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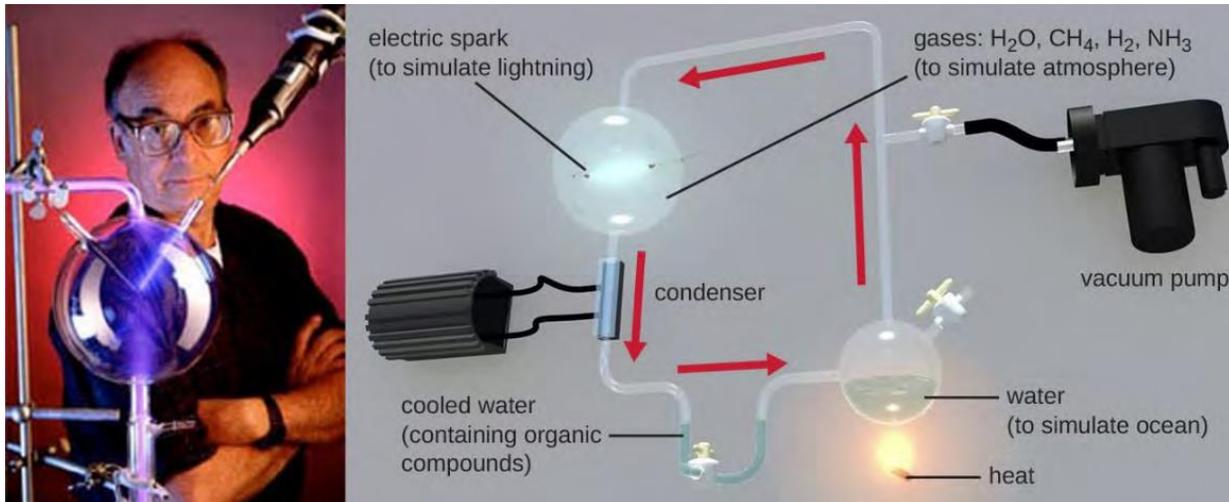
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2025-2026

Cell Biology
Stage (-3-)

LEC- ((4))

Biological molecules

By
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Scientist Stanley Miller (pictured) and Harold Urey demonstrated that organic compounds might have originated naturally from inorganic matter.

The Miller-Urey experiment was a crucial attempt to understand how life could have originated from non-living materials. Their results provided evidence that organic compounds could form naturally through chemical reactions in specific conditions, shedding light on the possible origins of life on Earth.

The Chemistry of the Cell Elements of Life

An element is one of the basic building blocks of matter; an element cannot be broken down by chemical means. Considering the variety of living and nonliving things in the world, it's remarkable that there are only 92 naturally occurring elements. It is even more surprising that over 90% of the human body is composed of just four elements: C, N, O, and H. Even so, other elements, such as iron, are important to our health. Iron-deficiency anemia results when the diet doesn't contain enough iron for the making of hemoglobin. When the above mentioned and others chemical elements combined in various ways, all known biomolecules could be formed.



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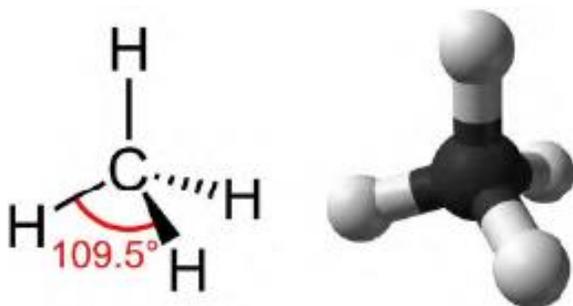


Cells contain many complex molecules called **macromolecules**.

Carbohydrates, lipids, proteins, and nucleic acids are all examples of large molecules

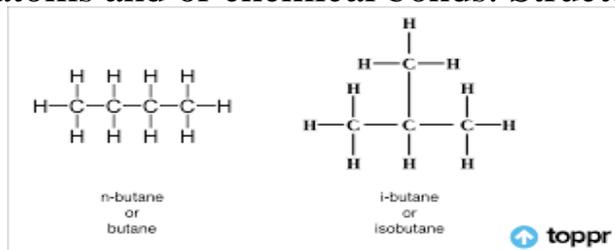
All of these macromolecules are organic molecules. **Organic molecules** generally refer to those molecules that have carbon as the principal element, bonded to hydrogen and other carbon atoms. Some carbon-containing compounds are not classified as organic, such as CO and CO₂. Molecules that do not contain carbon and hydrogen, such as water, are classified as inorganic.

Carbon atoms are the fundamental components for all carbohydrates, lipids, proteins, and nucleic acids. **Because carbon does not have a full valence electron shell, it is incredibly reactive. Carbon atoms can form up to four covalent bonds with other atoms to satisfy the octet rule.**



Methane has a tetrahedral geometry, with each of the four hydrogen atoms spaced 109.5° apart.

Hydrocarbons: are organic molecules consisting entirely of carbon and hydrogen, such as methane described above. Hydrocarbons form the backbones of large macromolecules and may be linear chains, carbon rings, or a combination of both. **Isomers:** are molecules that have the same chemical formula but differ from one another in the arrangement of their atoms and or chemical bonds. Structural isomers like butane and isobutane



Structural butane and isobutane isomers have a different covalent arrangement of atoms.



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Functional groups

groups within macromolecules that determine the chemical properties and functions of these molecules. These groups are attached to the carbon backbone at various points along its chain or ring structure.

Each type of macromolecule—carbohydrates, lipids, proteins, and nucleic acids—has its own set of characteristic functional groups. carboxyl and amino groups, while nucleic acids are composed of nucleotides that include a phosphate group.

These functional groups are key to the distinct chemical behavior and biological roles of each macromolecule in living organisms.

How macromolecules are synthesized and broken down

Most biologically important molecules are made from **single subunits**, or **building blocks**, called **monomers**. The monomers combine using covalent bonds to form larger molecules known as polymers. When monomers **combine**, **water is released as a by-product**. This type of reaction is called a **dehydration synthesis**, a condensation reaction, which means “to put together while losing water”. Conversely, the covalent bonds that hold the polymer together can also be broken if need be. When a **hydrolysis reaction occurs**, a **water molecule is used to break a chemical bond**. We will look more closely at each type of reaction below.

Functional Group	Structure	Properties
Hydroxyl		Polar
Methyl		Nonpolar
Carbonyl		Polar
Carboxyl		Charged, ionizes to release H ⁺ . Since carboxyl groups can release H ⁺ ions into solution, they are considered acids.
Amino		Charged, accepts H ⁺ to form NH ₃ ⁺ . Since amino groups can remove H ⁺ from solution, they are considered basic.
Phosphate		Charged, ionizes to release H ⁺ . Since phosphate groups can release H ⁺ ions into solution, they are considered acidic.
Sulphydryl		Polar

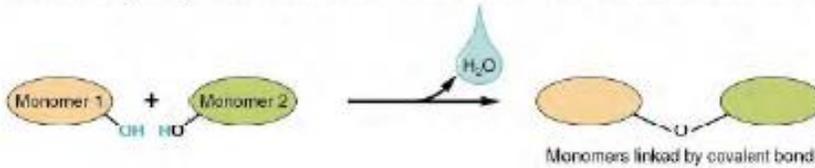


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(a) Dehydration synthesis

Monomers are joined by removal of OH from one monomer and removal of H from the other at the site of bond formation.



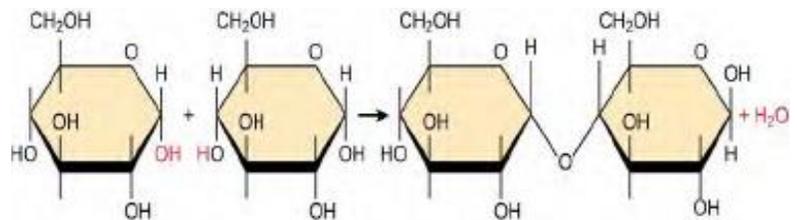
(b) Hydrolysis

Monomers are released by the addition of a water molecule, adding OH to one monomer and H to the other.



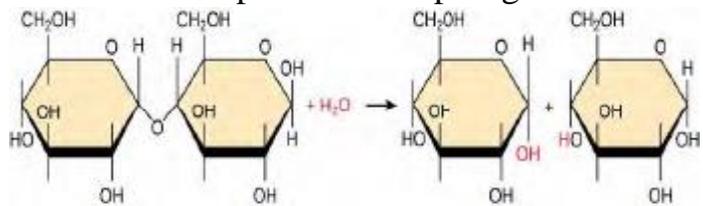
Dehydration Synthesis

In a dehydration synthesis, the hydrogen of one monomer combines with the hydroxyl group of another monomer, forming a water molecule. At the same time, the monomers then come together and share electrons resulting in the formation of a covalent bond.



Hydrolysis

Polymers can be broken down into monomers during hydrolysis reactions. Hydrolysis reactions occur when a water molecule is used to break a chemical bond. During these reactions, the polymer breaks into two components: one part gains a hydrogen atom (H^+), and the other gains a hydroxyl molecule (OH^-). Both the hydrogen and hydroxyl ions are a result of splitting a water molecule.



1. What is released when monomers are joined together in a dehydration synthesis reaction?

a. water b. oxygen c. monomers d. none of the above

2. Which of the statements below is correct?

a. During dehydration synthesis, macromolecules are broken down.

b. Water is involved in hydrolysis reactions but not dehydration synthesis.

c. Hydrolysis reactions build macromolecules. d. Enzymes are used in both dehydration synthesis and hydrolysis reactions.

3. What role do electrons play in dehydration synthesis?



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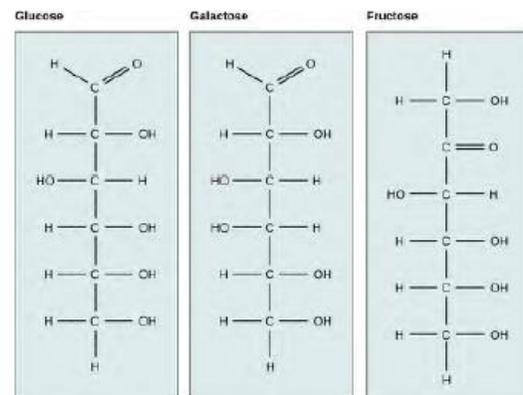
The four major categories of macromolecules are **carbohydrates, lipids, proteins, and nucleic acids**. Here are their main characteristics:

1. Carbohydrates:

- **Elements:** Carbon (C), Hydrogen (H), and Oxygen (O).
- **Monomers:** Monosaccharides (e.g., glucose, fructose).
- **Function:** Provide energy (short-term energy) and structural support (e.g., cellulose in plants).
- **Characteristics:** Soluble in water; can form complex structures (disaccharides, polysaccharides); energy storage and structural roles.

In **monosaccharides**, the number of carbon atoms usually ranges from three to six.

Most monosaccharides have names ending with the suffix **-ose**, such as glucose, galactose, and fructose .



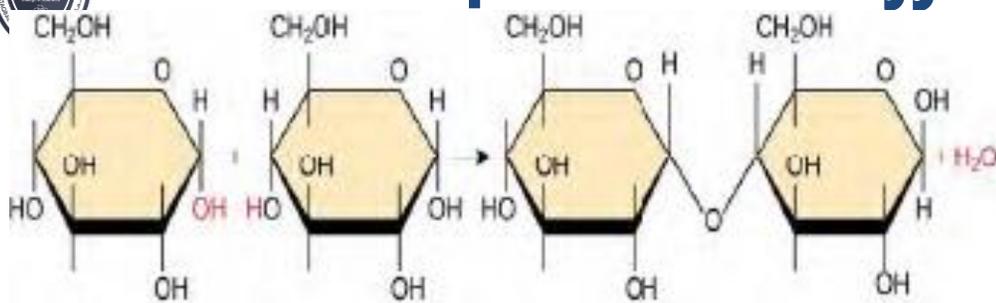
Galactose (part of lactose, or milk sugar) and fructose (found in fruit) are other common monosaccharides. Glucose, galactose, and fructose are all isomers meaning they have the same chemical formula ($\text{C}_6\text{H}_{12}\text{O}_6$) but differ structurally. Because of these structural differences, each molecule has different chemical properties. For example, the sugar fructose is sweeter than the sugar glucose.

Disaccharides : form when two monosaccharides undergo a dehydration synthesis.

During this process, the hydroxyl group ($-\text{OH}$) of one monosaccharide combines with a hydrogen atom of another monosaccharide, releasing a water molecule (H_2O). A covalent bond forms between the atoms in the two sugar molecules

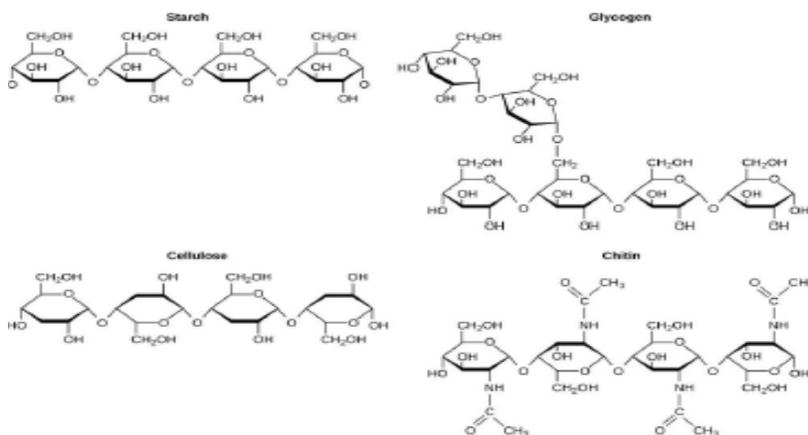


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Many disaccharide names also end with the suffix -ose. Lactose is a disaccharide made up of the monomers glucose and galactose. It is found naturally in milk. Maltose, or malt sugar, is a disaccharide formed from a dehydration synthesis between two glucose molecules, common disaccharide is sucrose, more commonly known as table sugar. Sucrose is composed of the monomers glucose and fructose.

polysaccharide is a chain of three or more monosaccharides linked together by covalent bonds. The chain may be branched or unbranched and is typically very large (i.e. thousands of monosaccharides). Starch, glycogen, cellulose, and chitin are all examples of polysaccharides



Q1 What are the differences between four types of carbohydrates in figure above ?

Q2

1. An example of a monosaccharide is _____. a. fructose b. maltose c. starch d. glycogen
2. Glycogen and chitin are examples of _____.
a. monosaccharides b. disaccharides c. lipids d. polysaccharides
3. Plant cell walls contain which of the following in abundance _____.
a. starch b. cellulose c. glycogen d. lactose



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2- Lipids:

Elements: Carbon (C), Hydrogen (H), and Oxygen (O), but in different proportions than carbohydrates.

Monomers: Fatty acids and glycerol.

Function: Energy storage, insulation, cell membrane structure, and signaling.

Characteristics: Hydrophobic (insoluble in water); includes fats, oils, phospholipids, and steroids; form membranes (phospholipid bilayers).

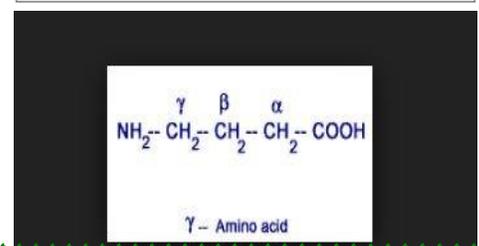
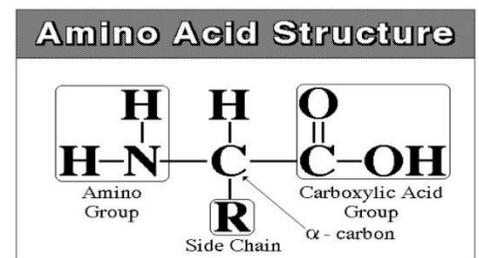
3- Proteins :

- **Elements:** Carbon (C), Hydrogen (H), Oxygen (O), and Nitrogen (N).
- **Monomers:** Amino acids (20 standard amino acids).
- **Function:** Catalyze reactions (enzymes), provide structural support (e.g., collagen), transport (e.g., hemoglobin), and regulate cellular functions (e.g., hormones).
- **Characteristics:** Polymers of amino acids; have complex structures (primary, secondary, tertiary, and quaternary); function depends on shape.

Proteins are the most abundant biomolecules of the living system. Chief sources of proteins are milk, cheese, pulses, peanuts, fish, meat, etc. They occur in every part of the body and form the fundamental basis of structure and functions of life. They are also required for growth and maintenance of body. **The word protein is derived from Greek word, “proteios” which means primary or of prime importance.**

All proteins are polymers of α -amino acids.

A protein is a biomolecule composed of amino acids joined together by **peptide bonds**. An amino acid is a molecule consisting of the basic amino group (NH₂), the acidic carboxylic group (COOH), a hydrogen atom, and an organic side group (R) attached to the carbon atom. Hence,





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It has the basic formula of $\text{NH}_2\text{CHR}\text{COOH}$.

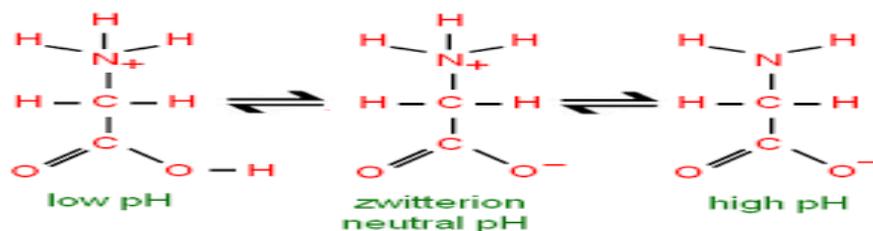
Amino acids are classified as to whether they are **non-essential** or essential. Non-essential (or dispensable) amino acids are **synthesized in the body**. **Essential (or indispensable) amino acids cannot be synthesized in the body** and can only be obtained through food.

Amino acids contain amino ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) functional groups. Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as α , β , γ , δ , ϵ and so on. Amino acids are generally represented by a three letter symbol, sometimes one letter symbol is also used.

Amino acids are classified as **acidic, basic or neutral depending upon the relative number of amino and carboxyl groups in their molecule**.

Equal number of amino and carboxyl groups makes it neutral; **more number of amino than carboxyl groups makes it basic** and **more carboxyl groups as compared to amino groups makes it acidic**.

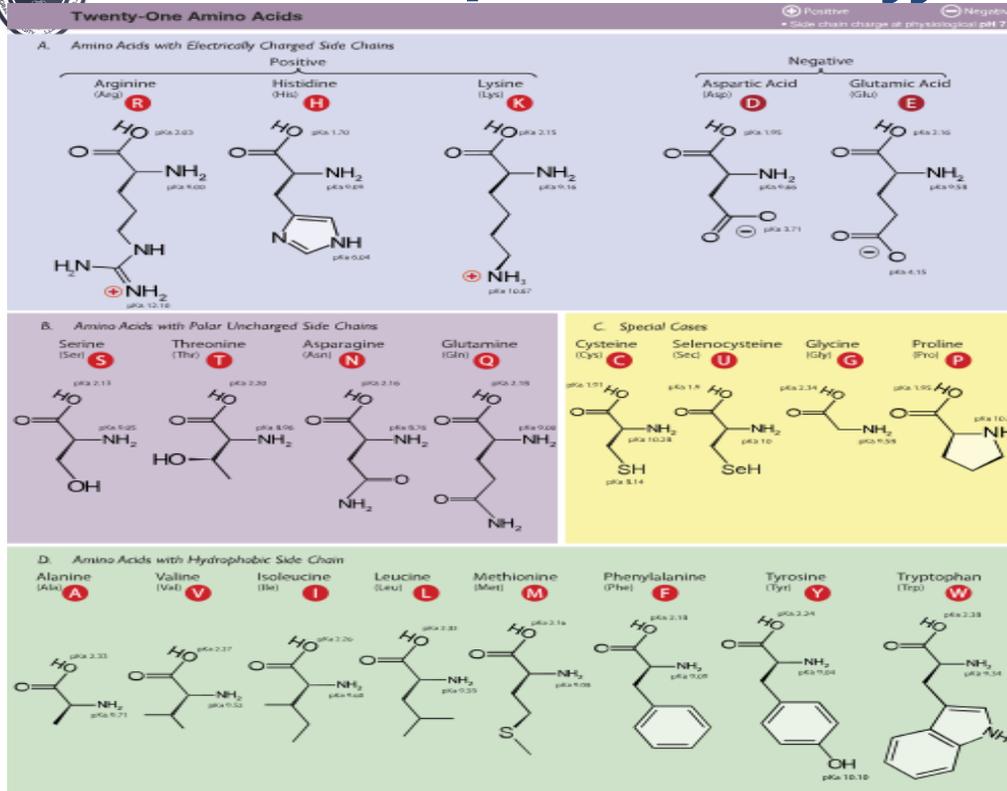
Amino acids are usually colorless, crystalline solids. These are water-soluble, high melting solids and behave like salts rather than simple amines or carboxylic



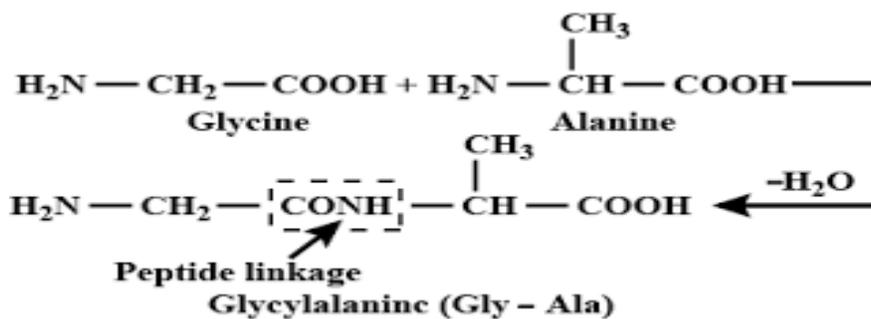
acids. This behavior is due to the presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule. In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion known as **zwitter ion**. This is neutral but contains both positive and negative charges.



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proteins are the polymers of α -amino acids and they are connected to each other by peptide bond or peptide linkage. Chemically, peptide linkage is an amide formed between $-\text{COOH}$ group and $-\text{NH}_2$ group. The reaction between two molecules of similar or different amino acids, proceeds through the combination of the amino group of one molecule with the carboxyl group of the other. This results in the elimination of a water molecule and formation of a peptide bond $-\text{CO}-\text{NH}-$. The product of the reaction is called a dipeptide because it is made up of two amino acids. For example, when carboxyl group of glycine combines with the amino group of alanine we get a dipeptide, glycylalanine.





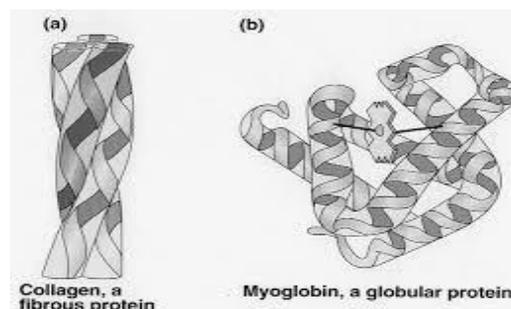
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If a third amino acid combines to a dipeptide, the product is called a **tripeptide**. A tripeptide contains three amino acids linked by two peptide linkages. Similarly when four, five or six amino acids are linked, the respective products are known as **tetrapeptide**, pentapeptide or **hexapeptide**, respectively. When the number of such amino acids is more than ten, then the products are called **polypeptides**.

Proteins can be classified into two types on the basis of their molecular shape.

(a) **Fibrous proteins** : When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fiber– like structure is formed. Such proteins are generally insoluble in water. Some common examples are keratin (present in hair, wool, silk) and myosin (present in muscles), etc.



(b) **Globular proteins** : This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. Insulin and albumins are the common examples of globular proteins.

Protein structure levels :

1- Primary Structure:

Description: The primary structure is the **linear sequence of amino acids** in the polypeptide chain, **linked by peptide bonds**.

Characteristics: The sequence of amino acids determines the **protein's ultimate shape and function**. Even a slight change in this sequence can significantly alter the protein's function.

2- Secondary Structure:

Description: The secondary structure refers to the **local folding of the polypeptide chain into regular structures** due to **hydrogen bonding** between the backbone atoms. The most common secondary structures are:

Alpha helix: A right-handed coil where the backbone forms hydrogen bonds with a nearby amino acid.

Beta sheet: Sheet-like structures formed by hydrogen bonds between strands of the polypeptide chain.

Characteristics: These structures contribute to the overall **stability of the protein** and



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are often found in the functional regions of proteins.

3- Tertiary Structure:

Description: The tertiary structure is the **three-dimensional shape** formed by the entire polypeptide chain, including the secondary structure elements. It is **stabilized by interactions between side chains (R groups)**, such as hydrogen bonds, ionic bonds, hydrophobic interactions, and disulfide bridges.

Characteristics: The folding at this level is crucial for the protein's function, as it determines the **protein's active site**, where it can interact with other molecules.

4- Quaternary Structure:

Description: Some proteins consist of more than one polypeptide chain (subunit). The quaternary structure is the arrangement of these multiple subunits in a protein. These subunits can be identical or different and interact to form a functional protein.

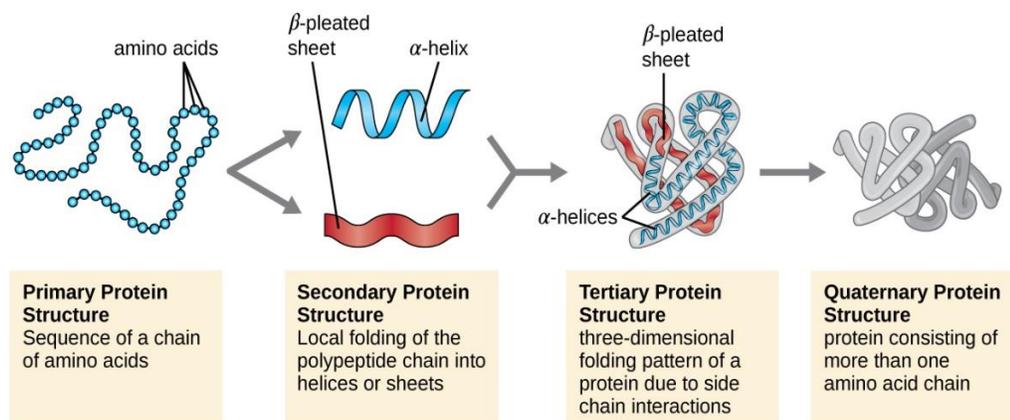
Characteristics: Hemoglobin, for example, has a quaternary structure with four subunits. The **interaction between subunits is essential for the protein's function**, such as cooperative binding of oxygen in hemoglobin.

Key Points:

Primary structure: determines the folding and function of the protein.

Secondary and tertiary structures: are important for maintaining the protein's shape and biological activity.

Quaternary structure: is relevant for proteins composed of multiple polypeptide chains.



Types and Functions of Proteins

1- **Enzymes** :are proteins that speed up the rate of chemical reactions. by decreasing the amount of activation energy needed to start the chemical reaction. Each enzyme has a specific substrate, a reactant that binds to the enzyme. An enzyme may assist in hydrolysis reactions or dehydration synthesis reactions. **Enzymes that break down their substrates are called catabolic enzymes**, whereas those that **build more complex**



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Molecules are called anabolic enzymes. Salivary amylase is an example of a catabolic enzyme. Salivary amylase hydrolyzes starch into simple sugars like glucose. An example of an anabolic enzyme is rubisco, which plants use during photosynthesis to make sugar from carbon dioxide.

2-Vitamins :It has been observed that certain organic compounds are required in small amounts in our diet but their deficiency causes specific diseases. These compounds are called vitamins. Most of the vitamins cannot be synthesised in our body but plants can synthesise almost all of them, so they are considered as essential food factors. However, the bacteria of the gut can produce some of the vitamins required by us.

Vitamins are classified into two groups depending upon their solubility in water or fat

- (i) **Fat soluble vitamins:** Vitamins which are soluble in fat and oils but insoluble in water are kept in this group. These are vitamins A, D, E and K. They are stored in liver and adipose (fat storing) tissues.
- (ii) **Water soluble vitamins:** B group vitamins and vitamin C are soluble in water so they are grouped together. Water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B12) in our body.

TABLE 16.1 Classification of Some Proteins and Their Functions

Class of Protein	Function	Examples
Structural	Provide structural components	<i>Collagen</i> is in tendons and cartilage. <i>Keratin</i> is in hair, skin, wool, and nails.
Contractile	Make muscles move	<i>Myosin</i> and <i>actin</i> contract muscle fibers.
Transport	Carry essential substances throughout the body	<i>Hemoglobin</i> transports oxygen. <i>Lipoproteins</i> transport lipids.
Storage	Store nutrients	<i>Casein</i> stores protein in milk. <i>Ferritin</i> stores iron in the spleen and liver.
Hormone	Regulate body metabolism and the nervous system	<i>Insulin</i> regulates blood glucose level. <i>Growth hormone</i> regulates body growth.
Enzyme	Catalyze biochemical reactions in the cells	<i>Sucrase</i> catalyzes the hydrolysis of sucrose. <i>Trypsin</i> catalyzes the hydrolysis of proteins.
Protection	Recognize and destroy foreign substances	<i>Immunoglobulins</i> stimulate immune responses.