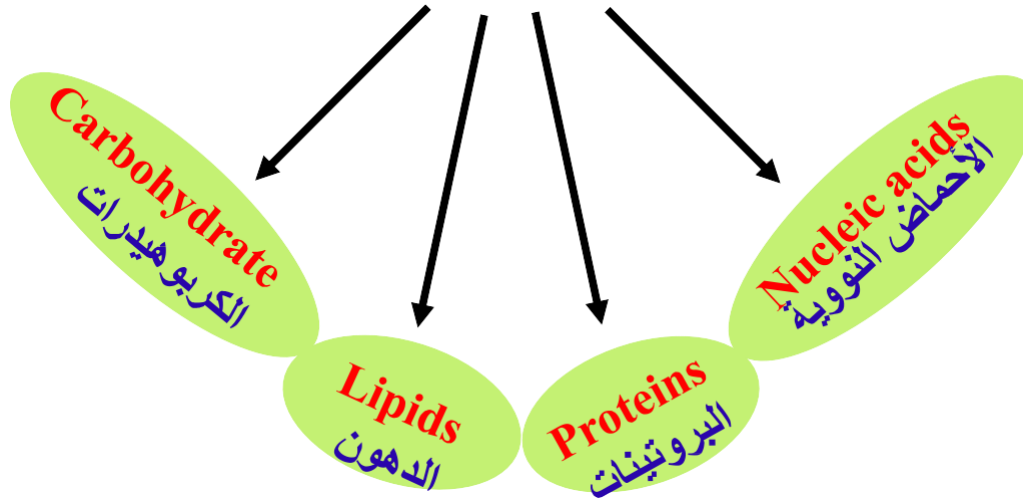


The Molecules of Cells

ORGANIC COMPOUNDS (**Molecules**)

INTRODUCTION TO ORGANIC COMPOUNDS (**Molecules**)



ORGANIC COMPOUNDS (**Molecules**)

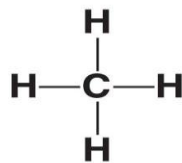


Life's molecular diversity is based on the properties of carbon

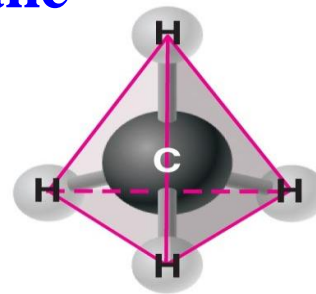
- Diverse molecules found in cells are composed of **carbon** bonded to other elements
- Carbon-based molecules are called **Organic Compounds**
- By sharing electrons, carbon can bond to four other atoms
- By doing so, **carbon can branch in up to four directions**
- Methane (CH_4) is one of the simplest organic compounds
 - **Four covalent bonds link four hydrogen atoms to the carbon atom**
 - Each of the four lines in the formula for **Methane** represents a pair of shared electrons

Methane

The four single bonds of carbon point to the corners of a tetrahedron.



Structural formula



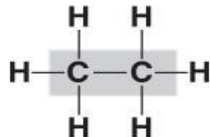
Ball-and-stick model



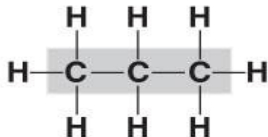
Space-filling model

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- Methane and other compounds composed of only carbon and hydrogen are called **hydrocarbons**
- Carbon atoms, with attached hydrogens, can bond together in chains of various lengths
- A chain of carbon atoms is called a **carbon skeleton**
- Carbon skeletons can be branched or unbranched
- Therefore, different compounds with the same molecular formula can be produced
- These structures are called **ISOMERS**

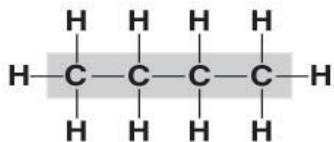


Ethane

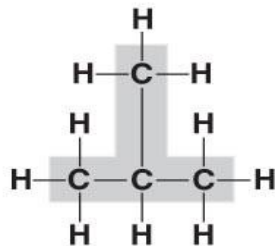


Propane

Carbon skeletons vary in length.

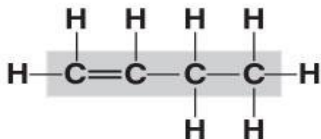


Butane

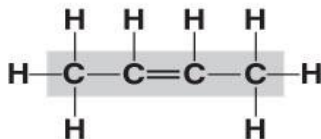


Isobutane

Branching. Skeletons may be unbranched or branched.

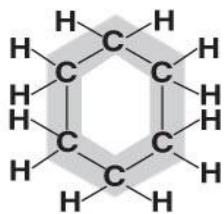


1-Butene

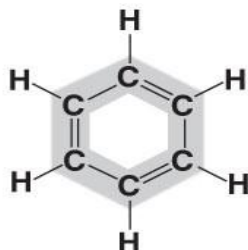


Butene-2

Skeletons may have double bonds, which can vary in location.



Cyclohexane



Benzene

Skeletons may be arranged in rings.

Variations in carbon skeletons

التنوع في الهياكل الكربونية

ORGANIC COMPOUNDS (**Molecules**)



Characteristic chemical groups help determine the properties of organic compounds

- **An organic compound has unique properties that depend upon**
 - 1. The size and shape of the molecule, and**
 - 2. The groups of atoms (functional groups) attached to it.**

- **A **functional group** affects a biological molecule's function in a characteristic way**

- **Compounds containing functional groups are **hydrophilic** (water-loving)**

- **This means that they are soluble in water, which is a necessary prerequisite for their roles in water-based life**

ORGANIC COMPOUNDS (Molecules)



➤ **The functional groups are**

- **Hydroxyl group** — consists of a hydrogen bonded to an oxygen
- **Carbonyl group** — a carbon linked by a double bond to an oxygen atom
- **Carboxyl group** — consists of a carbon bonded to a hydroxyl group and double-bonded to an oxygen
- **Amino group** — composed of a nitrogen bonded to two hydrogen atoms and a carbon skeleton
- **Phosphate group** — consists of a phosphorus atom bonded to four oxygen atoms

ORGANIC COMPOUNDS (**Molecules**)



Cells make a huge number of large molecules from a small set of small molecules

➤ **There are four classes of biological molecules**

- 1. Carbohydrates**
- 2. Proteins**
- 3. Lipids**
- 4. Nucleic acids**

➤ **The four classes of biological molecules contain very large molecules**

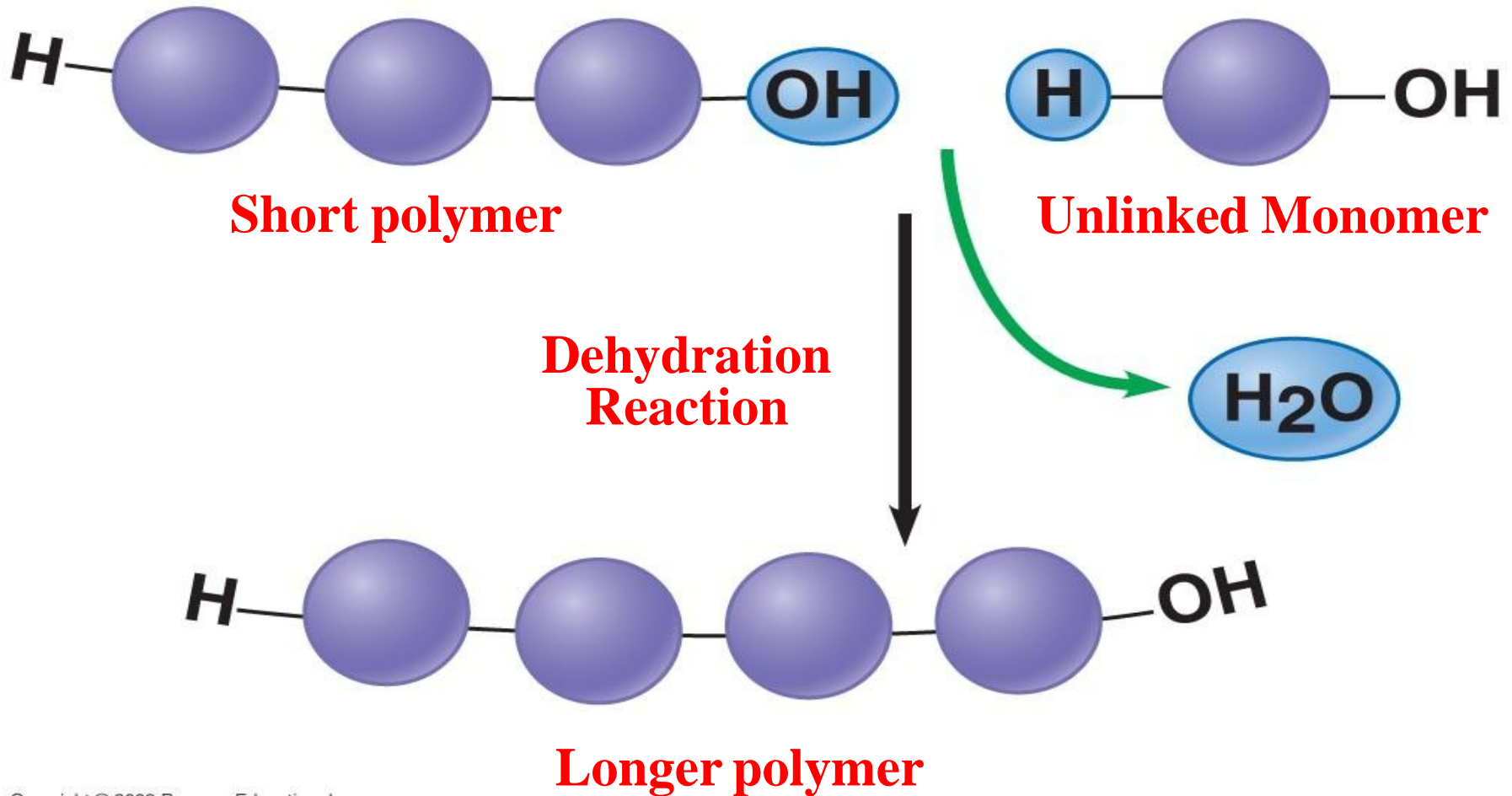
- They are often called **macromolecules** because of their large size
- They are also called **polymers** because they are made from identical building blocks strung together
- The building blocks are called **monomers**

ORGANIC COMPOUNDS (**Molecules**)

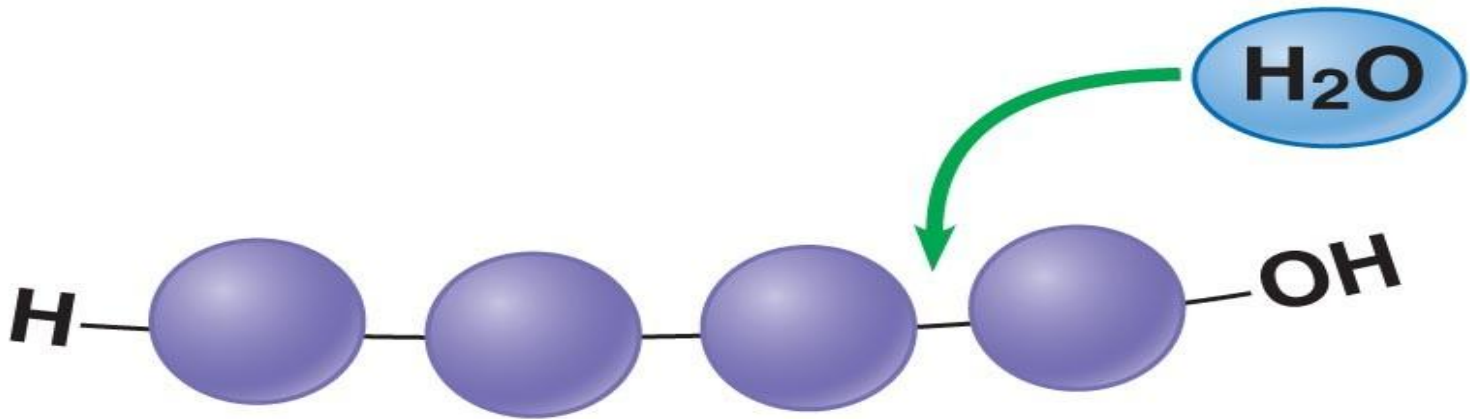


- **Monomers are linked together to form polymers through dehydration reactions, which remove water**
- **Polymers are broken apart by hydrolysis, the addition of water**
- **All biological reactions of this sort are mediated by enzymes, which speed up chemical reactions in cells**

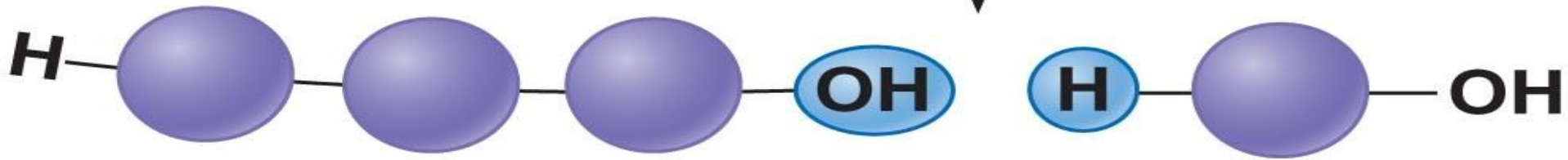
Dehydration reactions build a polymer chain



Hydrolysis breaks a polymer chain



Hydrolysis



CARBOHYDRATES



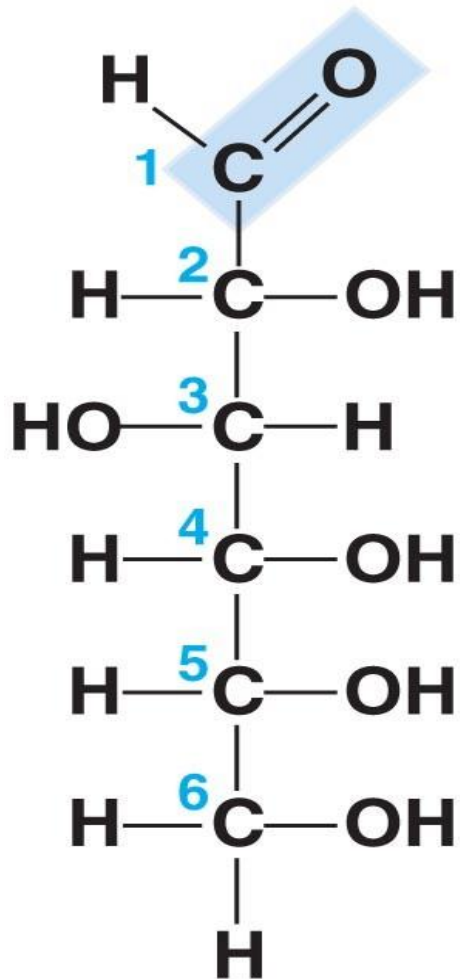
Monosaccharides are the simplest carbohydrates

- **Carbohydrates range from small sugar molecules (monomers) to large polysaccharides**
- **Sugar monomers are monosaccharides, such as glucose and fructose**
- **These can be hooked together to form the polysaccharides**

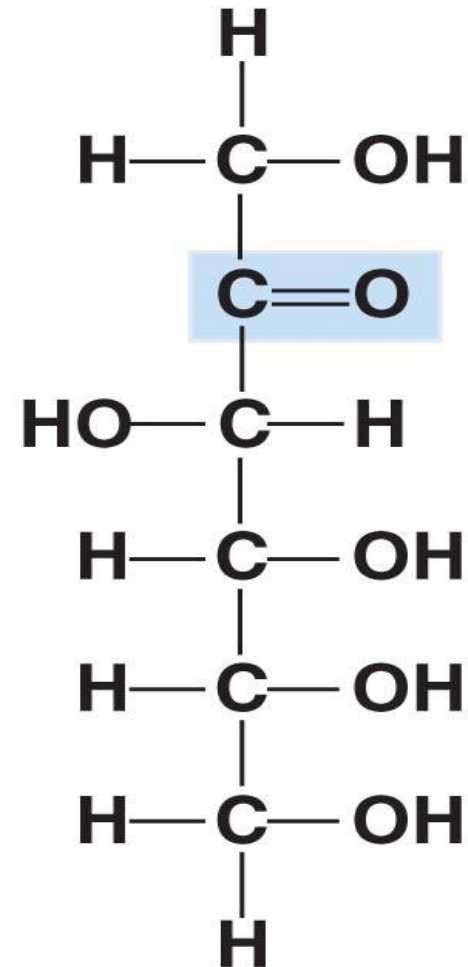
- **The carbon skeletons of monosaccharides vary in length**
 - **Glucose and fructose are six carbons long**
 - **Others have three to seven carbon atoms**

- **Monosaccharides are the main fuels for cellular work**
 - **Monosaccharides are also used as raw materials to manufacture other organic molecules**

Structures of glucose and fructose ($C_6H_{12}O_6$)



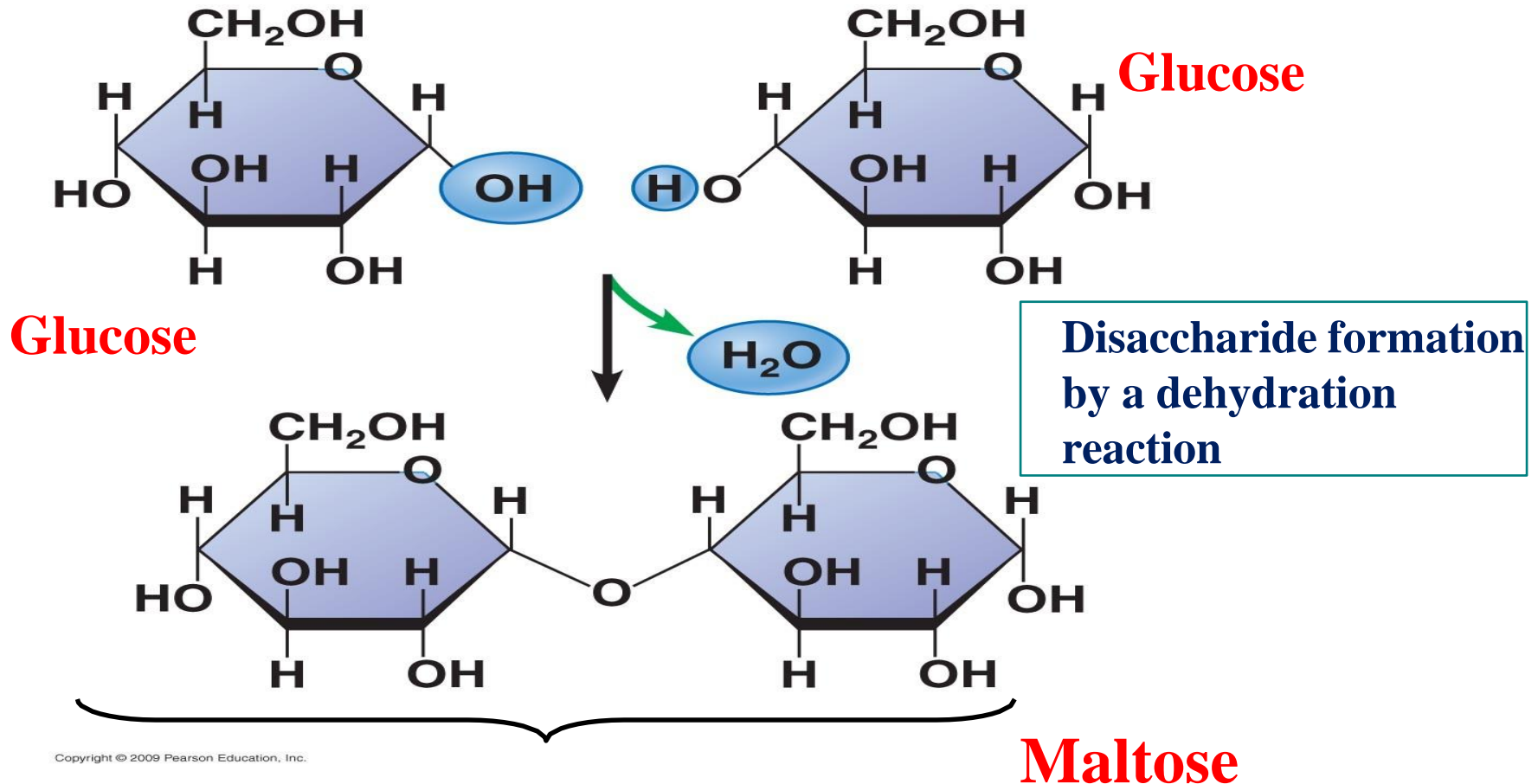
Glucose
(an aldose)



Fructose
(a ketose)

Cells link two single sugars to form disaccharides

- Two monosaccharides (monomers) can bond to form a disaccharide in a dehydration reaction
- An example is glucose monomer bonding to a fructose monomer to form sucrose, a common disaccharide

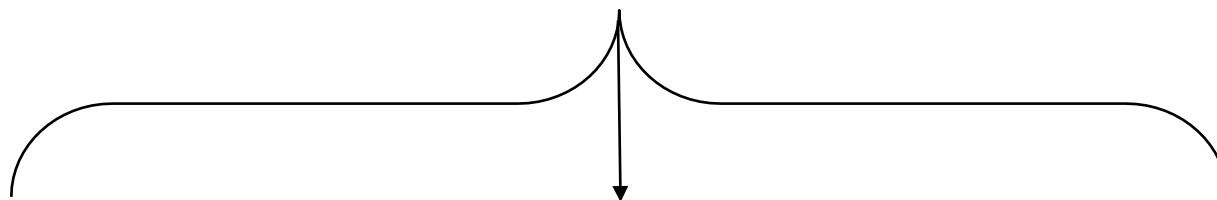


Polysaccharides are long chains of sugar units

- **Starch** is a storage polysaccharide composed of glucose monomers and found in plants
- **Glycogen** is a storage polysaccharide composed of glucose, which is hydrolyzed by animals when glucose is needed
- **Cellulose** is a polymer of glucose that forms plant cell walls
- **Chitin** is a polysaccharide used by insects and crustaceans to build an exoskeleton

LIPIDS

الليبيدات (الشحومات)



True Fats

الدهون الحقيقية

Phospholipids

الليبيدات (الدهون)
الفسفورية

Steroids

الاستيرويدات

ORGANIC COMPOUNDS (Molecules)



Fats are lipids that are mostly energy-storage molecules

- **Lipids** are water insoluble (hydrophobic, or water fearing) compounds that are important in energy storage
 - **They contain twice as much energy as a polysaccharide**
- **Fats** are lipids made from glycerol and fatty acids
- **Fatty acids link to glycerol by a dehydration reaction**
 - **A fat contains one glycerol linked to three fatty acids**
 - **Fats are often called triglycerides because of their structure**

ORGANIC COMPOUNDS (**Molecules**)



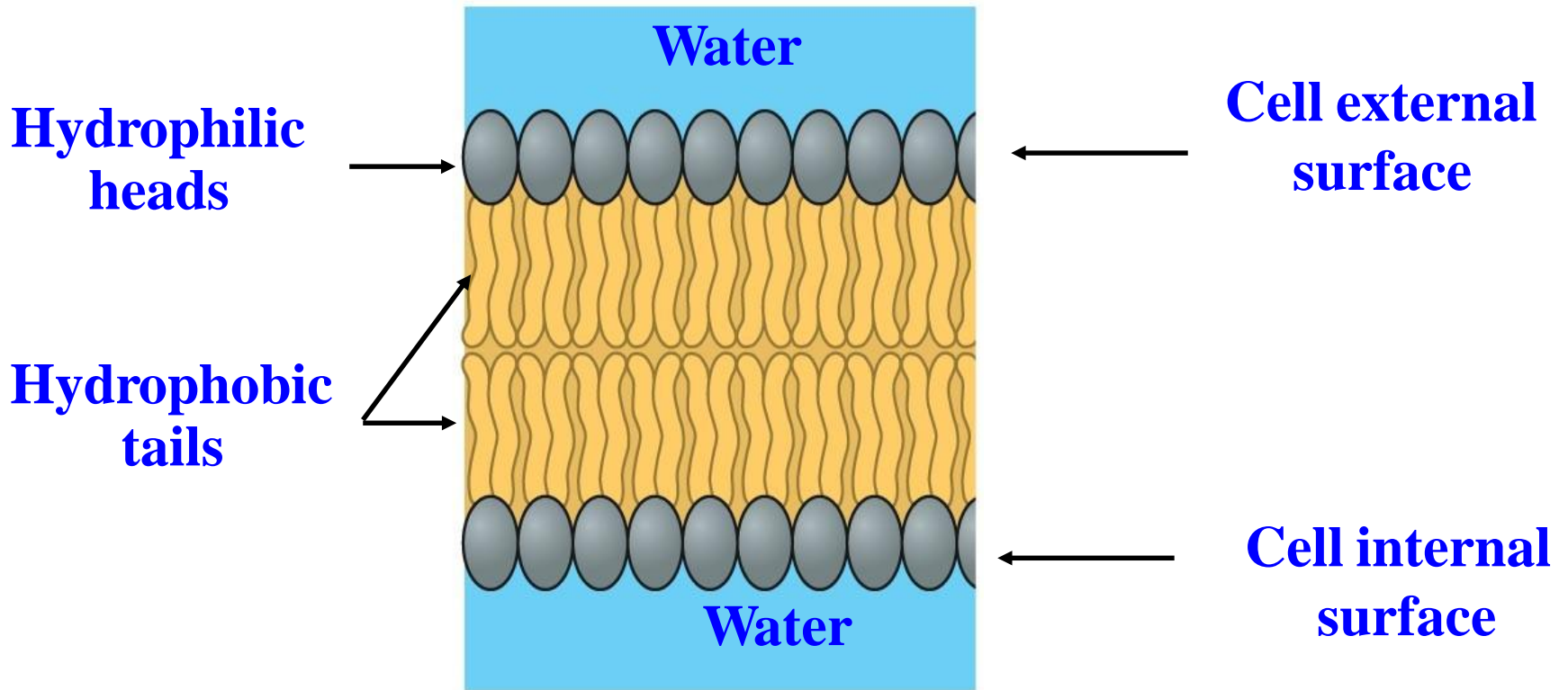
Some fatty acids contain double bonds

1. This causes **kinks or bends in the carbon chain** because the maximum number of hydrogen atoms cannot bond to the carbons at the double bond
2. These compounds are called **unsaturated fats** because they have fewer than the maximum number of hydrogens
3. Fats with the maximum number of **hydrogens** are called **saturated fats**

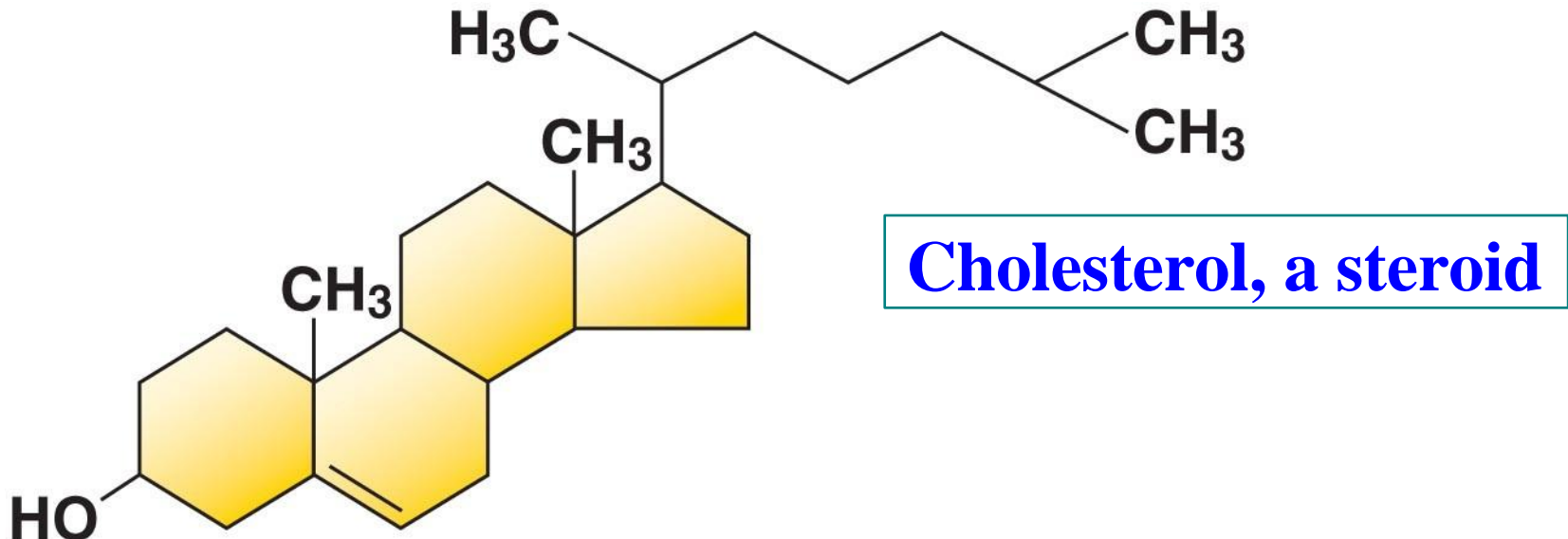
Phospholipids and steroids are important lipids with a variety of functions

- **Phospholipids** are structurally similar to fats and are an important component of all cells
1. For example, they are a major part of **cell membranes**, in which they cluster into a **bilayer** of phospholipids
 2. The **hydrophilic heads** are in contact with the water of the environment and the internal part of the cell
 3. The **hydrophobic tails** band in the center of the bilayer

Section of a phospholipid membrane



- **Steroids are lipids composed of fused ring structures**
- **Cholesterol is an example of a steroid that plays a significant role in the structure of the Cell Membrane**
- **In addition, cholesterol is the compound from which we synthesize Sex Hormones**



PROTEINS



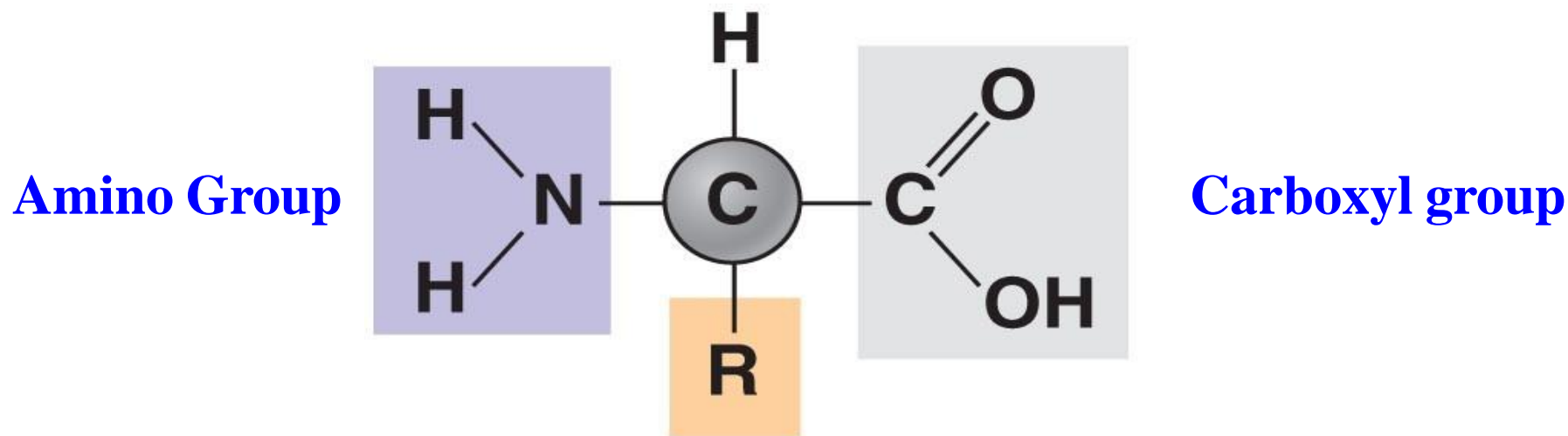
Proteins are essential to the structures and functions of life

- **A protein is a polymer built from various combinations of 20 amino acid monomers**
 - Proteins have unique structures that are directly related to their functions
 - **Enzymes, proteins that serve as metabolic catalysts, regulate the chemical reactions within cells**
- **Structural proteins provide associations between body parts**
- **Contractile proteins are found within muscle**
- **Defensive proteins include antibodies of the immune system**
- **Signal proteins are best exemplified by the hormones**
- **Receptor proteins serve as antenna for outside signals**
- **Transport proteins carry oxygen**

ORGANIC COMPOUNDS (Molecules)

Proteins are made from amino acids linked by peptide bonds

- Amino acids, the building blocks of proteins, have an amino group and a carboxyl group
- covalently bonded to a central carbon atom
 - Also bonded to the central carbon is a hydrogen atom and some other chemical group symbolized by R

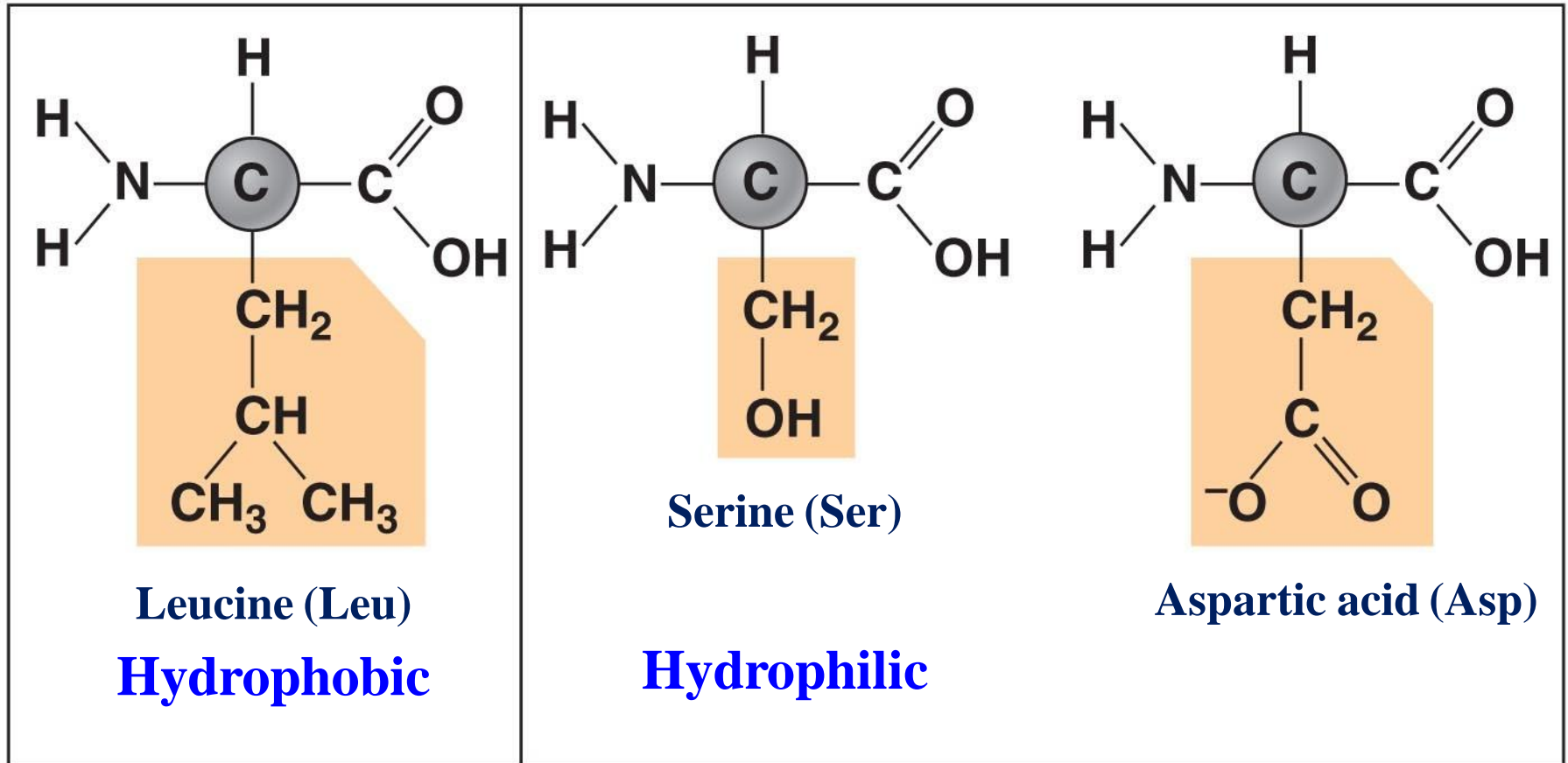


General structure of an amino acid

➤ **Amino acids are classified as hydrophobic or**

hydrophilic

- **Some amino acids have a non-polar R group and are hydrophobic**
- **Others have a polar R group and are hydrophilic, which means they easily dissolve in aqueous solutions**

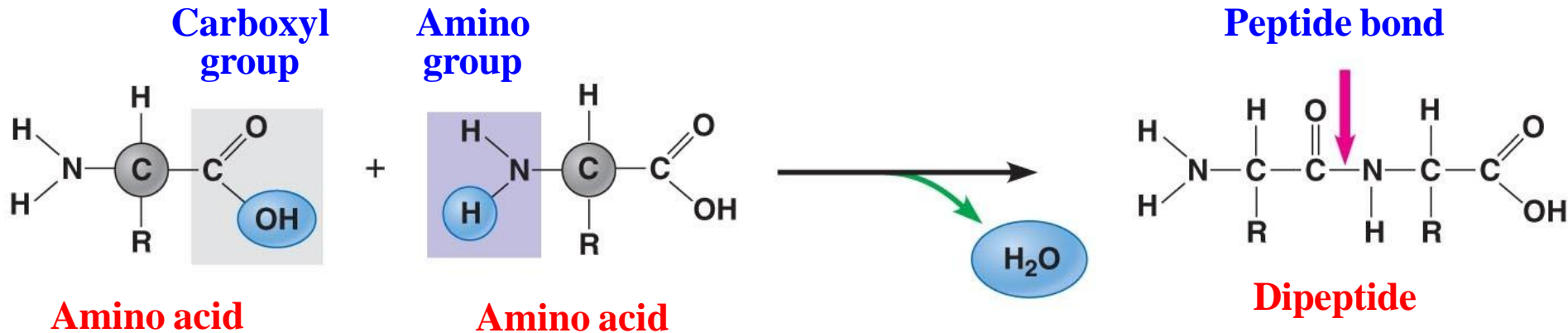




Amino acid monomers are linked together to form polymeric proteins

- This is accomplished by an enzyme-mediated dehydration reaction
- This links the carboxyl group (COOH) of one amino acid to the amino group (NH₂) of the next amino acid. The covalent linkage resulting is called a peptide bond

Peptide bond formation



A protein's specific shape determines its function

- **A polypeptide chain contains hundreds or thousands of amino acids linked by peptide bonds**
 - The amino acid sequence causes the polypeptide to assume a particular shape
 - The shape of a protein determines its specific function

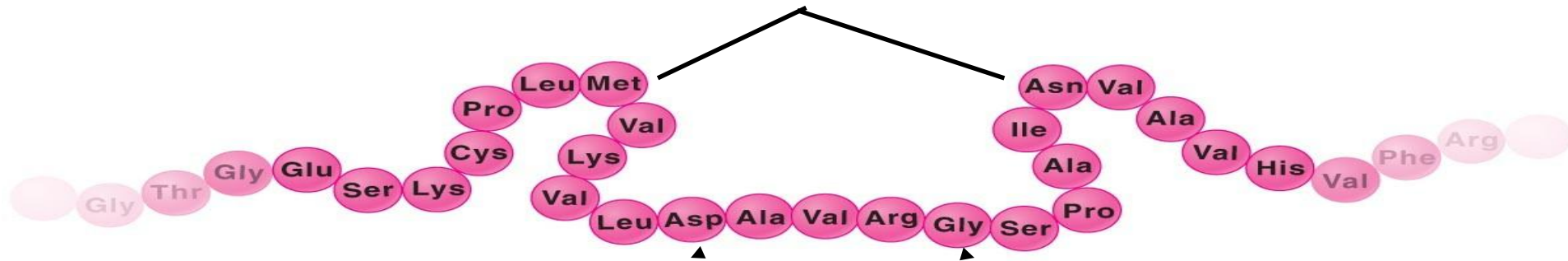
A protein's shape depends on four levels of structure

- **A protein can have four levels of structure**
 - **Primary structure**
 - **Secondary structure**
 - **Tertiary structure**
 - **Quaternary structure**

A protein's shape depends on four levels of structure

- **The primary structure of a protein is its unique amino acid sequence**
 - The correct amino acid sequence is determined by the cell's genetic information
 - The slightest change in this sequence affects the protein's ability to function

Amino acids



Primary structure

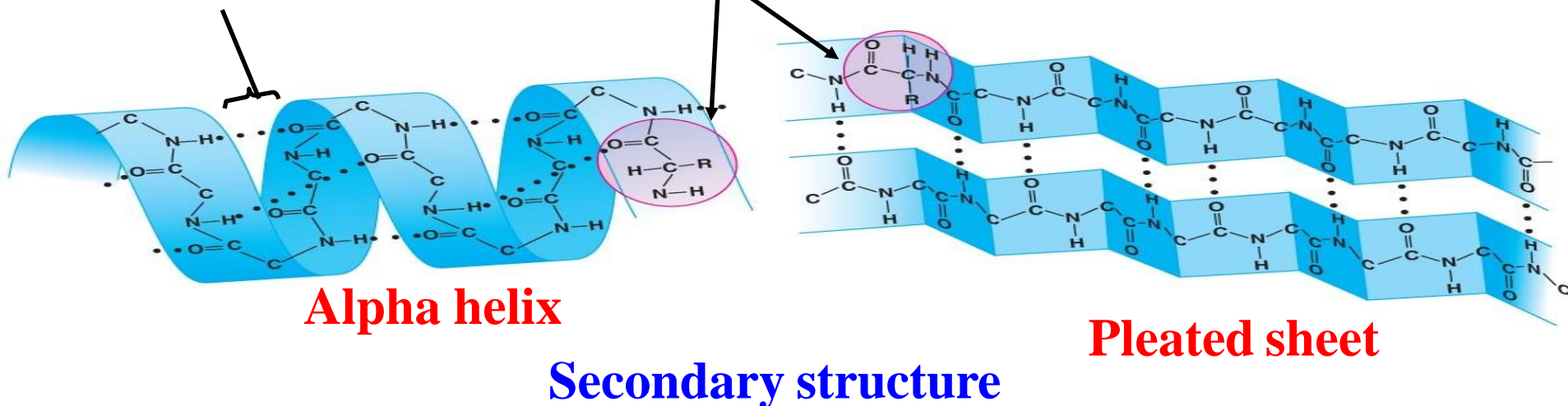
ORGANIC COMPOUNDS (Molecules)

➤ Protein secondary structure results from coiling or folding of the polypeptide

- Coiling results in a helical structure called an **alpha helix**
- Folding may lead to a structure called a **pleated sheet**
- Coiling and folding result from hydrogen bonding between certain areas of the polypeptide chain

Hydrogen bond

Amino acids



Alpha helix

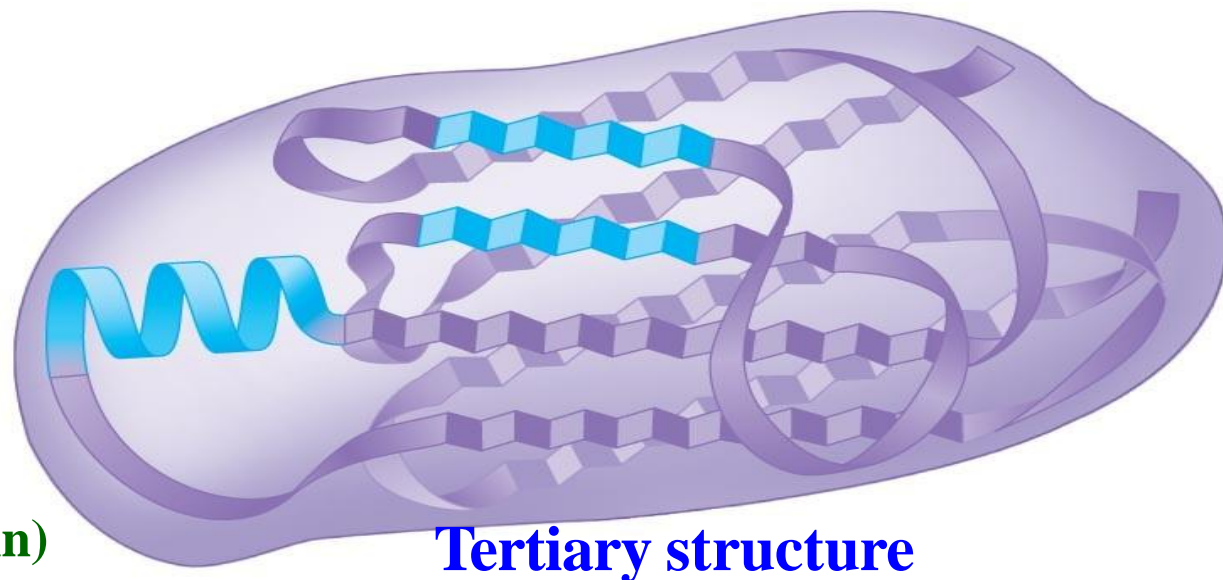
Pleated sheet

Secondary structure

ORGANIC COMPOUNDS (Molecules)

➤ **The overall three-dimensional shape of a protein is called its tertiary structure**

- Tertiary structure generally results from interactions between the **R groups of the various amino acids**
- Disulfide bridges are covalent bonds that further strengthen the protein's shape

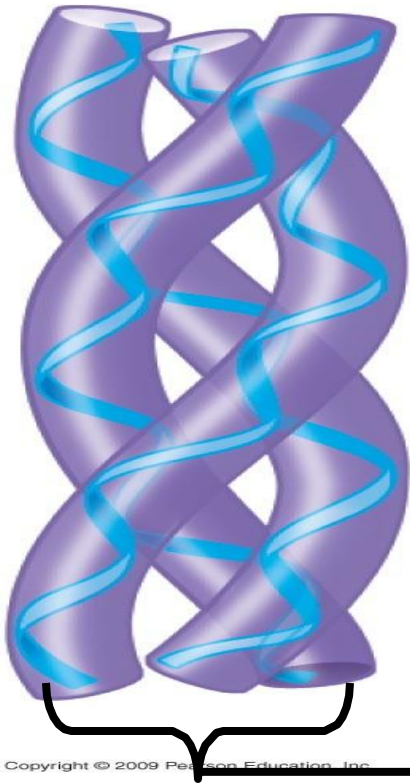


**Globular Polypeptide
(single subunit of transthyretin)**

- **Two or more polypeptide chains (subunits) associate providing quaternary structure**
 - **Collagen is an example of a protein with quaternary structure**
 - **Its triple helix gives great strength to connective tissue, bone, tendons and ligaments**

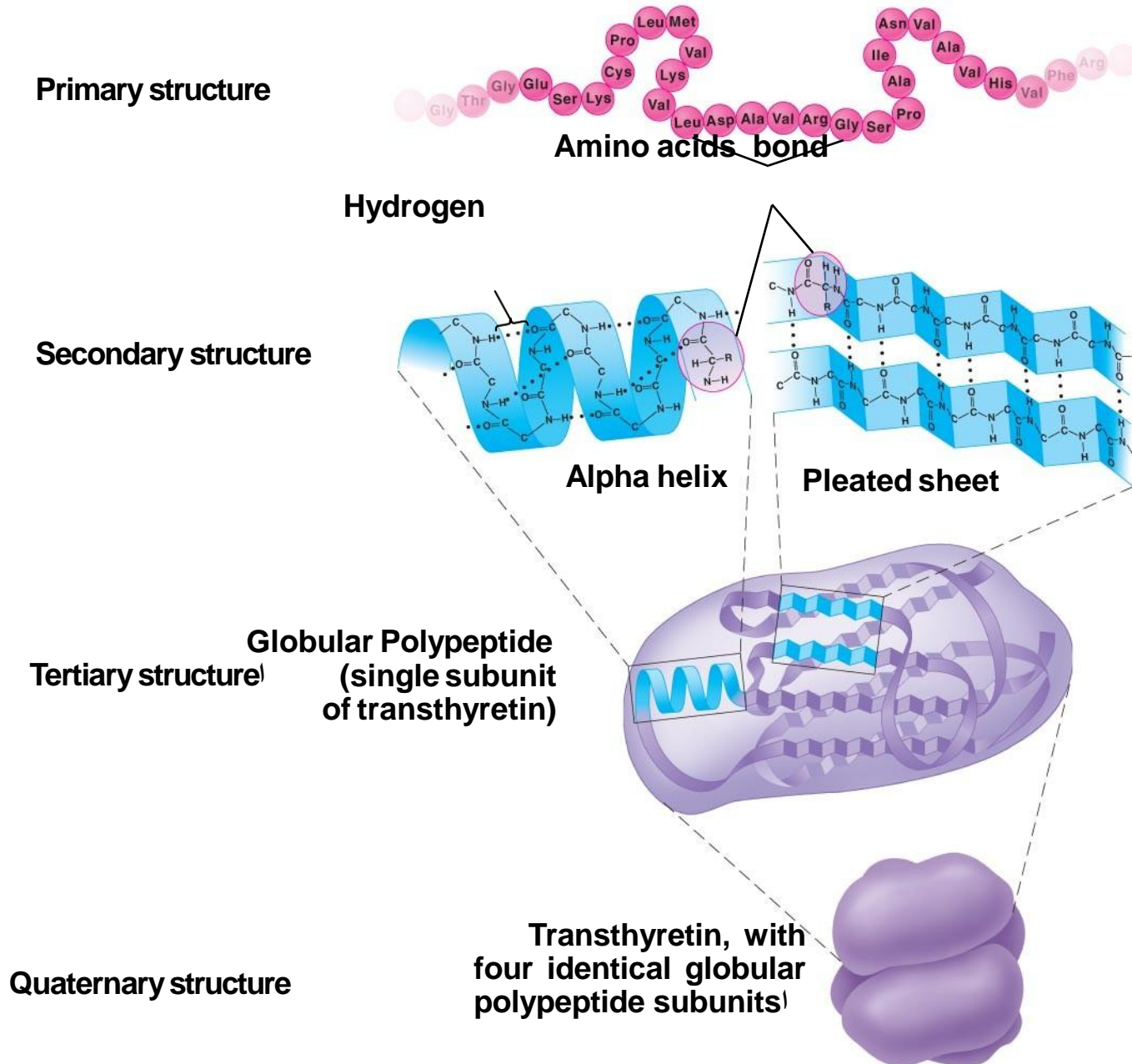
Polypeptide chain (alpha helix)

- **Collagen is a fibrous protein with helical subunits interwind into a larger triple helix.**
- **This arrangement gives the long fibers great strength**



Triple helix

Four Levels of Protein Structure



ORGANIC COMPOUNDS (**Molecules**)



If for some reason a protein's shape is **altered**, it can no longer **function**

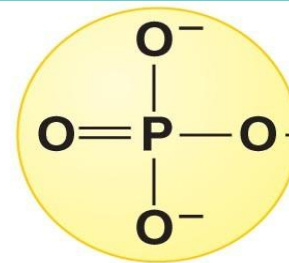
- **Denaturation will cause polypeptide chains to unravel and lose their shape and, thus, their function**
- **Proteins can be denatured by changes in salt concentration and pH**

NUCLEIC ACIDS

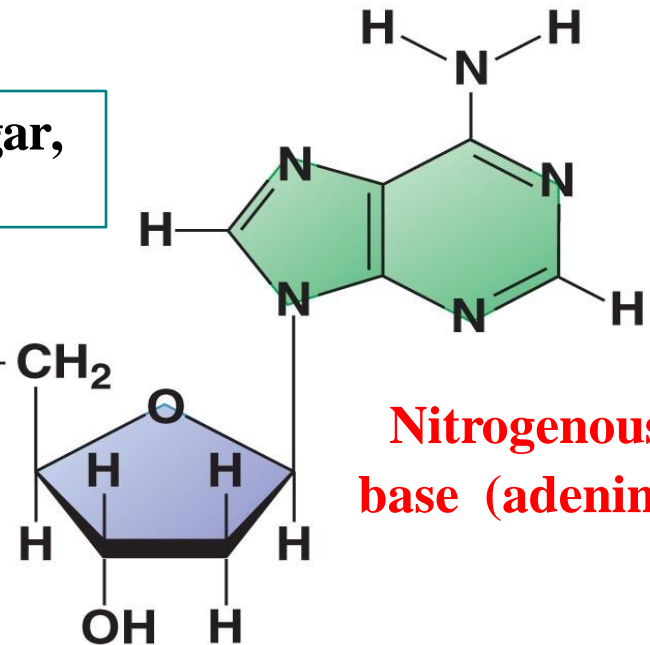
Nucleic acids are information-rich polymers of nucleotides

- DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are composed of monomers called nucleotides
 - Nucleotides have three parts
 1. A five-carbon sugar called ribose in RNA and deoxyribose in DNA
 2. A phosphate group
 3. A nitrogenous base

Nucleotide, consisting of a phosphate group, sugar, and a nitrogenous base



Phosphate Group



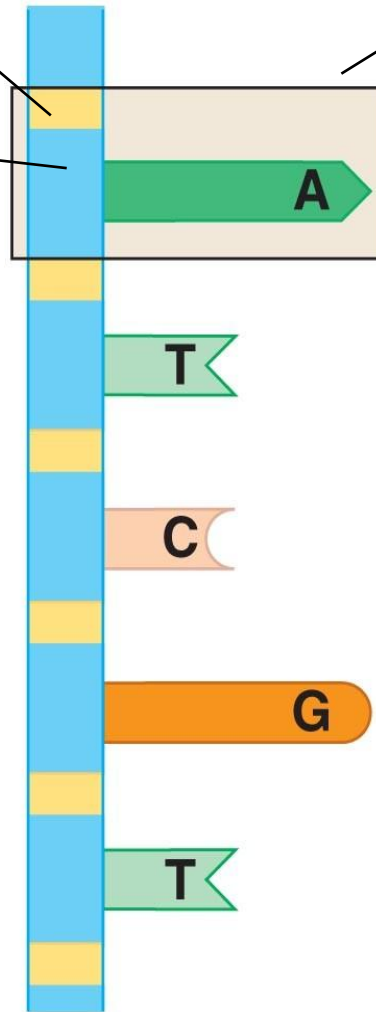
Nitrogenous base (adenine)

Sugar

- **DNA nitrogenous bases are:** **Phosphate**
- **adenine (A), thymine (T),**
cytosine (C), and guanine (G)
- **RNA also has A, C, and G, but instead**
of thymine (T), it has uracil (U)
- **A nucleic acid polymer is a polynucleotide. It**
is formed when the phosphate group of a
nucleotide monomer bonds to the sugar of
the next nucleotide
- **The result is a repeating sugar-phosphate**
backbone with protruding nitrogenous
bases

Sugar

Nucleotide

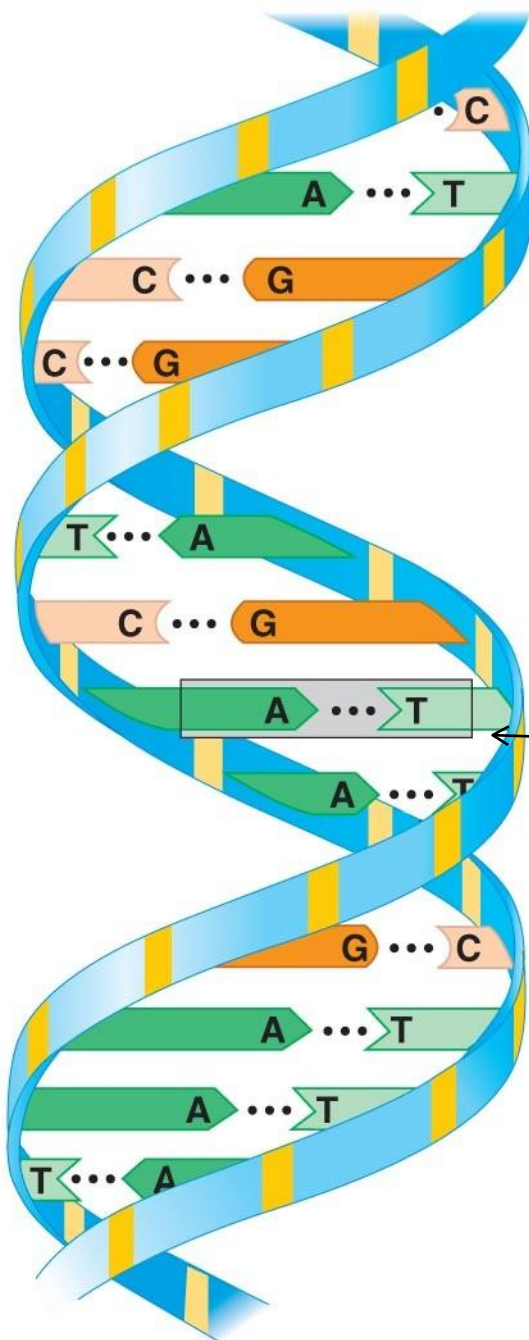


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Sugar-phosphate backbone

- **Two polynucleotide strands wrap around each other to form a DNA double helix**
 - **The two strands are associated because particular bases always hydrogen bond to one another**
 - **Usually A pairs with T, and C pairs with G, producing base pairs**
- **RNA is usually a single polynucleotide strand**
- **A particular nucleotide sequence that can instruct the formation of a polypeptide is called a gene**
 - **Most DNA molecules consist of millions of base pairs and, consequently, many genes**
 - **These genes, many of which are unique to the species, determine the structure of proteins and, thus, life's structures and functions**

DNA double helix



Base pair