The Structure and Function of Large Biological Molecules

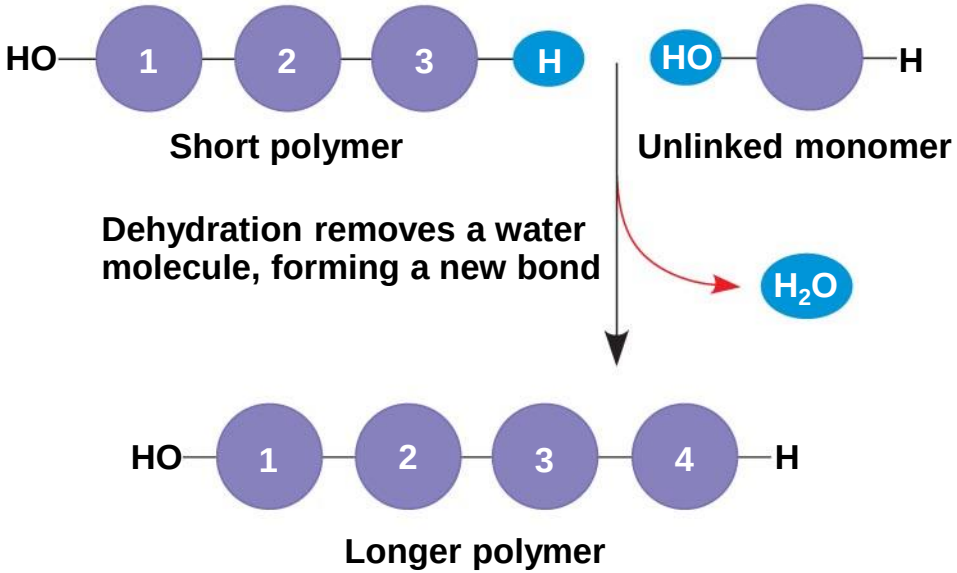
The Molecules of Life

- Living things are made of four classes of large biomolecules: carbohydrates, lipids, proteins, and nucleic acids
- **Macromolecules**
- ***Molecular structure and function are inseparable*** (form follows function)

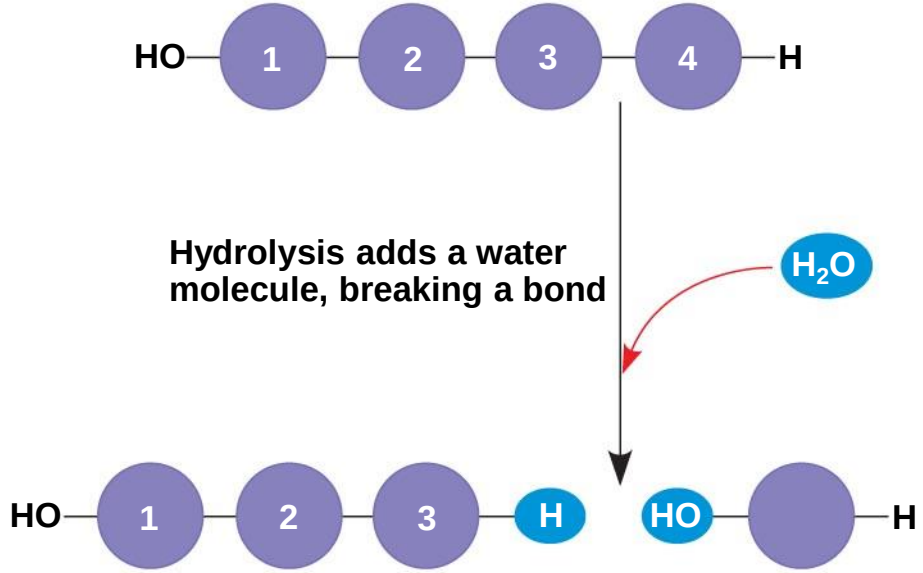
  - P**olymer-** long molecule consisting of many similar building blocks
  - Three out of four classes of organic molecules are polymers. They are:
    - Carbohydrates
    - Proteins
    - Nucleic acids

How many 50 units of different polymers can be formed using 4 different monomers?

The Synthesis and Breakdown of Polymers



(a) Dehydration reaction in the synthesis of a polymer



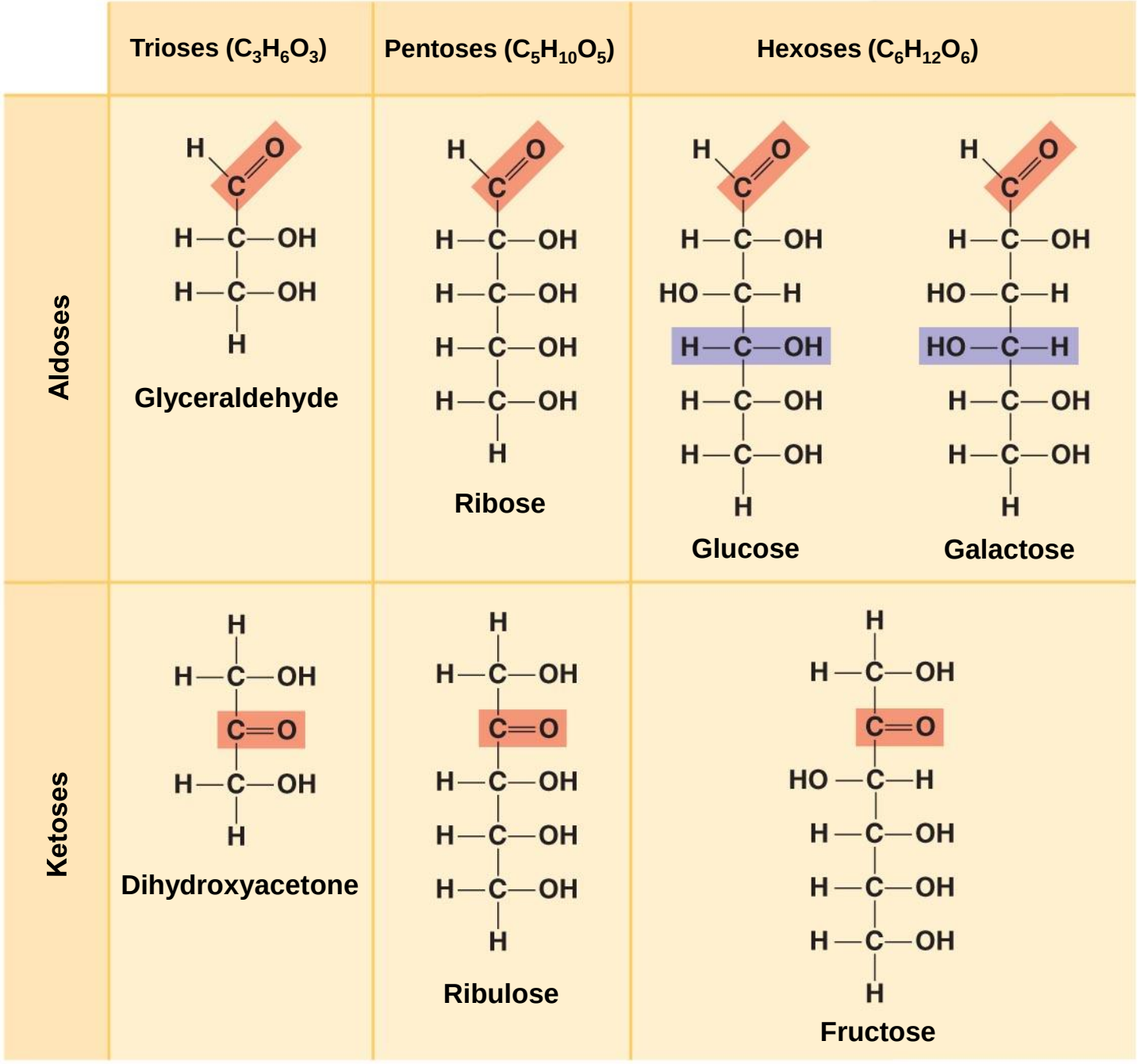
(b) Hydrolysis of a polymer

Carbohydrates serve as fuel and building material

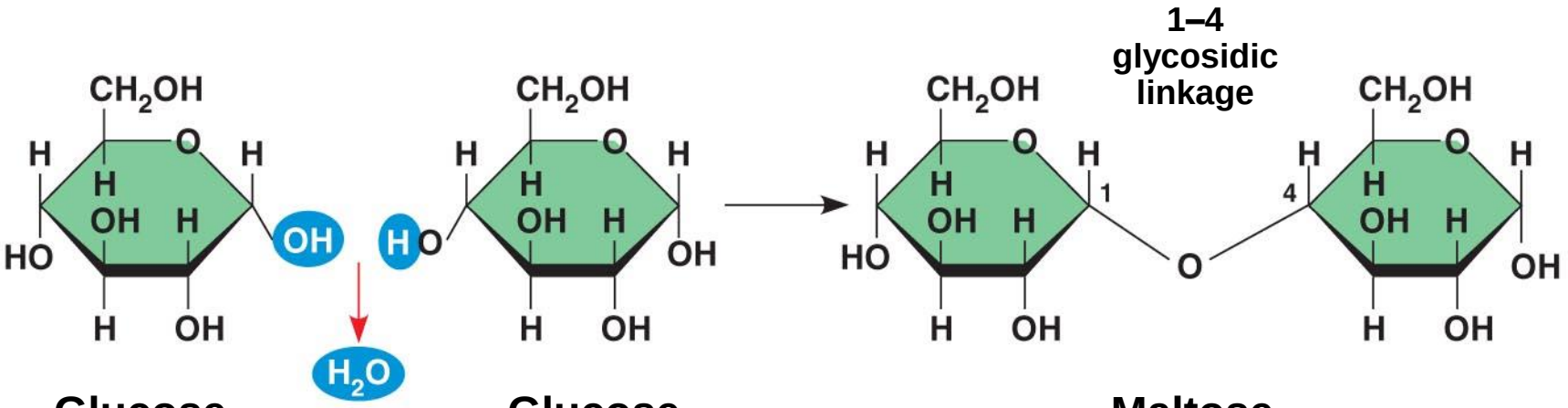
- **Carbohydrates** include sugars and polymers of sugars
- **Monosaccharides**, or single sugars are the simplest carbohydrates
- **Polysaccharides** are polymers composed of many sugar building blocks or carbohydrate macromolecules,

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

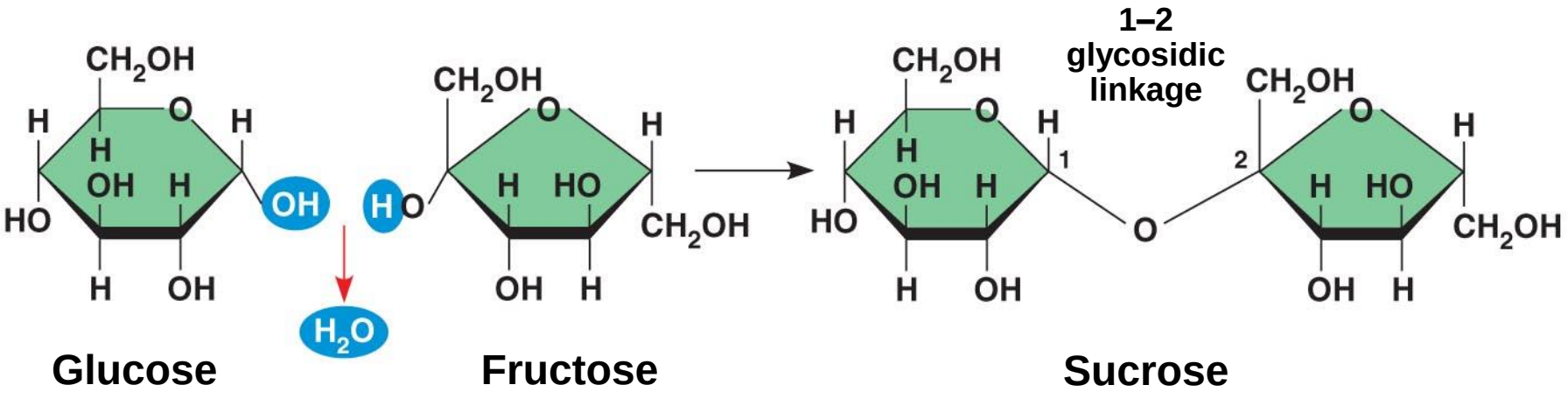
Fig. 5-3



Monosaccharides are a major fuel for cells and a raw material for building molecules

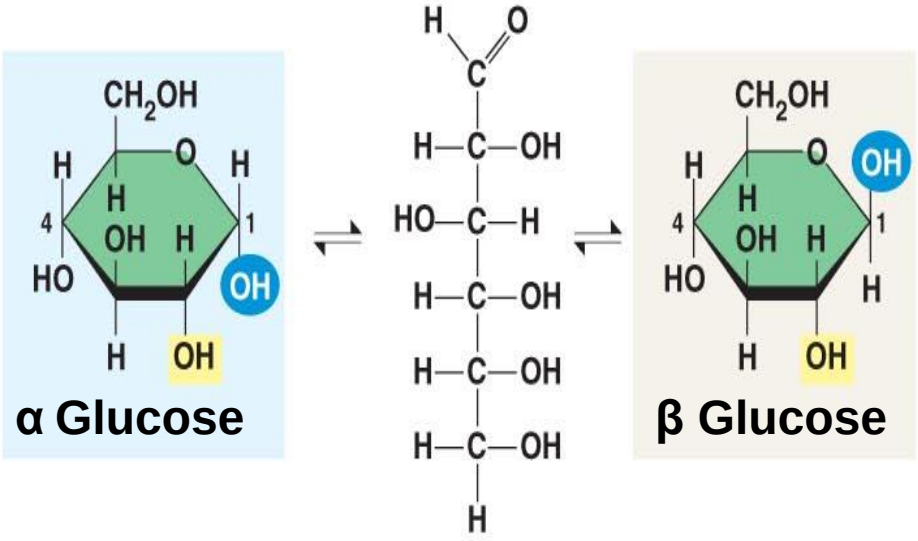


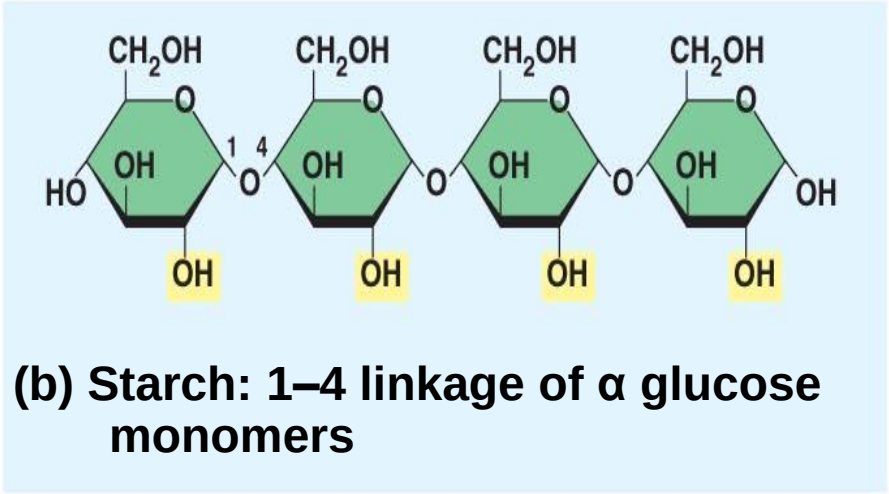
(a) Dehydration reaction in the synthesis of maltose



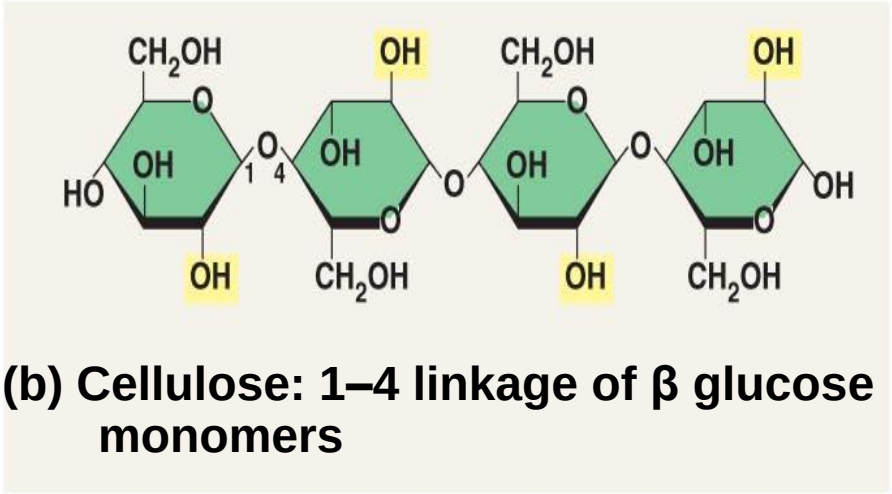
(b) Dehydration reaction in the synthesis of sucrose

(a) α and β glucose ring structures





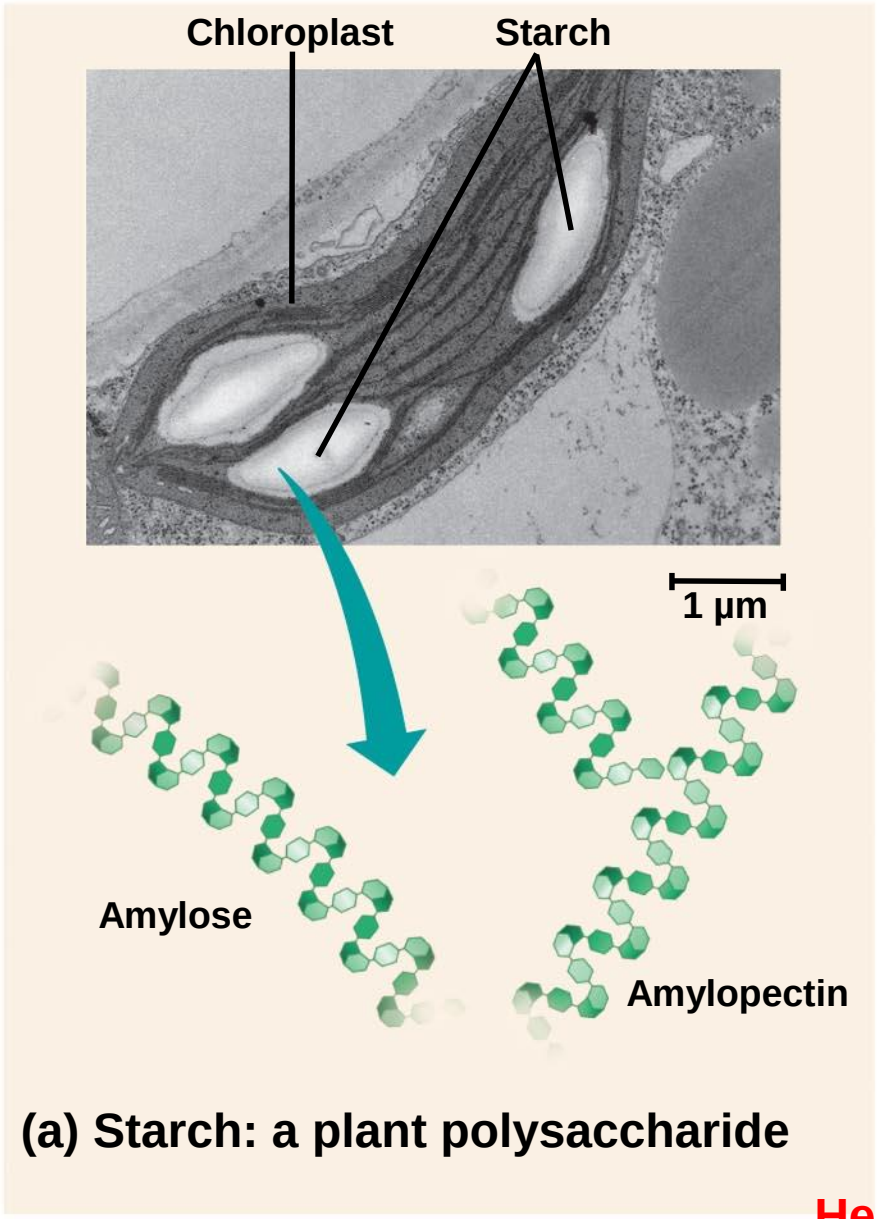
(b) Starch: 1–4 linkage of α glucose monomers



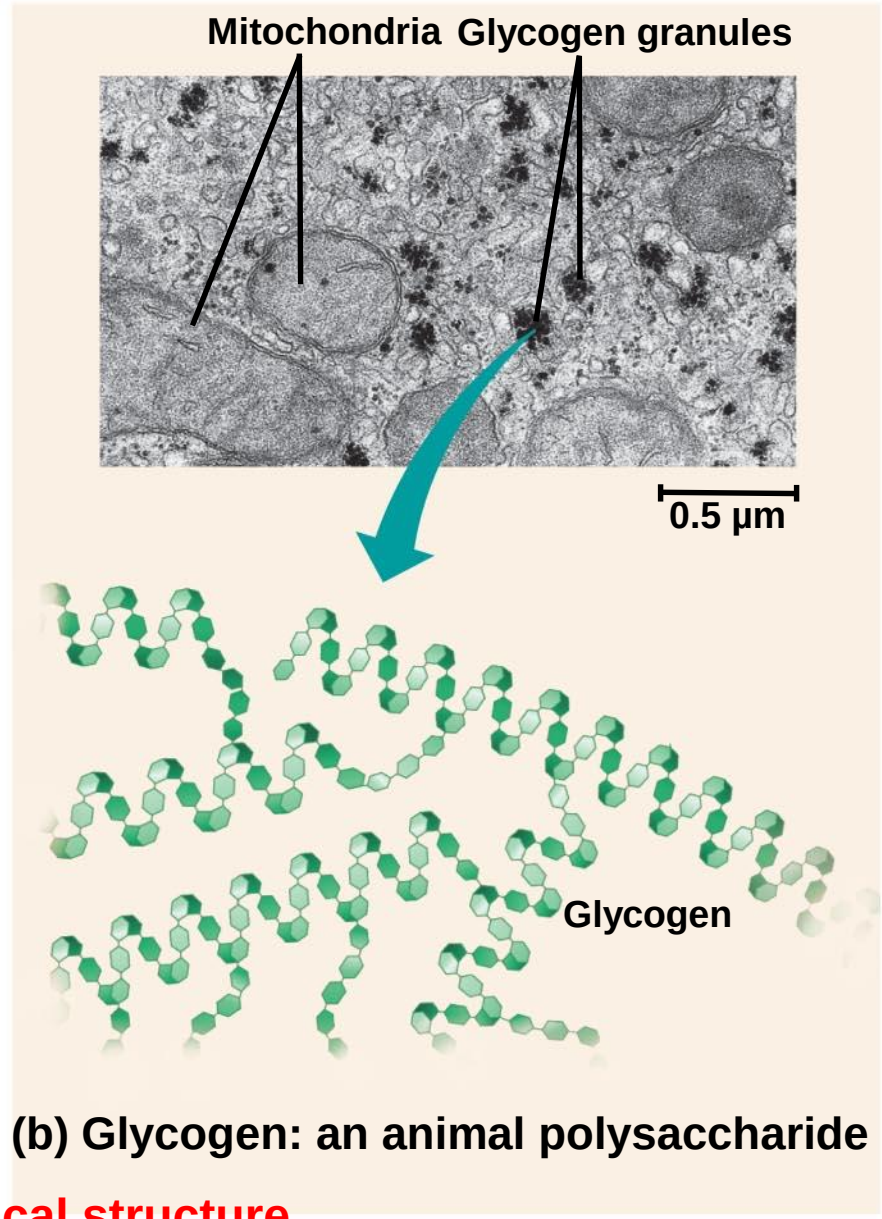
(b) Cellulose: 1–4 linkage of β glucose monomers

The structure and function of a polysaccharide are determined by **the sugar monomers in it and the positions of glycosidic linkages**

Storage Polysaccharides



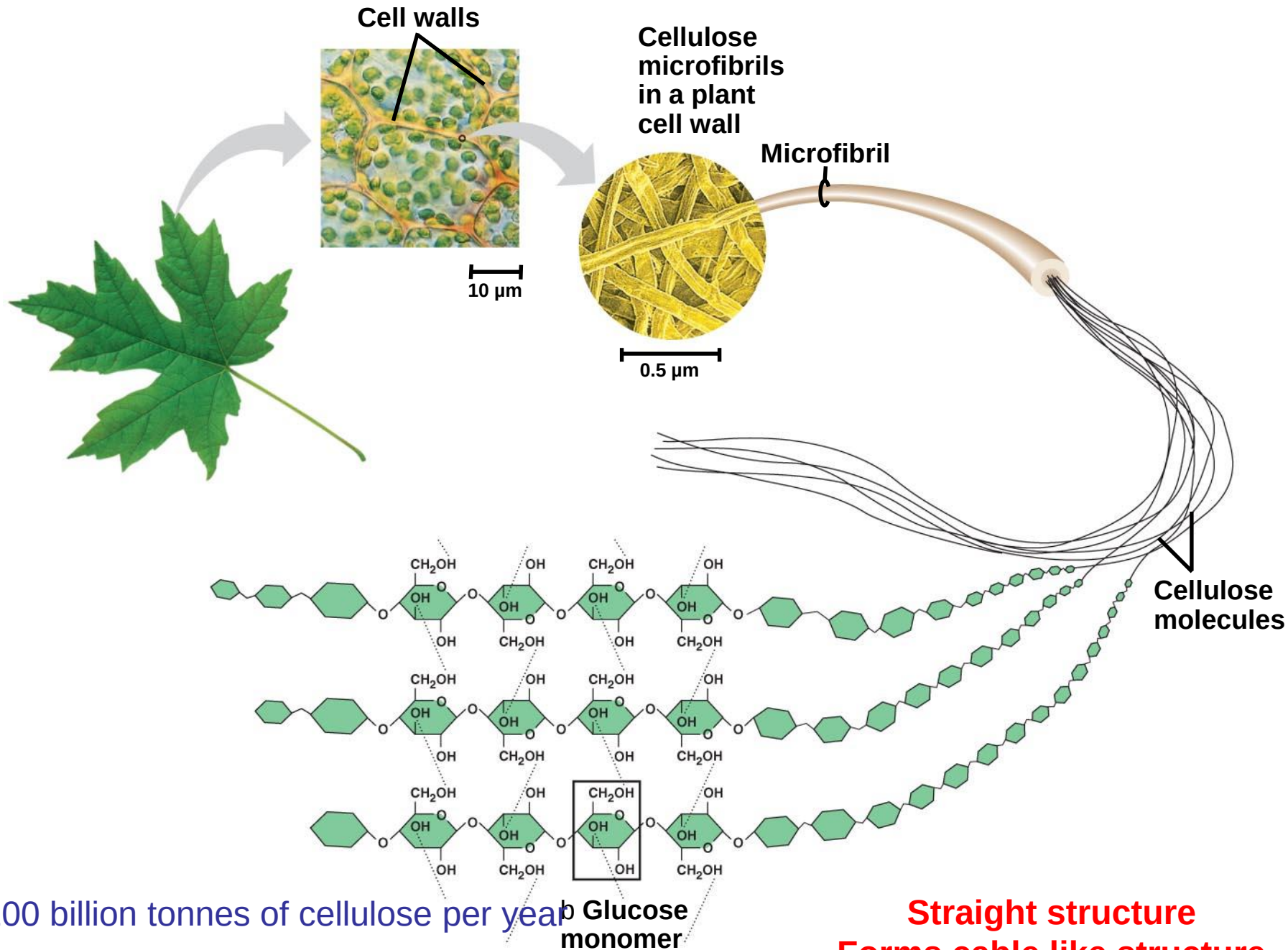
(a) Starch: a plant polysaccharide



(b) Glycogen: an animal polysaccharide

Helical structure

Structural Polysaccharides

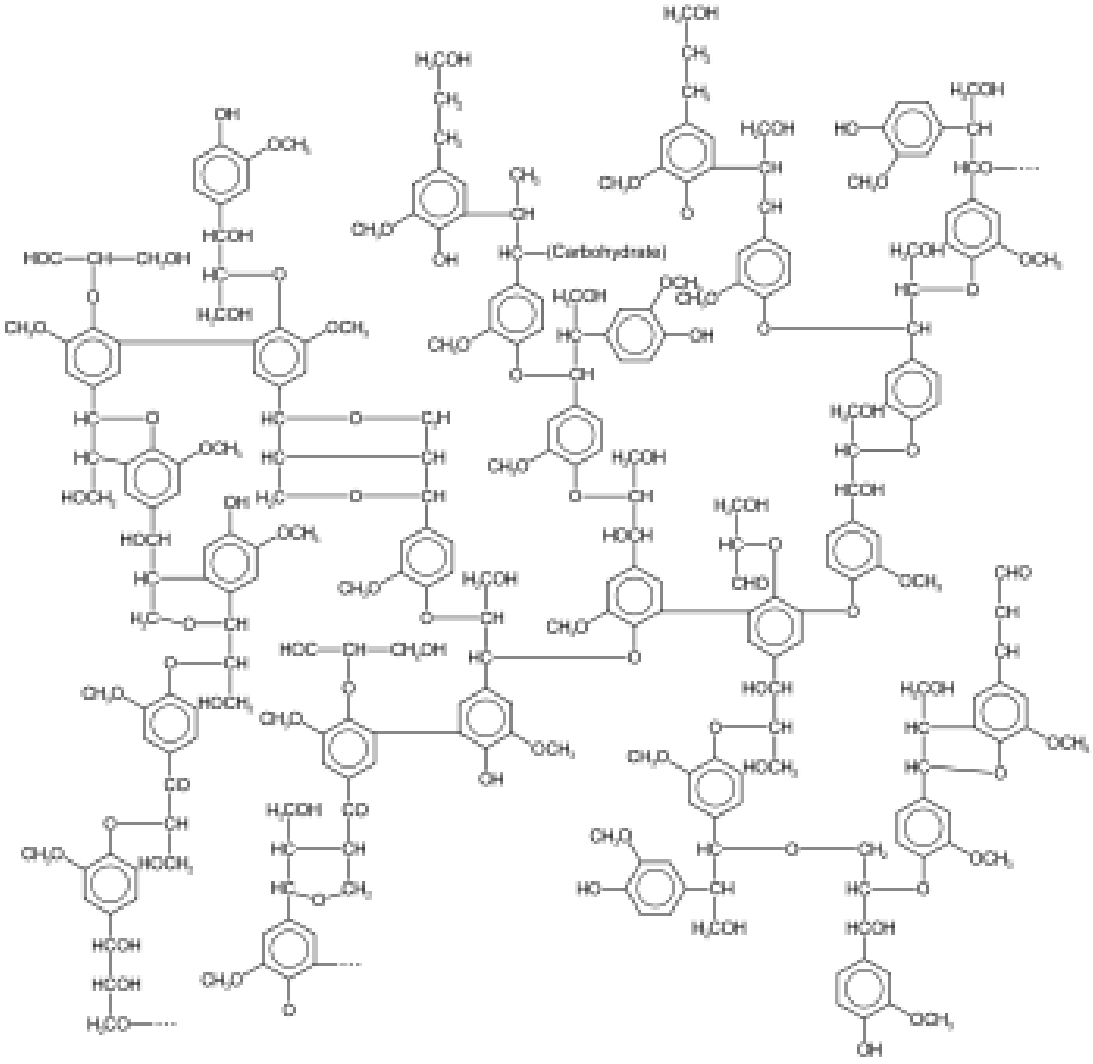


100 billion tonnes of cellulose per year

Straight structure
Forms cable like structure

Lignin

30% of the earth's non-fossil organic carbon is in the form of **lignin**.



Most abundant **aromatic polymer on earth and the second most abundant organic polymer of any kind**

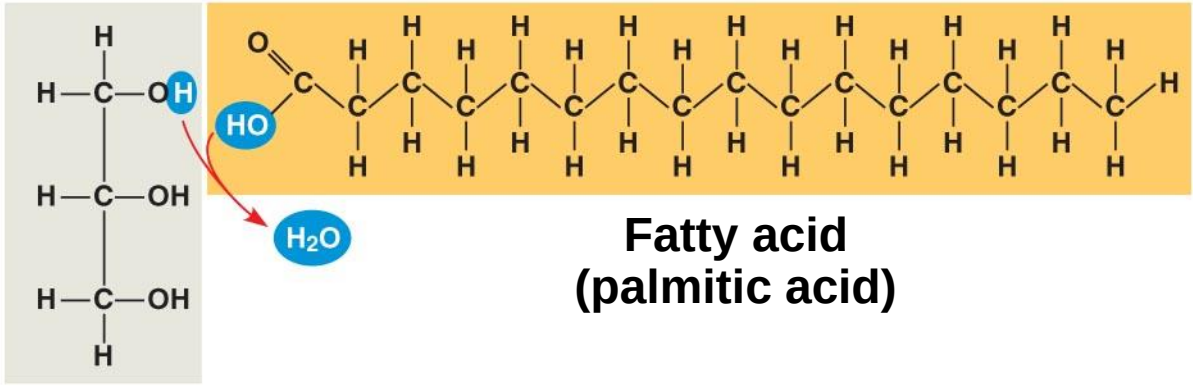
Lipids are a diverse group of hydrophobic molecules

- **Lipids**- the only large biomolecule class that can't form polymers
- Lipids are made of hydrocarbons which form nonpolar covalent bonds, making lipids hydrophobic
- The most important lipids are fats, phospholipids, and steroids

- **Fats-** Made from glycerol and fatty acids
- **Glycerol**- Three-carbon alcohol with a hydroxyl group attached to each carbon
- **Fatty acid-** Carboxyl group attached to a long carbon skeleton

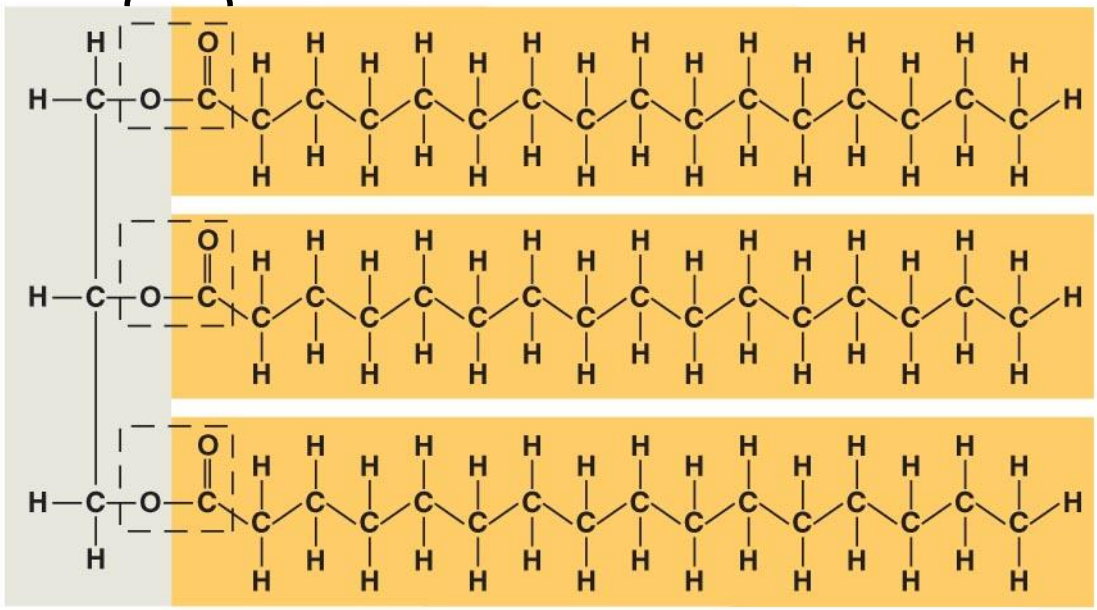
RCOOR'

Why fats separate from water?



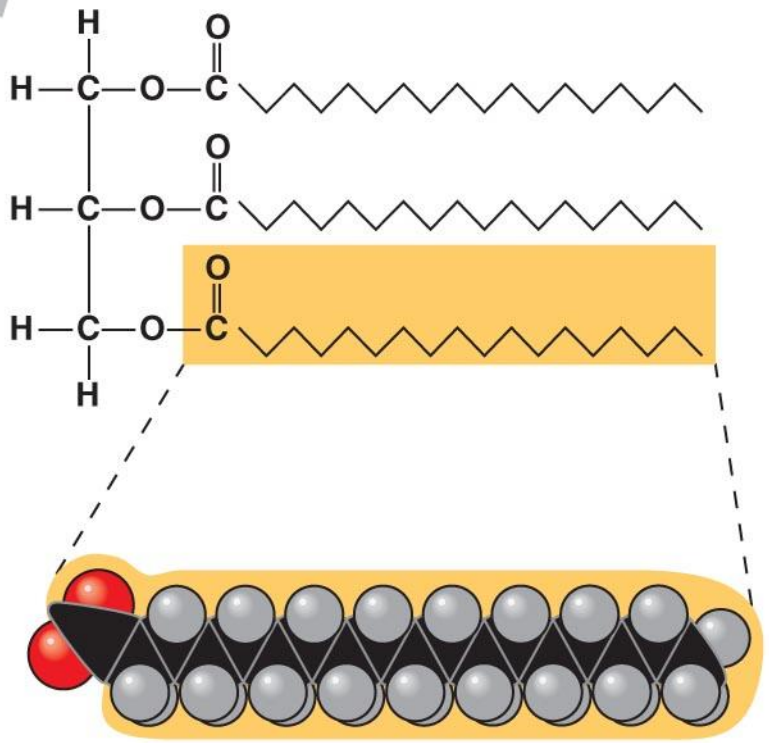
(a) Dehydration reaction in the synthesis of a fat

Ester linkage



(b) Fat molecule (triacylglycerol)

Saturated and Unsaturated fats



Structural formula of a saturated fat molecule

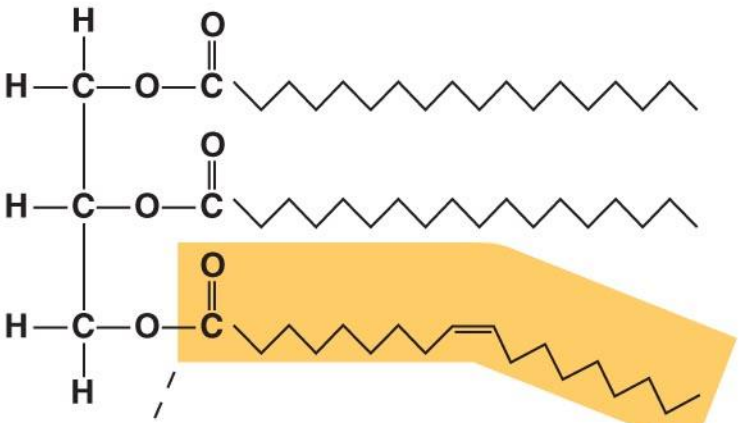
Stearic acid, a saturated fatty acid

(a) Saturated fat

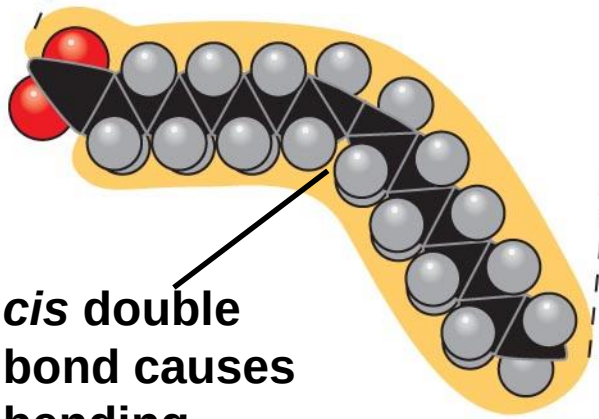
Fig. 5-12b

The major function of fats **is energy storage**. Adipose tissue also **cushions vital organs and insulates the body**

Structural formula of an unsaturated fat molecule



Oleic acid, an unsaturated fatty acid



(b) Unsaturated fat

Phospholipids

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

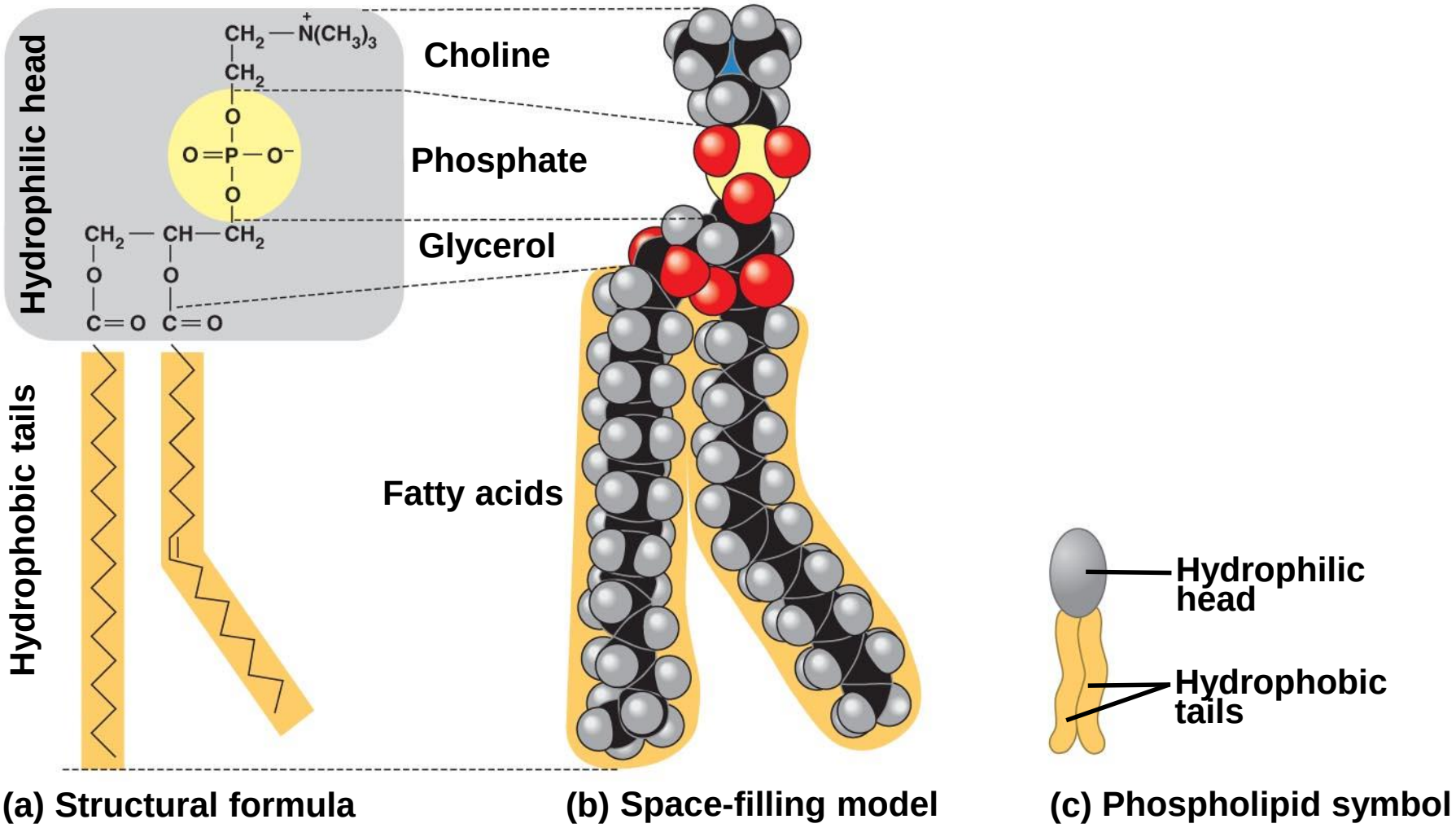
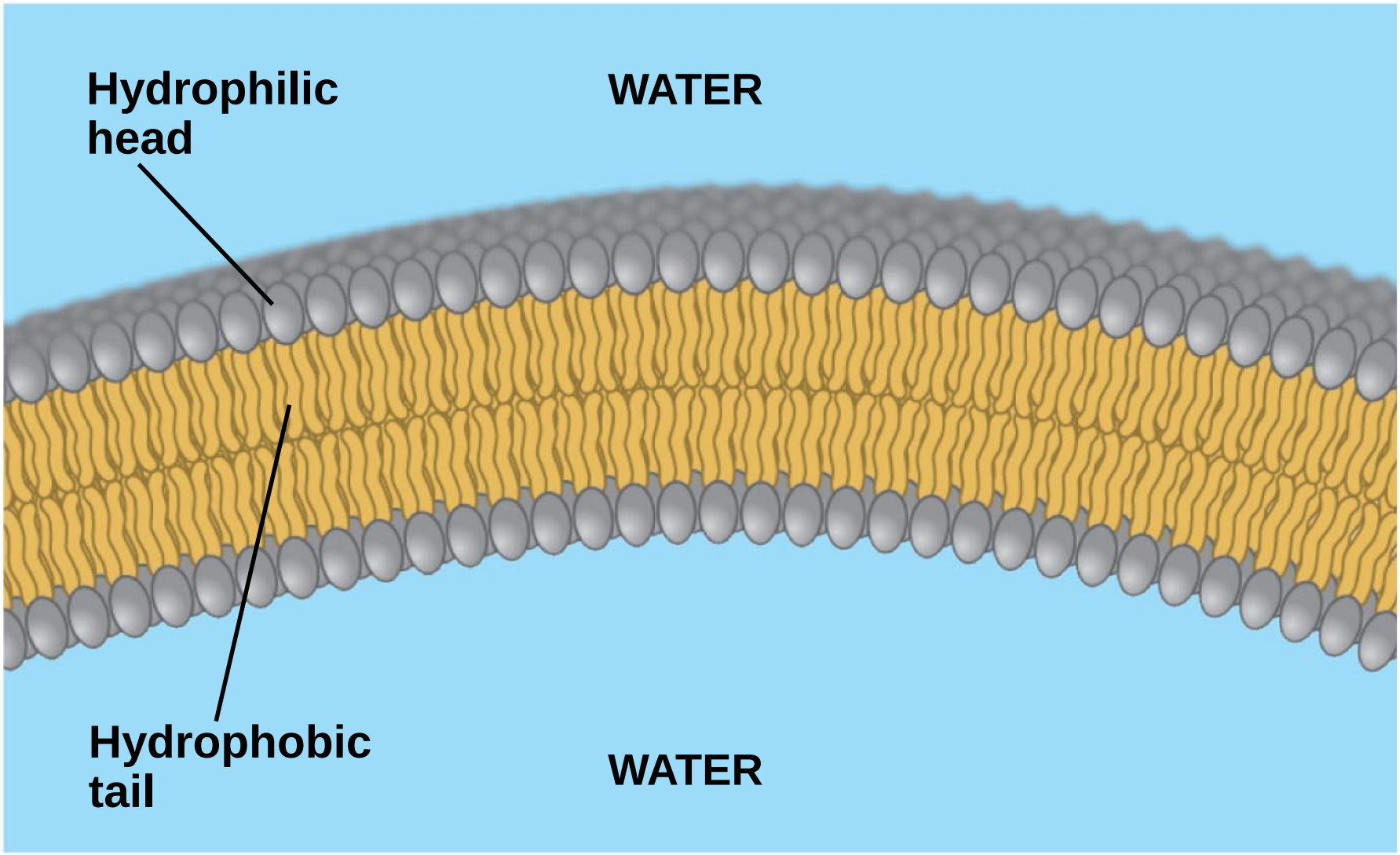


Fig. 5-14

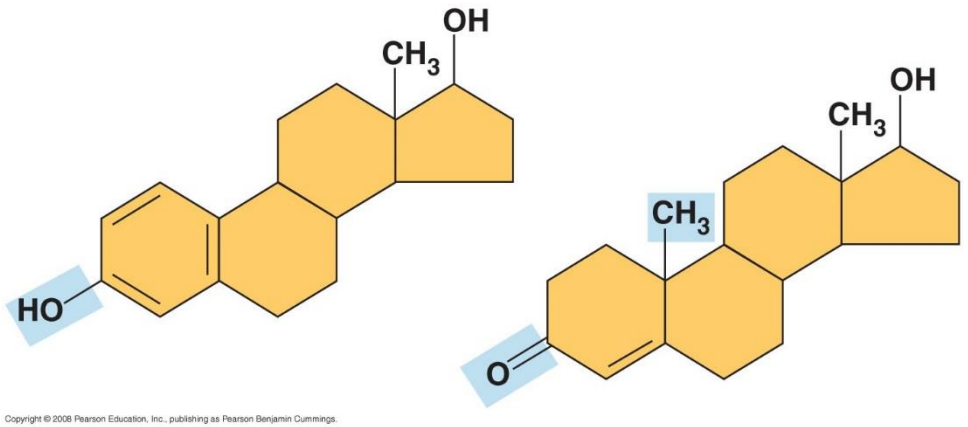


Steroids

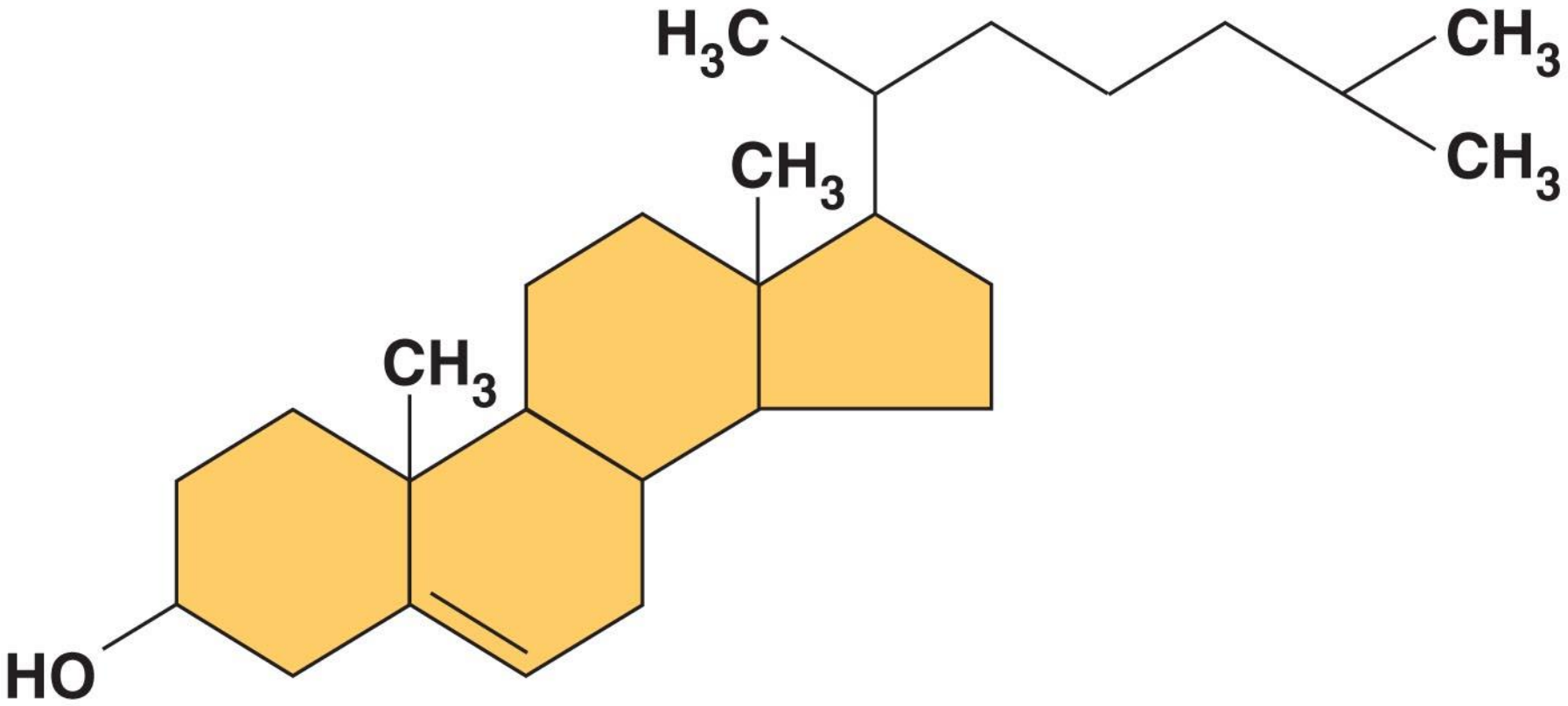
- **Steroids-** lipids having a carbon skeleton consisting of four fused rings
- **Cholesterol**- important steroid component in animal cell membranes; stabilizes membranes
- Cholesterol is essential in animals, but high levels in the blood may contribute to cardiovascular disease

Anti- inflammatory drug dexamethasone

Corticosteroid drugs — including **cortisone, hydrocortisone** and prednisone : **Lupus** treatment



Lupus is a chronic, **autoimmune disease** that can damage any part of the body (skin, joints, and/or organs inside the body).



Notice the similarity in ring structure between cholesterol and the hormones estradiol & testosterone.

Proteins have many structures, resulting in a wide range of functions

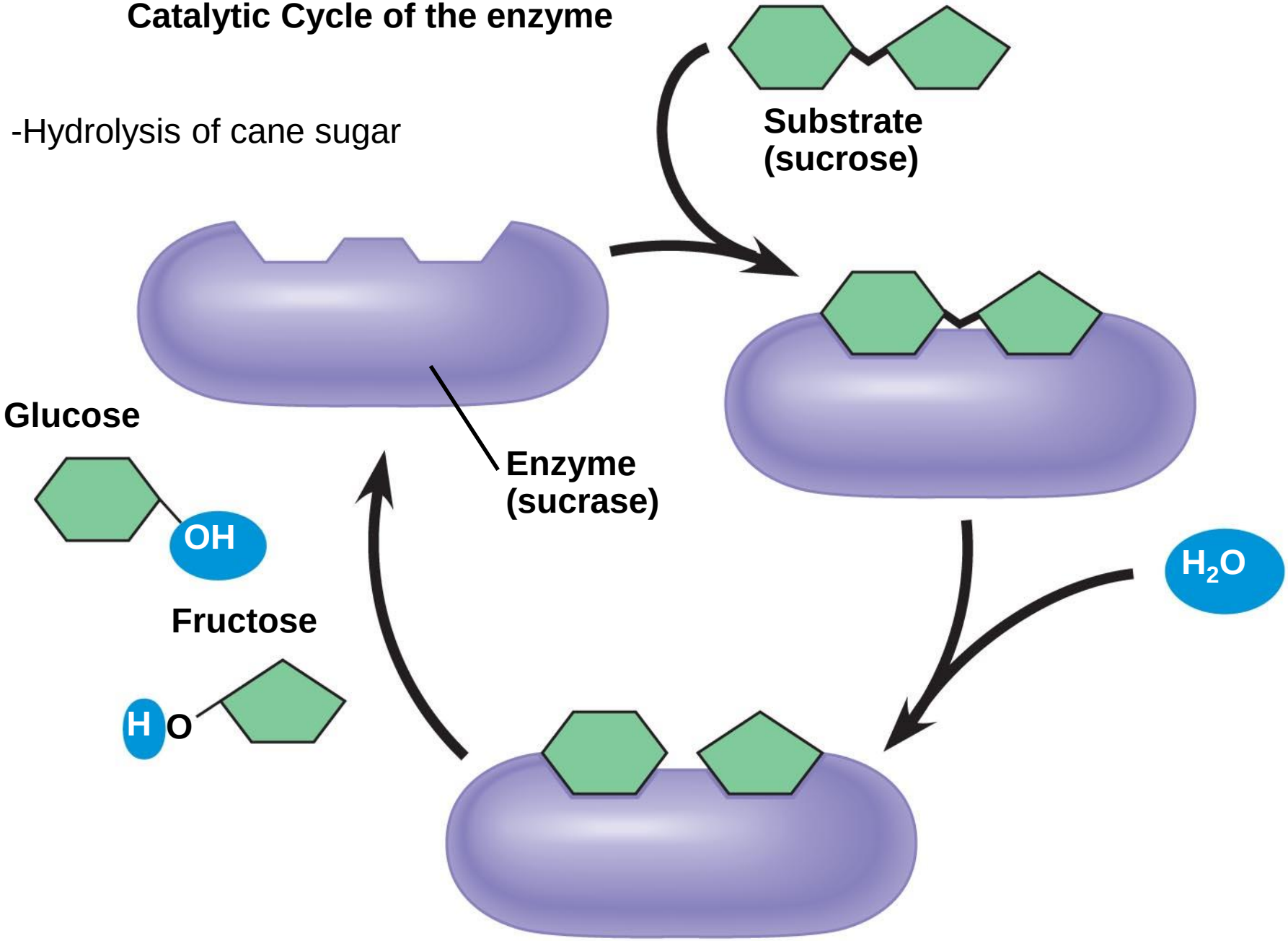
- Proteins are more than 50% of the dry mass of most cells
- Protein functions include
  - Structural support
  - storage
  - transport
  - cellular communications
  - movement
  - defense against foreign substances
- A **protein** consists of one or more polypeptides
- Greek word proteios, meaning **first place**

Table 5.1 An Overview of Protein Functions

Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes
Structural proteins	Support	Silk fibers; collagen and elastin in animal connective tissues; keratin in hair, horns, feathers, and other skin appendages
Storage proteins	Storage of amino acids	Ovalbumin in egg white; casein, the protein of milk; storage proteins in plant seeds
Transport proteins	Transport of other substances	Hemoglobin, transport proteins
Hormonal proteins	Coordination of an organism's activities	Insulin, a hormone secreted by the pancreas
Receptor proteins	Response of cell to chemical stimuli	Receptors in nerve cell membranes
Contractile and motor proteins	Movement	Actin and myosin in muscles, proteins in cilia and flagella
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.

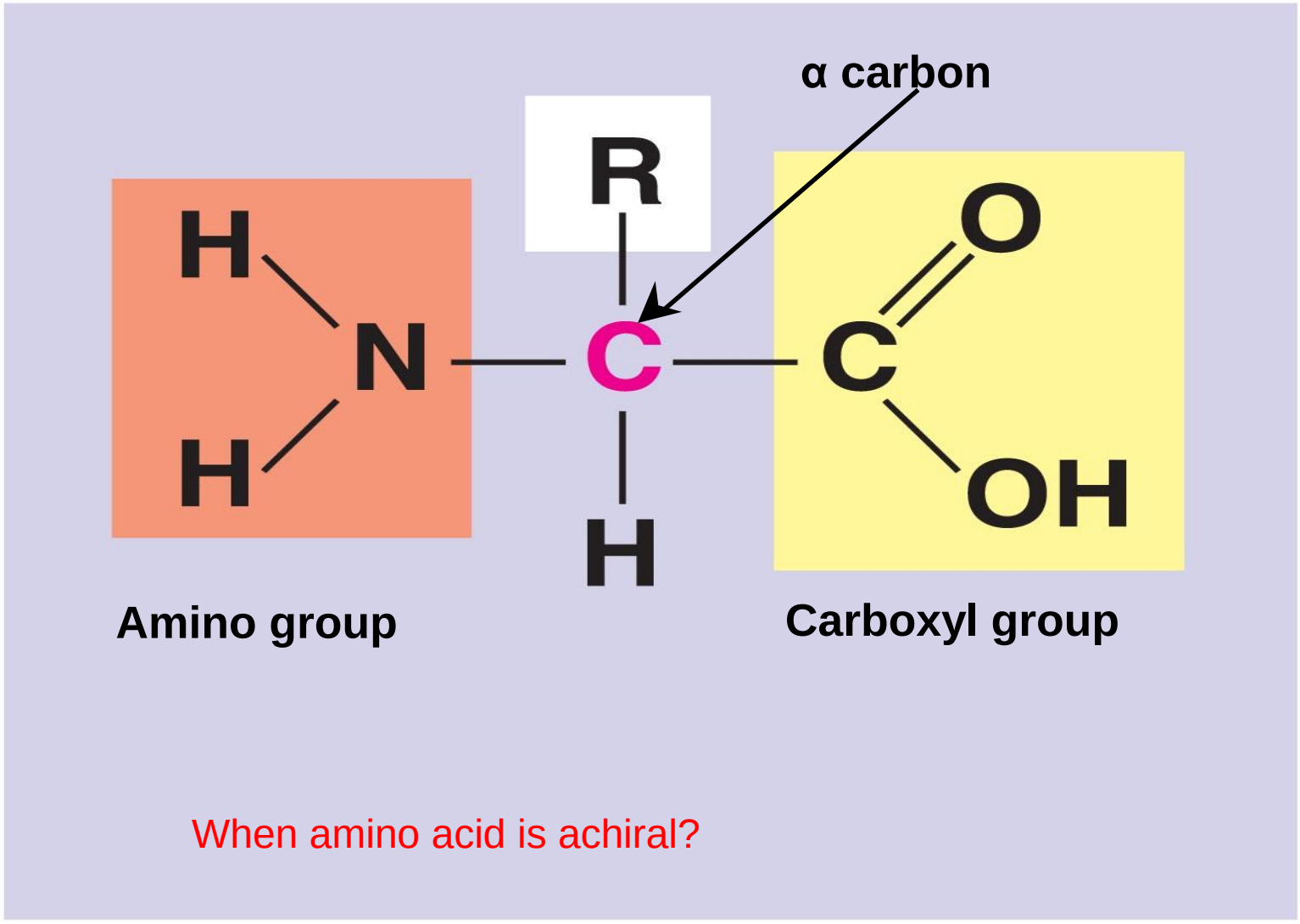
Catalytic Cycle of the enzyme

-Hydrolysis of cane sugar



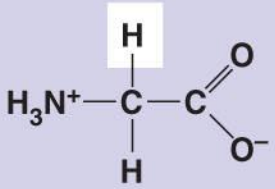
Amino acids

- **Amino acids-** organic molecules with carboxyl and amino groups

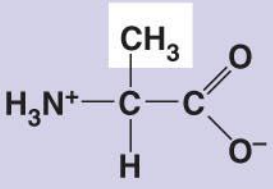


When amino acid is achiral?

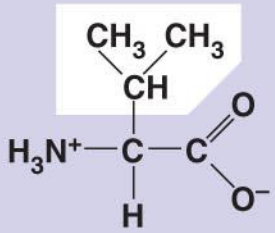
Nonpolar



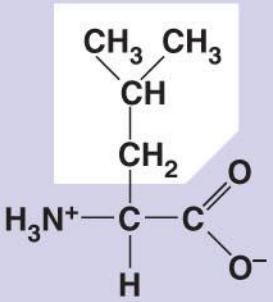
Glycine (Gly or G)



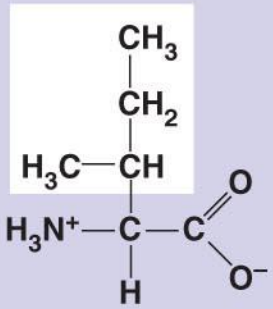
Alanine (Ala or A)



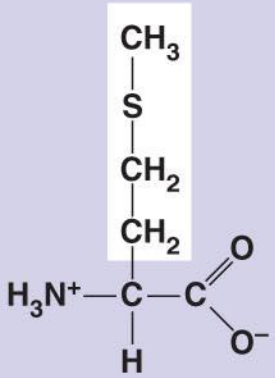
Valine (Val or V)



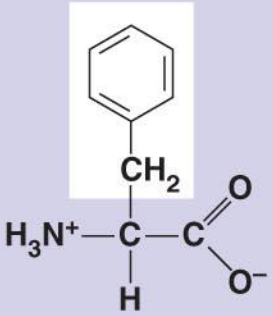
Leucine (Leu or L)



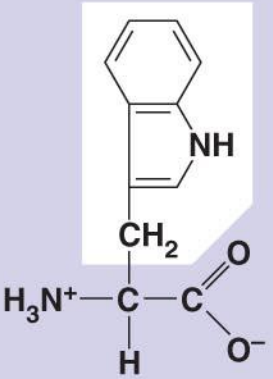
Isoleucine (Ile or I)



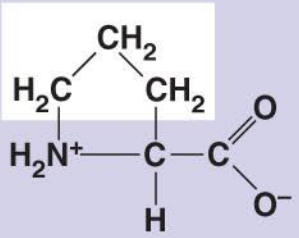
Methionine (Met or M)



Phenylalanine (Phe or F)

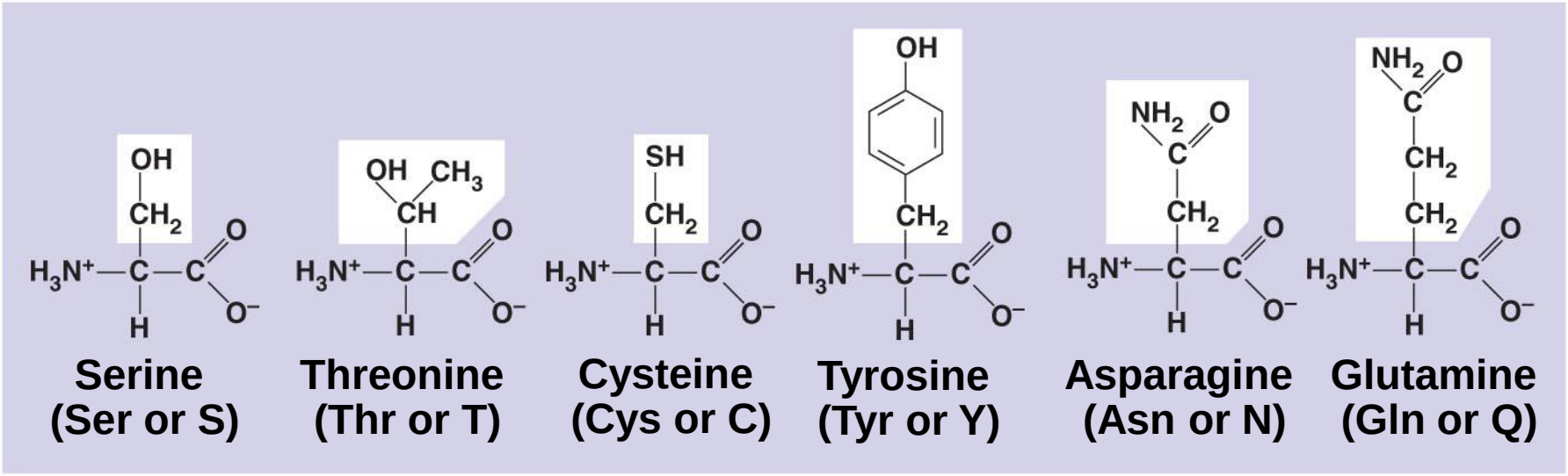


Tryptophan (Trp or W)

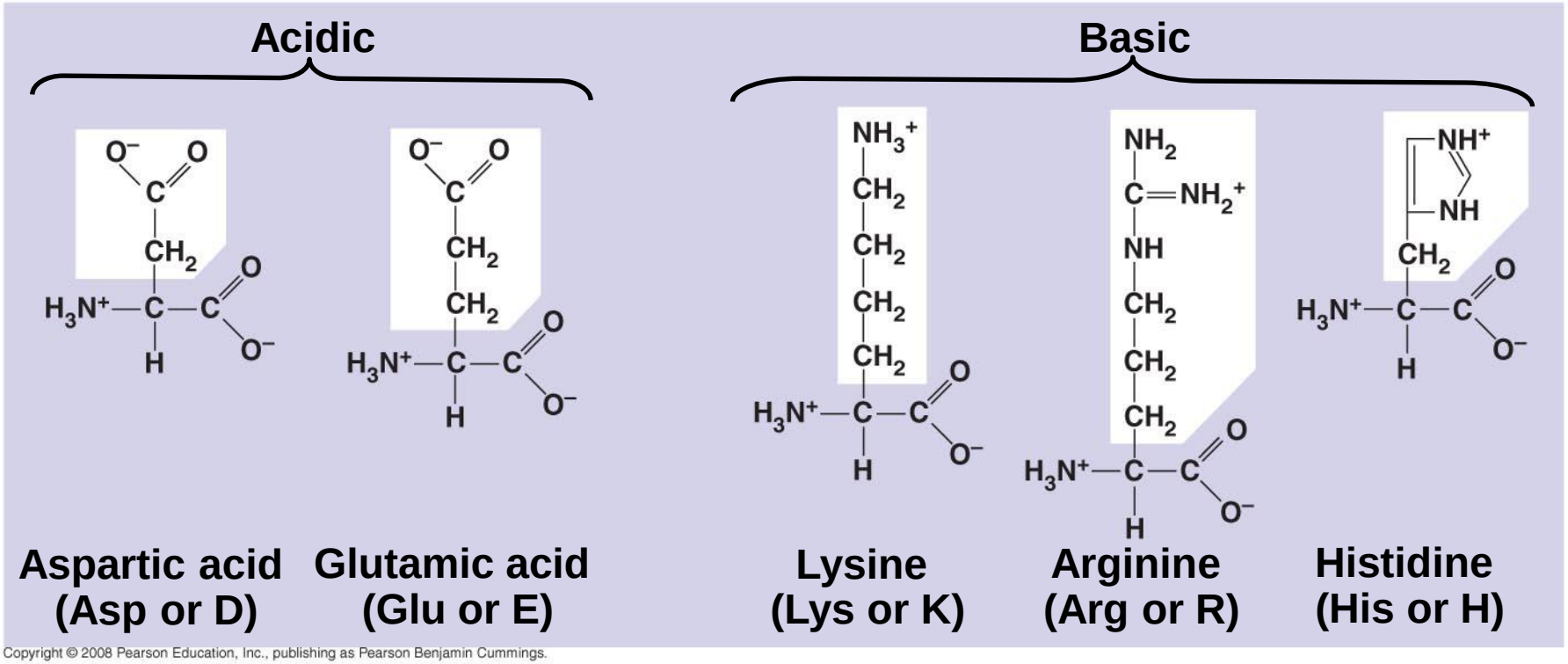


Proline (Pro or P)

Polar

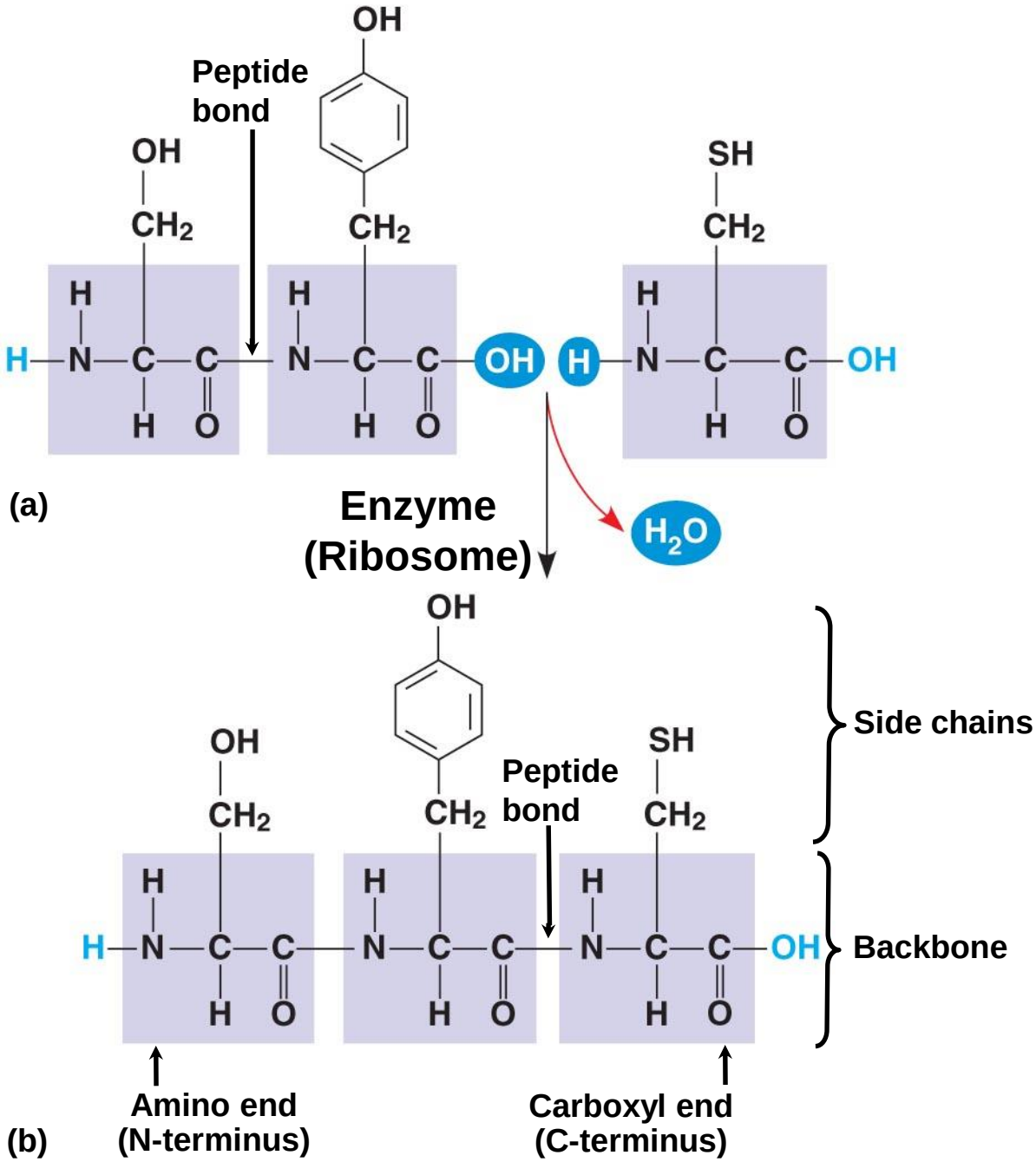


Electrically charged



Amino Acid Polymers

- Amino acids are linked by **peptide bonds** to make polypeptides
- **Polypeptide-** polymer of amino acids (similar monomers), range in length from few to over a thousand monomers
- Each has a **unique linear** amino acid sequence
- **All proteins are polypeptides**



Protein Structure and Function

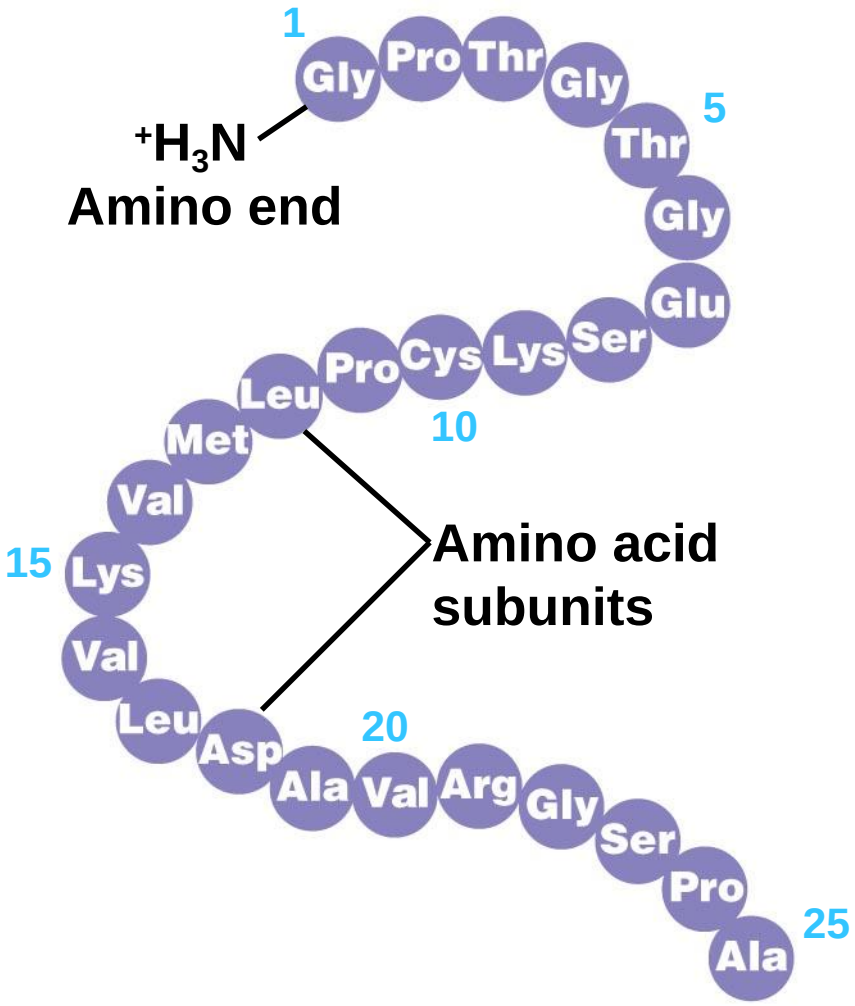
Proteins have many structures, resulting in a wide range of functions

- Functional proteins are one or more polypeptides twisted, folded, and coiled into a unique shape
- A protein's amino acid sequence determines its three-dimensional structure
- The structure determines its function (form follows function)

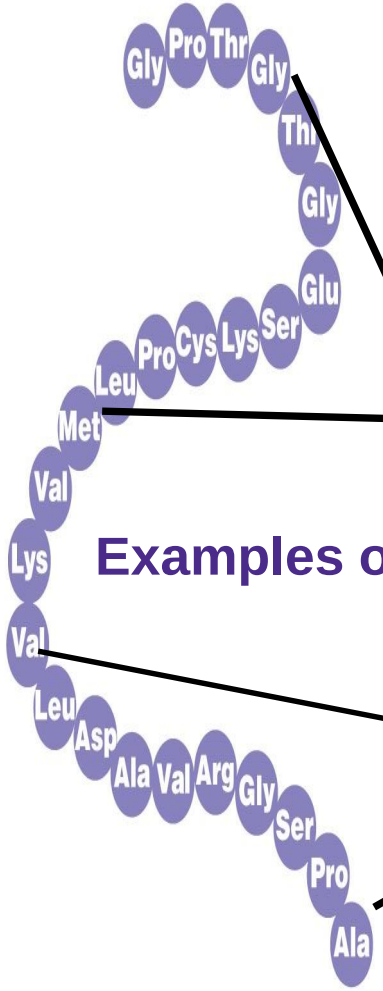
Four Levels of Protein Structure

- Primary- the unique sequence of amino acids
- Secondary- coils & folds in polypeptide chain
- Tertiary- due to interactions among various side chains (R groups)
- Quaternary- seen when a protein is made of multiple polypeptide chains

Primary Structure

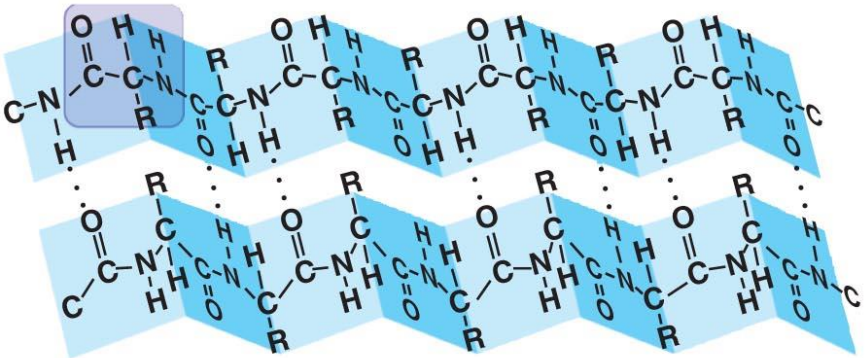


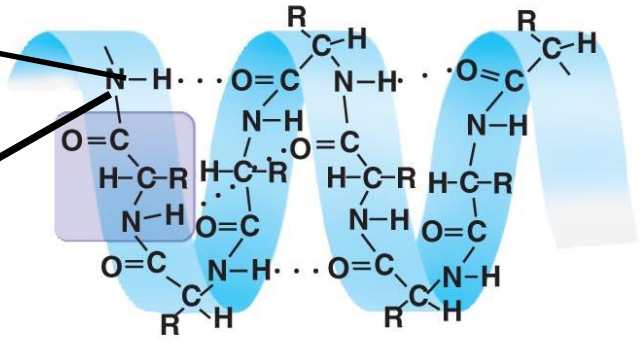
Secondary Structure



Examples of amino acid subunits

β pleated sheet



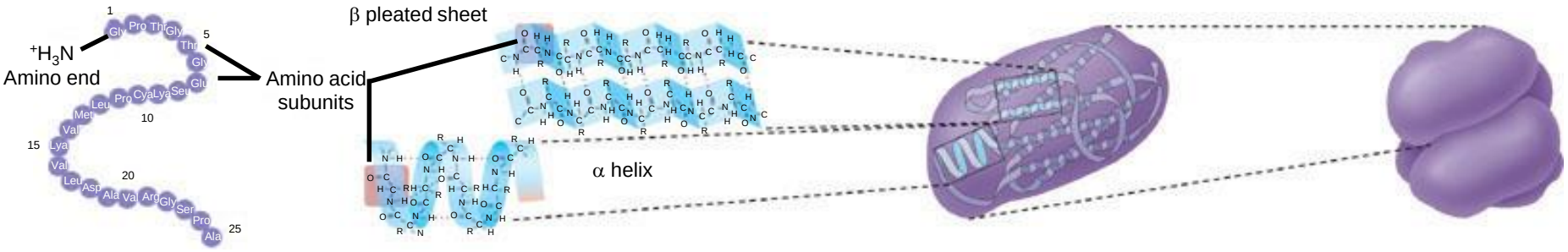


α helix

- **Secondary structure** coils and folds result from hydrogen bonds between repeating parts of the polypeptide backbone

Team work of many hydrogen bonds makes spider silk fiber stronger **than a steel strand of the same weight**

- **Tertiary structure** is due to interactions between R groups (not backbone constituents)
  - R group interactions include **hydrogen** and **ionic bonds**, also **hydrophobic** and **van der Waals** interactions
  - **Disulfide bridges** are strong covalent bonds that reinforce the protein's structure
- **Quaternary structure-** two or more polypeptide chains form one macromolecule

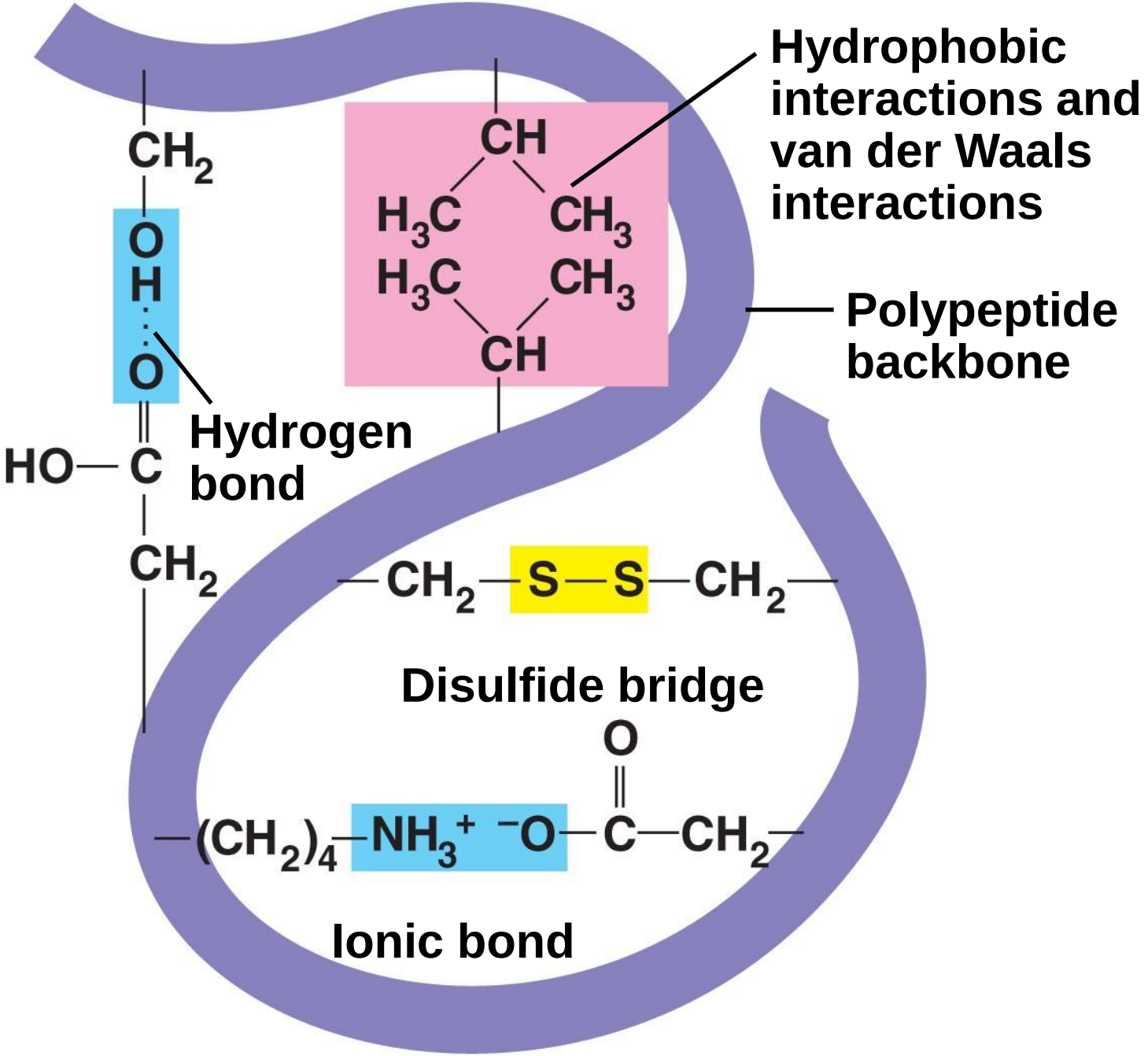


Primary level

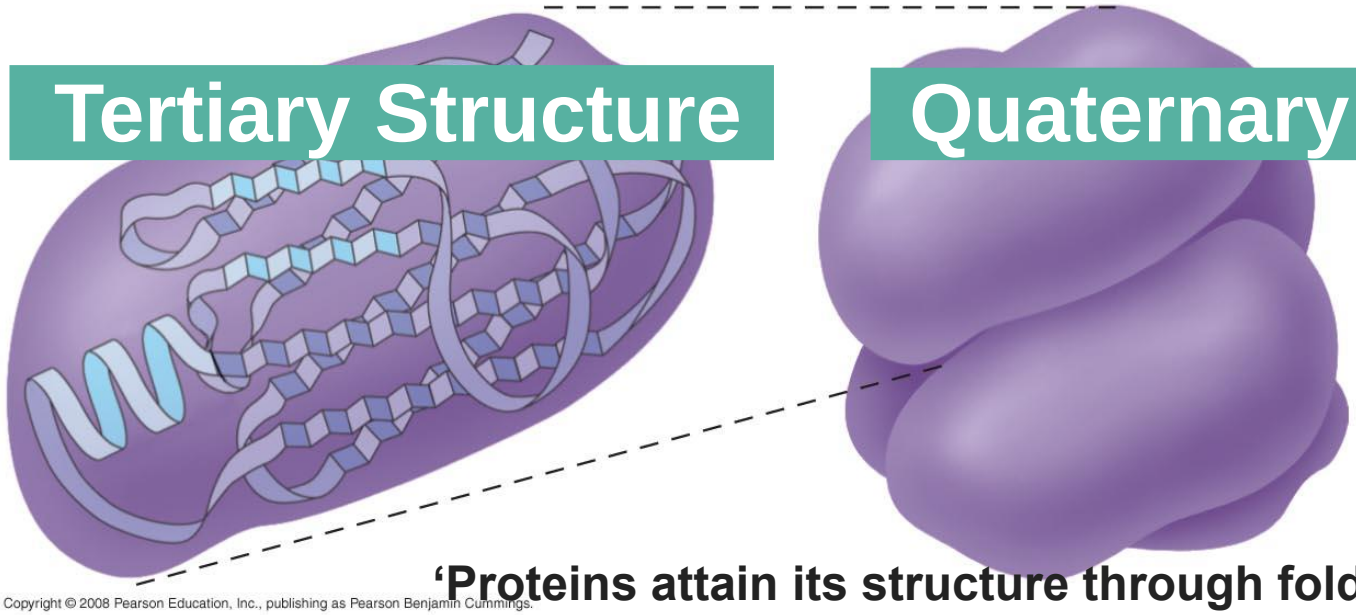
Secondary level

Tertiary level

Quaternary level



Quaternary Structure



'Proteins attain its structure through folding'

Coils or sheets due to R-group interactions

Protein subunits of an enzyme held together by hydrogen bonds, disulfide,Van der Waals forces, etc.

Protein folding is the physical process by which a protein chain acquires its native 3-D structure, a conformation, that is usually biologically functional, in an expeditious and reproducible manner.