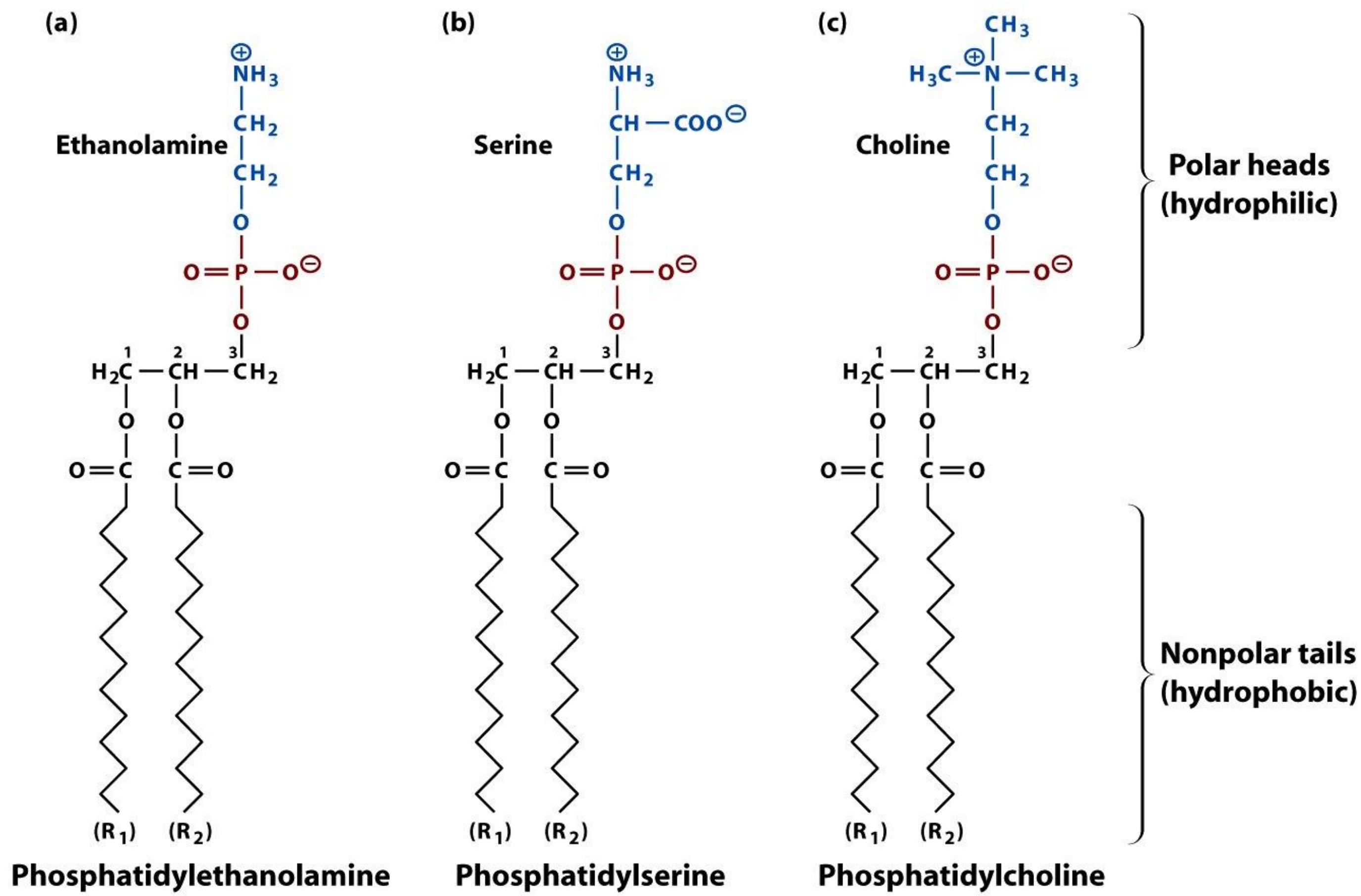
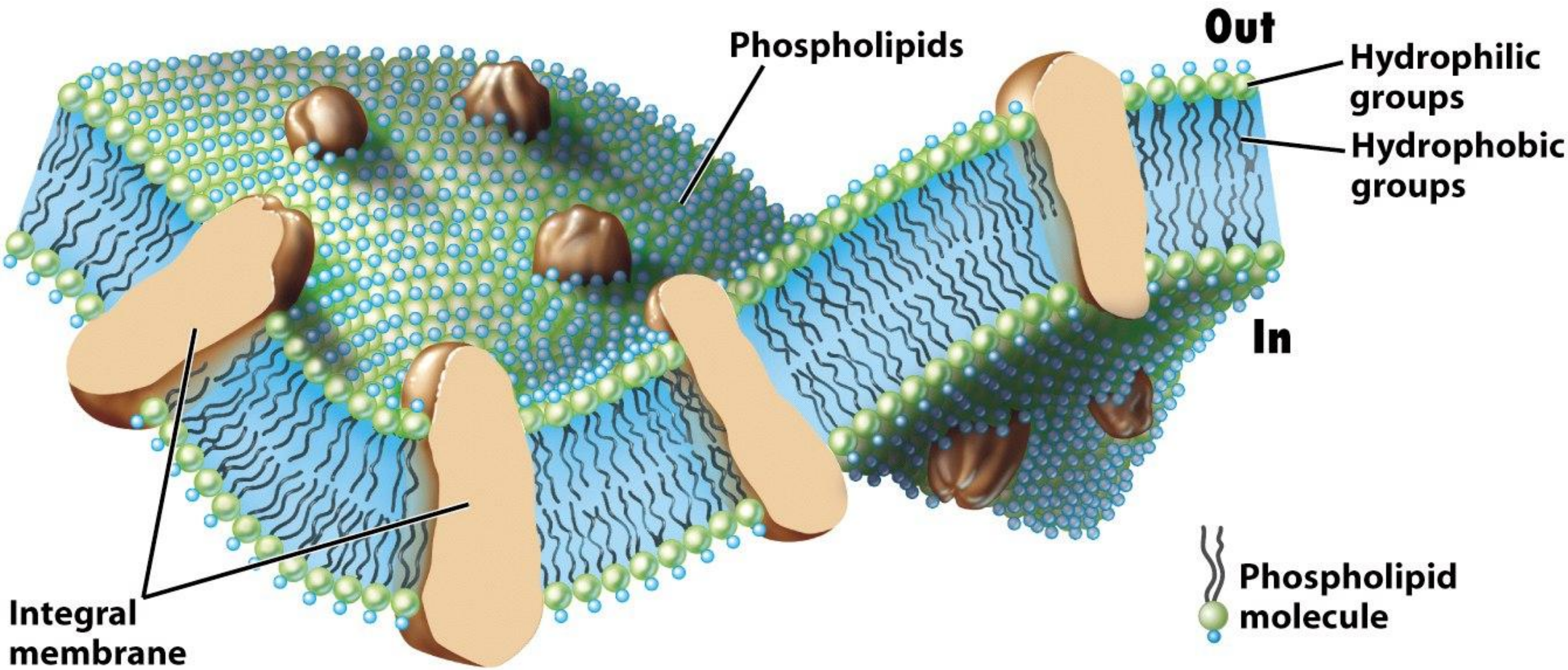


Figure 9-7 Principles of Biochemistry, 4/e

Membranes

- *E. coli* phosphatidylethanolamine & Phosphatidylcholine



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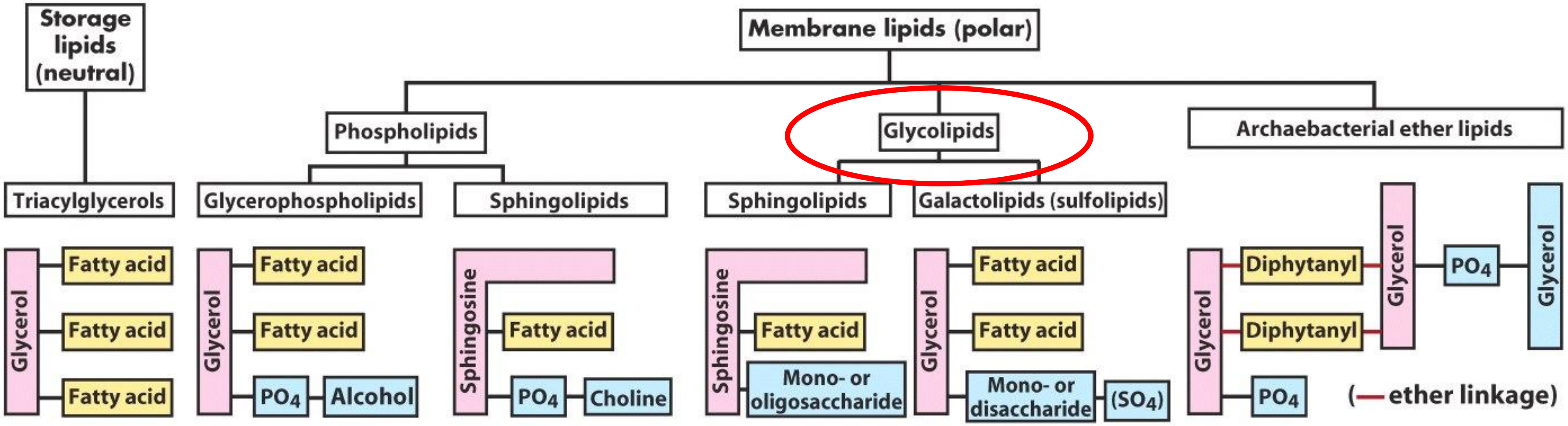
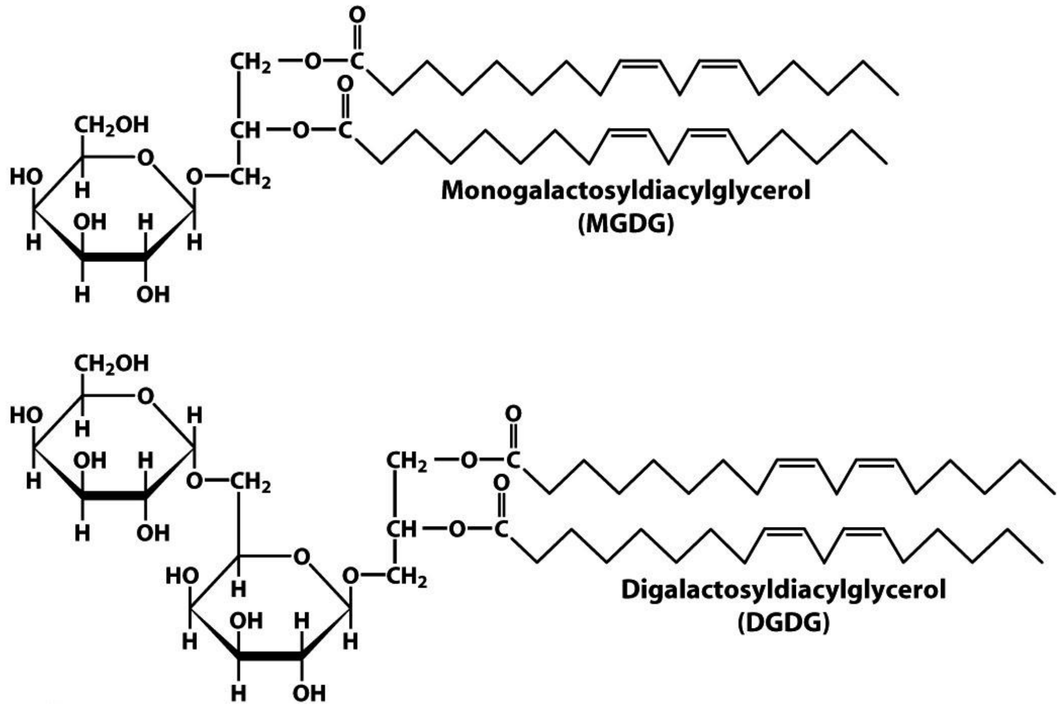
Major Classes of Lipids

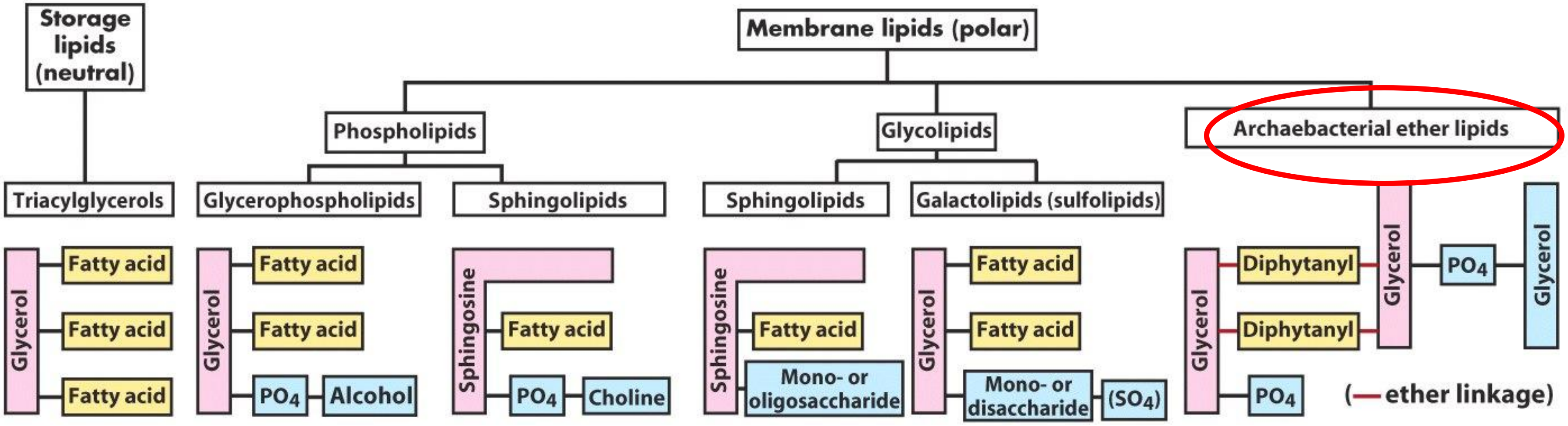


Glycolipids

- **Galactolipids of chloroplast thylakoid membranes.**
- Predominate in plant cells.
- In monogalactosyldiacylglycerols (MGDGs) and digalactosyldiacylglycerols (DGDGs), almost all the acyl groups are derived from linoleic acid, 18:2($\Delta^{9,12}$), and the head groups are uncharged.



Major Classes of Lipids



Membrane Lipid of Archaea

- **Diphytanyl tetraether** lipid
- The diphytanyl moieties (yellow) are long hydrocarbons composed of eight five-carbon **isoprene** groups condensed end-to-end

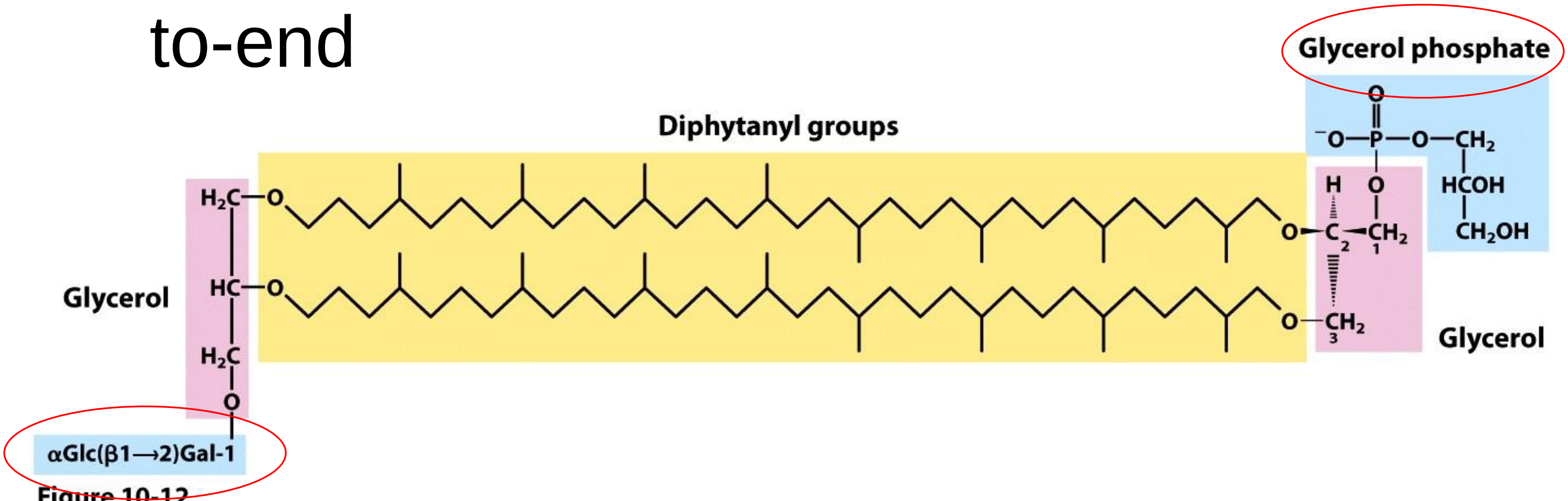


Figure 10-12
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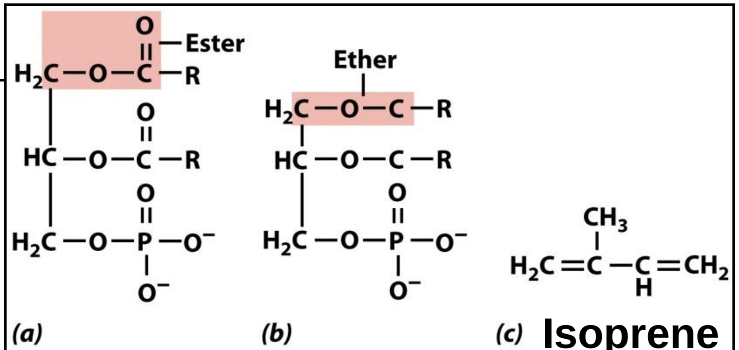
Archaeal Membranes

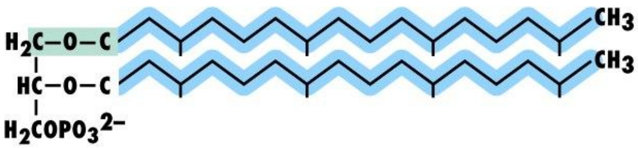
-Attachment to glycerol by ether linkages (no ester linkages!)

-Hydrocarbon: repeating isoprene (C5) units (no fatty acids!)



Isoprene

Figure 4-18 Brock Biology of Microorganisms 11/e



a) Glycerol diethers „Lipidbilayer“ (phytanyl C20)

b) Diglycerol tetraethers „Lipidmonolayer“ (dibiphytanyl C40)

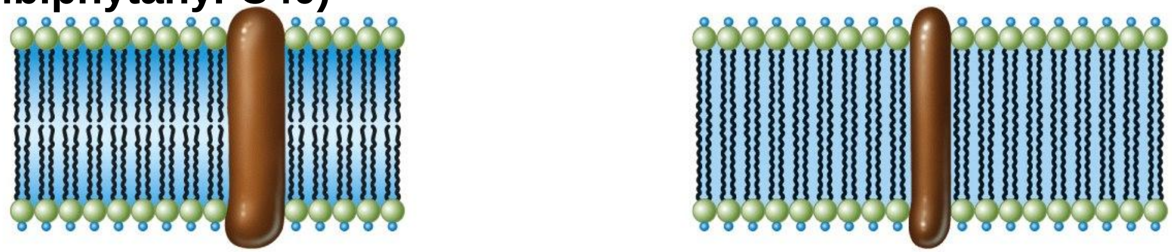


Figure 4-19 Brock Biology of Microorganisms 11/e

Lipids as signals, cofactors and pigments

Cholesterol

- **Sterols** are **structural lipids in eukaryotic membranes** (can not be synthesized by Bacteria, not in the mitochondrial membrane !)
- The C-3 hydroxyl group (pink in both representations) is the polar head group. For storage and transport of the sterol, this hydroxyl group condenses with a fatty acid to form a sterol ester.

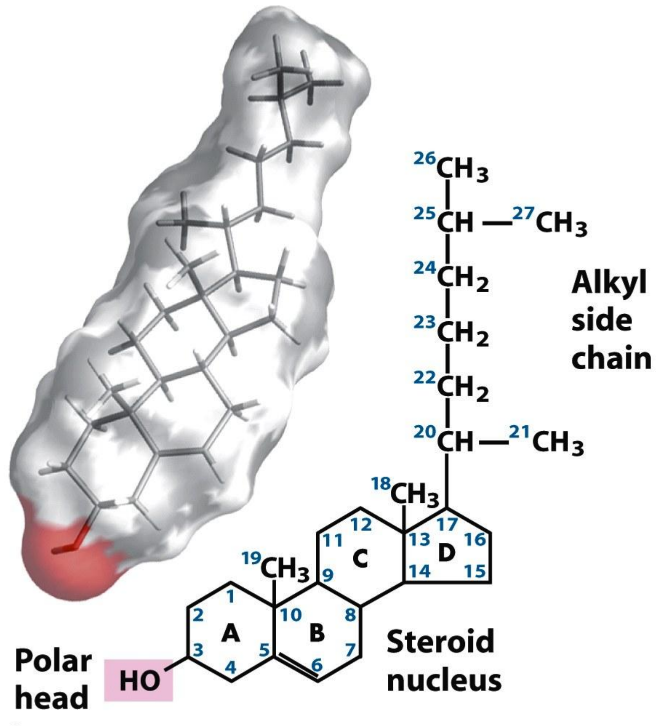


Figure 10-17
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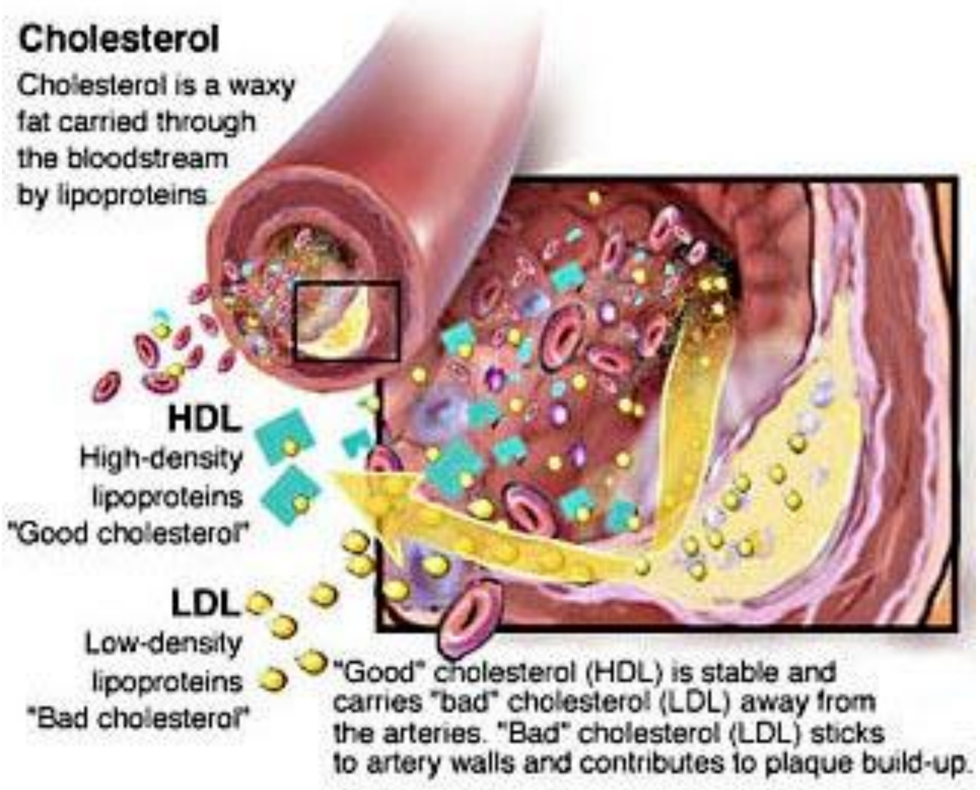
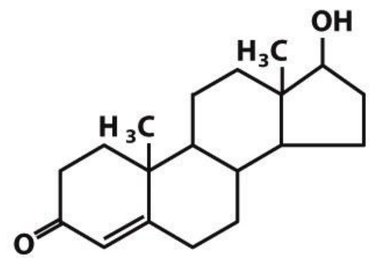
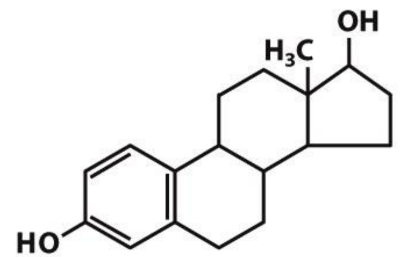


Steroid Hormones Carry Messages between Tissues

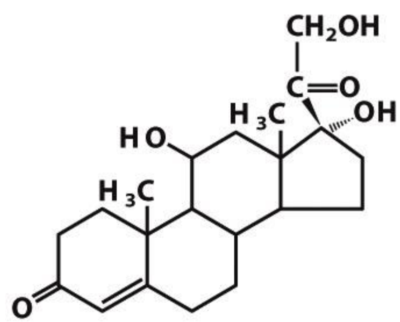
- Derived from **cholesterol.**
- **Testosterone**, the male sex hormone, is produced in the testes.
- **Estradiol**, one of the female sex hormones, is produced in the ovaries and placenta.
- **Cortisol** and **aldosterone** are hormones synthesized in the cortex of the adrenal gland; they regulate glucose metabolism and salt excretion, respectively.



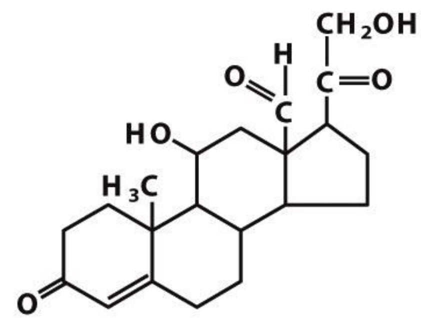
Testosterone



Estradiol



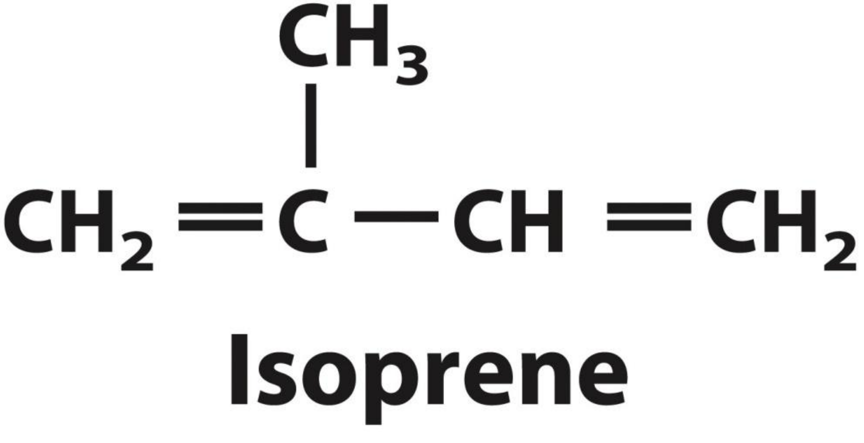
Cortisol



Aldosterone

Vitamins

- Compounds essential for health of human (vertebrates)
- **Fat soluble vitamins** A, D, E, K
- **Isoprenoid compounds** (condensation of multiple isoprene units.
- Vitamin **D** (D_3 cholecalciferol) and **A** (retinol) serve as hormone precursors.



Some other biologically active isoprenoid compounds or derivatives

(a)
Vitamin E: an antioxidant

(b)
Vitamin K_1: a blood-clotting cofactor (phylloquinone)

(c)
Warfarin: a blood anticoagulant

(d)
Ubiquinone: a mitochondrial electron carrier (coenzyme Q) (n = 4 to 8)

(e)
Plastoquinone: a chloroplast electron carrier (n = 4 to 8)

(f)
Dolichol: a sugar carrier (n = 9 to 22)

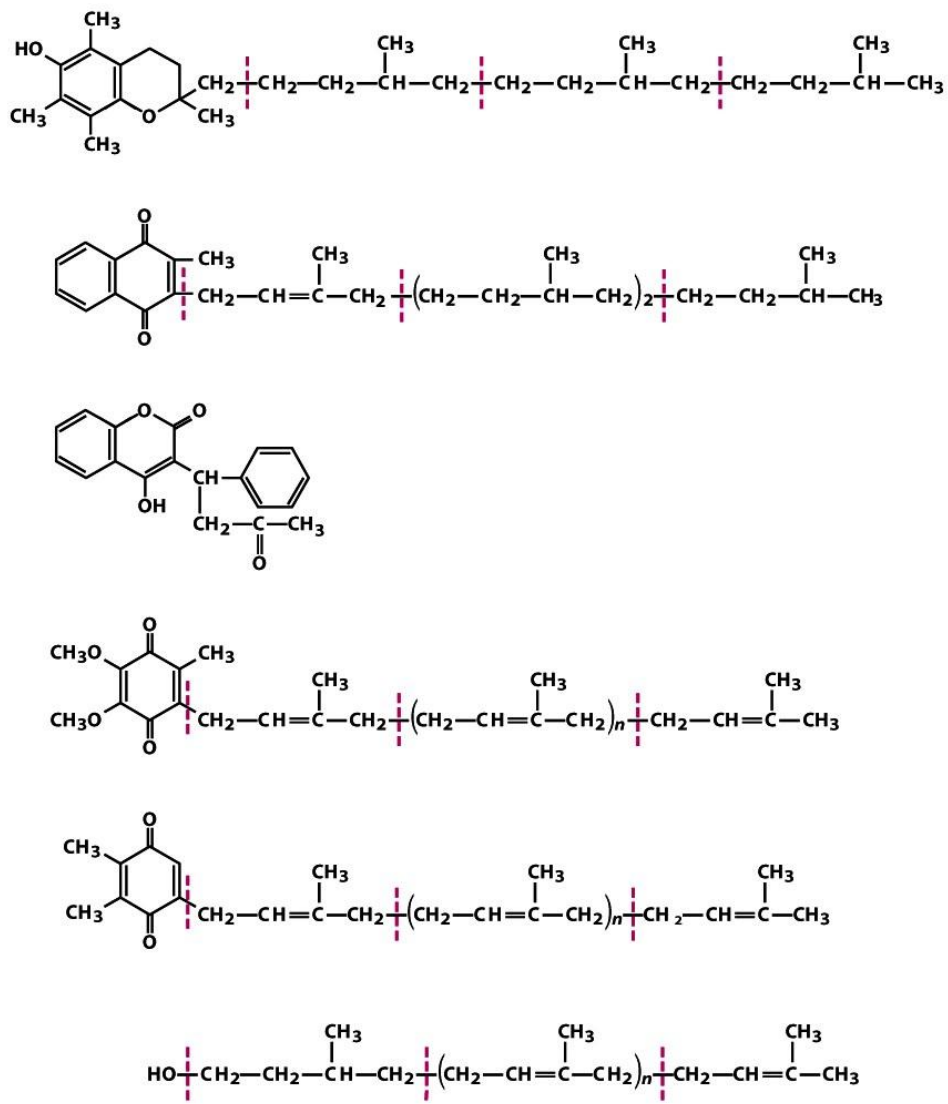


Figure 10-22

Extraction, Separation, and Identification of Cellular Lipids

- (a) Tissue is homogenized in a chloroform/methanol/water mixture, which on addition of water and removal of unextractable sediment by centrifugation yields two phases.
- Different types of extracted lipids in the chloroform phase may be separated by
  - (b) **adsorption chromatography** on a column of silica gel, through which solvents of increasing polarity are passed, or
  - (c**) thin-layer chromatography (TLC)**, in which lipids are carried up a silica gel-coated plate by a rising solvent front, less polar lipids traveling farther than more polar or charged lipids. TLC with appropriate solvents can also be used to separate closely related lipid species; for example, the charged lipids phosphatidylserine, phosphatidylglycerol, and phosphatidylinositol are easily separated by TLC.

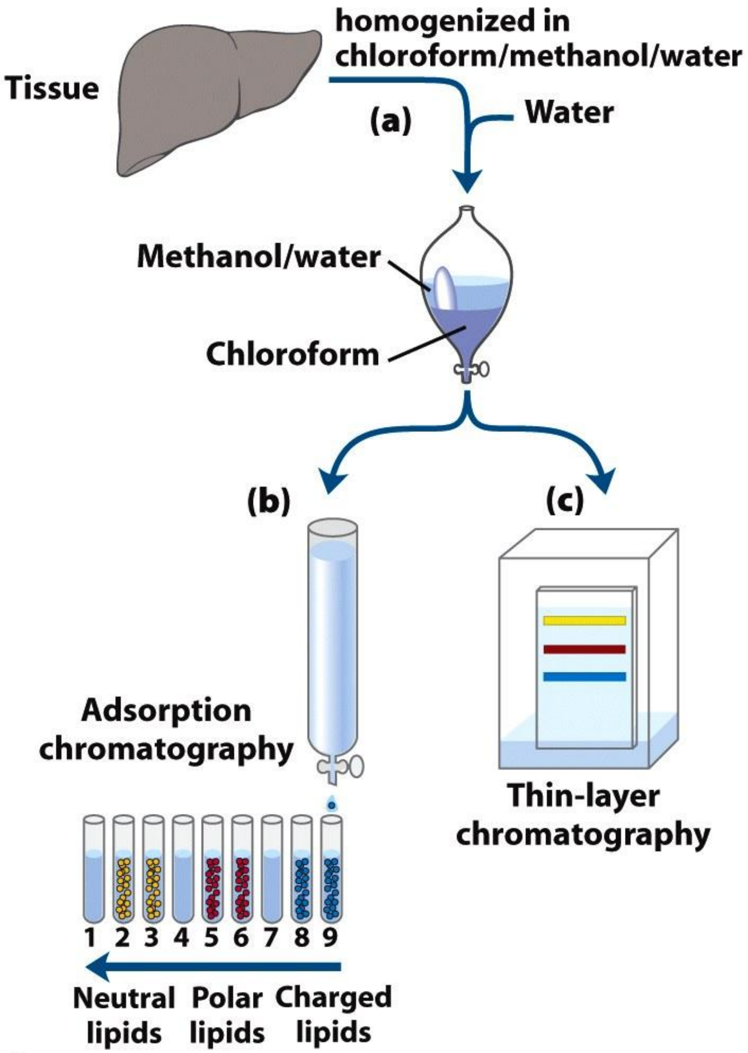


Figure 10-24 part 1
Lehninger Principles of Biochemistry, Fifth Edition

Extraction, Separation, and Identification of Cellular Lipids

- For the determination of **fatty acid composition**, a lipid fraction containing ester-linked fatty acids is **transesterified** in a warm aqueous solution of NaOH and methanol
  - (d), producing a mixture of fatty acyl methyl esters. These methyl esters are then **separated on the basis of chain length and degree of saturation** by
  - (e) **gas-liquid chromatography** (GLC) or
  - (f) **high-performance liquid chromatography** (HPLC).

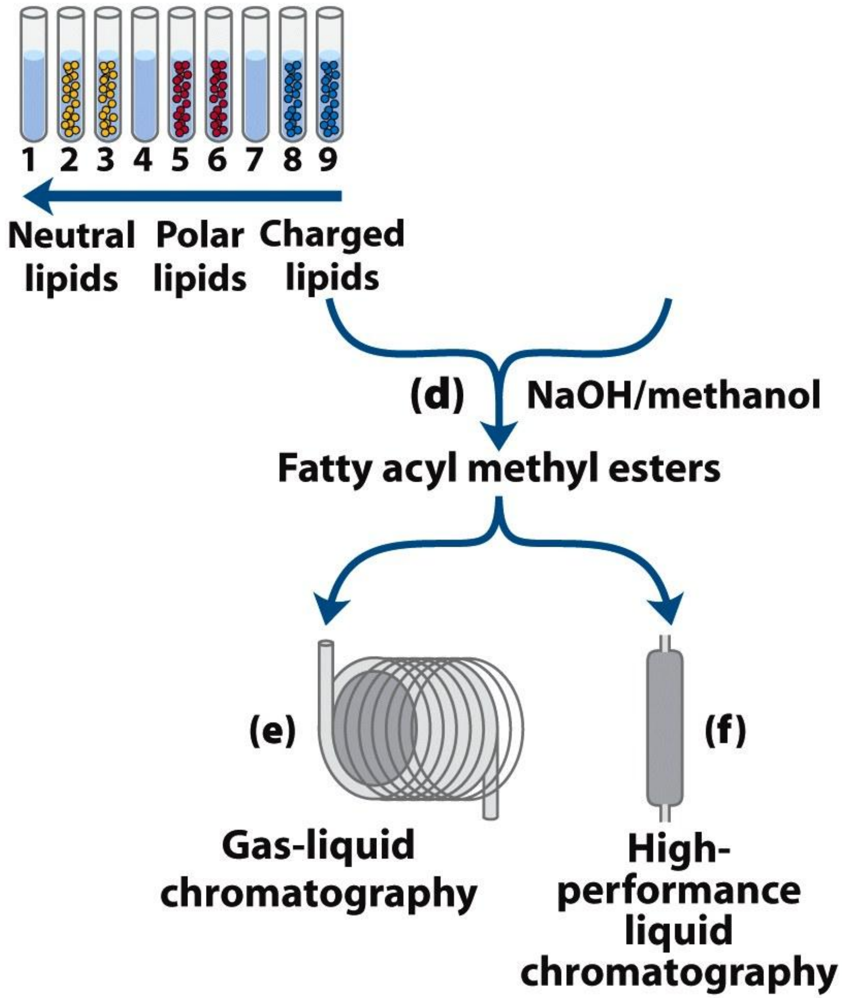


Figure 10-24 part 2
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Extraction, Separation, and Identification of Cellular Lipids

- Precise determination of molecular mass by **mass spectrometry** allows unambiguous identification of individual lipids.

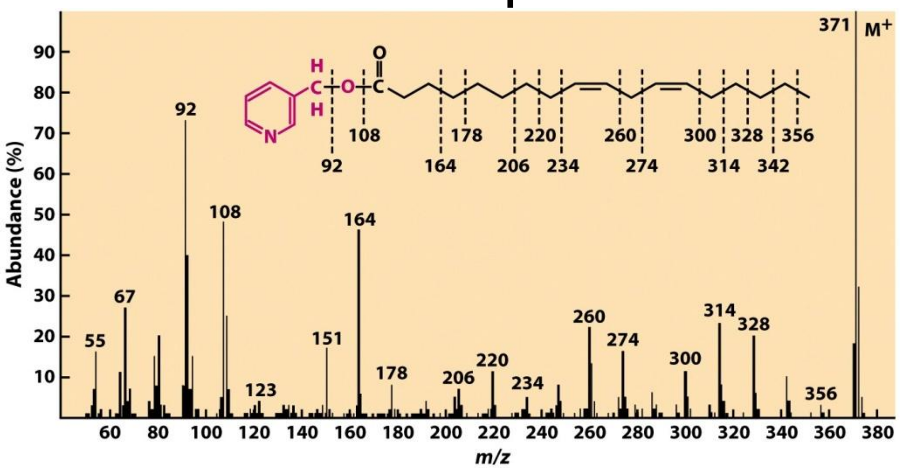


Figure 10-25
Lehninger Principles of Biochemistry, Fifth Edition

The derivative shown here is a picolinyl ester of linoleic acid—18:2($\Delta^{9,12}$) (M_r 371)—in which the alcohol is picolinol (red). When bombarded with a stream of electrons, this molecule is volatilized and converted to a parent ion (M^+; M_r 371), in which the N atom bears the positive charge, and a series of smaller fragments produced by breakage of C–C bonds in the fatty acid.

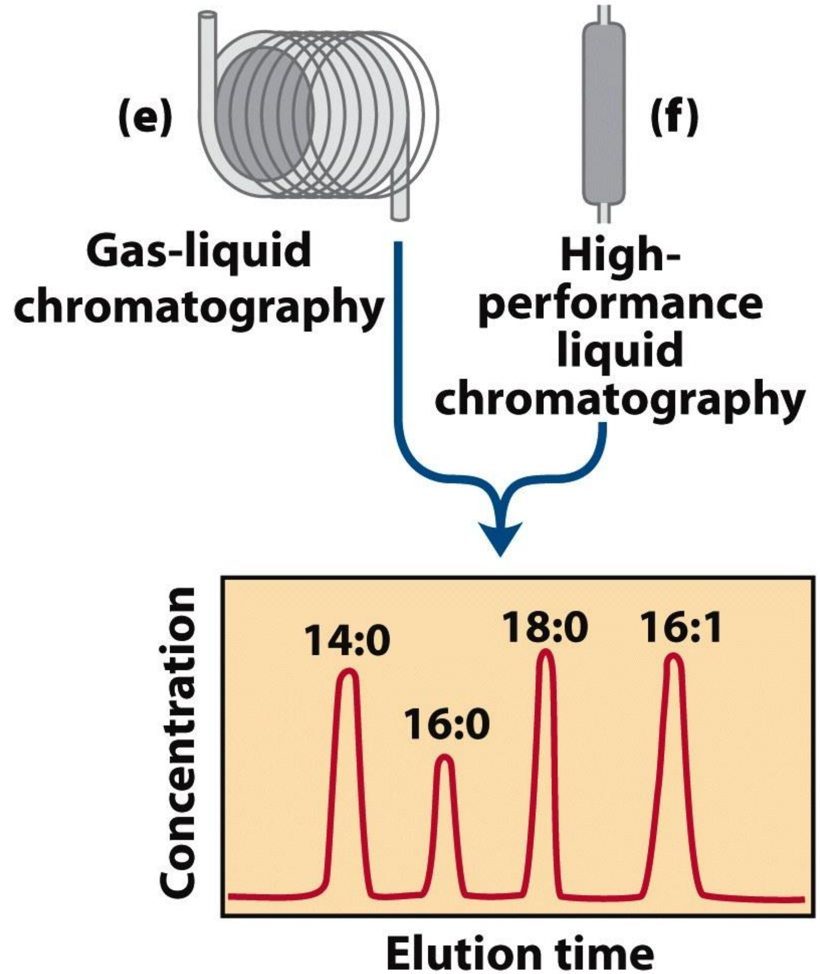
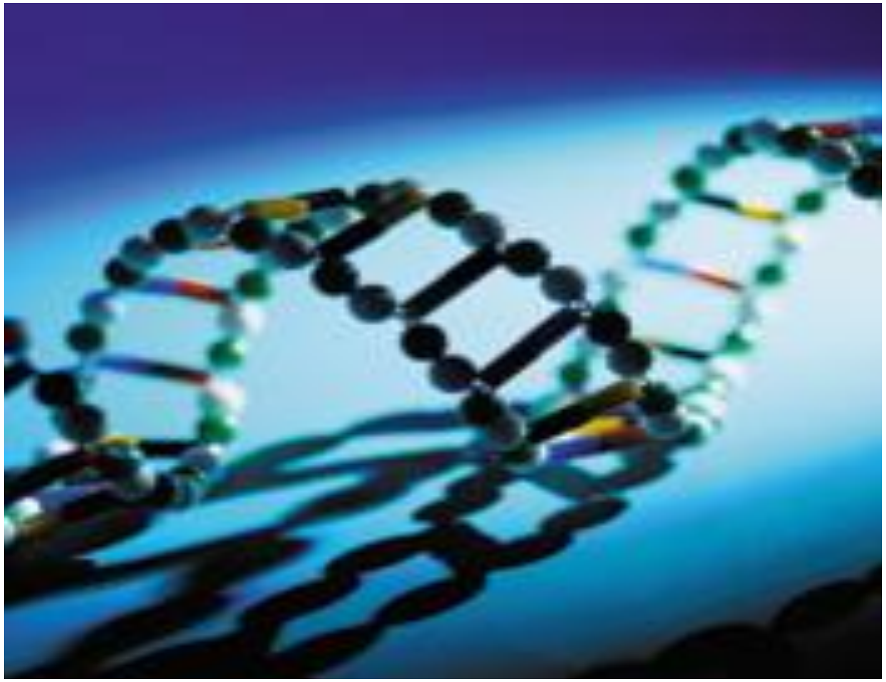


Figure 10-24 part 3
Lehninger Principles of Biochemistry, Fifth Edition

Einige Fragen....

- <u>Lipide</u>
- 1) Was ist ein Lipid. Geben sie ein Beispiel und nennen sie die entsprechende Funktion.
- 2) Was versteht man unter gesättigten und ungesättigten Fettsäuren. Geben sie jeweils ein Beispiel. Wie verhalten sie sich bei Raumtemperatur?
- 3) Skizzieren und beschreiben sie den Aufbau eines Speicherlipids. Wo kommen diese Verbindungen vor?
- 4) Beschreiben sie den Aufbau eines Wachses. Geben sie ein Beispiel und nennen sie die charakteristischen Eigenschaften.
- 5) Skizzieren und beschreiben sie den Aufbau eines Glycerophospholipids. Wo kommen diese Verbindungen vor?
- 6) Was ist die Besonderheit bei archaealen Membranlipiden?
- 7) Geben sie jeweils ein Beispiel für ein Lipid als Signalmolekül, Cofaktor oder Pigment.
- 8) Wie werden zelluläre Lipide analysiert und identifiziert.

Nucleotides & Nucleic Acids



Nucleotides & Nucleic Acids

- They play crucial roles in:
- Nucleotides
  - Energy currency in metabolic transactions
  - Chemical links in cell response (hormones, extracellular stimuli)
  - Constituents of nucleic acids (DNA & RNA)
  - Molecular respositories of genetic information

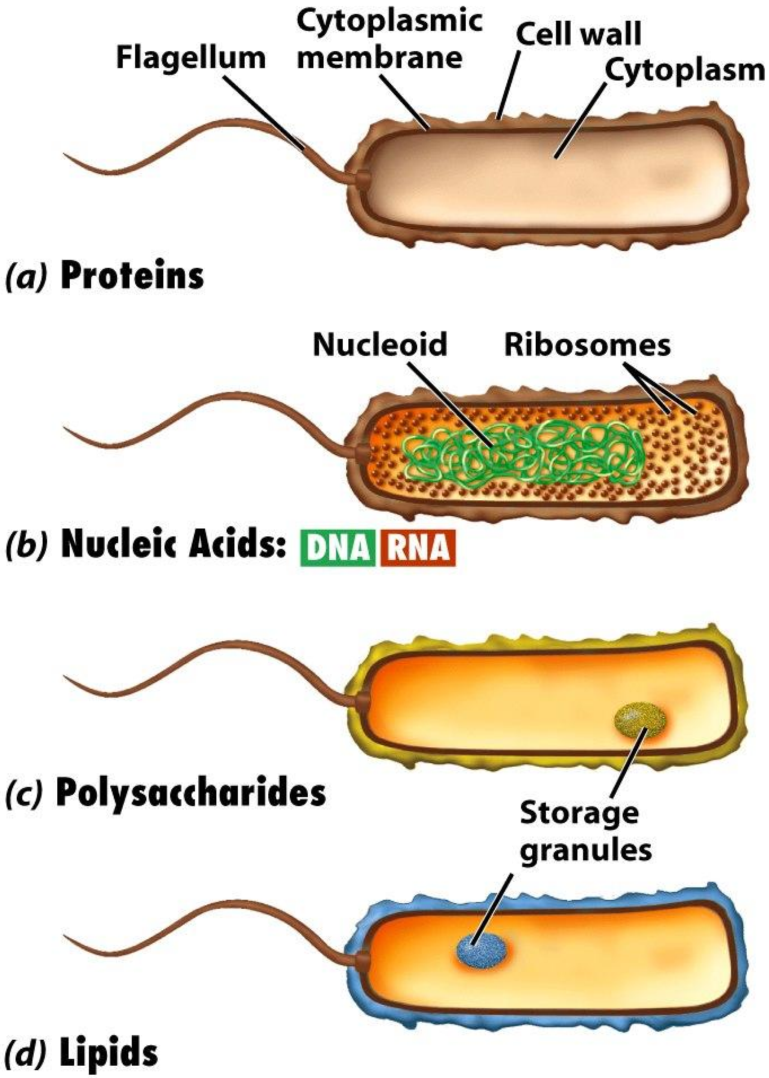


Figure 3-3 Brock Biology of Microorganisms 11/e

Nucleotides

- Three building blocks:
  - Nitrogen-containing base
  - Pentose
  - At least one phosphate

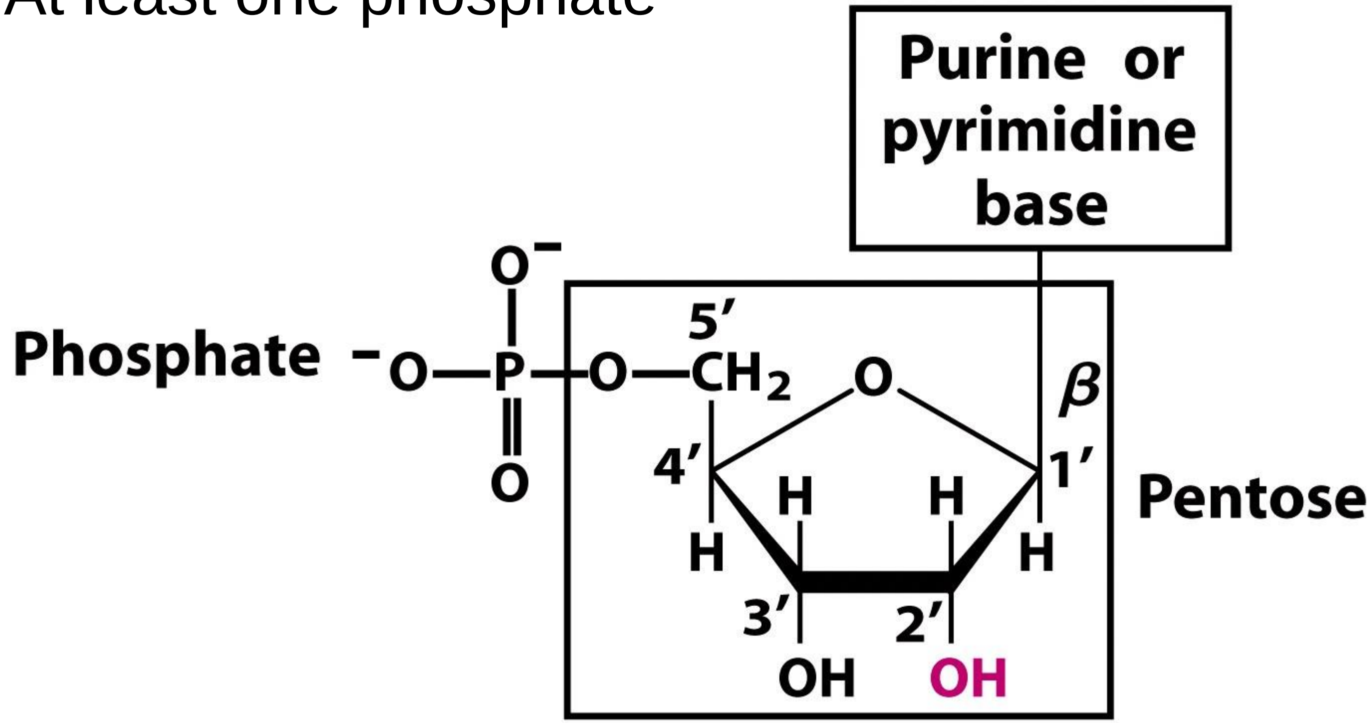
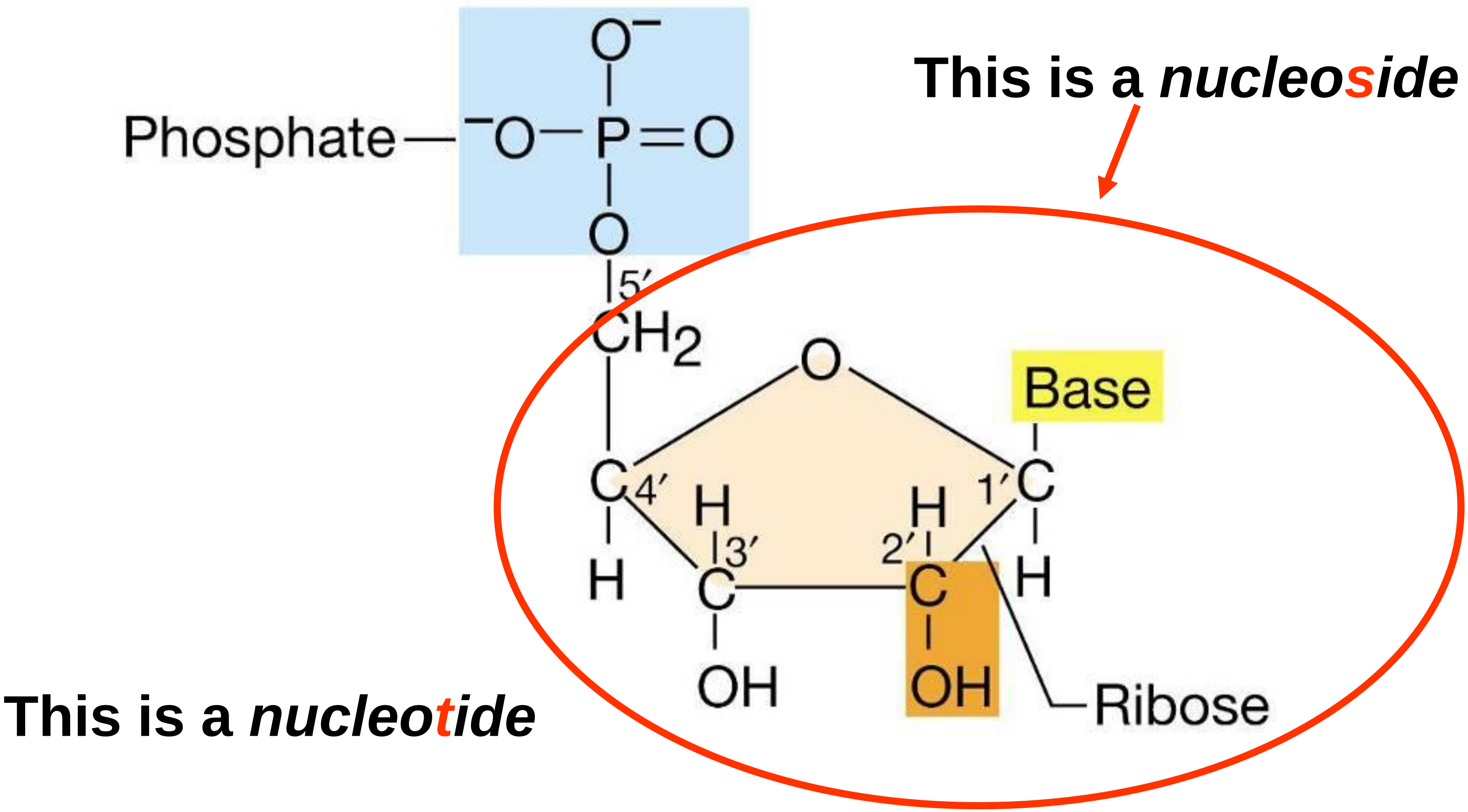


Figure 8-1a
Lehninger Principles of Biochemistry, Fifth Edition

Nucleosides & Nucleotides

- **Nucleotides** (sugar, base and phophate)
- **Nucleoside** (sugar and base, without phosphate)



Ribose

- In solution, the straight-chain (aldehyde) and ring (*β*-furanose) forms of free ribose are in equilibrium. RNA contains only the ring form, ***β*-D-ribofuranose**.
- Deoxyribose undergoes a similar interconversion in solution, but in DNA exists solely as ***β*-2′-deoxy-D-ribofuranose**.

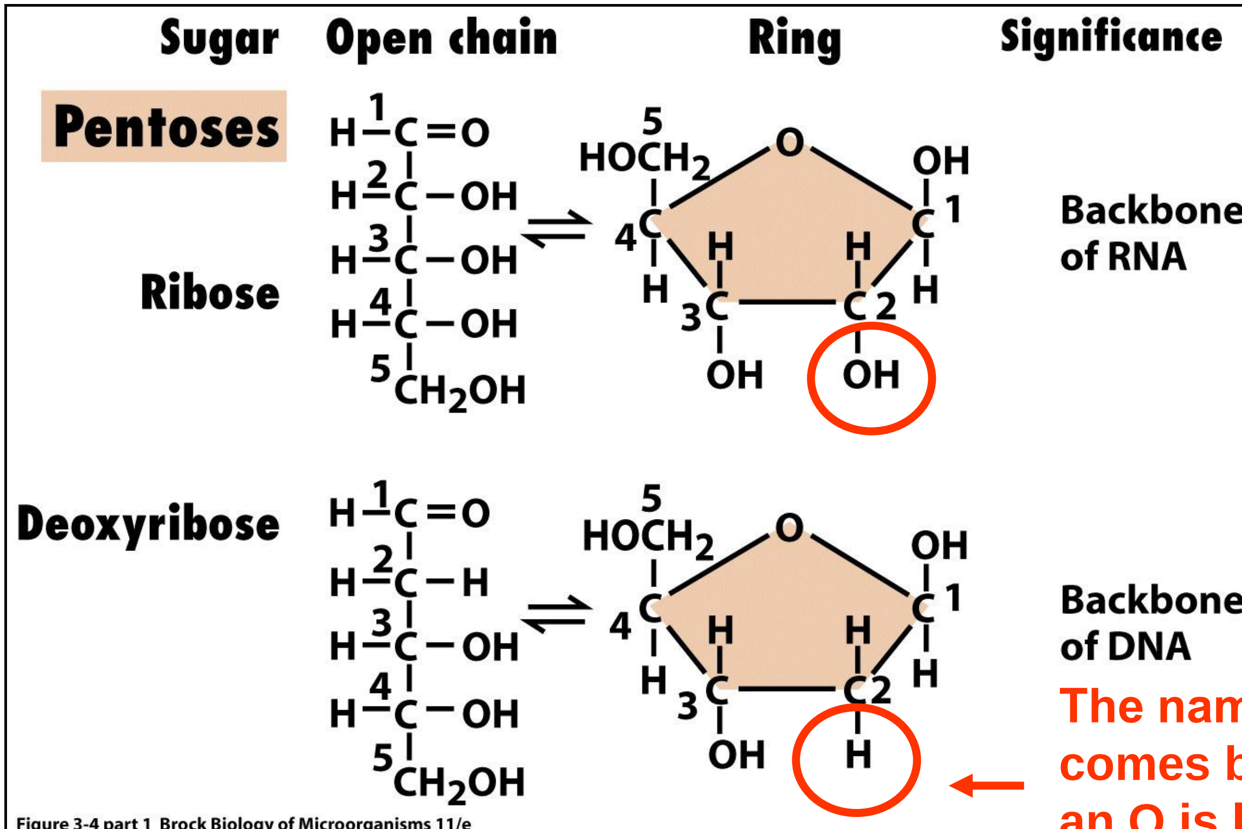
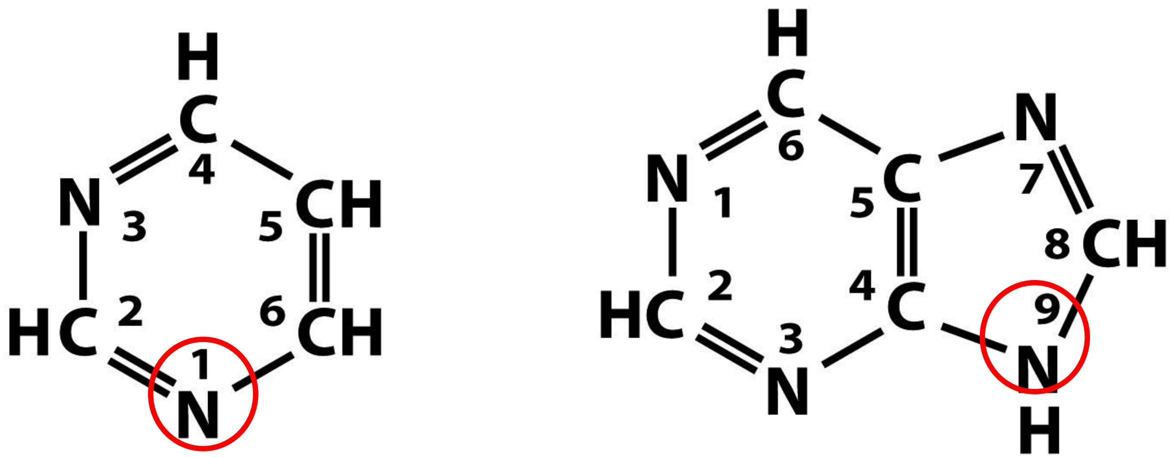


Figure 3-4 part 1 Brock Biology of Microorganisms 11/e

The name „deoxy“ comes because here an O is lacking

Pyrimidine and Purine Bases

- The nitrogenous bases are derivatives of two parent compounds:
  - Glycoside linkage between carbon atom (C1) and nitrogen atom (N1, pyrimidine base, N9 purine base)



Pyrimidine **Purine**

Figure 8-1b
Lehninger Principles of Biochemistry, Fifth Edition

Pyrimidine and Purine Bases

- Major purine and pyrimidine bases of nucleic acids.

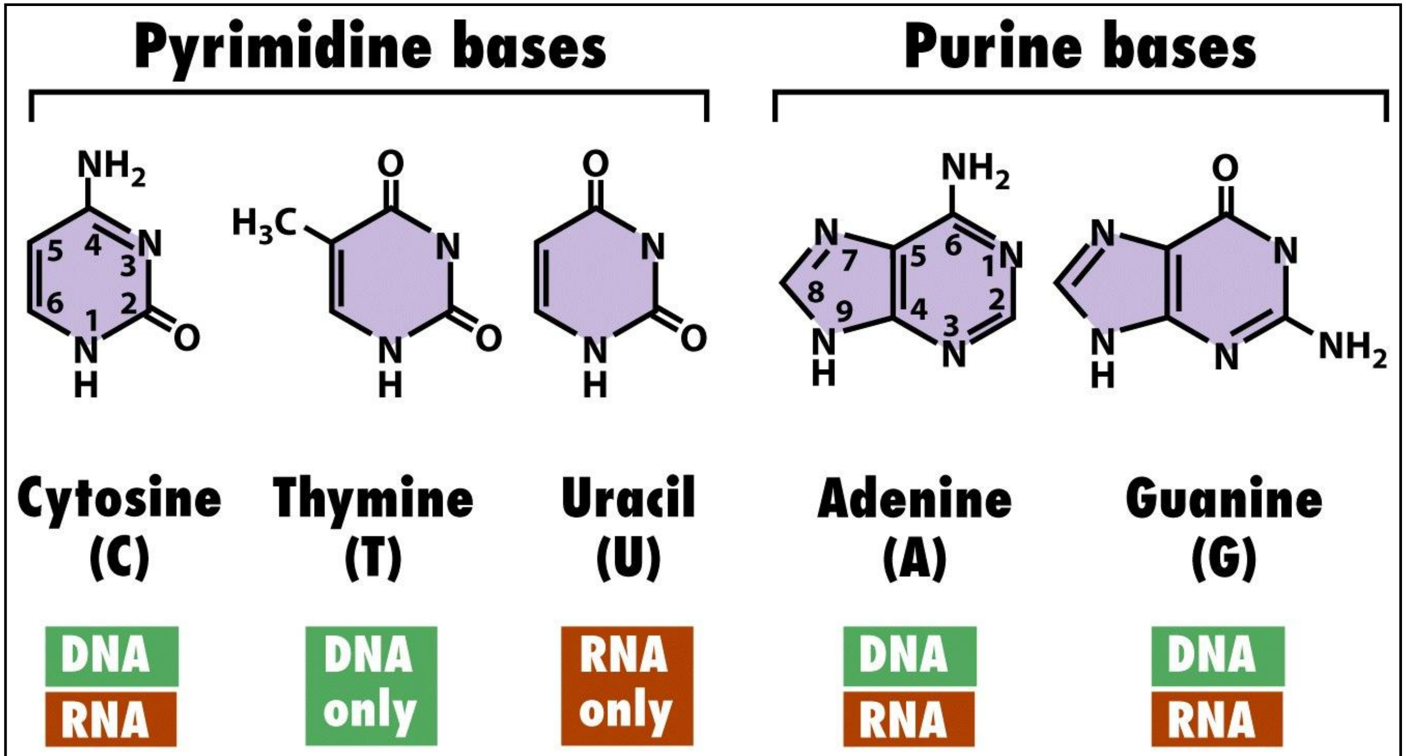


Figure 3-9 Brock Biology of Microorganisms 11/e

Tautomers of Bases

- **Tautomers** of adenine, cytosine, guanine, thymine, and uracil.
- At **physiological pH**, the equilibria of these tautomerization reactions lie far in the direction of the **amino** and **lactam** forms.

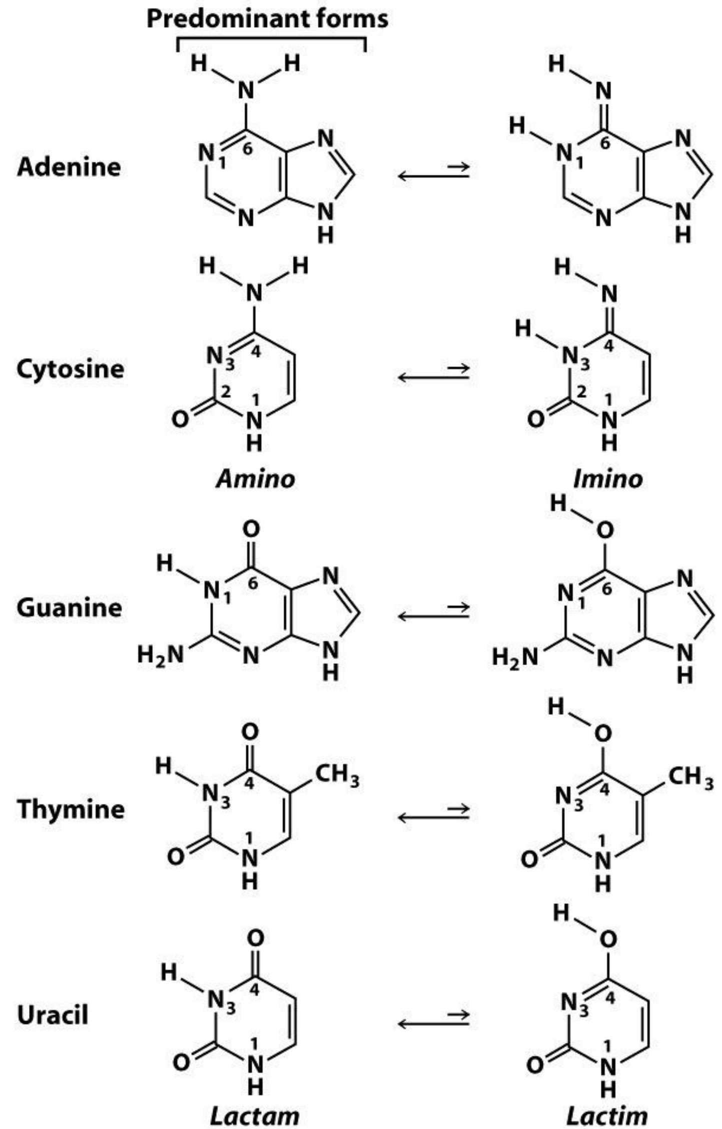


Figure 19-5 Principles of Biochemistry, 4/e

Nomenclature

TABLE 8–1 Nucleotide and Nucleic Acid Nomenclature

Base	Nucleoside	Nucleotide	Nucleic acid
Purines			
Adenine	Adenosine Deoxyadenosine	Adenylate Deoxyadenylate	RNA DNA
Guanine	Guanosine Deoxyguanosine	Guanylate Deoxyguanylate	RNA DNA
Pyrimidines			
Cytosine	Cytidine Deoxycytidine	Cytidylate Deoxycytidylate	RNA DNA
Thymine	Thymidine or deoxythymidine	Thymidylate or deoxythymidylate	DNA
Uracil	Uridine	Uridylate	RNA

Note: "Nucleoside" and "nucleotide" are generic terms that include both ribo- and deoxyribo- forms. Also, ribonucleosides and ribonucleotides are here designated simply as nucleosides and nucleotides (e.g., riboadenosine as adenosine), and deoxyribonucleosides and deoxyribonucleotides as deoxynucleosides and deoxynucleotides (e.g., deoxyriboadenosine as deoxyadenosine). Both forms of naming are acceptable, but the shortened names are more commonly used. Thymine is an exception; "ribothymidine" is used to describe its unusual occurrence in RNA.

Table 8-1
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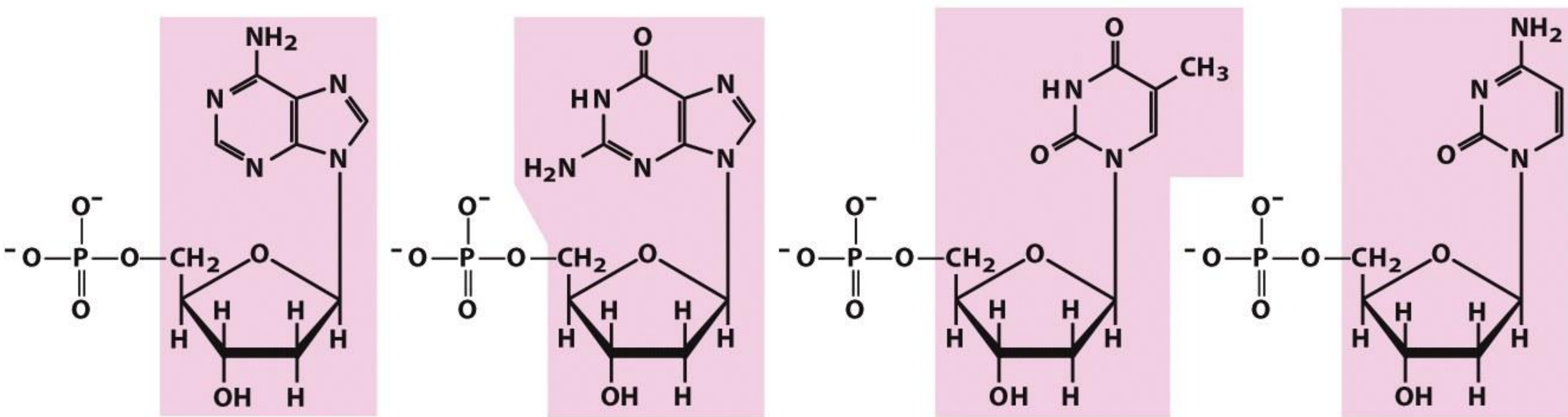
Deoxyribonucleotides of Nucleic Acid



Nucleotide:	**Deoxyadenylate (deoxyadenosine 5′-monophosphate)**	**Deoxyguanylate (deoxyguanosine 5′-monophosphate)**	**Deoxythymidylate (deoxythymidine 5′-monophosphate)**	**Deoxycytidylate (deoxycytidine 5′-monophosphate)**
Symbols:	**A, dA, dAMP**	**G, dG, dGMP**	**T, dT, dTMP**	**C, dC, dCMP**
Nucleoside:	**Deoxyadenosine**	**Deoxyguanosine**	**Deoxythymidine**	**Deoxycytidine**

Deoxyribonucleotides

Figure 8-4a
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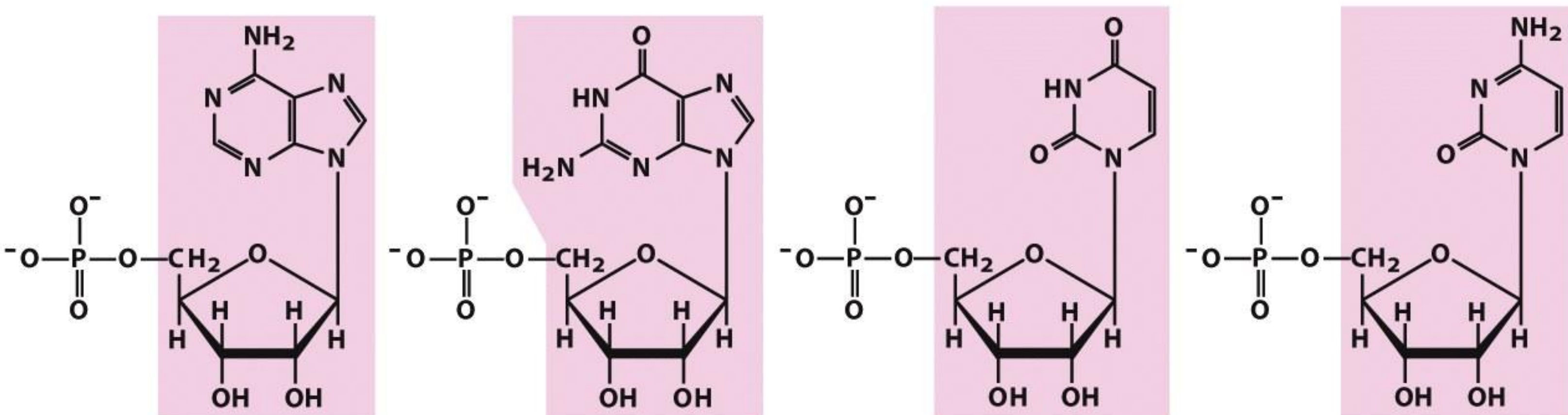
Ribonucleotides of Nucleic Acid



Nucleotide:	Adenylate (adenosine 5′-monophosphate)	Guanylate (guanosine 5′-monophosphate)	Uridylate (uridine 5′-monophosphate)	Cytidylate (cytidine 5′-monophosphate)
Symbols:	A, AMP	G, GMP	U, UMP	C, CMP
Nucleoside:	Adenosine	Guanosine	Uridine	Cytidine

Ribonucleotides

Figure 8-4b
Lehninger Principles of Biochemistry, Fifth Edition

Minor Purine and Pyrimidine bases

- Minor bases of **DNA** (shown as nucleosides).
- 5-Methylcytidine occurs in the DNA of animals and higher plants,
- *N*^{6}-methyladenosine in bacterial DNA, and
- 5-hydroxymethylcytidine in the DNA of bacteria infected with certain bacteriophages.

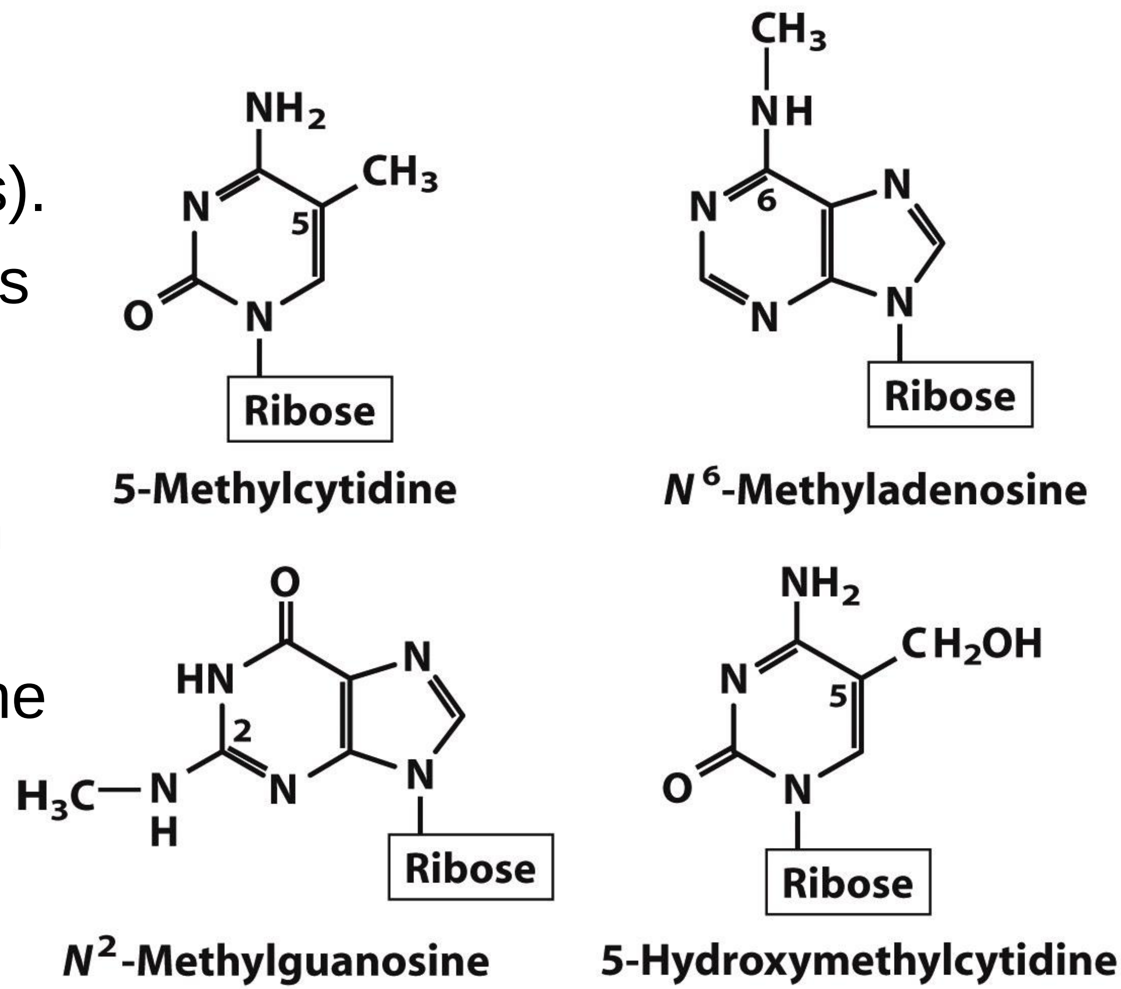


Figure 8-5a
Lehninger Principles of Biochemistry, Fifth Edition

Minor Purine and Pyrimidine bases

- Some minor bases of **tRNAs**.
- **Inosine** contains the base hypoxanthine.
- Note that **pseudouridine**, like uridine, contains uracil; they are distinct in the point of attachment to the ribose:
  - in uridine, uracil is attached through N-1, the usual attachment point for pyrimidines;
  - in pseudouridine, through C-5.

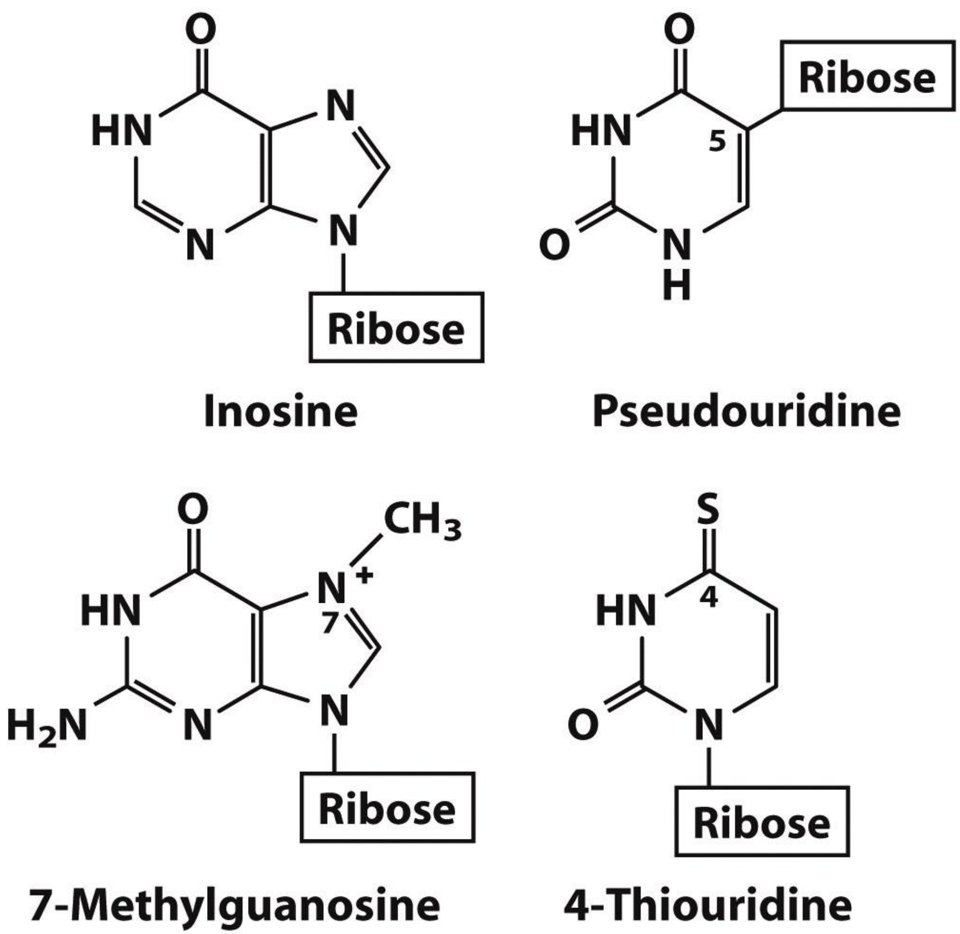


Figure 8-5b
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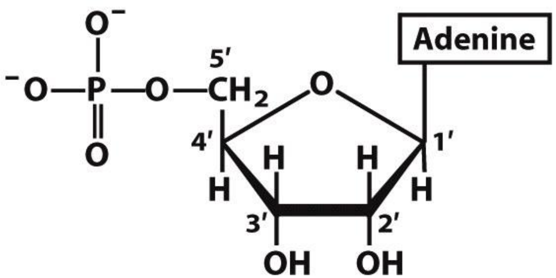
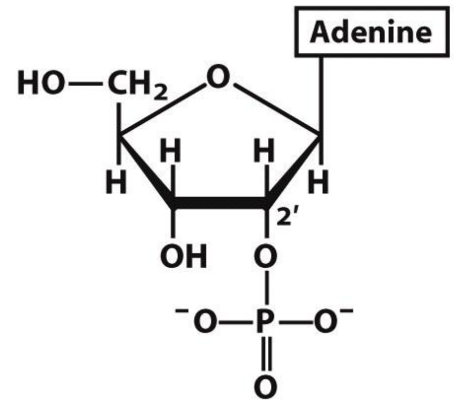
Adenosine Monophosphates

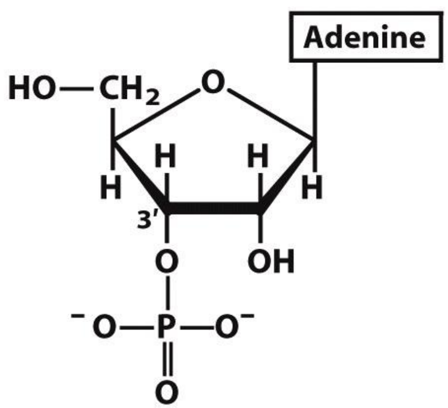
- Adenosine 2′-monophosphate, 3′-monophosphate, and 2′,3′-cyclic monophosphate are formed by enzymatic and **alkaline hydrolysis of RNA**.



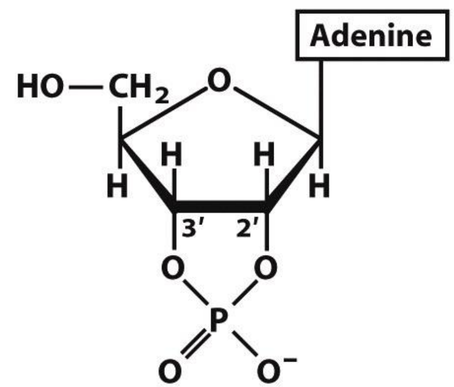
Adenosine 5′-monophosphate



Adenosine 2′-monophosphate



Adenosine 3′-monophosphate

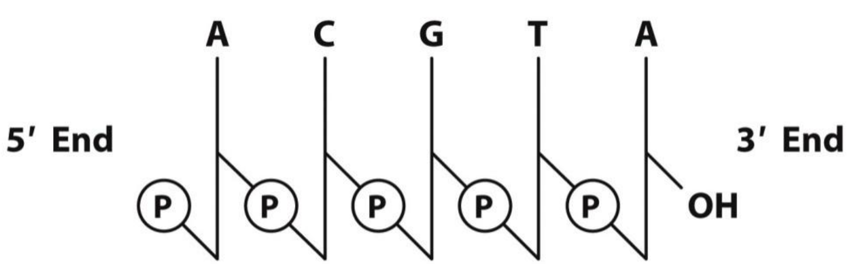


Adenosine 2′,3′-cyclic monophosphate

Figure 8-6

Phosphodiester linkages in the covalent backbone of DNA and RNA

- The **phosphodiester bonds** (one of which is shaded in the DNA) link successive nucleotide units.
- The backbone of alternating pentose and phosphate groups in both types of nucleic acid is **highly polar**.
- The 5′ end of the macromolecule lacks a nucleotide at the 5′ position, and the 3′ end lacks a nucleotide at the 3′ position.



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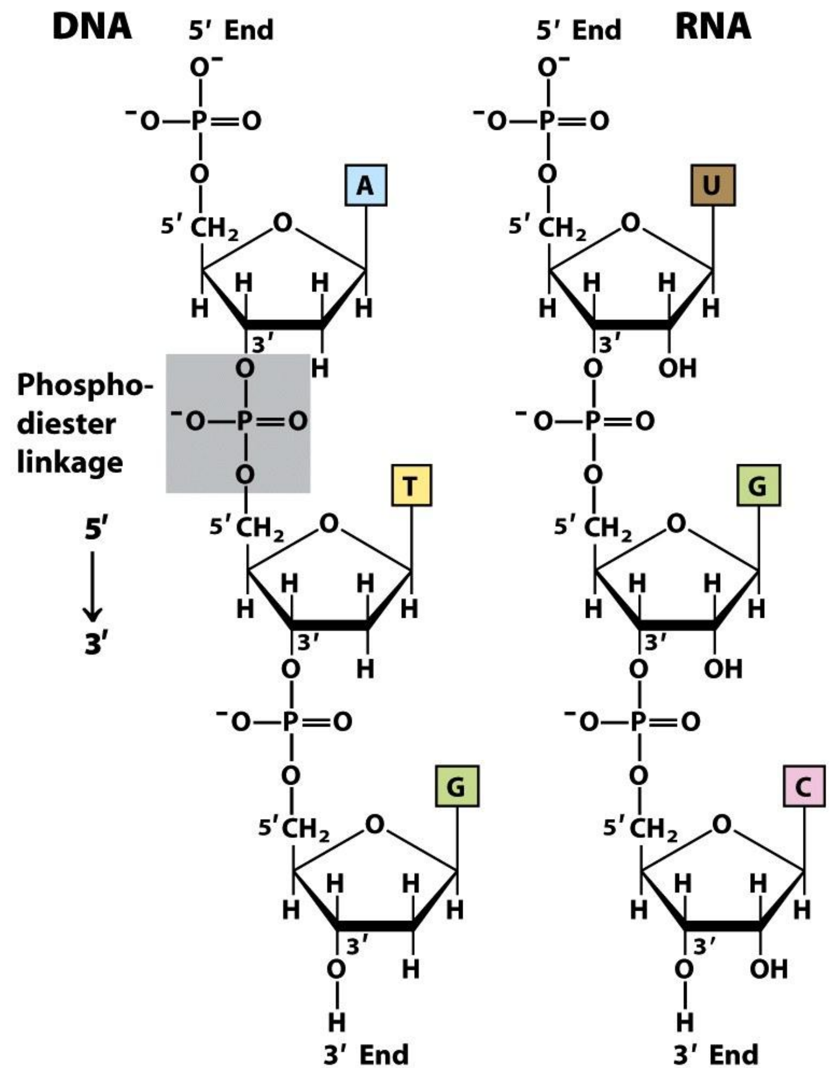

Figure 8-7
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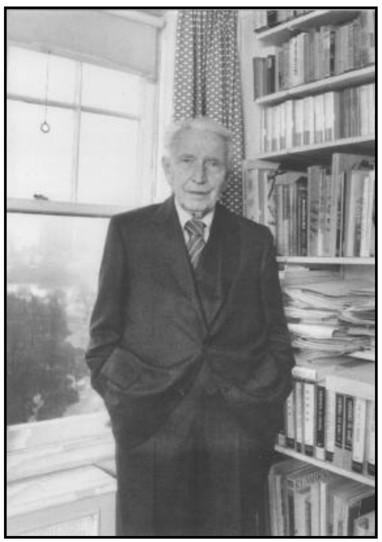
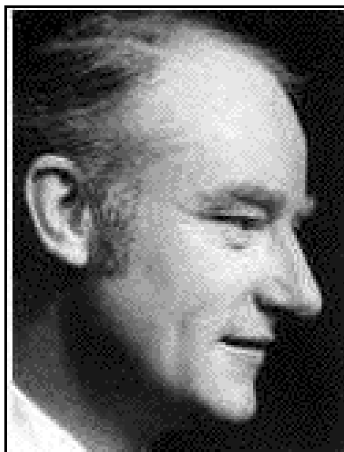
DNA as a double helix

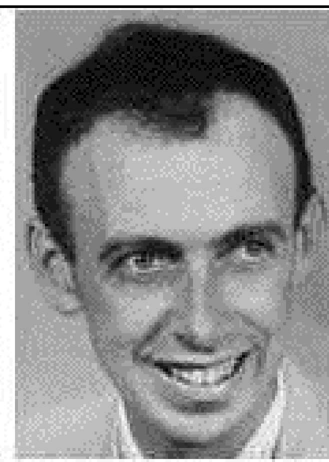
- **1947 Chargaff,**
  A=T, G=C equalities (Chargaff's rule)
- **1950s Crick, Watson, Wilkins & Franklin, double helix**



Erwin Chargaff



Francis Crick

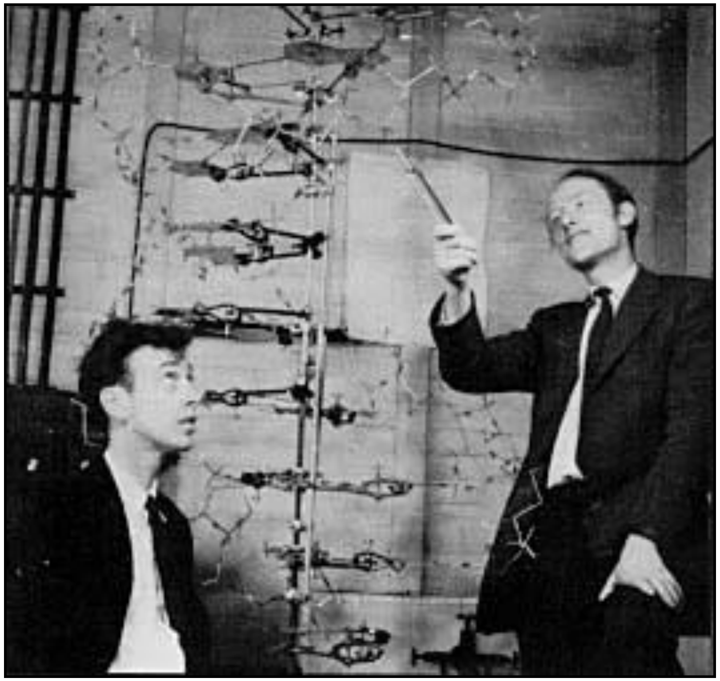


James Watson

Maurice Wilkins

Rosalind Franklin

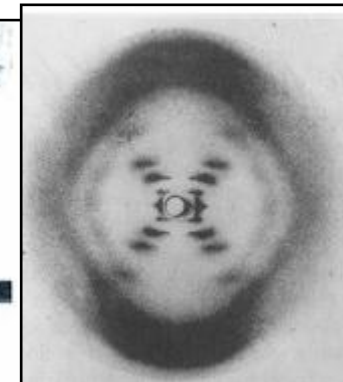
DNA as a double helix



Watson and Crick (1953)

Nobelpreis 1962

(Watson, Crick & Wilkins)



Rosalind Franklin

&Maurice Wilkins

-Röntgenbeugungsbilder

Base Pairing

- Hydrogen-bonding patterns in the base pairs defined by Watson and Crick

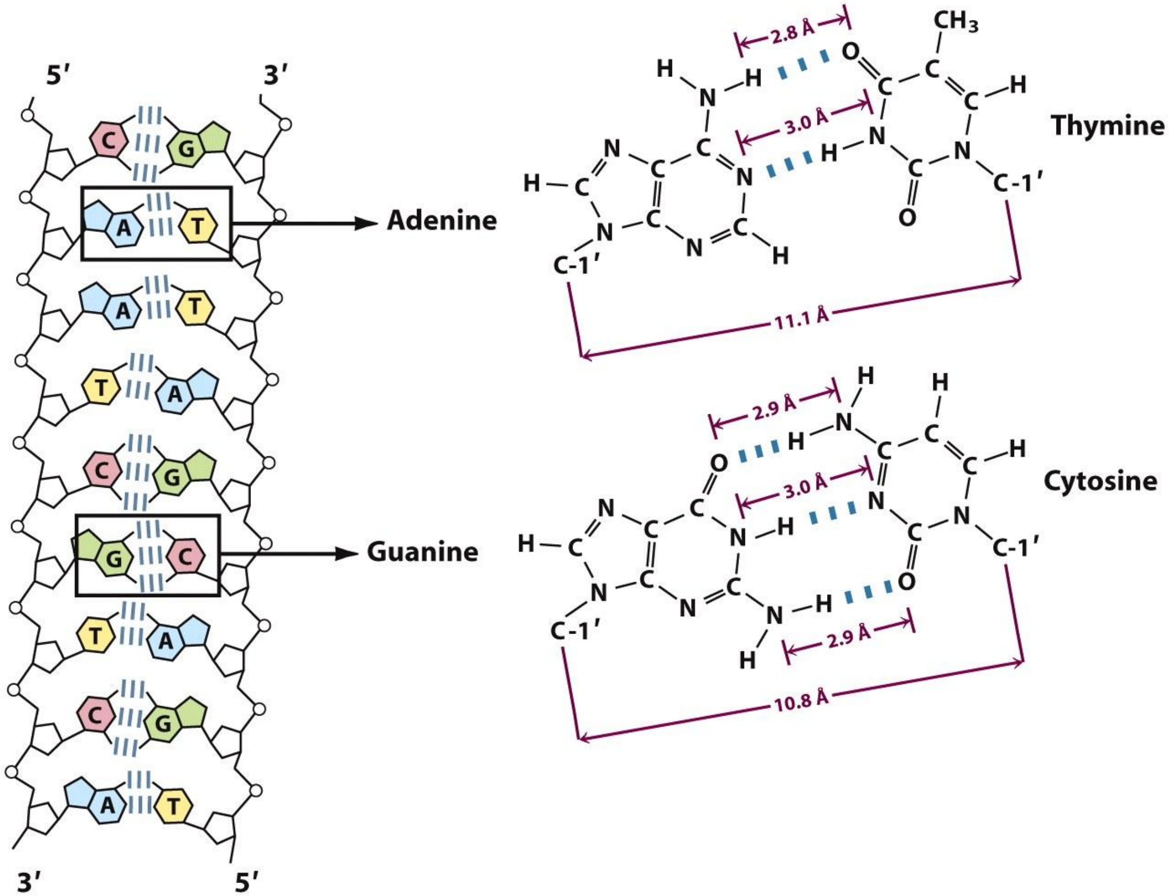


Figure 8-11
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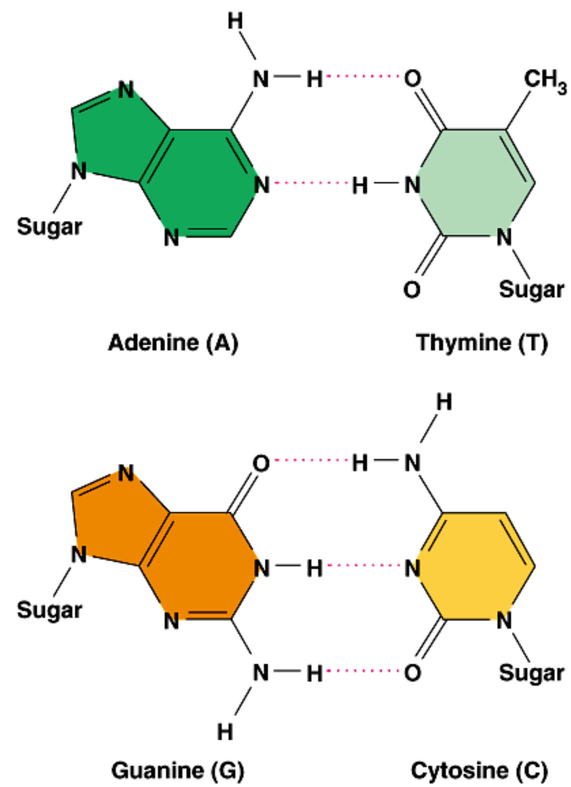

The DNA Double Helix

- Two DNA strands are antiparallel

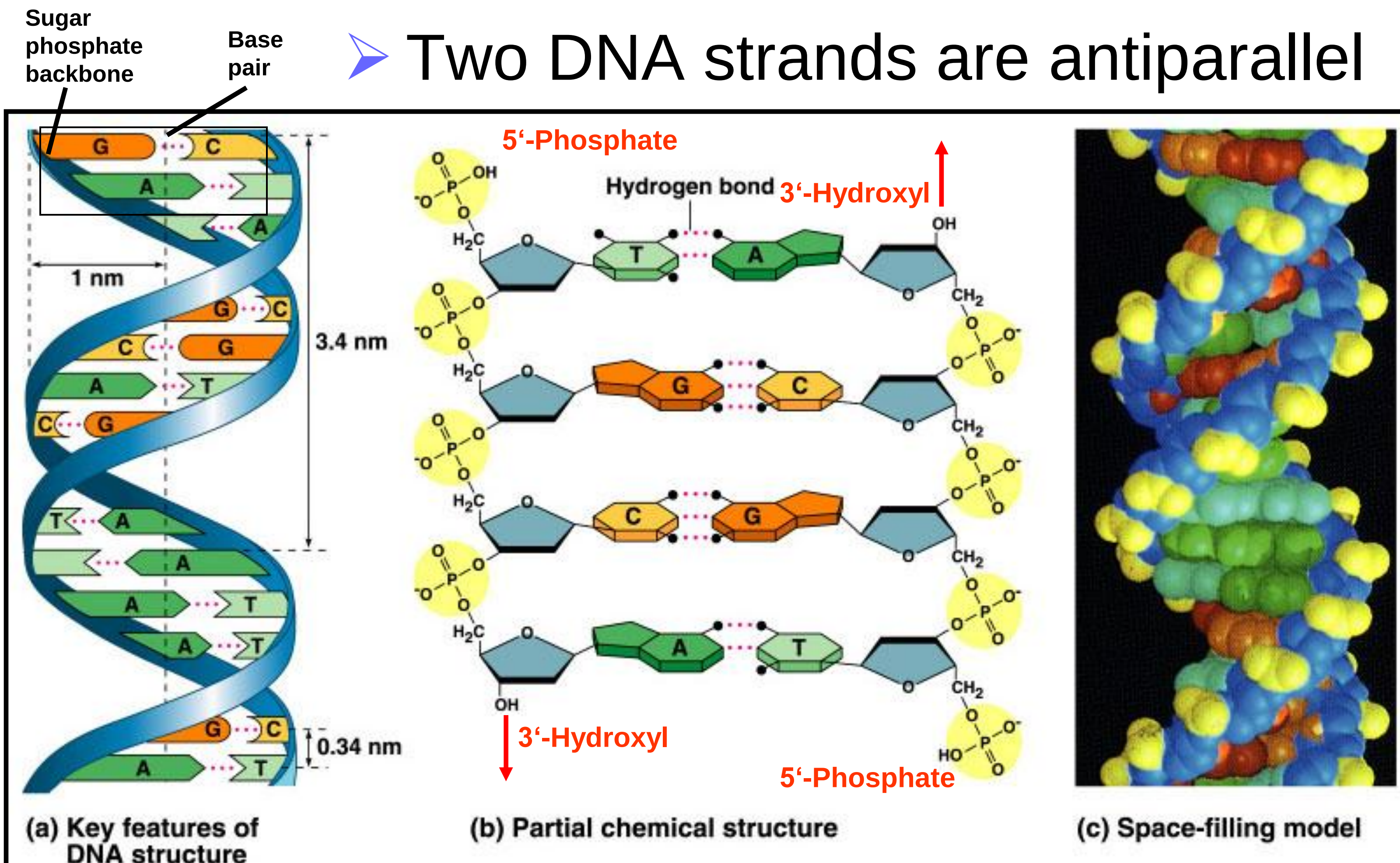

FIGURE 16.5 Biology 6/e

Structural Variation of DNA

- The conformation of a nucleotide in DNA is affected by rotation about seven different bonds.
- Six of the bonds rotate freely.
- Limited rotation at bond 4.

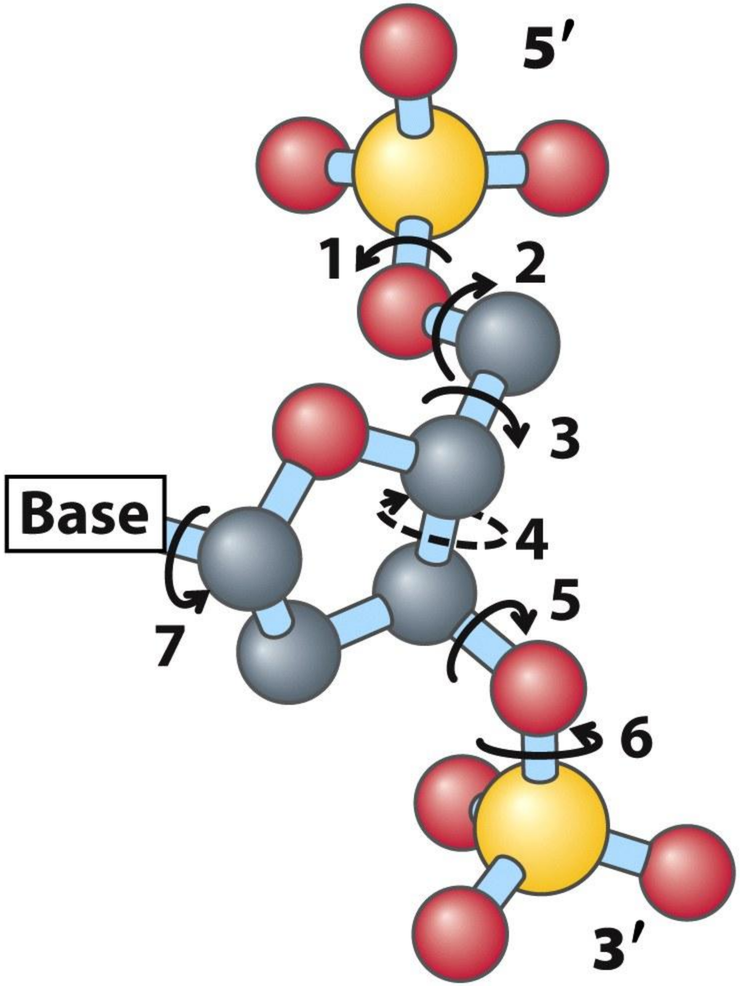

Figure 8-16a
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Structural Variation of DNA

- For **purine bases** in nucleotides, only two conformations with respect to the attached ribose units are sterically permitted, **anti or syn**.
- **Pyrimidines** generally occur in the **anti** conformation.

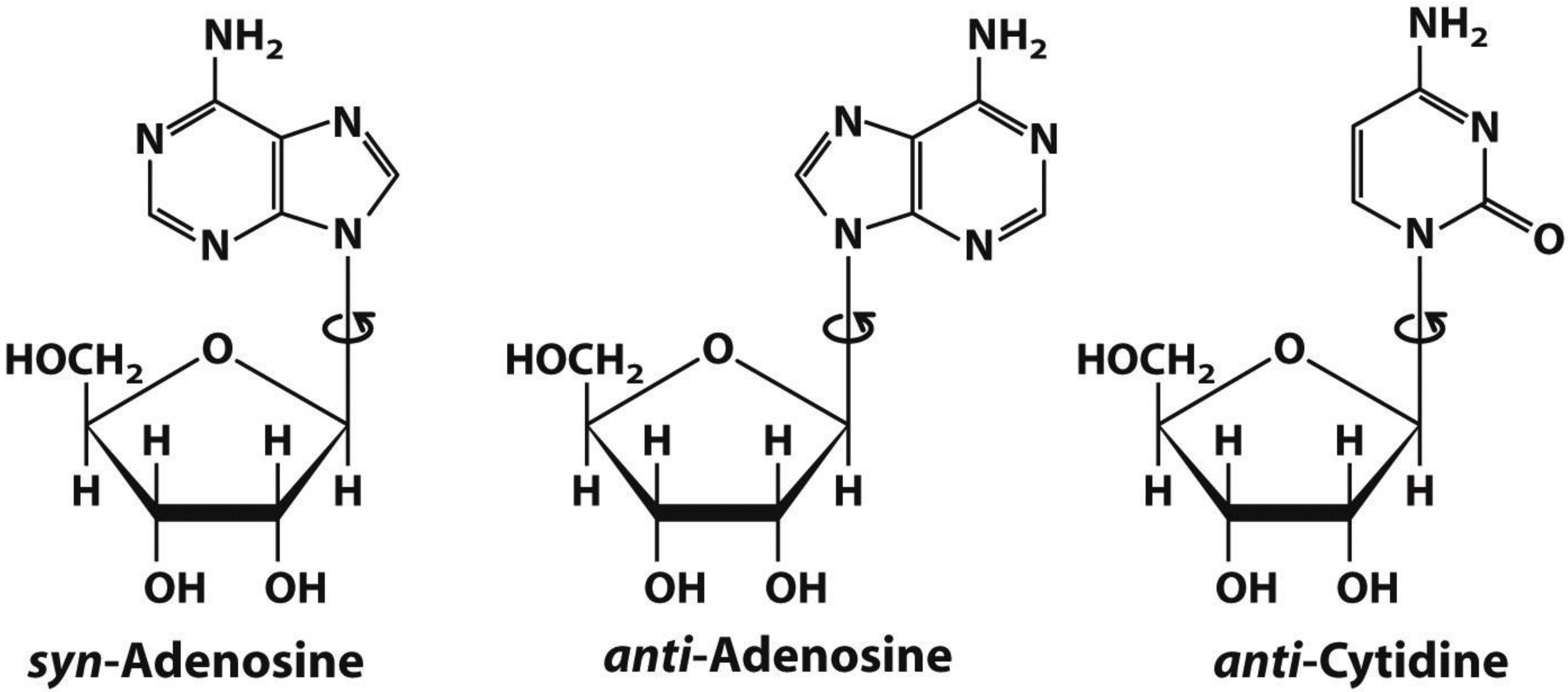

Figure 8-16b
Lehninger Principles of Biochemistry, Fifth Edition

Conformation of dsDNA

- Comparison of A, B, and Z forms of DNA (Each structure shown here has 36 base pairs).
- The **A-DNA** conformation (left) is favored when DNA is dehydrated. Right handed helix. Occurrence in cells unclear.
- **B-DNA** (center) is the conformation normally found inside cells. Right handed helix (Watson-Crick helix)
- The **Z-DNA** conformation (right) is favored in certain G/C-rich sequences. Left handed helix, DNA backbone with zigzag appearance; Purine residues flip to syn-conformation altering with pyrimidines in anti-conformation.

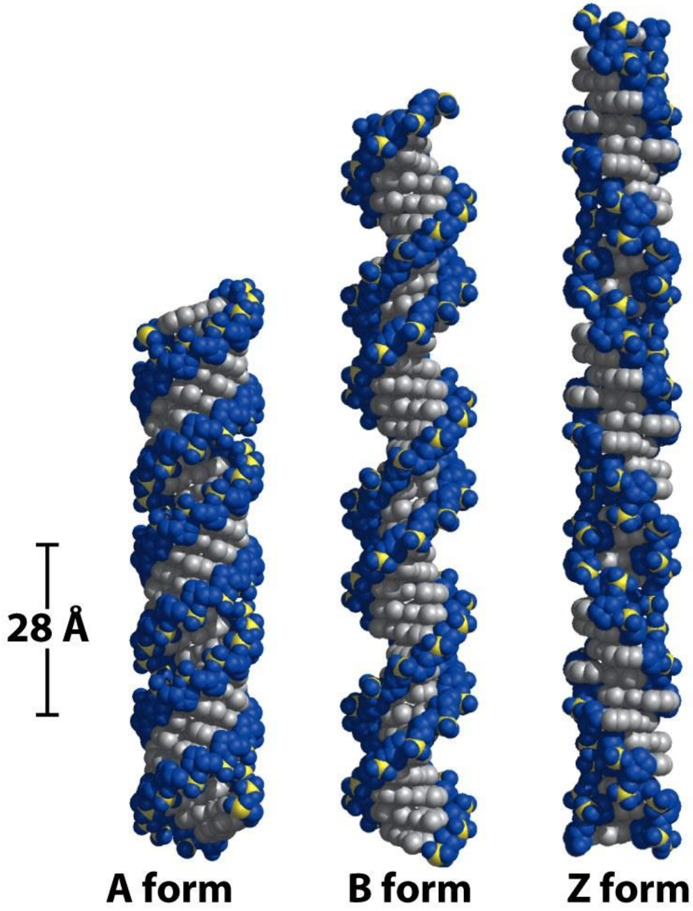

Figure 8-17 part 1
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Unusual DNA Structures

- Palindromes are sequences of **double-stranded nucleic acids** with **twofold symmetry**. **ROTATOR**
- A **mirror repeat** has a **symmetric** sequence within each strand.

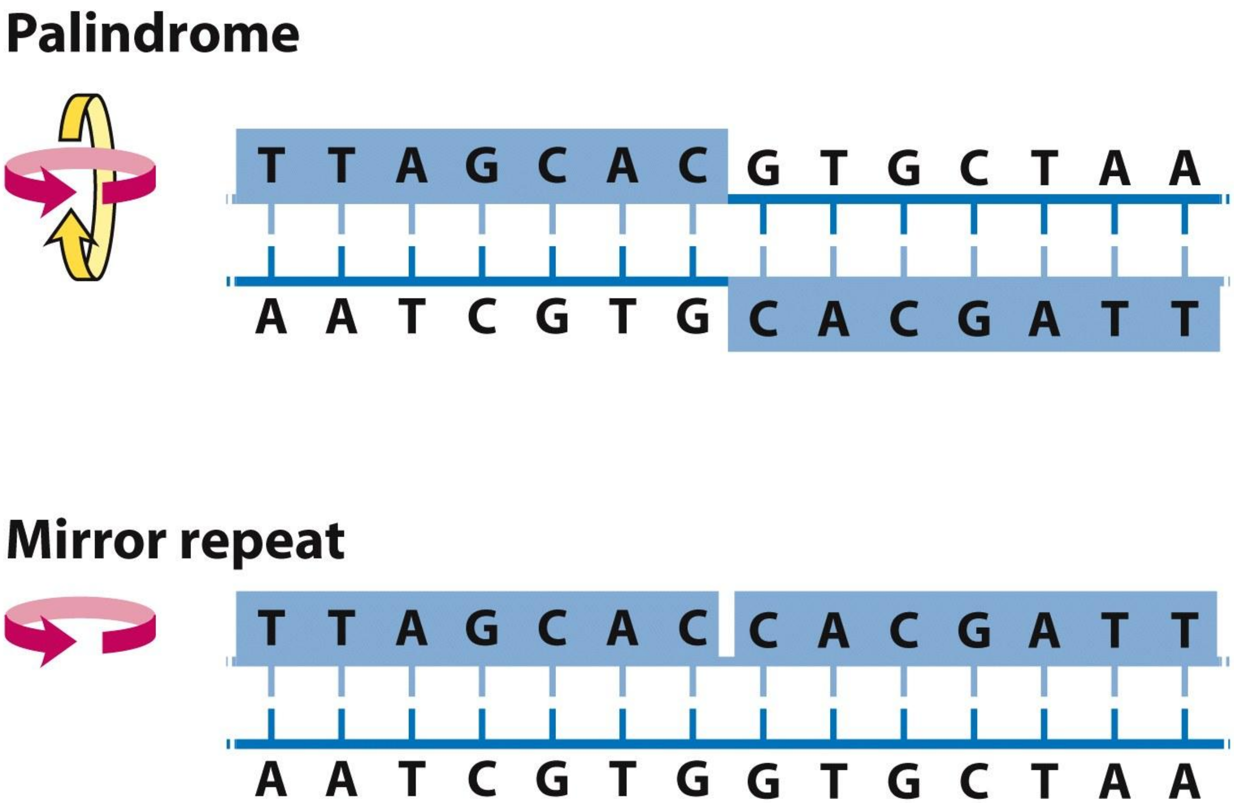

Figure 8-18
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Hairpins and Cruciforms

- **Palindromic DNA (or RNA)** sequences can form alternative structures **with intrastrand base pairing**.
- (a) When only a **single DNA (or RNA) strand** is involved, the structure is called a **hairpin**.
- (b) When **both strands of a duplex DNA** are involved, it is called a **cruciform**.

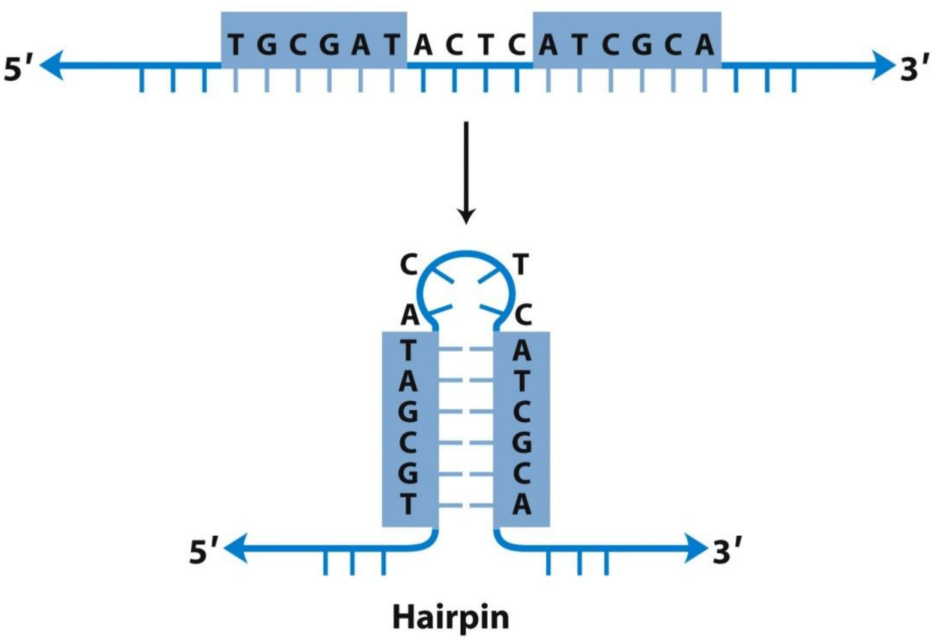

Figure 8-19a
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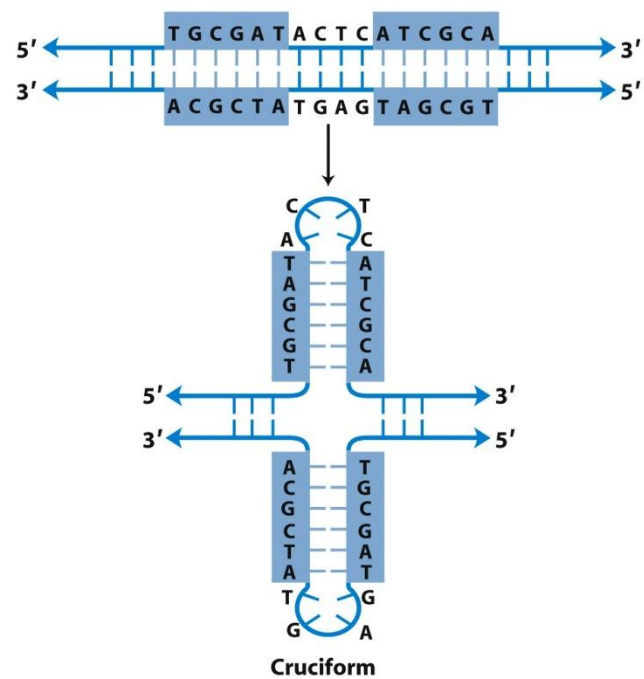

Figure 8-19b
Lehninger Principles of Biochemistry, Fifth Edition

DNA structures containing three or four DNA strands

- **Triplex DNA**: The DNA double helix can under certain conditions accommodate a third strand in its major groove.
- Natural DNA only forms a triplex if the targeted strand is **rich in purines - guanine (G) and adenine (A)** - which in addition to the bonds of the Watson-Crick base pairing can form two further hydrogen bonds, and the 'third strand' oligonucleotide has the matching sequence of pyrimidines - cytosine (C) and thymine (T).

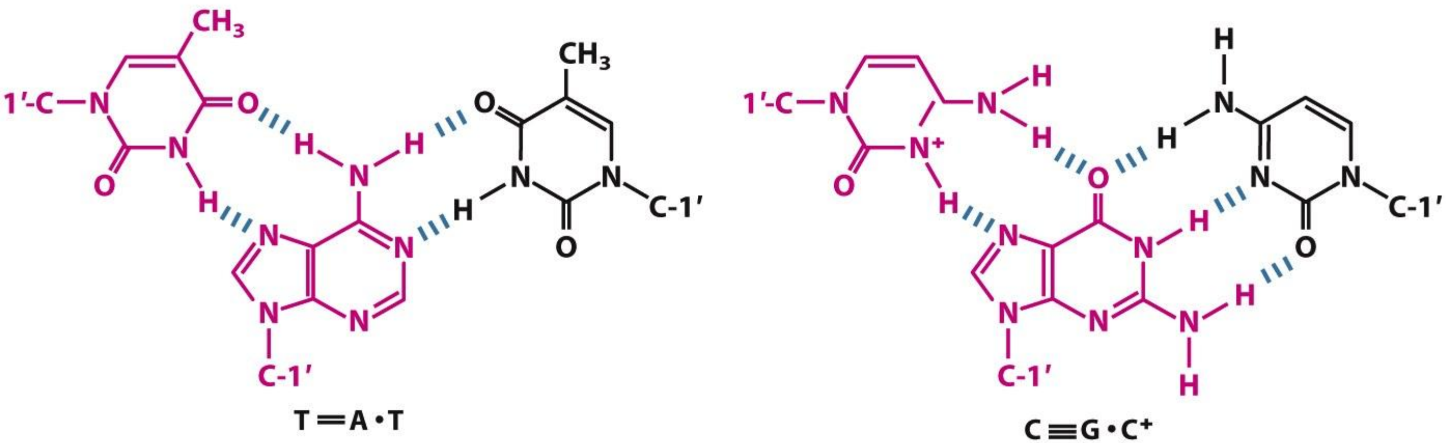

Figure 8-20a
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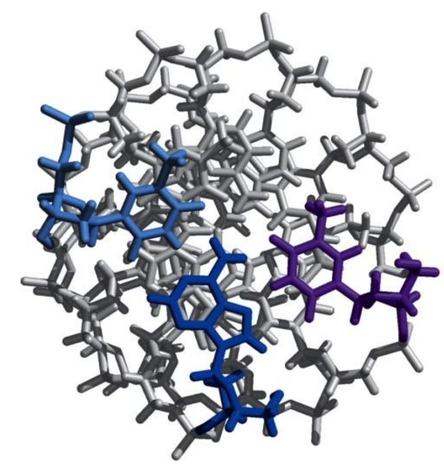
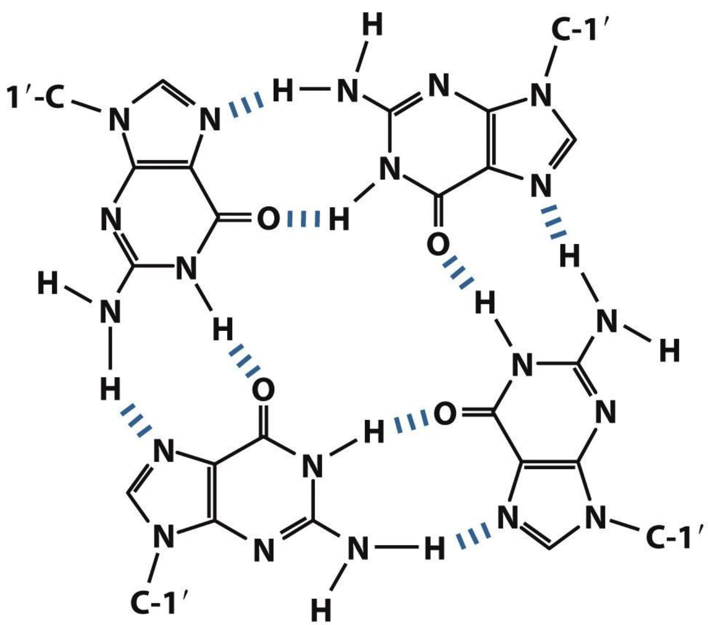


Figure 8-20b
Lehninger Principles of Biochemistry, Fifth Edition

Guanosine Tetraplex Structure

- Only for DNA sequences with **high portion of guanosine**.
- Function of tetraplex structures of regulatory sequences in **transcriptional regulation** suggested



Guanosine tetraplex

Figure 8-20c
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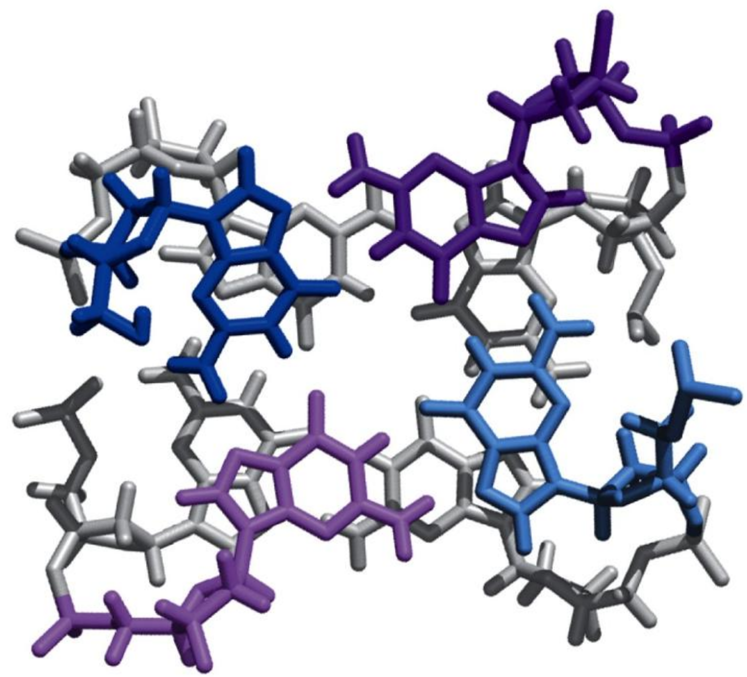

Figure 8-20d
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Absorption spectra of double-stranded and single-stranded DNA

- At pH 7.0, doublestranded DNA has an absorbance maximum near 260 nm.
- Denatured DNA absorbs 12% to 40% more ultraviolet light than doublestranded DNA.

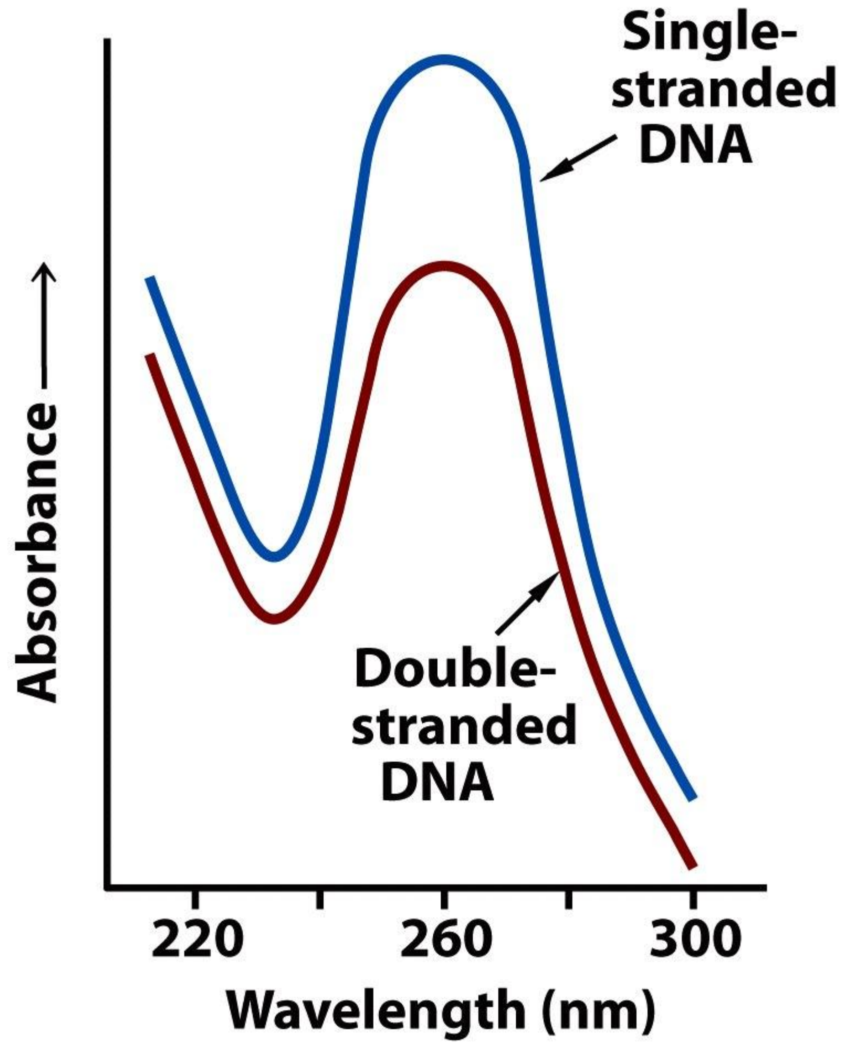

Figure 19-16 Principles of Biochemistry, 4/e

Melting Curve of DNA

- The **melting point (T_m)** corresponds to the inflection point of the sigmoidal curve
- Poly(AT) melts at a lower temperature than either naturally occurring DNA or poly(GC) since more energy is required to disrupt stacked G/C base pairs.
- **Heat denaturation of DNA**

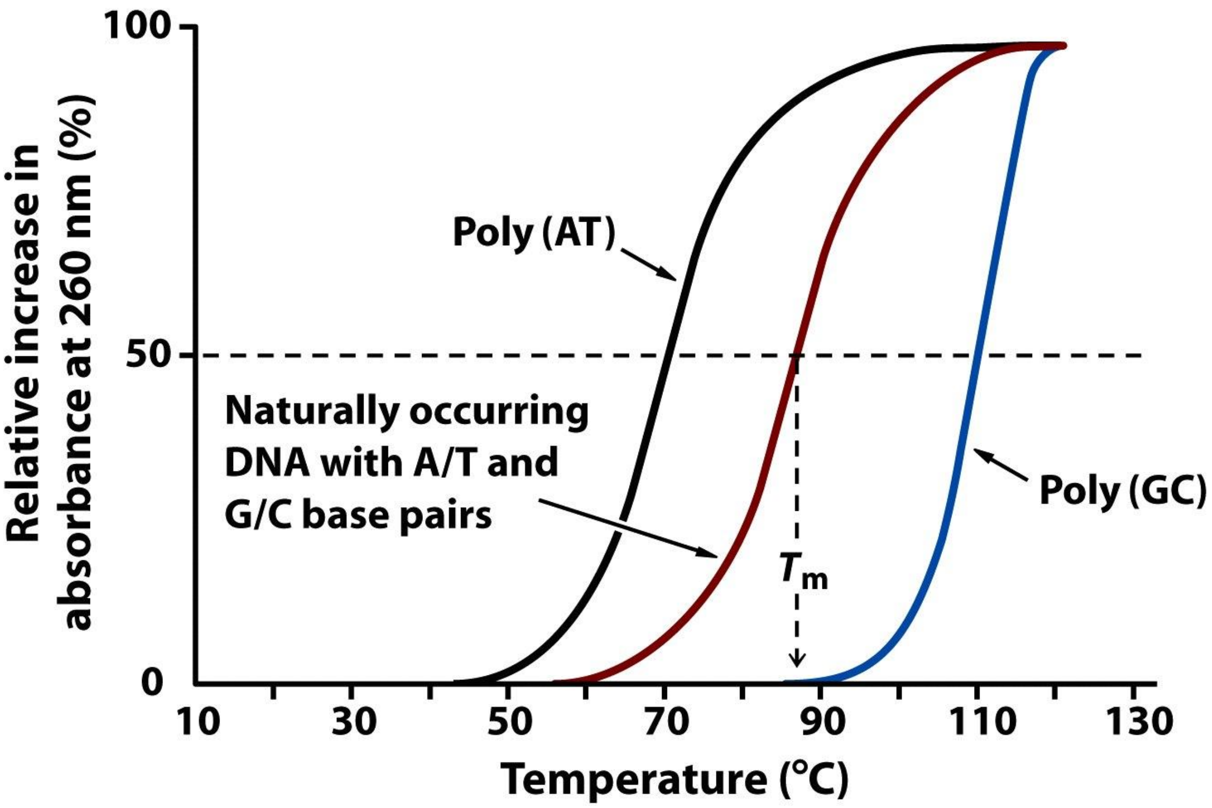

Figure 19-17 Principles of Biochemistry, 4/e

DNA Hybridization

- Two DNA samples are completely denatured by heating.
- When the two solutions are mixed and slowly cooled, DNA strands of each sample associate with their normal complementary partner and anneal to form duplexes.
- If the two DNAs have significant sequence similarity, they also tend to form partial duplexes or hybrids with each other.

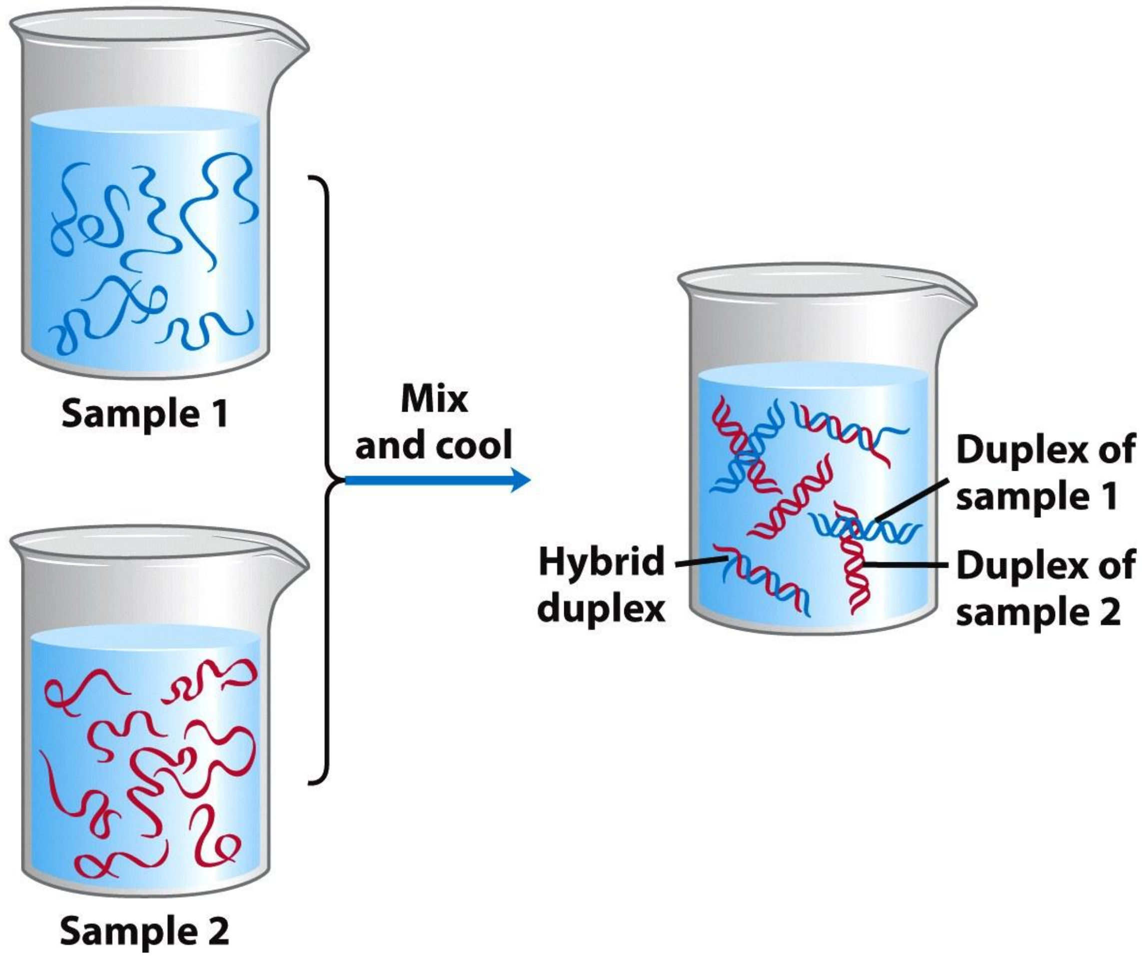

Figure 8-29
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Suercoiled DNA

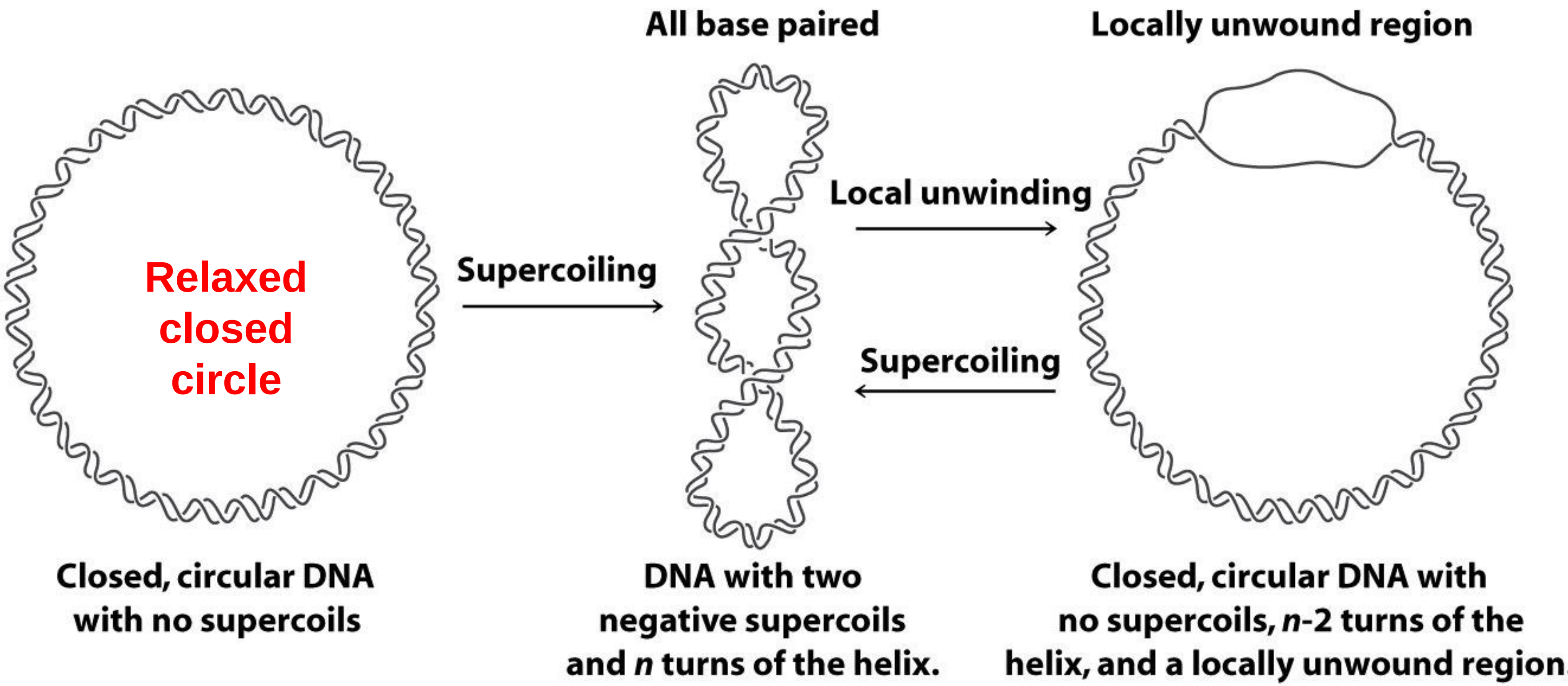

Figure 19-19 Principles of Biochemistry, 4/e

Nucleosome & Chromatin Structure

Nucleosomes

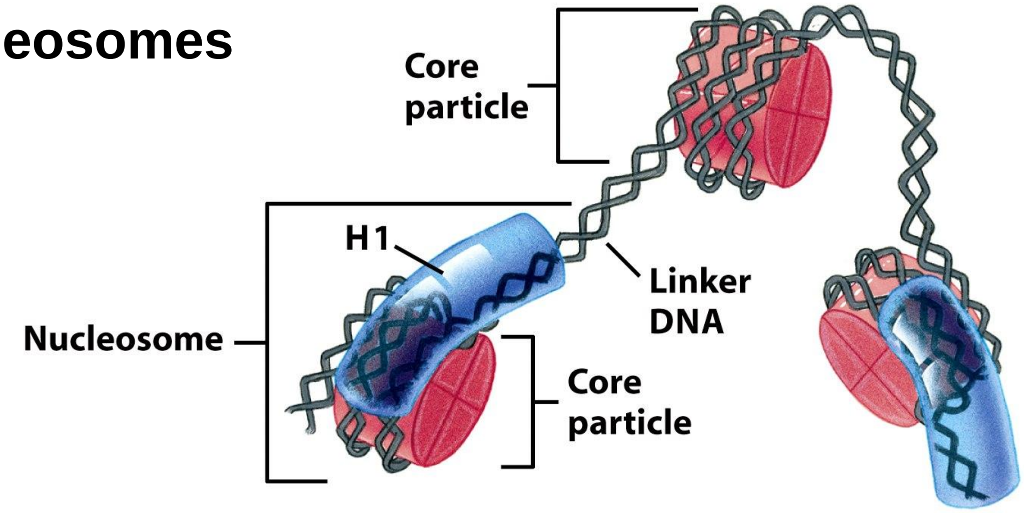

Figure 19-23b Principles of Biochemistry, 4/e
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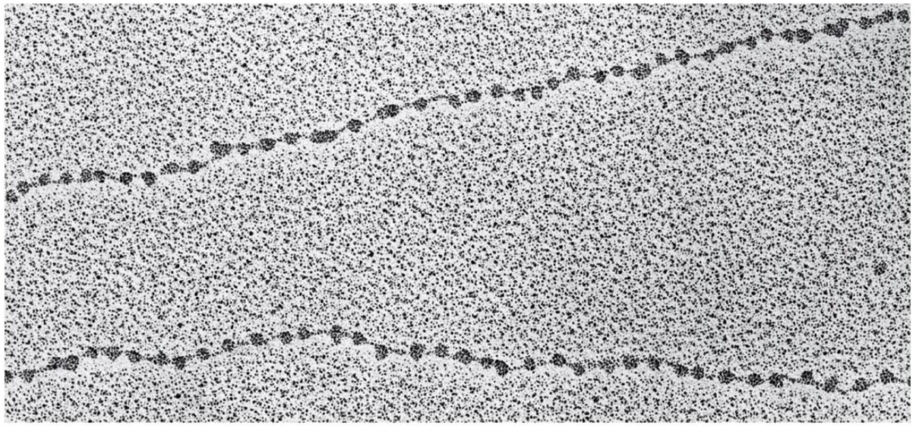

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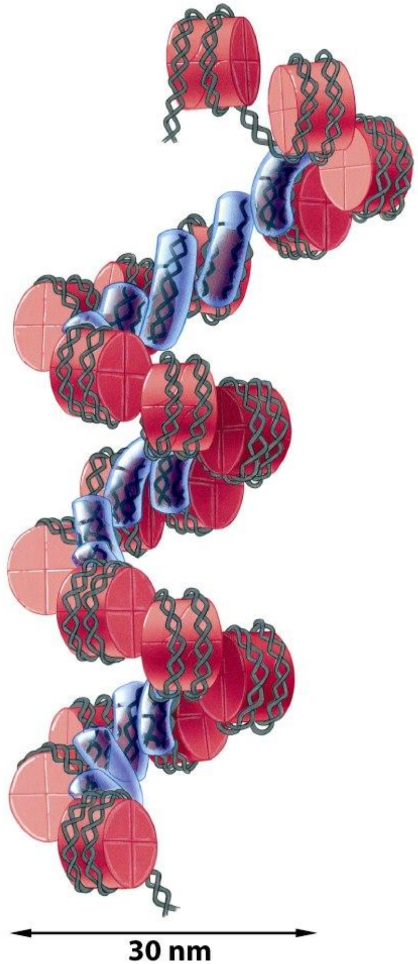
Extended chromatin



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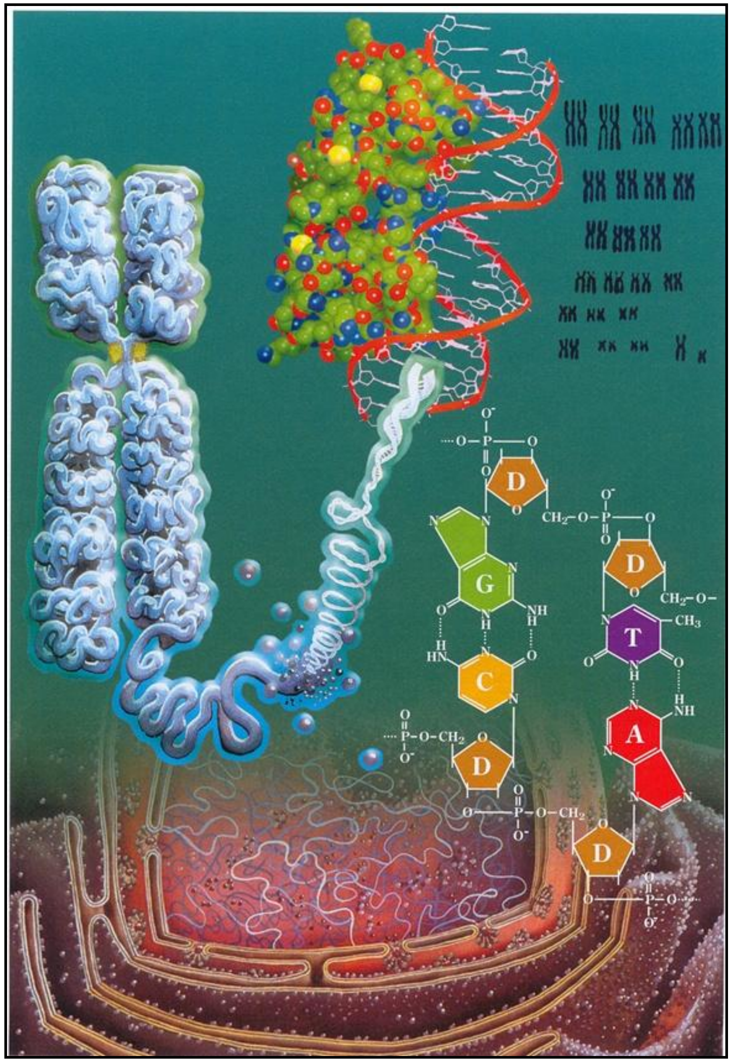
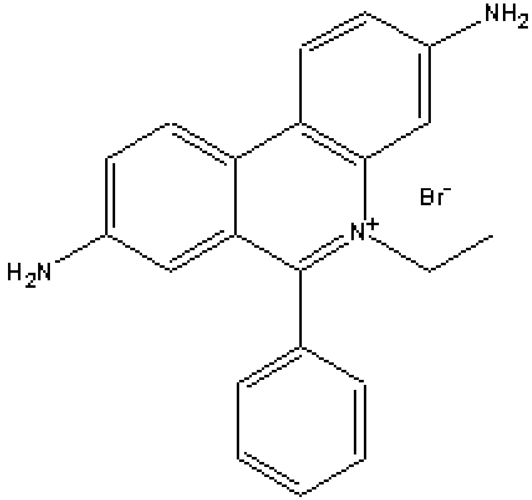
Chromatin fiber

Chromosomes

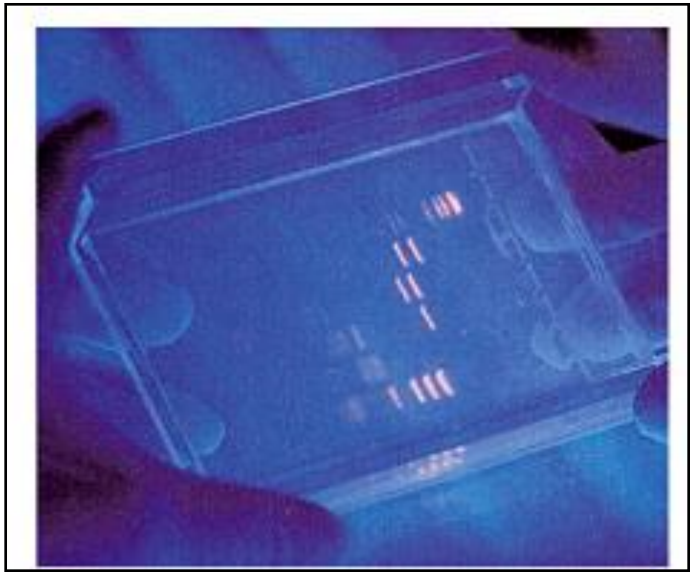


Inercalating Agents

- Acridine orange or ethidium bromide, which is often used to detect DNA in electrophoresis
- Cause frameshift mutations



Ethidiumbromide



Radiation

- Several forms of radiation are highly mutagenic.
- Nonionizing and ionizing radiation.

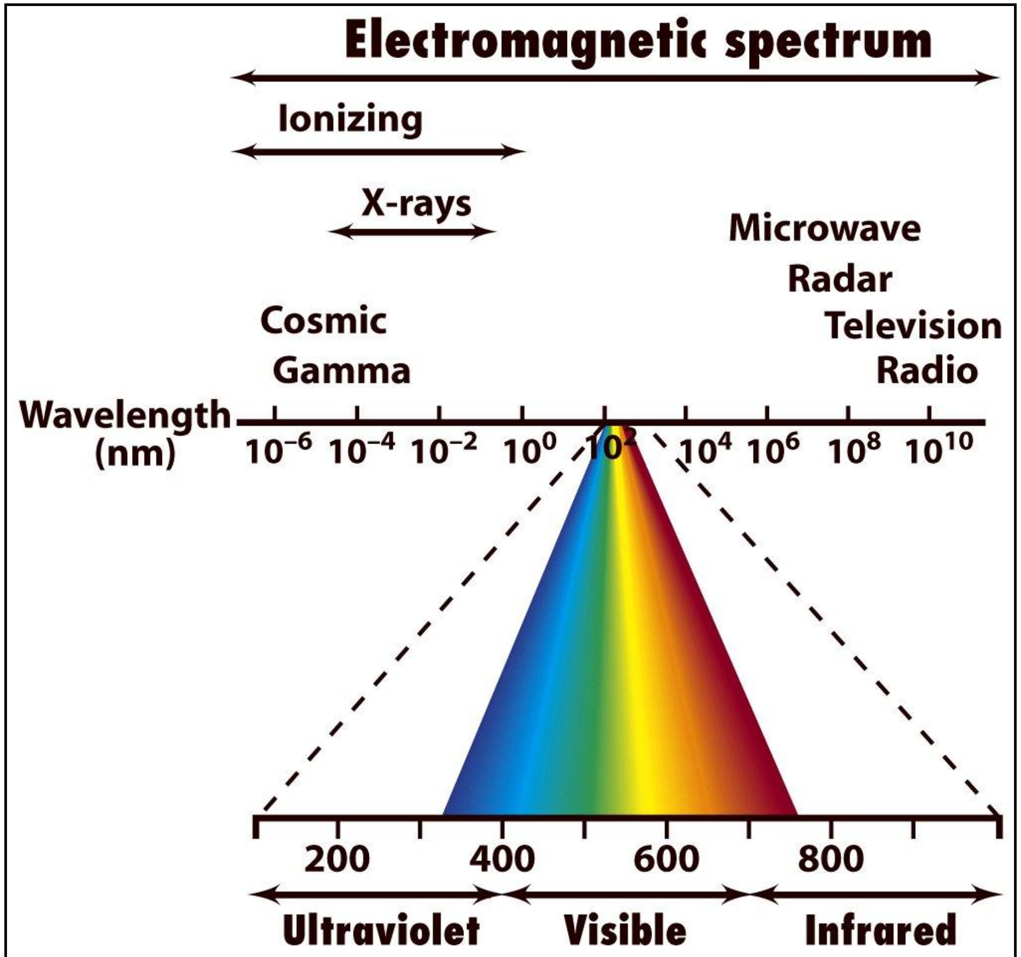
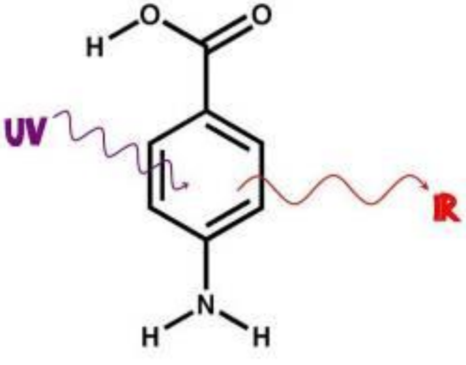


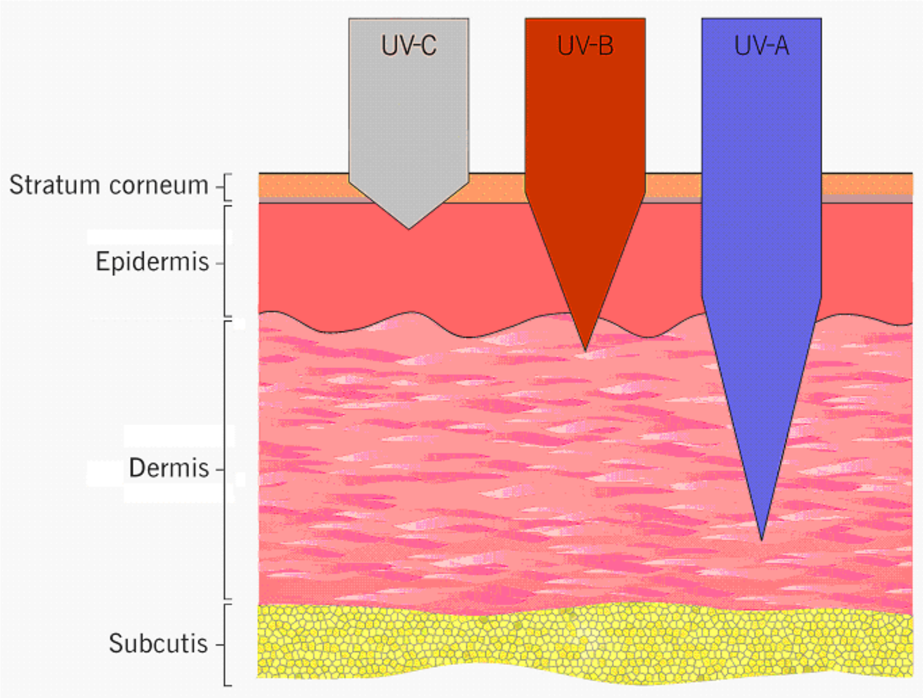
Figure 10-6 Brock Biology of Microorganisms 11/e

UV Damage to DNA



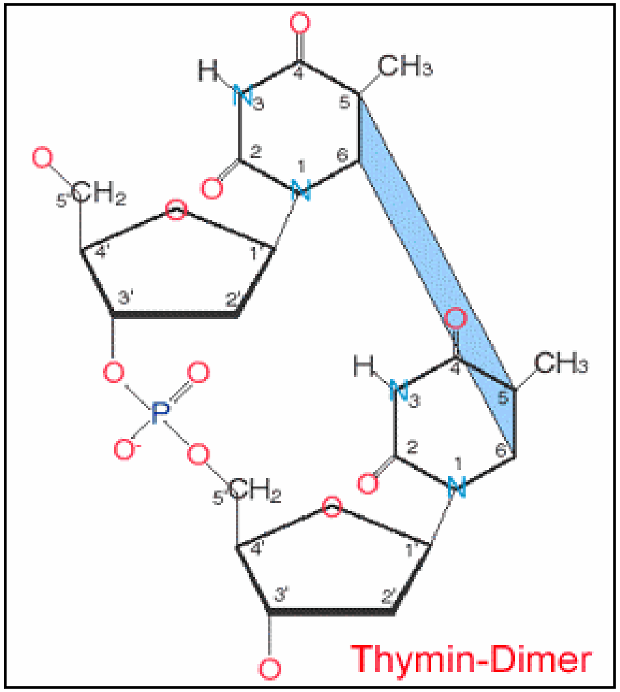
para-aminobenzoic acid

Sunscreen



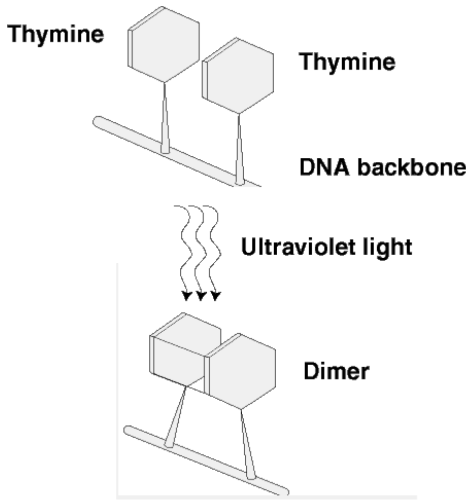
Thymin-Dimers by UV

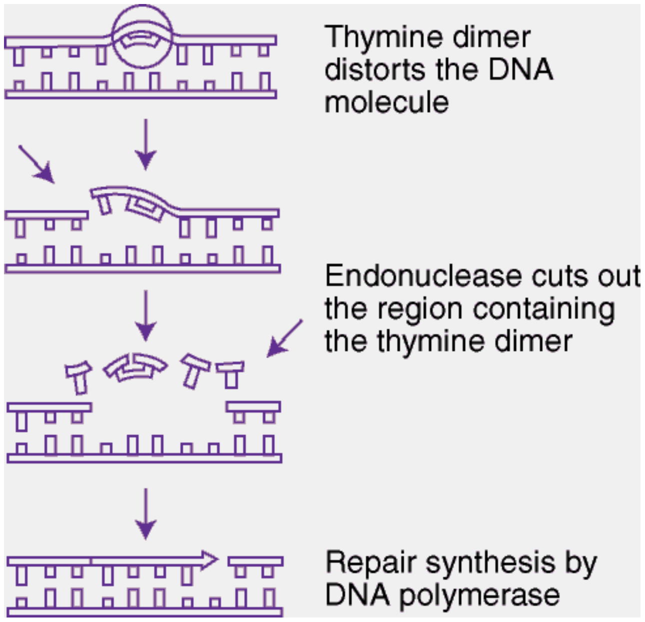
- Purine and pyrimidine bases absorb ultraviolet (UV) radiation strongly (Max $_{\text{DNA and RNA}}$ = **260 nm**)
- **Killing of cells** is due to the **effect of UV on DNA**.
- Best known the **formation of pyrimidine dimers**.
- Most common T-T dimers (pyrimidine-cyclobutane-dimers) beside T-C and C-T-dimers.



UV damage to DNA & Repair

- In Bacteria, fungi, plant and animals but not in humans: **Photolyases**
- **Base and nucleotide excision repair** (BER)
- Light independent , 3 major steps (Human):
  - 1) Identification of error on one strand, excision by nuclease, usually a gap of several nucleotides is formed.
  - 2) DNA polymerase fills the gap, the intact strand serves as template
  - 3) DNA-ligase closes the break





Central Dogma of Molecular Biology

Information flow

DNA → RNA → Protein (except viruses)

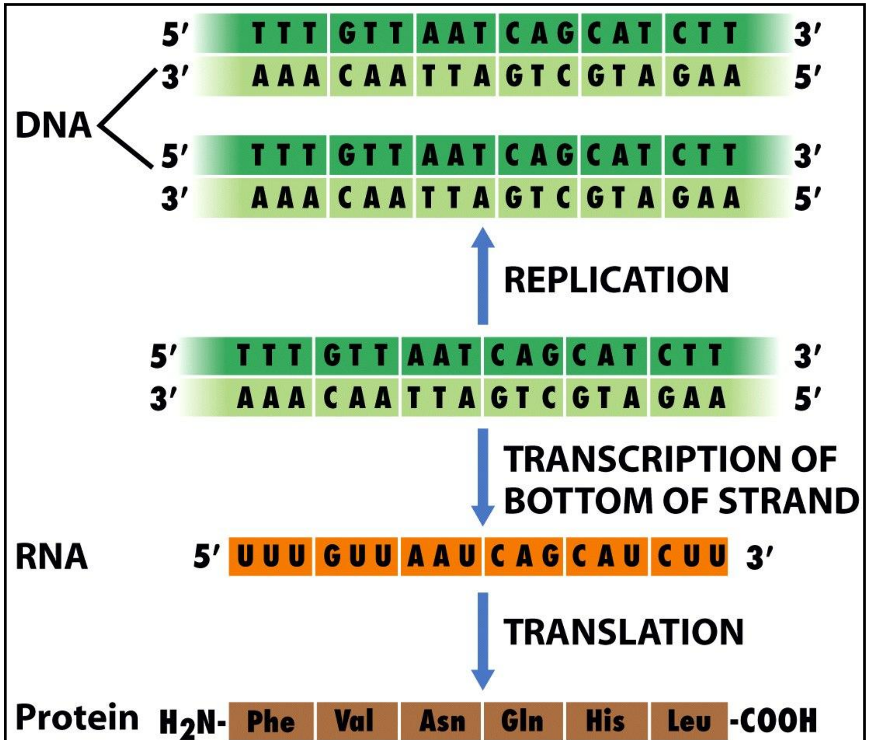


Figure 7-1 Brock Biology of Microorganisms 11/e

Ribonucleic acid (RNA)

- Ribose
- C, U (no T), A, G,
- Base pairing matches DNA (G=C, A=U)
- mostly single-stranded, secondary structures

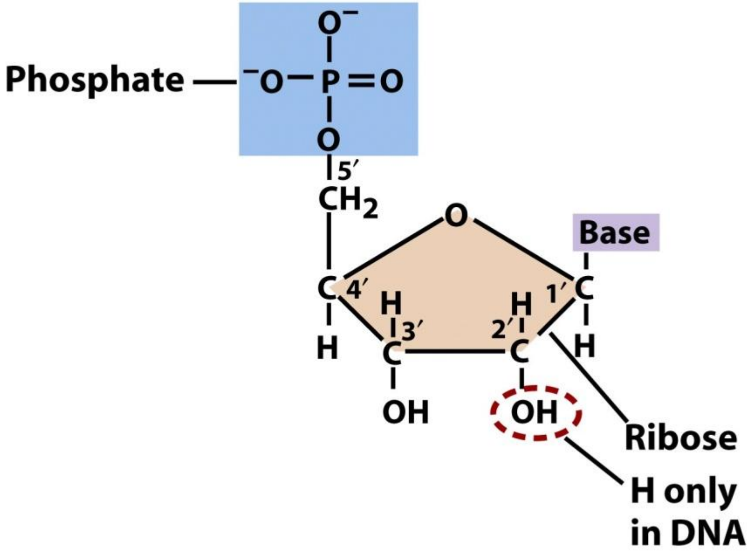


Figure 3-8 Brock Biology of Microorganisms 11/e

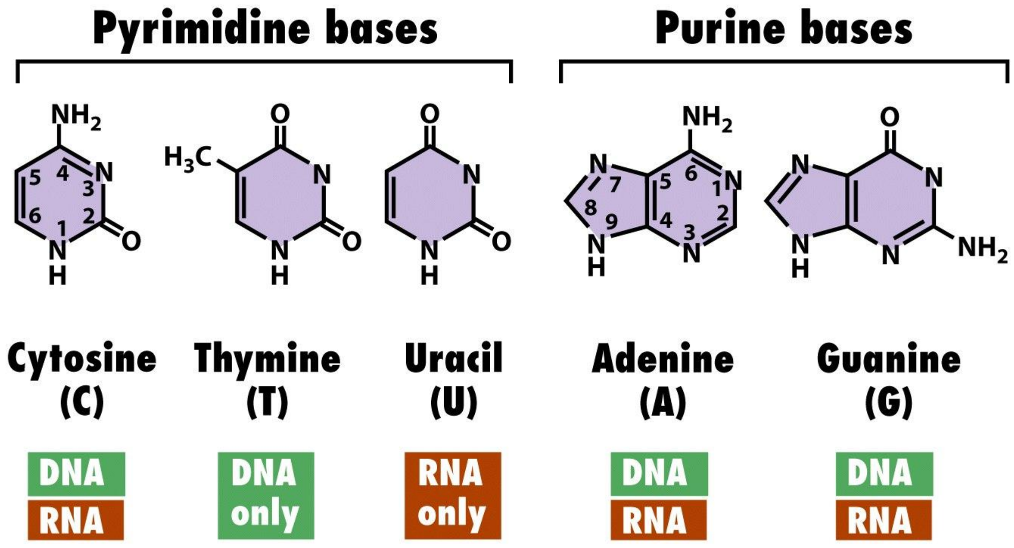


Figure 3-9 Brock Biology of Microorganisms 11/e

Three major types of RNA

- **messenger RNA (mRNA)**
- **transfer RNA (tRNA)**
- **ribosomal RNA (rRNA)**

- **Two types of function:**
- **genetic**
  - **carries genetic information of DNA (mRNA)**
- **structural**
  - **e.g. -structural role in ribosome (rRNA),**
  - **amino acid transfer (tRNA),**
  - **catalytic (enzymatic) activity (ribozymes)**

RNA Structure

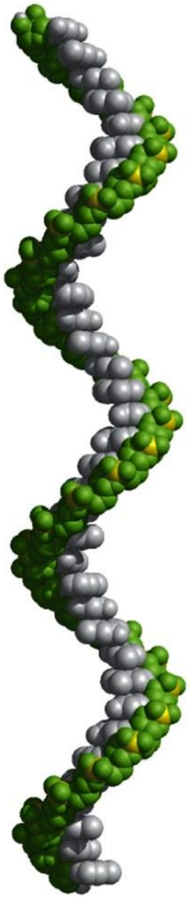


Figure 8-22
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Typical right-handed stacking pattern of single-stranded RNA

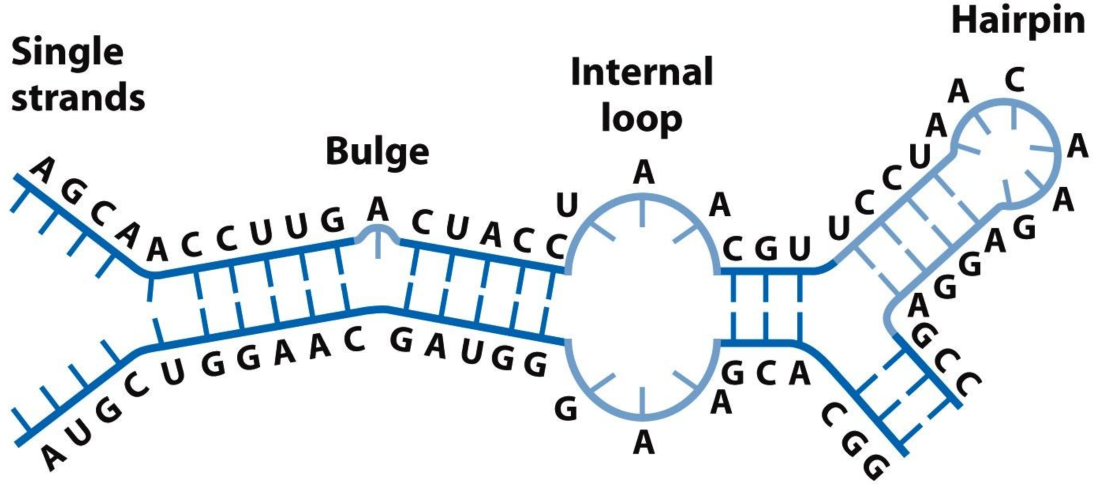

Figure 8-23a
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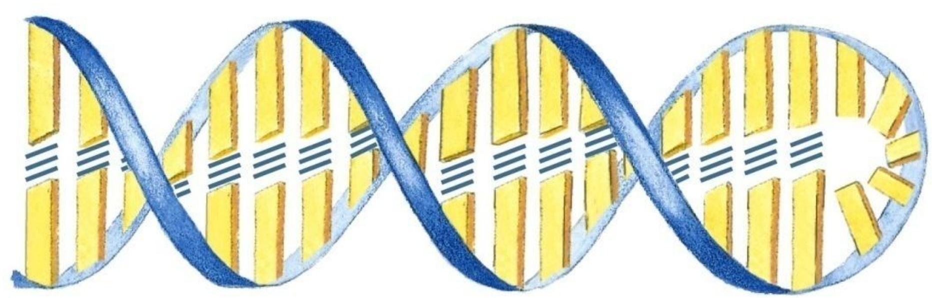
Secondary structure of RNA



Hairpin double helix

Figure 8-23b
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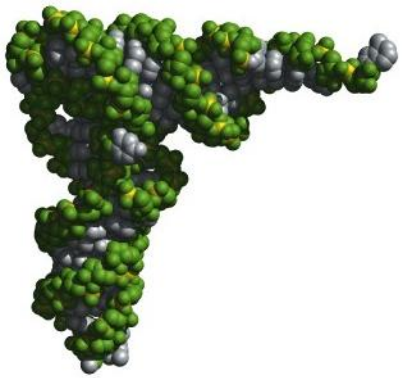
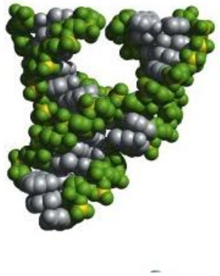
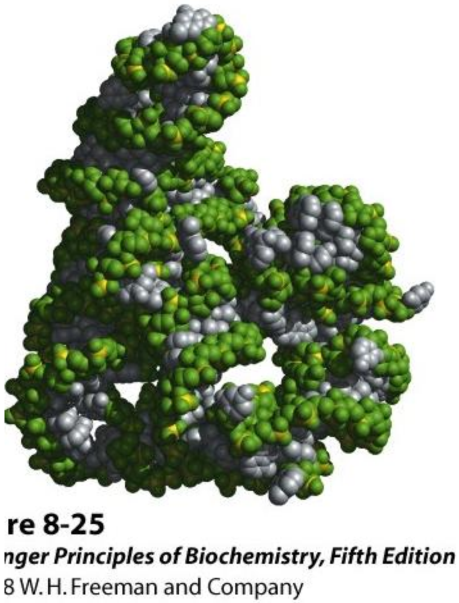
Three-dimensional structure in RNA



Phenylalanine tRNA of yeast



Hammerhead ribozyme



Segment of mRNA known as an intron

Other Functions of Nucleotides

Energy currency of the cell

Adenosinetriphosphate (ATP)

- **The phosphate ester and phosphoanhydride bonds of ATP.**
- Hydrolysis of an anhydride bond yields more energy (about 30 kJ/mol) than hydrolysis of the ester (about 14 kJ/mol).
- A carboxylic acid anhydride and carboxylic acid ester are shown for comparison.

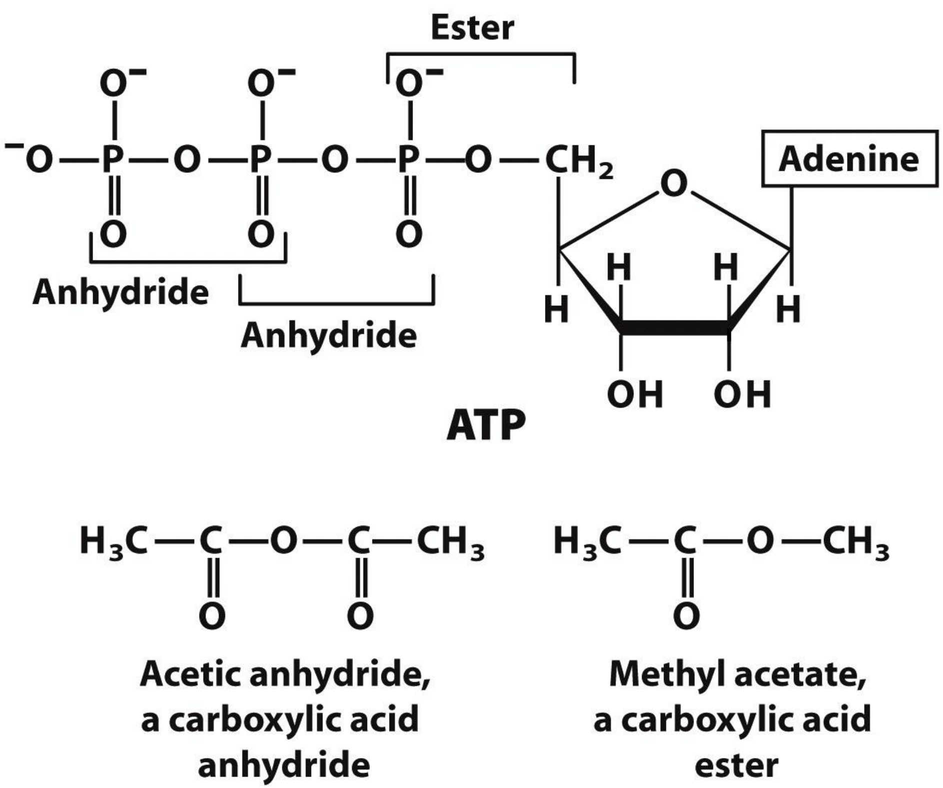


Figure 8-37

Some Coenzymes containing Adenosine

- The adenosine portion is shaded in light red.
- **Coenzyme A (CoA)** functions in **acyl group transfer** reactions; the acyl group (such as the acetyl or acetoacetyl group) is attached to the CoA through a **thioester linkage to the *β*-mercaptoethylamine** moiety.
- **NAD⁺** functions in **electron/ hydride transfers**, and
- **FAD**, the active form of vitamin B_2 (riboflavin), in **electron/hydride transfers**.

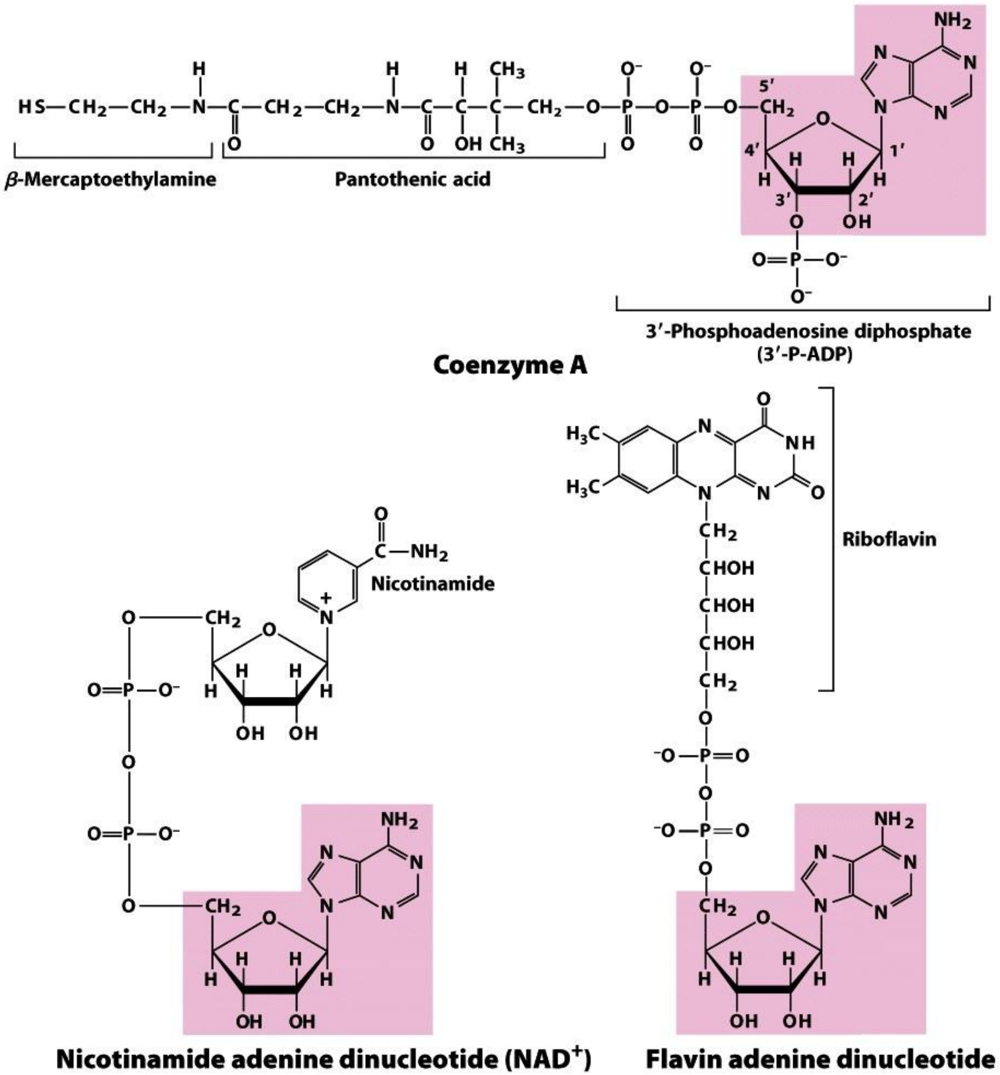


Figure 8-38
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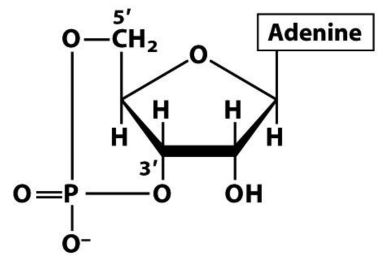
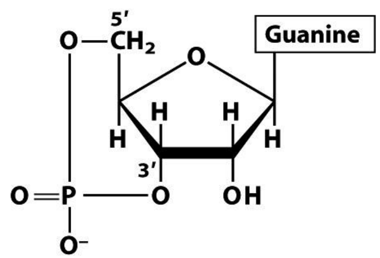
Regulatory Nucleotides

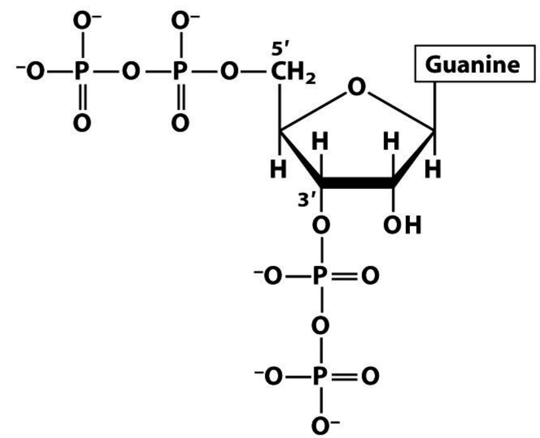
- **Second messengers** are often nucleotides.
- **cAMP**; formed from ATP by adenylate cyclase, regulatory function in all cells except plants.
- **cGMP**; many cells , regulatory function in many cells.
- **ppGpp**; produced in bacteria in response to a slowdown in protein synthesis during amino aicd starvation. (Inhibits synthesis of rRNA and tRNA needed for protein synthesis).



Adenosine 3′,5′-cyclic monophosphate (cyclic AMP; cAMP)



Guanosine 3′,5′-cyclic monophosphate (cyclic GMP; cGMP)



Guanosine 5′-diphosphate, 3′-diphosphate (guanosine tetraphosphate) (ppGpp)

Figure 8-39
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Einige Fragen....

Nukleotide und Nukleinsäuren

- 1) Beschreiben und vergleichen sie den Aufbau von DNA und RNA.
- 2) Nennen und zeichnen sie jeweils eine Purinbase und eine Pyrimidinbase.
- 3) Beschreiben sie den Aufbau eines Nukleosids und eines Nukleotids.
- 4) Beschreiben sie den Aufbau der DNA (Rückgrat etc.).
- 5) Welche Konformationen der doppelsträngigen (ds) DNA kennen sie?
- 6) Was würden sie für die Schmelzkurven für Poly(AT) und Poly(GC) DNA erwarten? Warum?
- 7) Wie schädigt UV Licht DNA? Beschreiben sie die Reaktion.
- 8) Welches Enzym bzw. welche Enzyme können die Schäden in Bakterien bzw. im Menschen reparieren?