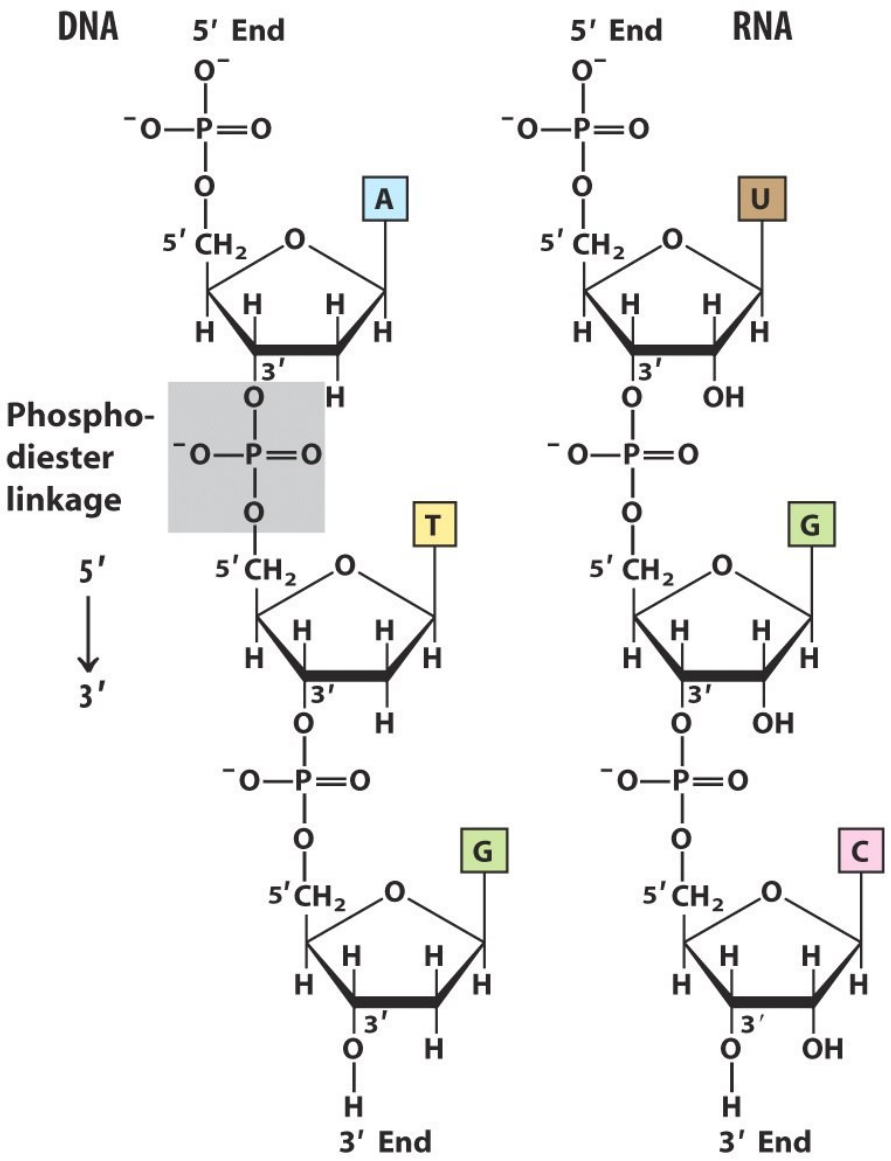
12/02/2024

Nucleic acid structure



- **Nucleic acids** also known as **polynucleotides** are chains of nucleotides whose **phosphate bridge** the **3' and 5' positions** of neighboring ribose units, known as **phosphodiester bond**.

- Each nucleotide residue is named after the base.

- 5'end and 3' end of the nucleic acid.

- by convention, DNA & RNA strand has direction from 5' to 3'. (5'-ATG-3').

- Nucleic acid contains information in the form of its sequence of residues.

- Negatively charged at physiological PH.

• **Chargaff's rules:** DNA has equal numbers of adenine and thymine residues (A=T) and equal numbers of guanine and cytosine residues (G=C). (late 1940s)

1953 Waston-Crick structure of DNA

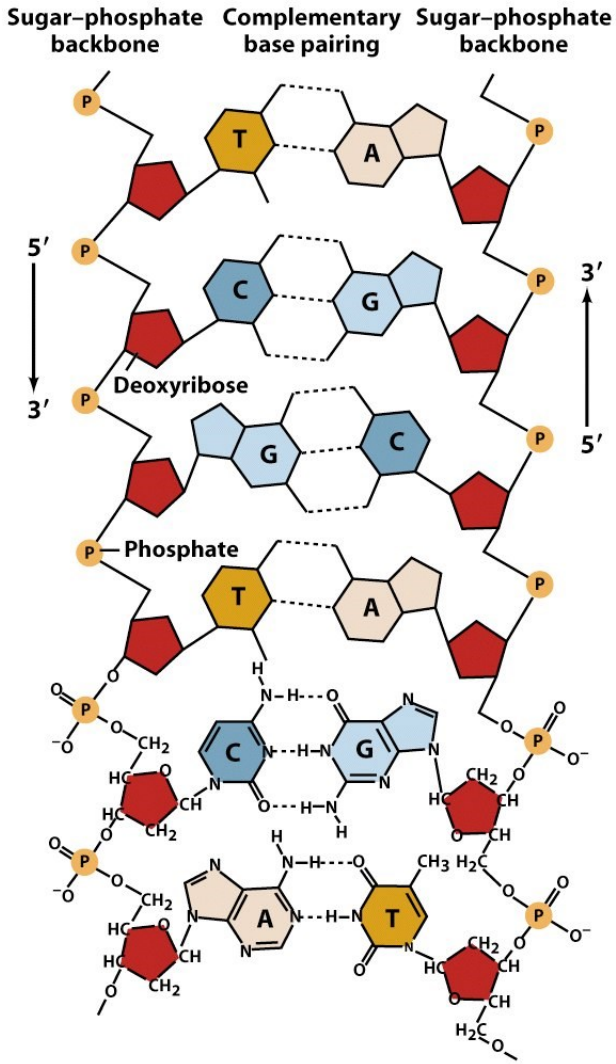


Figure 3-8 Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

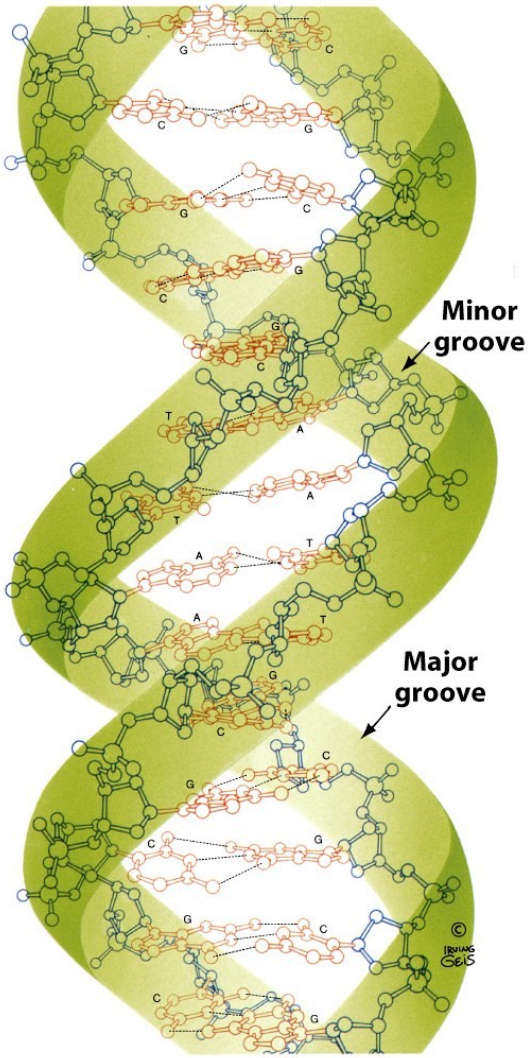


Figure 3-6 Fundamentals of Biochemistry, 2/e

1. Two polynucleotide chains wind around a common axis to form a **double helix**.

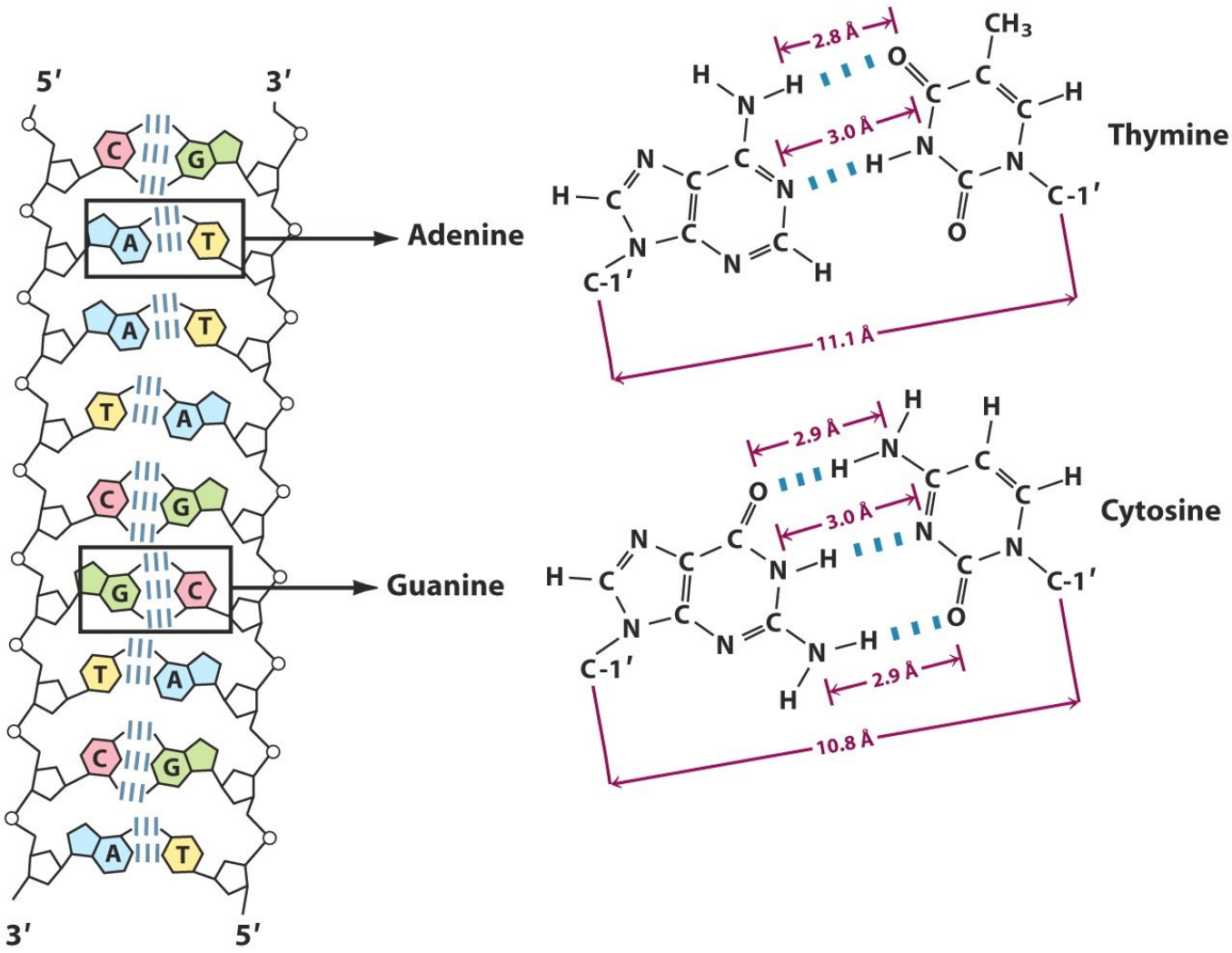
2. Two strands of DNA are **anti-parallel** but each forms a **right-handed helix**.

3. The **bases point inward** and pair through **hydrogen bonds**.

4. Complementary base pairings are ***A* pairs with T** and ***G* pairs with *C***.

5. The surface of the double helix contains two grooves of unequal width: the **major and minor grooves**.

Hydrogen bonds in DNA base pairing



Single stranded nucleic acids

Single stranded DNA is rare.
RNA primarily occurs as single strands, which usually form compact structures rather than loose extended chains.
Base pairing often occurs intramolecularly, forming **stem-loop** structures.

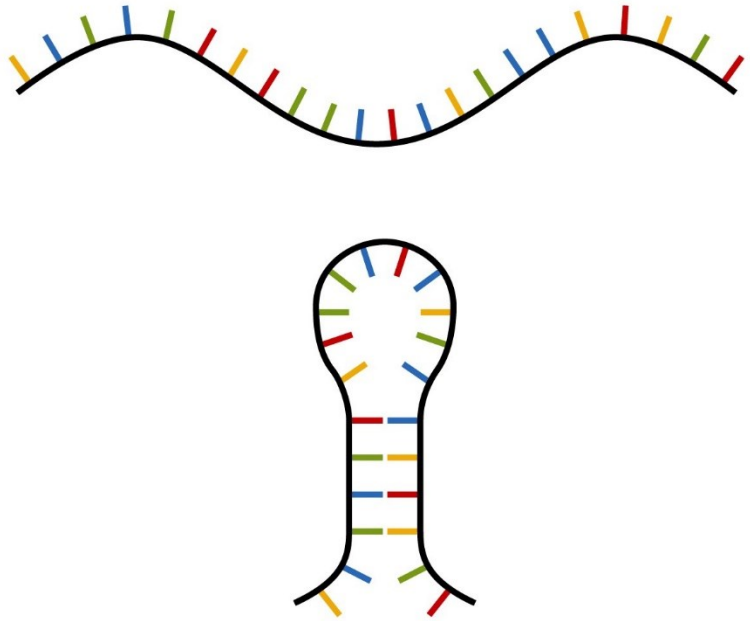


Figure 3-9 Fundamentals of Biochemistry, 2/e

3. Overview of Nucleic acid function

- **DNA Carries Genetic Information**

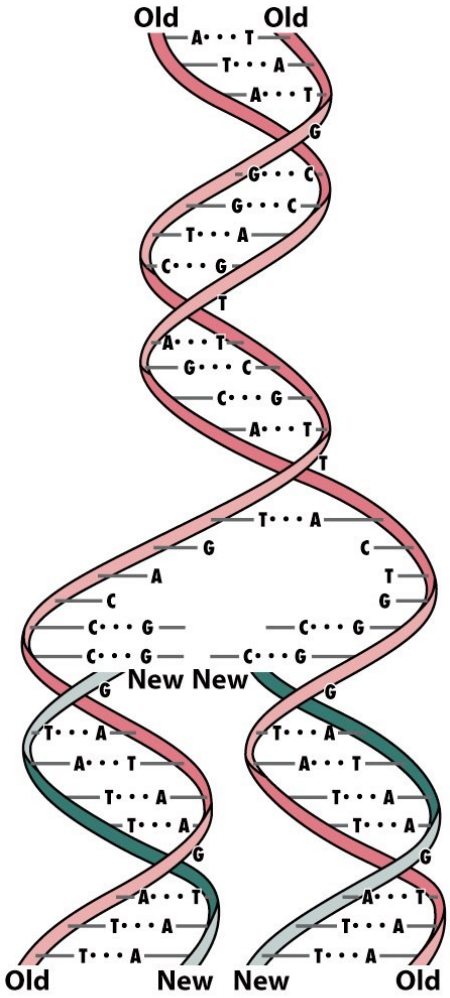


Figure 3-11 Fundamentals of Biochemistry, 2/e

• The double stranded or duplex nature of DNA facilitates its **replication**.

• When a cell divides, each DNA strand act as **a template** for the assembly of its complementary strand.

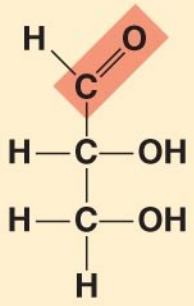
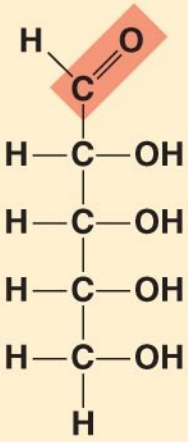
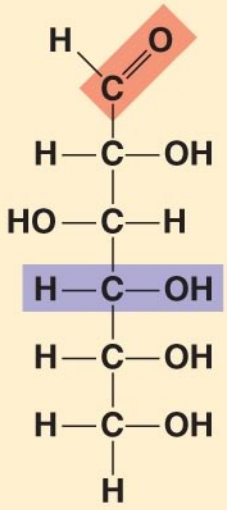
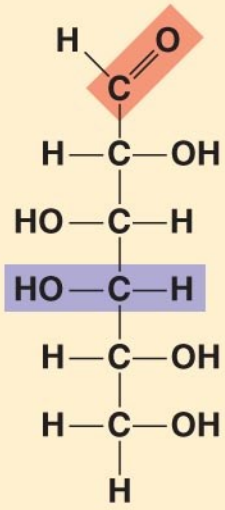
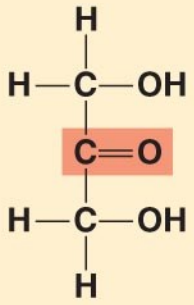
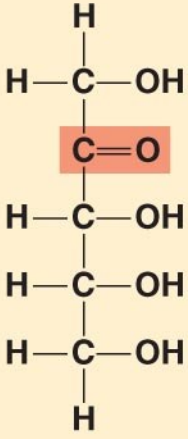
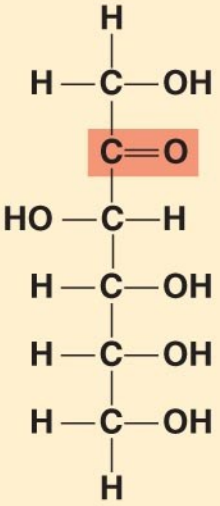
• Each daughter cells contains a complete set of DNA molecules. And each DNA molecule consists of **one parental strand** and **one daughter strand.**

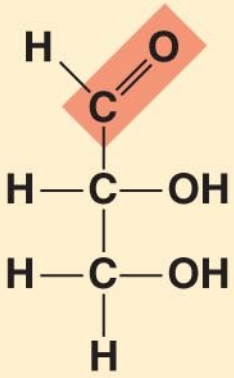
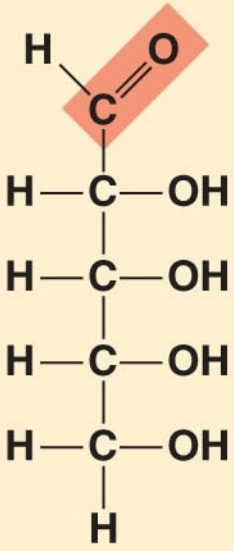
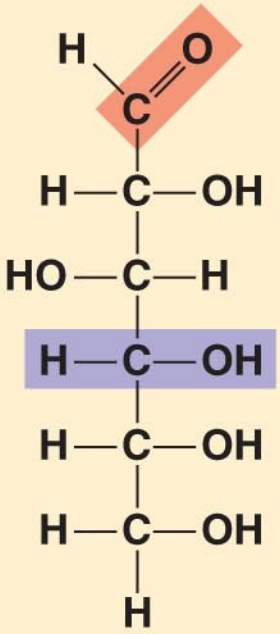
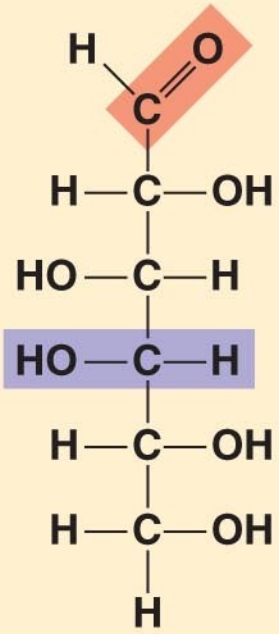
Carbohydrates serve as fuel and building material

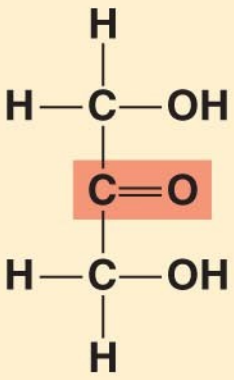
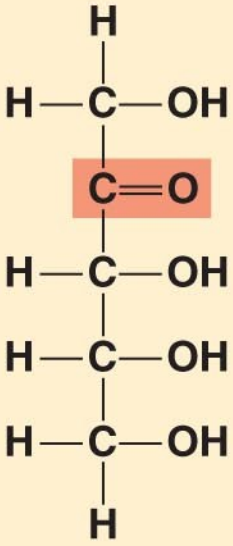
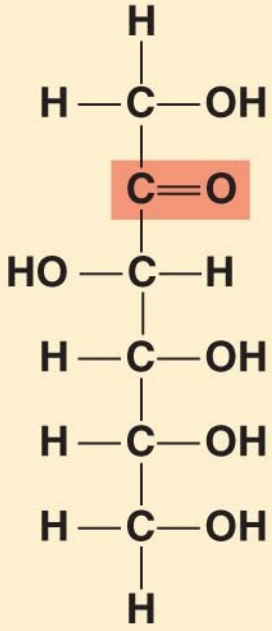
- **Carbohydrates** include sugars and the polymers of sugars
- The simplest carbohydrates are monosaccharides, or single sugars
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks

Sugars

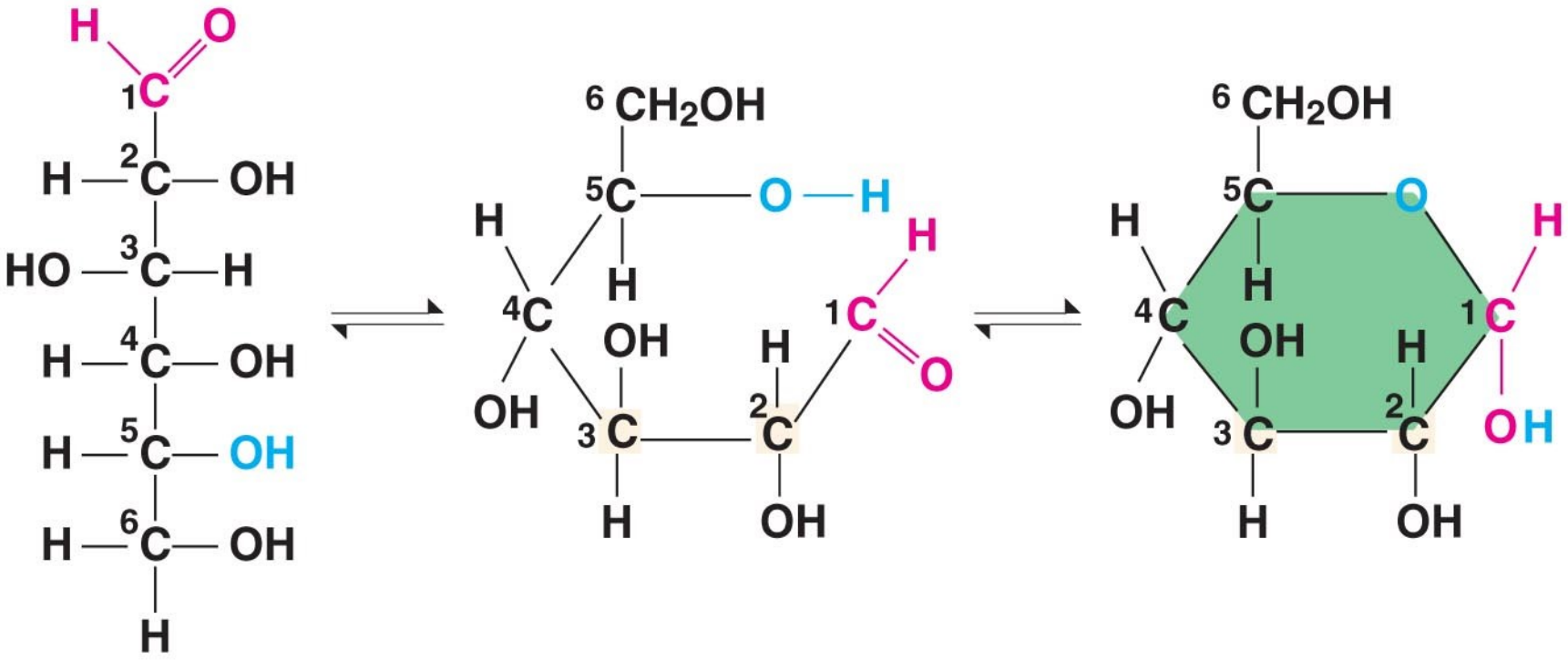
- **Monosaccharides** have molecular formulas that are usually multiples of CH_2O
- Glucose ($C_6H_{12}O_6$) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

	Trioses ($C_3H_6O_3$)	Pentoses ($C_5H_{10}O_5$)	Hexoses ($C_6H_{12}O_6$)	
Aldoses	 Glyceraldehyde	 Ribose	 Glucose	 Galactose
Ketoses	 Dihydroxyacetone	 Ribulose	 Fructose	

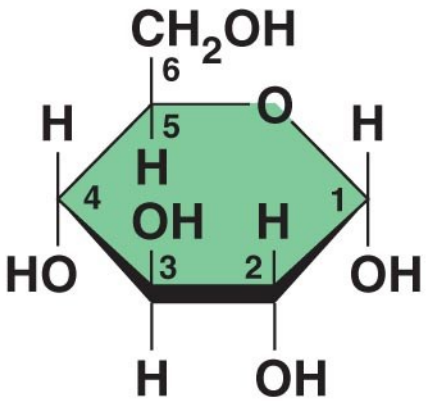
	Trioses ($C_3H_6O_3$)	Pentoses ($C_5H_{10}O_5$)	Hexoses ($C_6H_{12}O_6$)	
Aldoses	 Glyceraldehyde	 Ribose	 Glucose	 Galactose

	Trioses ($C_3H_6O_3$)	Pentoses ($C_5H_{10}O_5$)	Hexoses ($C_6H_{12}O_6$)
Ketoses	 Dihydroxyacetone	 Ribulose	 Fructose

- Though often drawn as linear skeletons, in aqueous solutions many sugars form rings
- Monosaccharides serve as a major fuel for cells and as raw material for building molecules

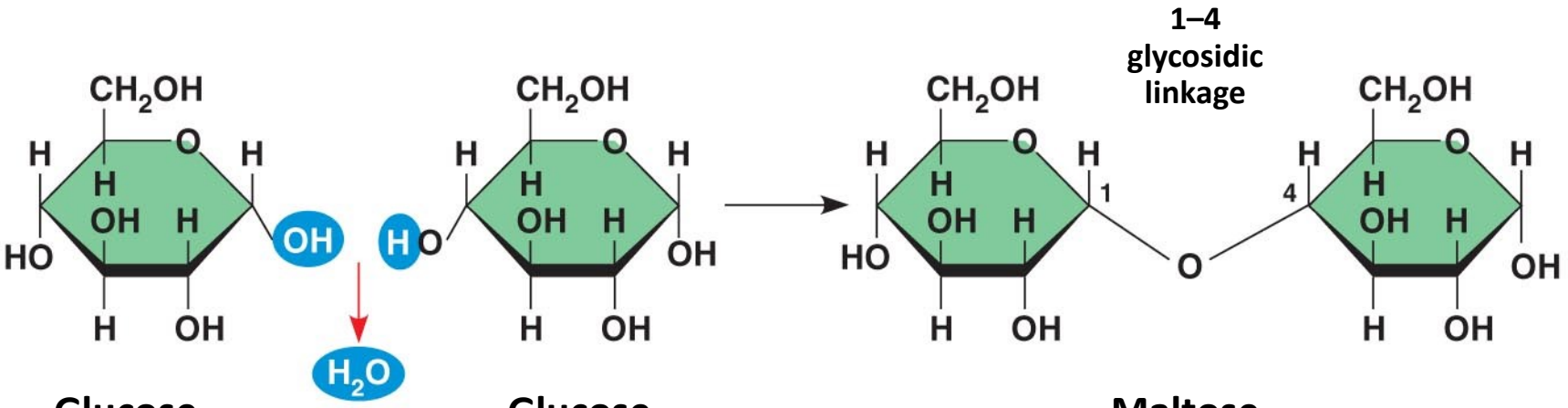


(a) Linear and ring forms

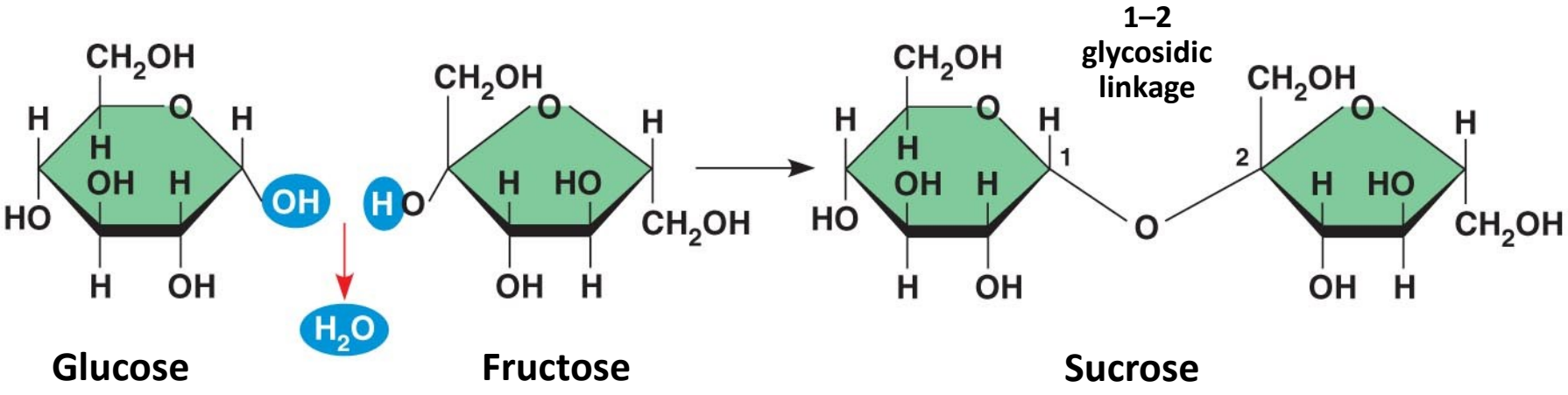


(b) Abbreviated ring structure

- A **disaccharide** is formed when a dehydration reaction joins two monosaccharides
- This covalent bond is called a **glycosidic linkage**



(a) Dehydration reaction in the synthesis of maltose



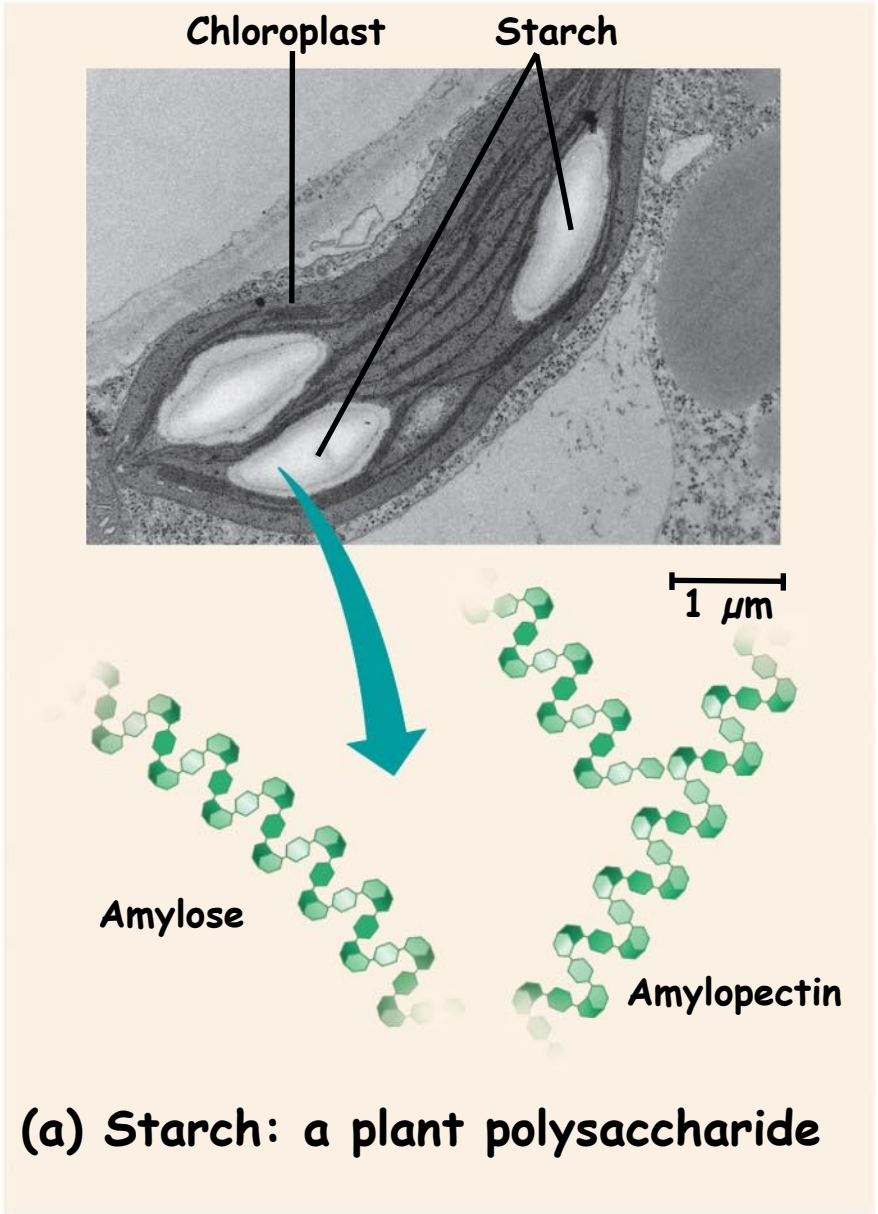
(b) Dehydration reaction in the synthesis of sucrose

Polysaccharides

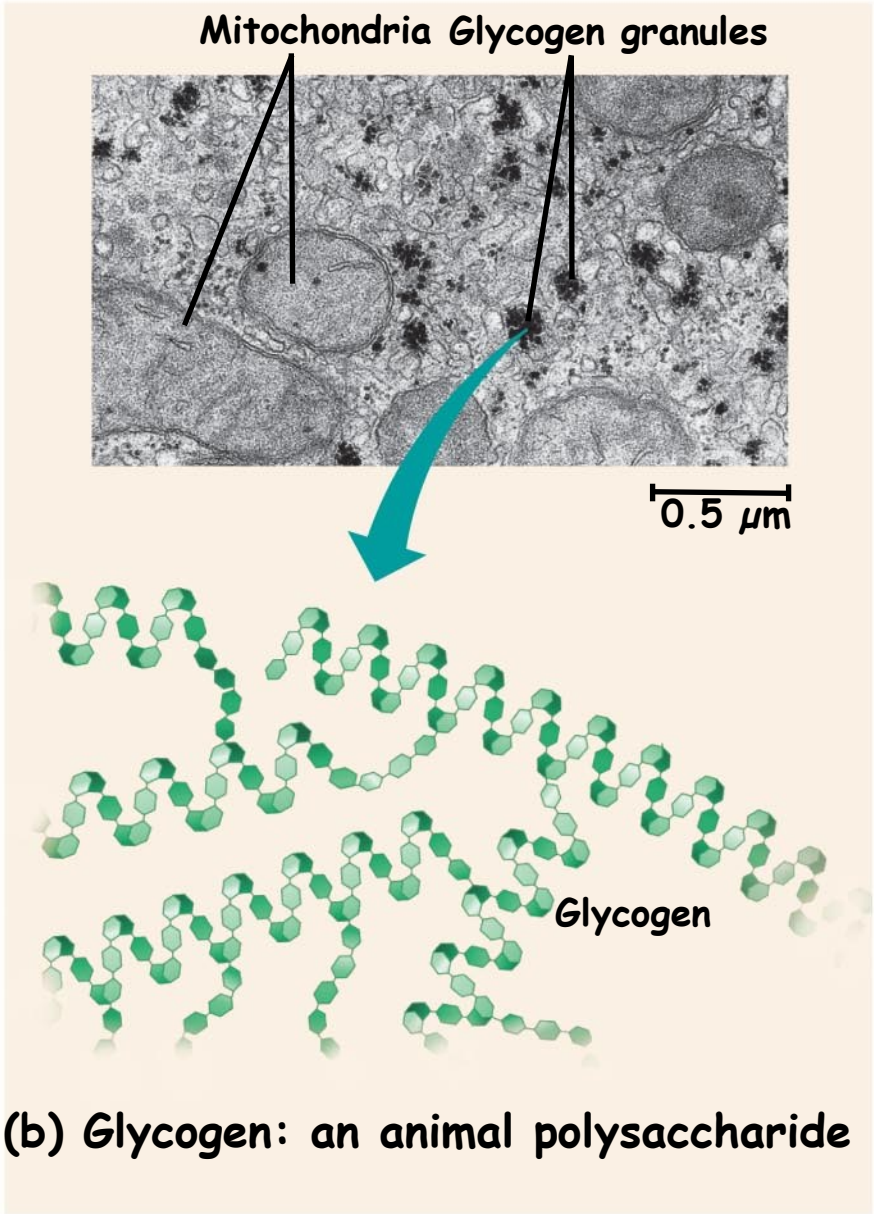
- **Polysaccharides**, the polymers of sugars, have storage and structural roles
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages

Storage Polysaccharides

- **Starch**, a storage polysaccharide of plants, consists entirely of glucose monomers
- Plants store surplus starch as granules within chloroplasts and other plastids



(a) Starch: a plant polysaccharide



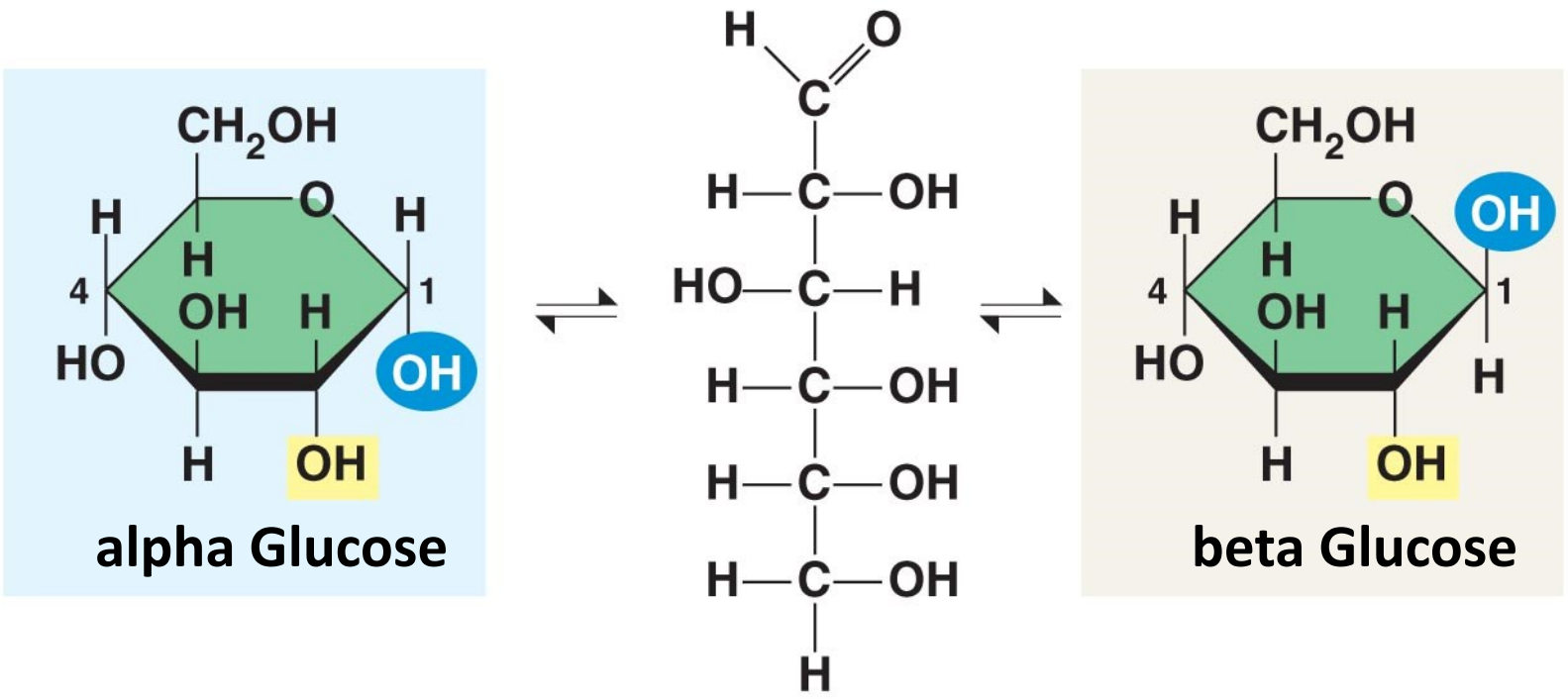
(b) Glycogen: an animal polysaccharide

- **Glycogen** is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in liver and muscle cells

Structural Polysaccharides

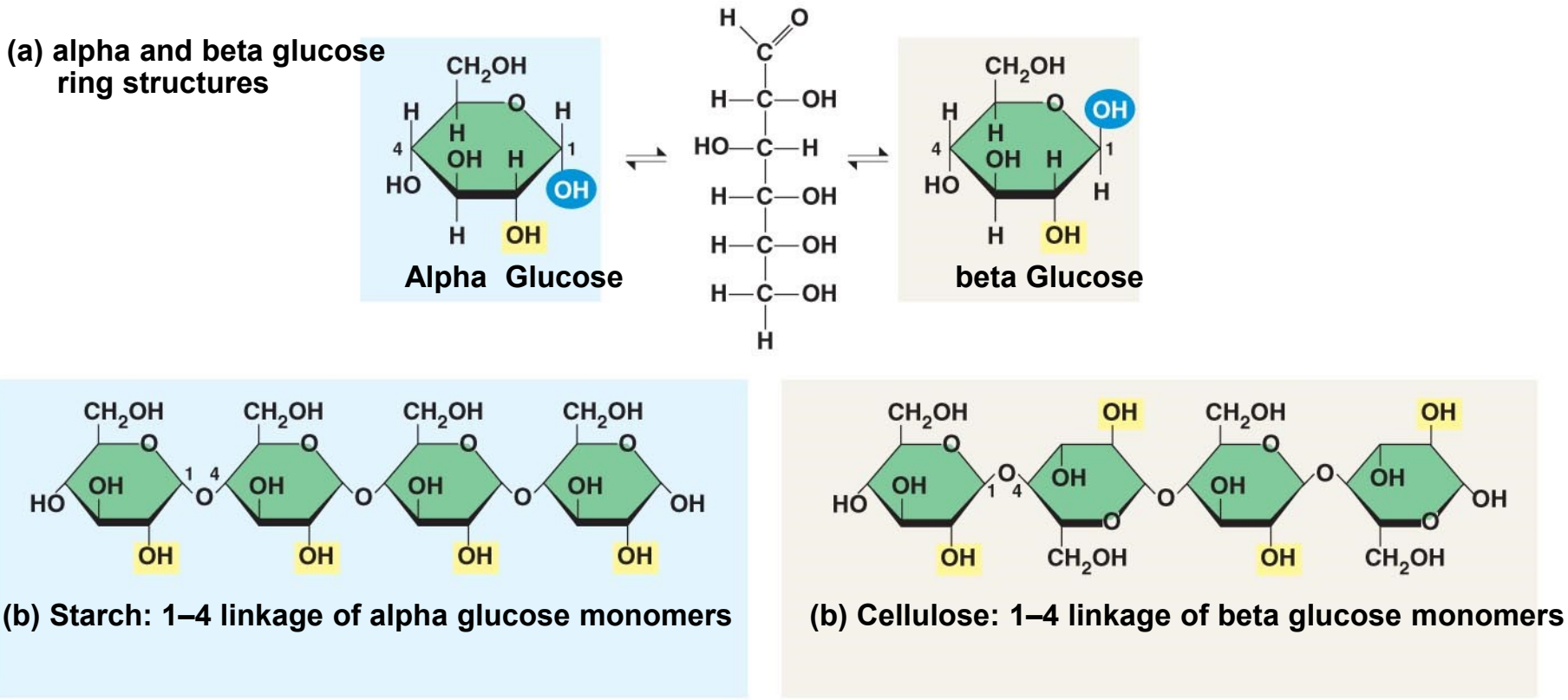
- The polysaccharide **cellulose** is a major component of the tough wall of plant cells
- Like starch, cellulose is a polymer of glucose, but the glycosidic linkages differ
- The difference is based on two ring forms for glucose: alpha (α) and beta (β)

Fig. 5-7a

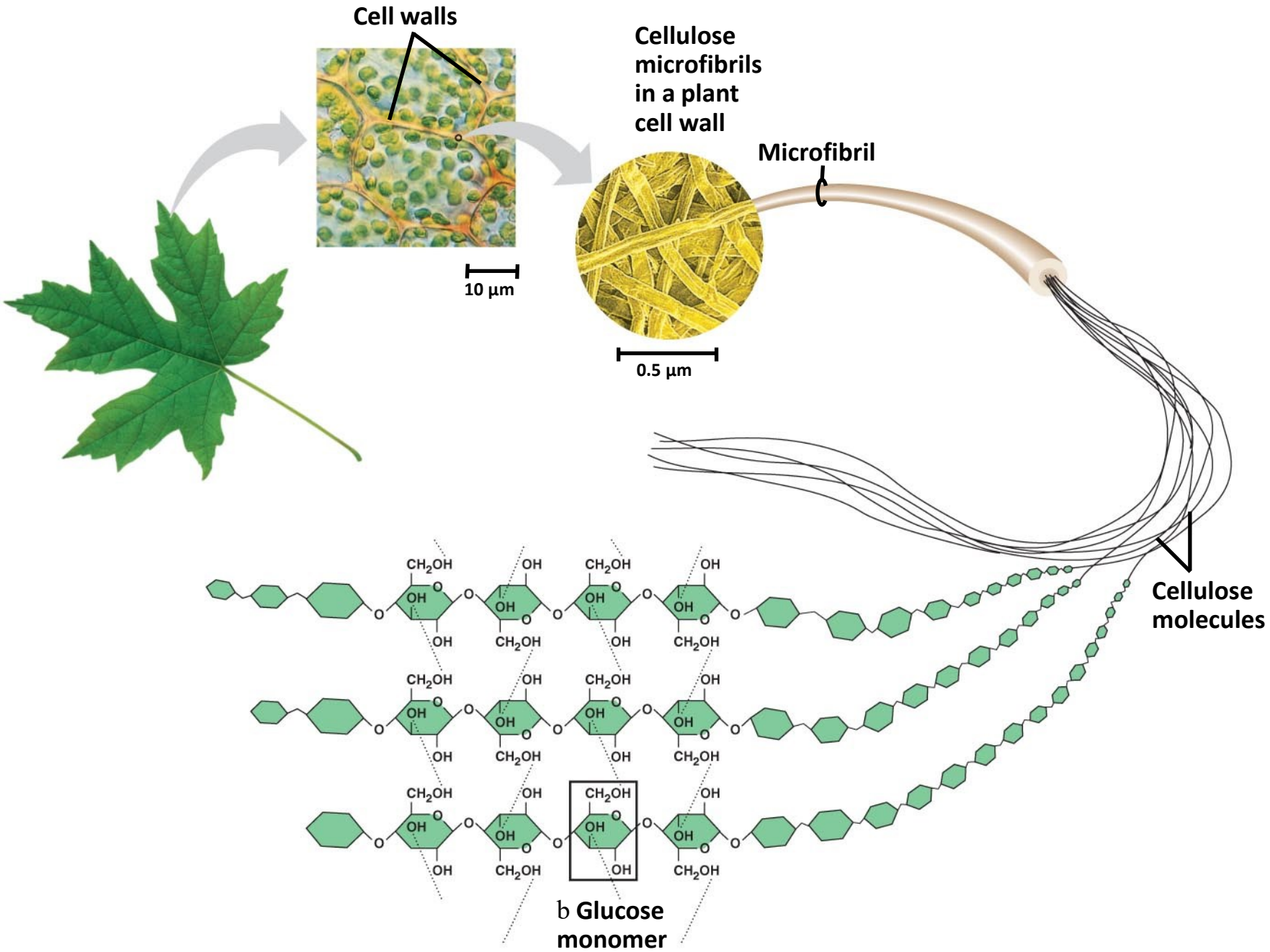


(a) alpha and beta glucose ring structures

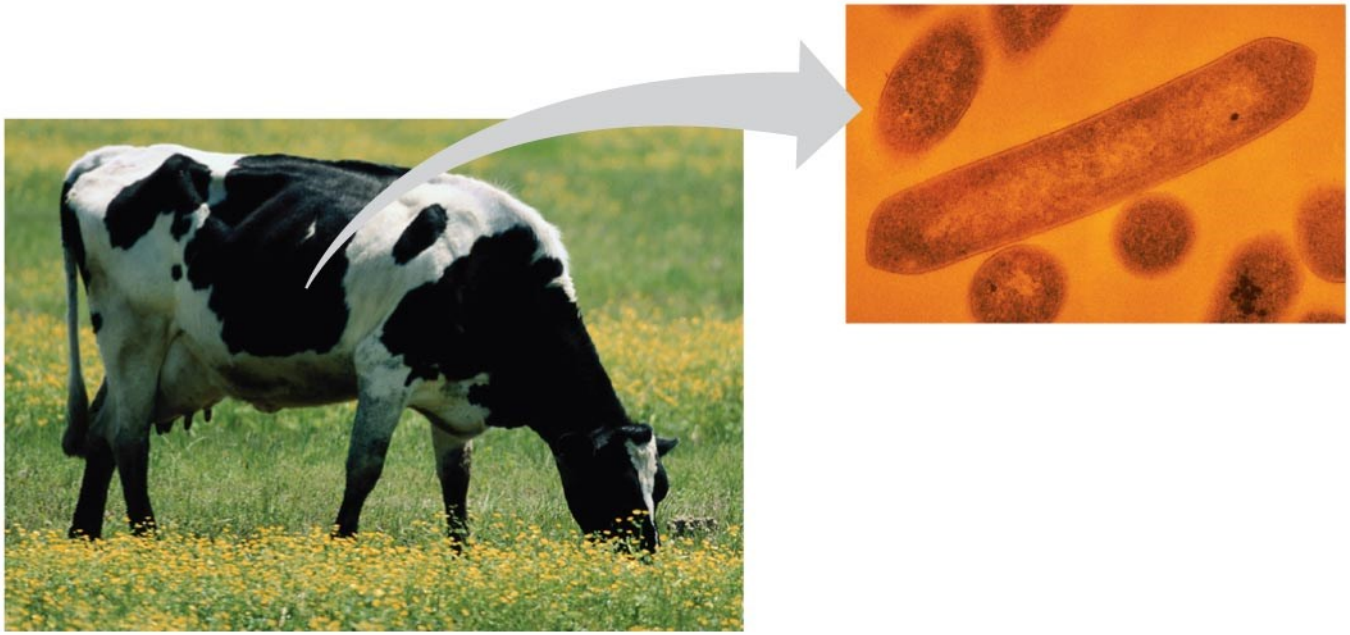
Fig. 5-7



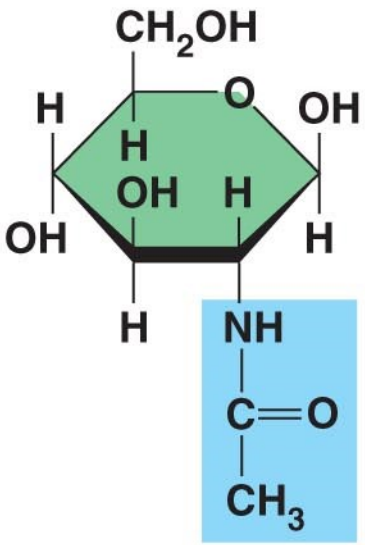
- Polymers with α glucose are helical
- Polymers with β glucose are straight
- In straight structures, H atoms on one strand can bond with OH groups on other strands
- Parallel cellulose molecules held together this way are grouped into microfibrils, which form strong building materials for plants



- Enzymes that digest starch by hydrolyzing α linkages can't hydrolyze β linkages in cellulose
- Cellulose in human food passes through the digestive tract as insoluble fiber
- Some microbes use enzymes to digest cellulose
- Many herbivores, from cows to termites, have symbiotic relationships with these microbes

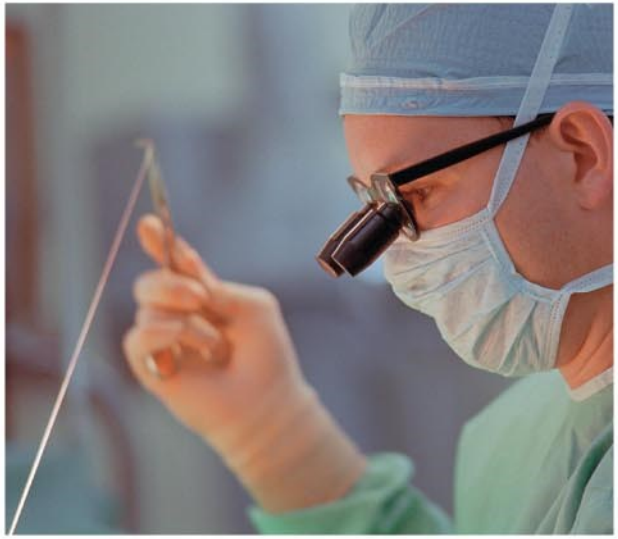


- **Chitin**, another structural polysaccharide, is found in the exoskeleton of arthropods
- Chitin also provides structural support for the cell walls of many fungi



(a) The structure of the chitin monomer.

(b) Chitin forms the exoskeleton of arthropods.



(c) Chitin is used to make a strong and flexible surgical thread.

16/02/2024

Lipids are a diverse group of hydrophobic molecules

- **Lipids** are the one class of large biological molecules that do not form polymers
- The unifying feature of lipids is having little or no affinity for water
- Lipids are hydrophobic because they consist mostly of hydrocarbons, which form nonpolar covalent bonds
- The most biologically important lipids are **fats(triglycerides), phospholipids, and steroids**

Fats(triglycerides)

- **Fats** are constructed from two types of smaller molecules: glycerol and fatty acids
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A **fatty acid** consists of a carboxyl group attached to a long carbon skeleton

Triacylglycerols (energy stores)

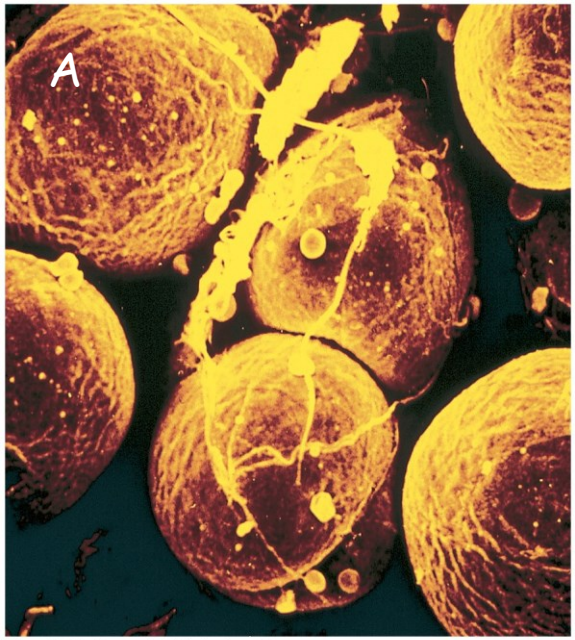
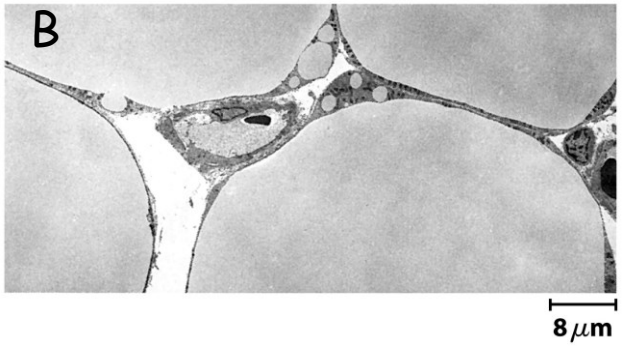
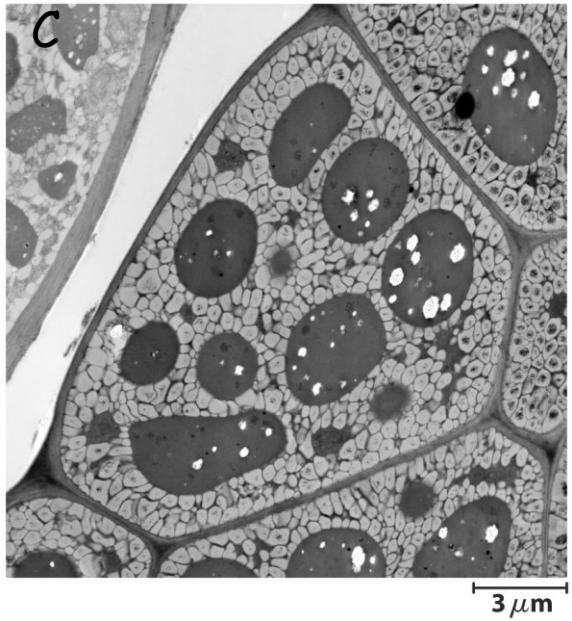


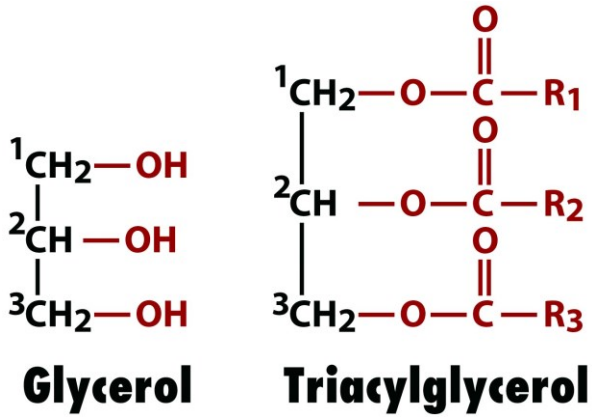
Figure 9-2 Fundamentals of Biochemistry, 2/e



A and B, SEM and TEM of adipocytes of guinea pig, that each contains a fat droplet nearly fills the entire cell.



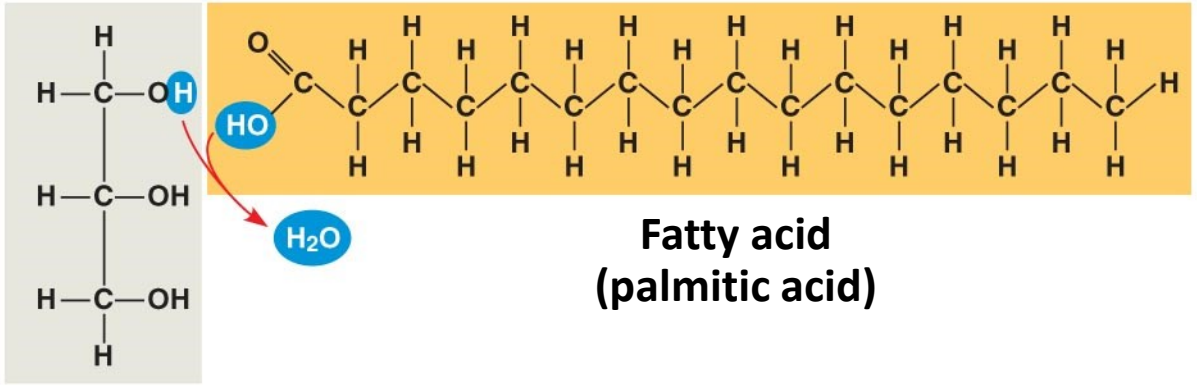
C. a cytoledon cell from seed of a plant. The stored oils are in the light colored oil bodies.



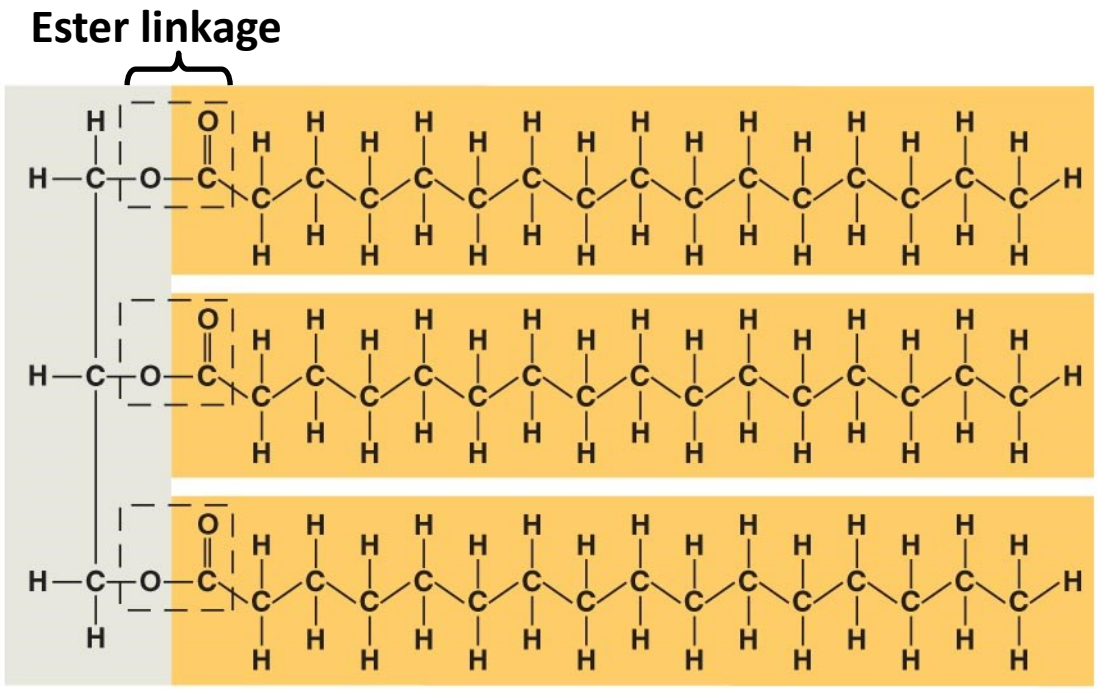
Unnumbered figure pg 236a Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

The **fats and oils** that occur in plants and animals consist largely of mixtures of **triacylglycerols** (also called **triglycerides**), these are **fatty acids triesters of glycerol**. They function as energy reservoirs, thus they are the most abundant class of lipids, though they are **not components of cellular membranes**.

Fig. 5-11



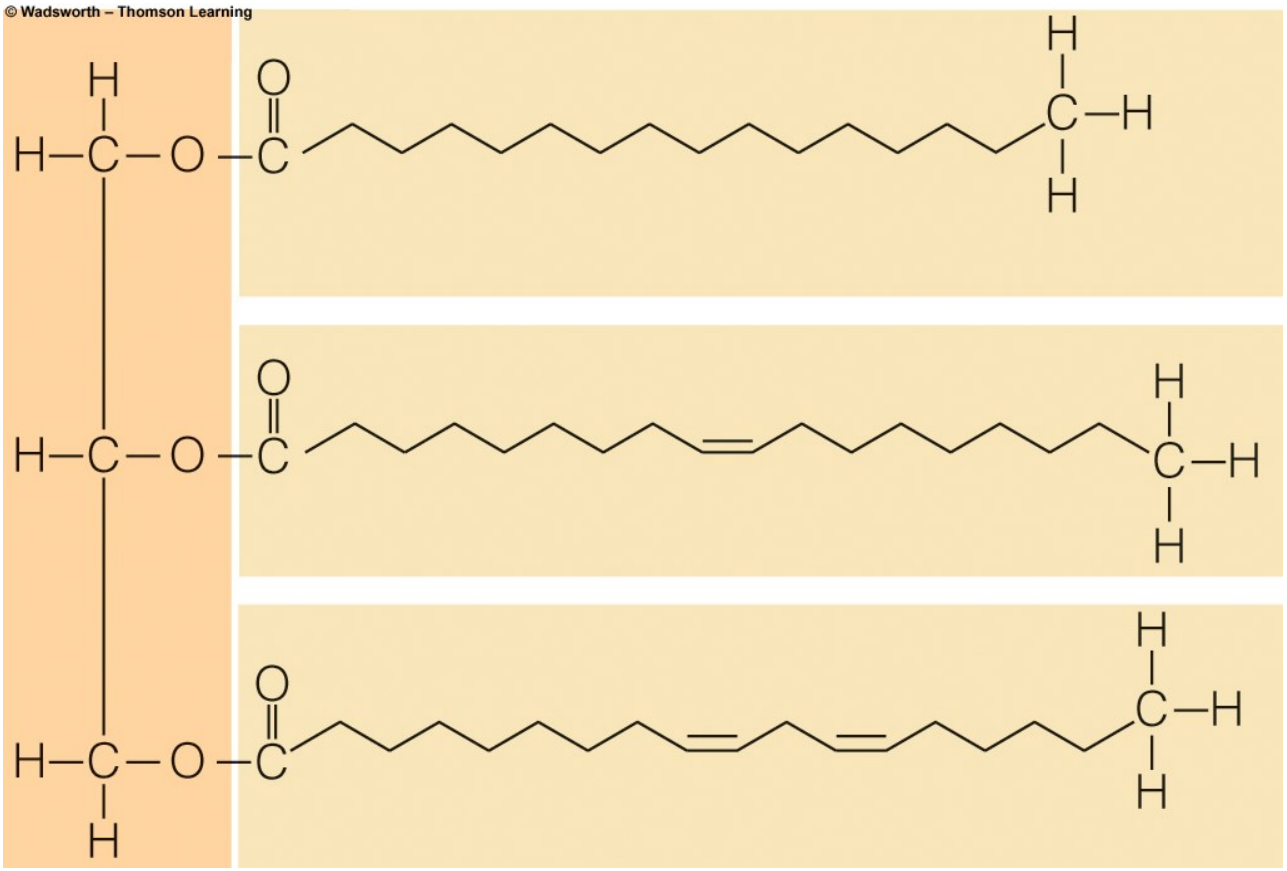
(a) Dehydration reaction in the synthesis of a fat



(b) Fat molecule (triacylglycerol)

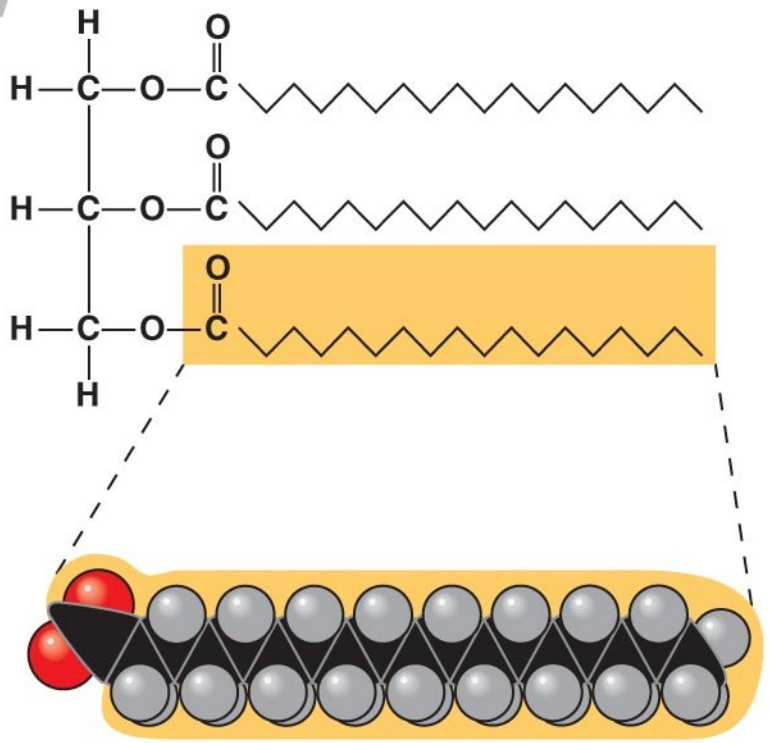
Fatty Acids & Triglycerides

- glycerol + 3 fatty acids → triglyceride + H_2O



- Fats separate from water because water molecules form hydrogen bonds with each other and exclude the fats
- In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a **triacylglycerol**, or triglyceride

- Fatty acids vary in length (number of carbons) and in the number and locations of double bonds
- **Saturated fatty acids** have the maximum number of hydrogen atoms possible and no double bonds
- **Unsaturated fatty acids** have one or more double bonds

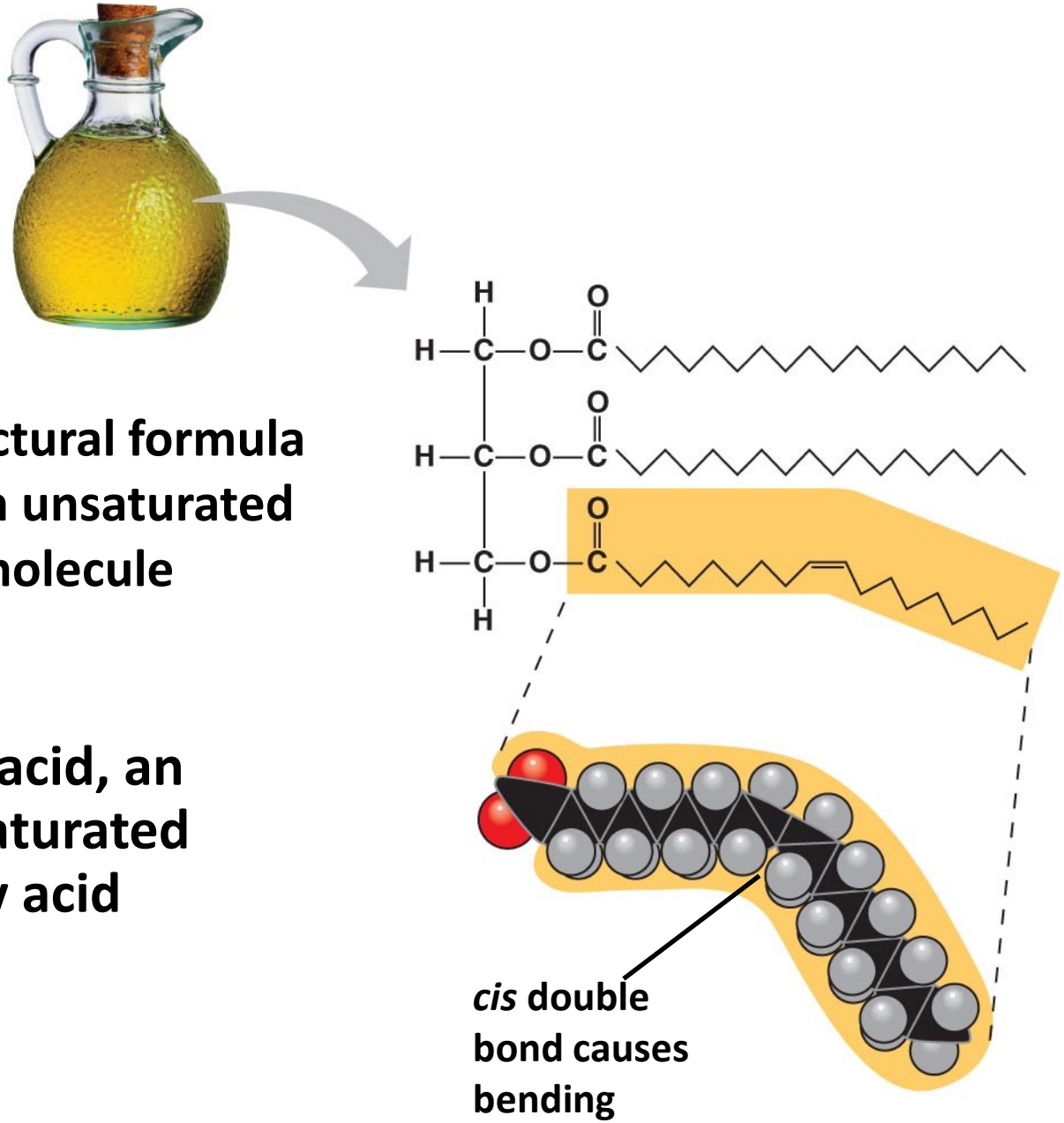


Structural formula of a saturated fat molecule

Stearic acid, a saturated fatty acid

(a) Saturated fat

Fig. 5-12b



(b) Unsaturated fat

- Fats made from saturated fatty acids are called saturated fats, and are solid at room temperature
- Most animal fats are saturated
- Fats made from unsaturated fatty acids are called unsaturated fats or oils, and are liquid at room temperature
- Plant fats and fish fats are usually unsaturated

- A diet rich in saturated fats may contribute to cardiovascular disease through plaque deposits
- Hydrogenation is the process of converting unsaturated fats to saturated fats by adding hydrogen
- Hydrogenating vegetable oils also creates unsaturated fats with *trans* double bonds
- These *trans* fats may contribute more than saturated fats to cardiovascular disease

- The major function of fats is energy storage
- Humans and other mammals store their fat in adipose cells
- Adipose tissue also cushions vital organs and insulates the body

Phospholipids

- In a **phospholipid**, two fatty acids and a phosphate group are attached to glycerol
- The two fatty acid tails are hydrophobic, but the phosphate group and its attachments form a hydrophilic head

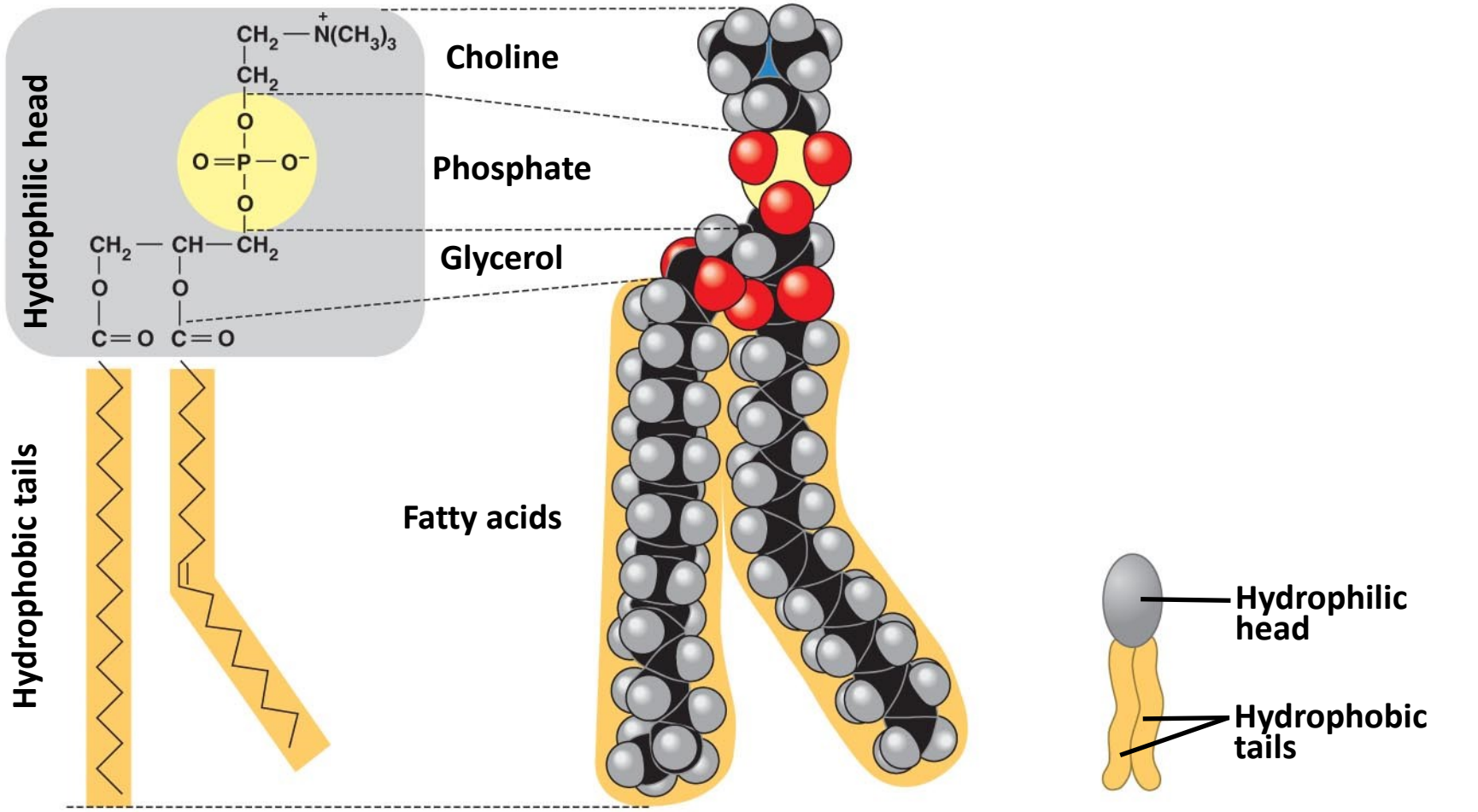
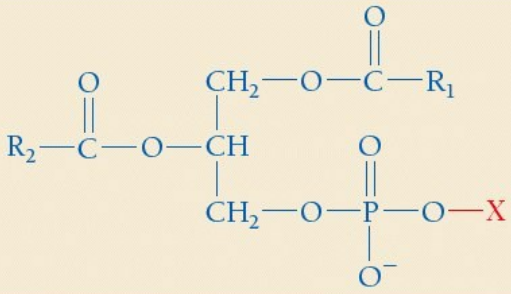


Table 9-2 The Common Classes of Glycerophospholipids



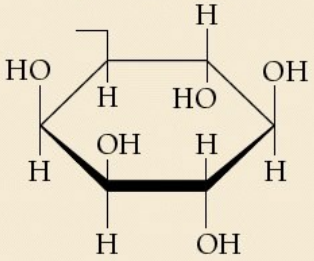
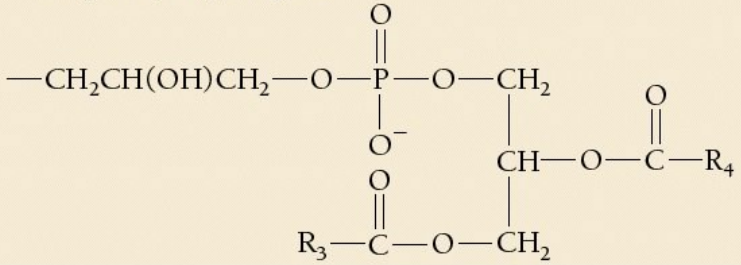
Name of X—OH	Formula of −X	Name of Phospholipid	
Water	—H	Phosphatidic acid	PA
Ethanolamine	$-CH_2CH_2NH_3^+$	Phosphatidylethanolamine	PE
Choline	$-CH_2CH_2N(CH_3)_3^+$	Phosphatidylcholine (lecithin)	PC
Serine	$-CH_2CH(NH_3^+)COO^-$	Phosphatidylserine	PS
myo-Inositol		Phosphatidylinositol	PI
Glycerol	$-CH_2CH(OH)CH_2OH$	Phosphatidylglycerol	PG
Phosphatidylglycerol		Diphosphatidylglycerol (cardiolipin)	DPG

Table 9-2 Fundamentals of Biochemistry, 2/e

- When phospholipids are added to water, they self-assemble into a bilayer, with the hydrophobic tails pointing toward the interior
- The structure of phospholipids results in a bilayer arrangement found in cell membranes
- Phospholipids are the major component of all cell membranes

Lipid bilayer

Why bilayer form?

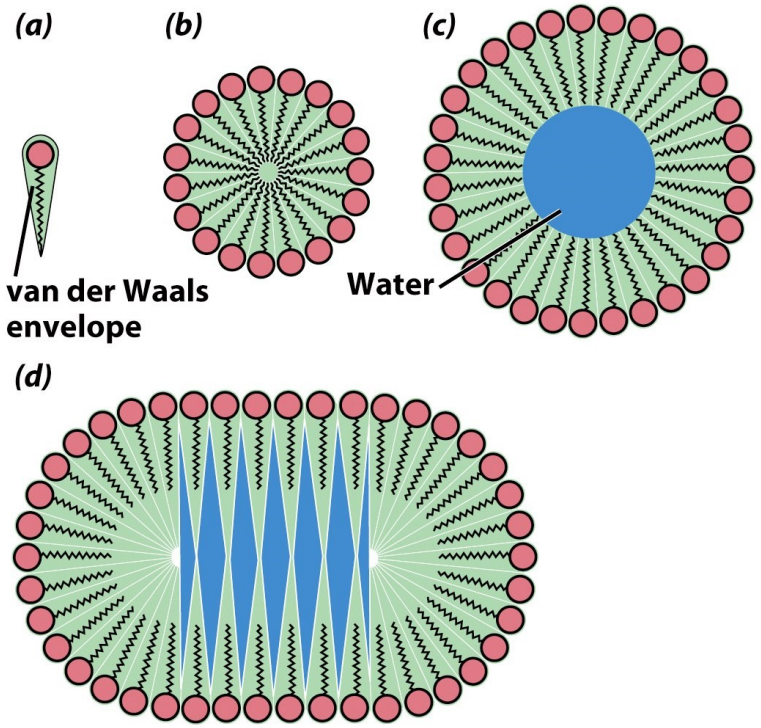


Figure 9-13 Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

Aggregates of single-tailed lipids. The **tapered** van der Waals envelope of these lipids (a) permits then to pack efficiently to form a spherical micelle (b). The diameter of the micelles depends on the length of the tails. The water filled center is energetically unfavorable (c) and (d).

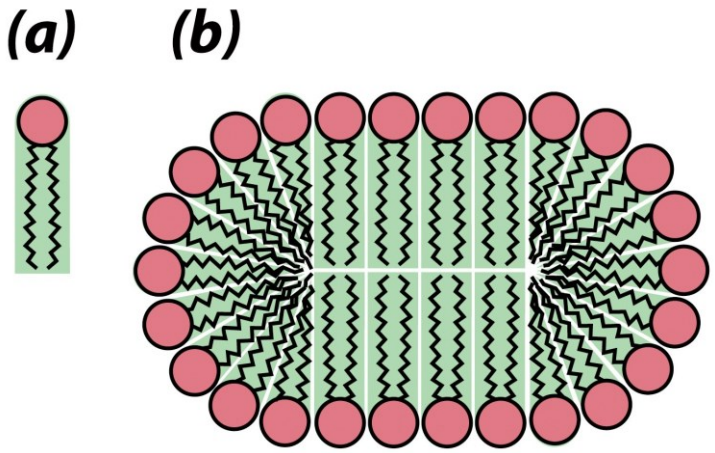
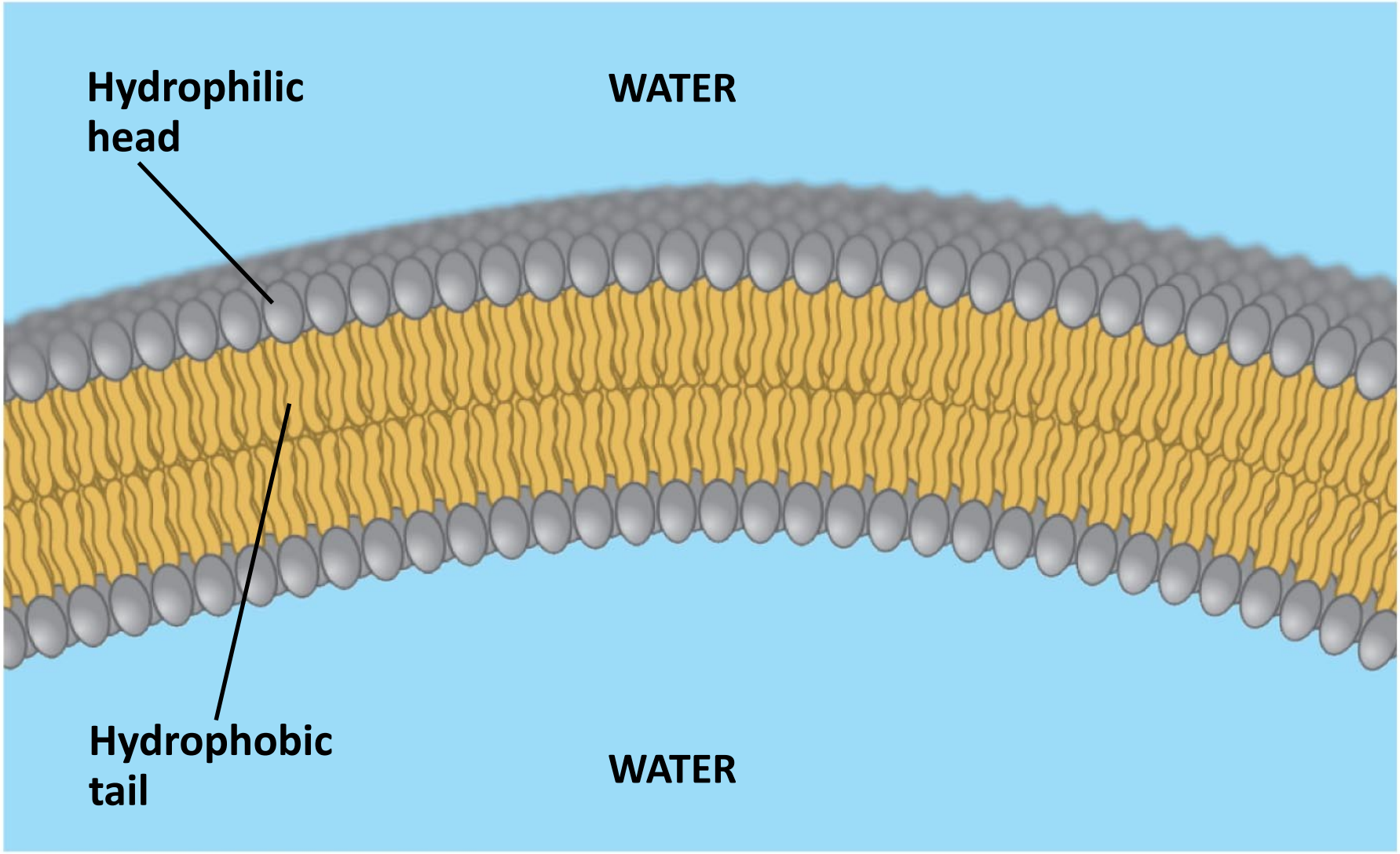


Figure 9-14 Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

Bilayer formation by phospholipids. The **cylindrical** van der Waals envelope of these lipids (a) cause them to form extended disk-like micelles (b) that are better described as lipid bilayers. The lipid bilayers are **~ 50-60 Å thick**.

Fig. 5-14



Lipid mobility

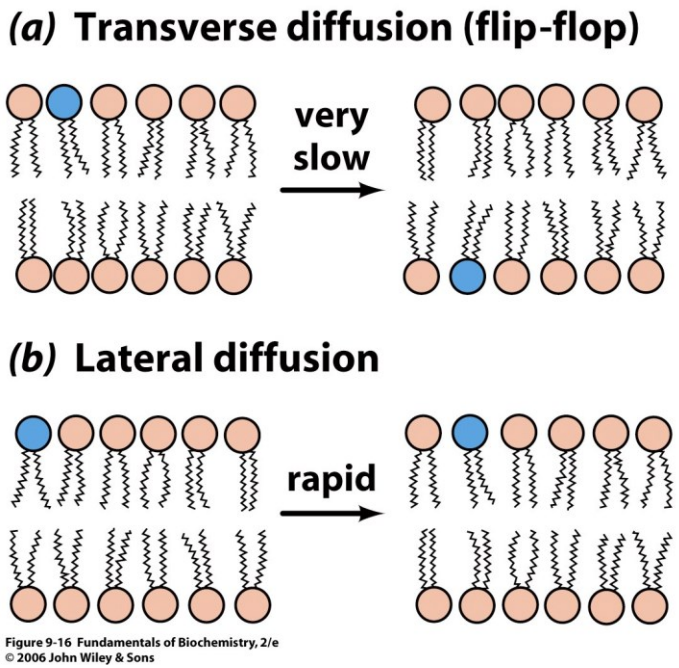


Figure 9-16 Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

a. The transfer of a lipid molecule across a bilayer, a process termed **transverse diffusion**, or a **flip-flop**, is an extremely rare event.
b. In contrast, lipids are highly mobile in the plane of the bilayer (**lateral diffusion**: pairwise exchange of neighboring lipid molecules in the same bilayer leaflet), > 1mm/sec.

Therefore, the lipid bilayer can be considered to be a two-dimensional fluid.

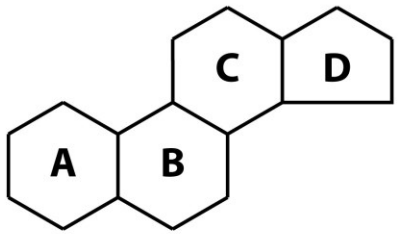
Steroids

- **Steroids** are lipids characterized by a carbon skeleton consisting of four fused rings
- **Cholesterol**, an important steroid, is a component in animal cell membranes
- Although cholesterol is essential in animals, high levels in the blood may contribute to cardiovascular disease

Steroids

Steroids are derivatives of a compound that consists of **four fused nonpolar rings** (right).

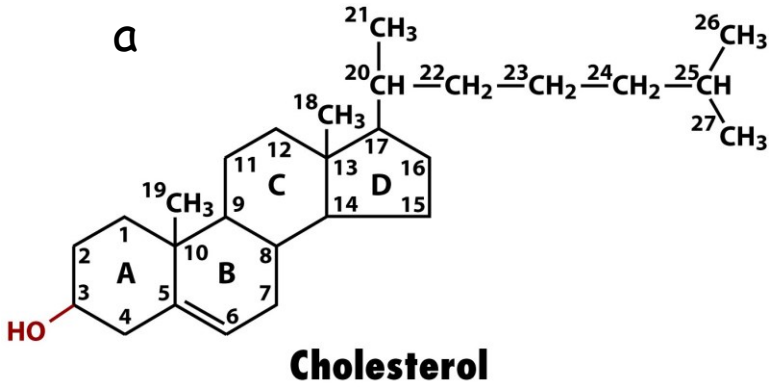
Cholesterol is the most abundant steroid in animals.



Cyclopentanoperhydrophenanthrene

Unnumbered figure pg 242a Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

a



Cholesterol

Figure 9-10a Fundamentals of Biochemistry, 2/e
© 2006 John Wiley & Sons

b

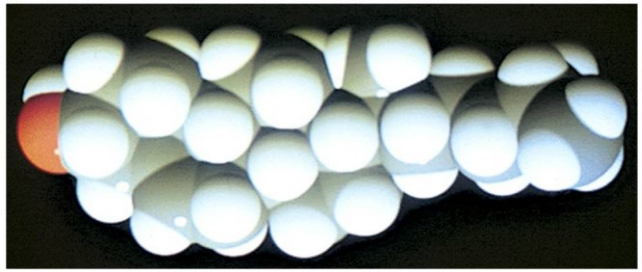


Figure 9-10b Fundamentals of Biochemistry, 2/e

- major component of animal plasma membranes
- weak amphiphilic character
- fused ring system provides greater rigidity.
- modulates the fluidity of membranes