BIOCHEMISTRY

Student Learning Outcomes (SLOs)

- Explain the basis of classification and structure-function relationship of carbohydrates.
- Explain the role of various carbohydrates in health and diseases.
- Identify the nutritional importance of carbohydrates and their role as energy storage.
- Explain the bases of classification and structure-function relationships of proteins.
- Describe the role of various proteins in maintaining body functions and their nutritional importance.
- Describe the role of enzymes as biocatalyst and relate this role to various functions such as digestion of food.
- Identify factors that affect enzyme activity such as the effects of temperature and pH.
- Explain the role of inhibitors of enzymes catalyzed reactions.
- Describe the basis of classification and structure-function relationship of lipids.
- Identify the nutritional and biological importance of lipids.
- Identify the structural components of DNA and RNA.
- Differentiate between the structures of DNA polymer (double strand) and RNA (single strand).
- Relate DNA sequences to its function as storage of genetic information.
- Relate RNA sequence (transcript) to its role in transfer of information to protein (translation)

- Identify the sources of minerals such as iron, calcium, phosphorous, and zinc.
- Describe the pole of iron, calcium, phosphorus, and zinc in nutrition.
- Explain why animals and humans have large glycogen deposits for sustainable muscular activities, Hibernating animals (polar bear, reptiles and amphibians) accumulate fat to meat energy resources during hibernation.
- Identify complex carbohydrates which provide lubrication to the elbow and knee.
- Describe fibrous proteins from hair and silk.
- Explain how cholesterol and amino acids serve as hormones.
- Identify insulin as a protein hormone whose deficiency leads to diabetes mellitus.
- Explain the role of minerals in structure and function.
- Identify calcium as a requirement for coagulation.
- Identify how milk proteins can be precipitated by lowering the pH using lemon juice.

Life requires energy. Where does this energy come from? Can you use sunlight directly for all life functions? Plants capture this energy and transform it into chemical energy. How? They store this energy in substances such as carbohydrates, proteins, and lipids. We need these compounds to exist. To ensure adequate nutrition, our food should have a balanced proportion of carbohydrates, proteins, and lipids. We also need enough amounts of vitamins, minerals, and fiber.

Certain compounds found in every living cell act as the cell's information and control centers. They can reproduce, store, and transmit genetic information. What are these compounds? This chapter will help you identify these important compounds.

15.1 Carbohydrates

Carbohydrates are the most abundant class of organic compounds. Carbohydrates are macromolecules composed of elements carbon, hydrogen, and oxygen. Each carbon is bonded to at least one oxygen atom. All carbohydrates contain an aldehyde or keto group and a hydroxyl group.

Carbohydrates have the general formula $C_x(H_2O)_y$. This formula suggests that they are hydrates of carbon with few exceptions. Recall that plants synthesize carbohydrates through photosynthesis.

$$6H_2O_{(\ell)} + 6CO_{2(g)} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_{6(aq)} + 6O_{2(g)}$$

Plants convert glucose into starch and cellulose.

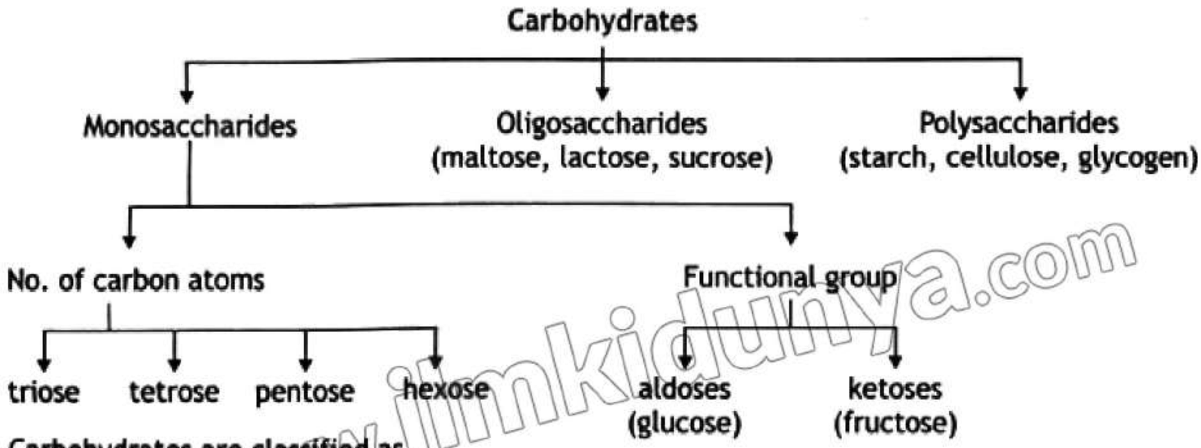
Functions of Carbohydrates

Functions of carbohydrates involve:

(a) Provide energy to cells.
(b) Provide structural support to the body.
(c) Support the organism's growth and development.

The complex structure of carbohydrates allows them to be stored easily and in great amounts. The branched complex carbohydrates can easily hydrolyse to produce small glucose molecules, which can easily be absorbed by the cells as an energy source.

15.1.2 Classification of Carbohydrates

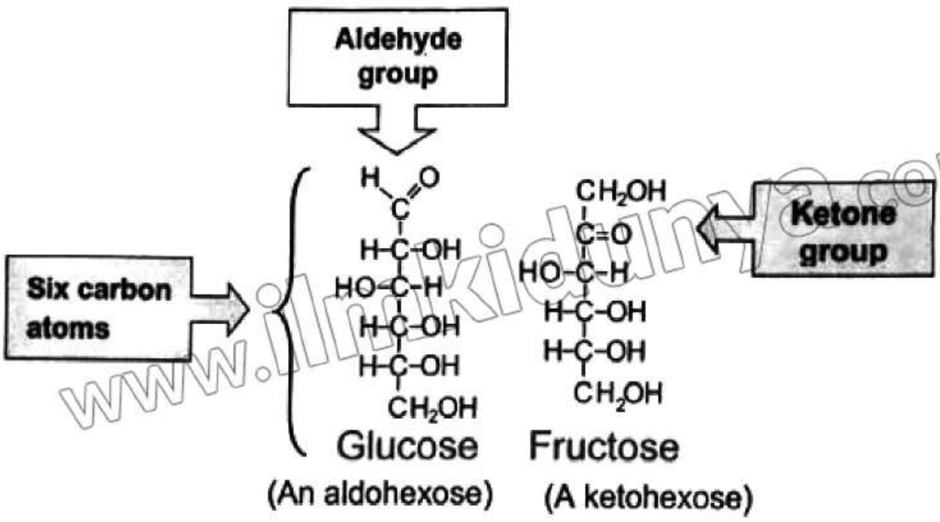


Carbohydrates are classified as

i) Monosaccharide
ii) Oligosaccharides
iii) Polysaccharides

1. Monosaccharides

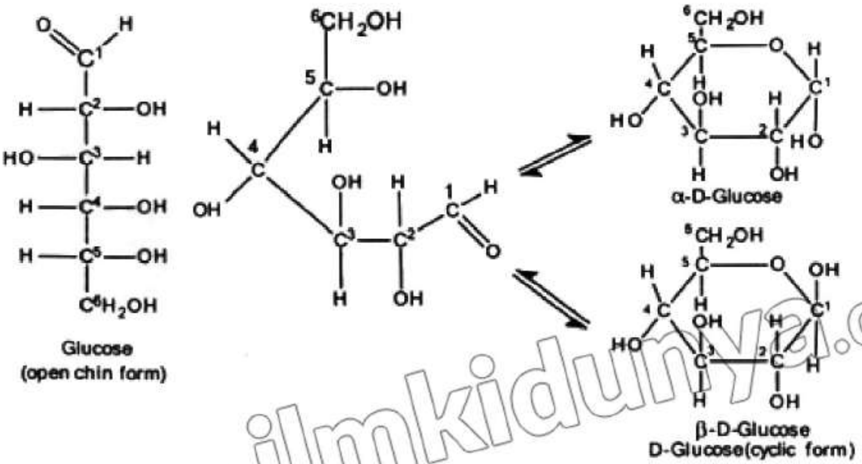
Monosaccharides are the simplest carbohydrates. They cannot be hydrolyzed. They have general formula $(CH_2O)_n$ where n is 3 to 6 carbon atoms. They are further classified as trioses, tetroses, pentoses, hexoses etc. This classification is based on the number of carbon atoms they contain. The two most familiar monosaccharides are glucose and fructose. Both have

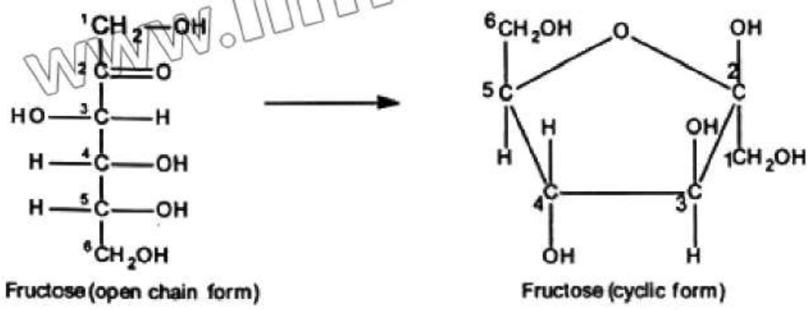


molecular formula $C_6H_{12}O_6$. Is glucose a pentose? Glucose is a pentahydroxy aldehyde, whereas fructose is a pentahydroxy ketone. Their open-chain structures are as follows. They are called simple sugars.

Some monosaccharide molecules can rotate the plane of plane-polarized light to the right (clockwise). They are called dextro-rotatory or dextrose sugars.

Glucose, manose, galactose, and dextrose sugars. Monosaccharides are white crystalline solid. They are soluble in water and have a sweet taste. They cannot be hydrolyzed. They are reducing in nature.





2. Oligosaccharides

Carbohydrates which upon hydrolysis from 2 to 10 molecules of monosaccharides or simple sugars are called oligosaccharides.

Therefore, depending upon the number of monosaccharide units they produce on hydrolysis, they are further classified as disaccharides, trisaccharides, etc. Prefixes di, tri, tetra, penta, etc. indicate the number of monosaccharide units, they produce on hydrolysis. They are white crystalline solids. They have a sweet taste and are soluble in water.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Lactose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Galactose}}{C_6H_{12}O_6}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Glucose}}{C_6H_{12}O_6}$$

CONCEPT ASSESSMENT EXERCISE 15.1

1. Classify sucrose, lactose and maltose as mono, di or tri-saccharides. Give reason.
2. Is galactose, a monosaccharide?
3. Raffinose, $C_{18}H_{32}O_{16}$ hydrolyses as follows. Is raffinose a disaccharide?

$$C_{18}H_{32}O_{16} + 2H_2O \longrightarrow 3C_6H_{12}O_6$$

3. Polysaccharides

The Carbohydrates which upon hydrolysis form hundreds to thousands of units of simple sugars are called polysaccharides. Starch and cellulose are polysaccharides. They are amorphous solids. They are tasteless and insoluble in water. They are non-reducing in nature.

Some common carbohydrates, with their structures are shown in Table 15.2:

Table 15.1: Some common carbohydrates, with their structures

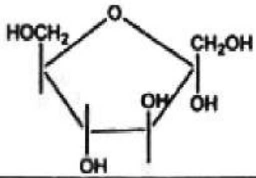
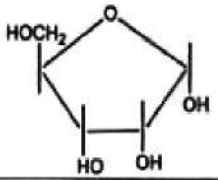
Name	Type	Structures	Occurrence
Glucose	Monosaccharide, aldose, hexose		Occurs abundantly in plants and animals
Fructose	Monosaccharide, ketose, hexose		In fruit and honey
Ribose	Monosaccharide, aldose, pentose		Component of the molecules of ribonucleic acid (RNA) and vitamin B_{12}
Sucrose	Disaccharide	glucose — fructose	Sugar cane, sugar beet (commonly simply called, 'sugar')
Maltose	Disaccharide	glucose — glucose	Malt
Lactose	Disaccharide	glucose — galactose	Milk
Starch	Polysaccharide	chains of glucose units	Plant storage organs, e.g. potato, wheat grain
Cellulose	Polysaccharide	Chains of glucose units (linked differently to those in starch)	Structural material of plants

Table 15.2: Summary of Carbohydrates

Carbohydrates		
Monosaccharides	**Disaccharides**	**Polysaccharides**
Glucose	Sucrose	Starch
Galactose	Maltose	Glycogen
Fructose	Lactose	Cellulose
Ribose		
Glyceraldehyde		

15.1.3 Carbohydrates and Health Conditions:

How do different types of carbohydrates impact health?

The type of carbohydrates you eat can affect your health. For example;

- Foods high in simple carbohydrates (added sugars), especially fructose, raise triglyceride levels, which can increase the risk of cardiovascular disease. Your body breaks down carbohydrates into simple sugars, which are absorbed into the bloodstream
- Monitoring your carbohydrate intake is critical to controlling blood sugar. It can cause diabetes.
- Excessive consumption of simple carbohydrates and high-calorie foods can promote weight gain or obesity.
- A high-fiber diet, including whole grains, can help lower cholesterol and reduce the risk of cardiovascular disease.
- Fiber-rich carbohydrates support the growth of beneficial gut bacteria and promote a healthy digestive system.

15.1.4 Nutritional importance of carbohydrates

There are five main functions of carbohydrates in the human body.

These are energy production, energy storage, macromolecule building, protein sparing, and fat metabolism support.

- Dietary carbohydrates provide glucose that the body's cells can use for energy. 1 g of glucose provides us with 15.6 kJ of energy.
- Excess glucose is converted to glycogen, a storage form of carbohydrates. It is also converted into fat and stored in the body's fat cells. Hundreds of grams of glycogen are stored in the liver and muscles. This glycogen is broken down into glucose when the body needs quick energy, such as during intense physical activity.
- Fiber is a type of carbohydrate that promotes good digestion by reducing constipation and lowering the risk of gastrointestinal disorders. Fiber can also help lower bad cholesterol and LDL levels, reducing your risk of heart disease.
- Carbohydrates play a role in various metabolic pathways. These can be converted into intermediate compounds that are used in the synthesis of other molecules such as amino acids and fatty acids.

- Carbohydrates prevent protein from being used as an energy source. When enough carbohydrates are available, proteins can focus on their primary jobs, such as building and repairing tissue.
- Some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP.

15.1.5 Glycogen - A store house

What is glycogen? Glycogen is a type of stored glucose molecule made up of a large number of connected glucose molecules. It is the primary source of energy for our cells and is stored in our liver and muscles when the body does not need to use glucose for energy. When body requires energy due to a lack of glucose, the glycogen is reconverted into glucose and provides energy to the body in the form of ATP. This rapid glucose breakdown and release of energy is essential for the body cells, especially when we are in a state of high energy demand, such as when we exercise or respond to stress.

15.1.6 Complex carbohydrates for joint lubrication

We have special substances in our bodies that help our elbow and knee joints function smoothly. Three of these are glucosamine, glycosaminoglycans (GAGs), and proteoglycans. They play a vital role in maintaining joint health and flexibility. Glucosaminoglycans (CAGs) are the most abundant heteropolysaccharide in the body. They are long unbranched molecules containing a repeating disaccharide unit. GAGs are a major component of joint cartilage.

15.2 Proteins

Proteins are nitrogenous high molecular weight polymers. The building blocks of all **proteins** are the amino acids, therefore, all proteins produce amino acids on hydrolysis. Proteins are complex nitrogenous substances that produce amino acids on complete hydrolysis.

15.2.1 Classification of Proteins

Classification of Proteins

- Structure-based
  - Primary structure
  - Secondary structure
  - Tertiary structure
  - Quaternary structure
- Constitution-based
  - Simple Proteins
  - Compound or Conjugated Proteins
  - Derived Proteins
- Shapes-based
  - Fibrous proteins
  - Globular proteins
- Functions-based
  - Enzymes
  - Structural
  - Transport
  - Storage
  - Hormonal
  - Defensive
  - Receptor
  - GPCRs
  - Contractile
  - Regulatory

Proteins are large complex molecules that play an important role in various biological processes. The classification of proteins is based on their structure, function, and the sequence of amino acids that make up their primary structure. The relationship between protein structure and function is closely related because the specific three-dimensional arrangement of a protein determines its function. Here is an overview of the basis of protein classification and the relationship between structure and function:

1. Structure-based classification:

Based on their structure, proteins can be divided into four major categories:

1. Primary structure
2. Secondary structure
3. Tertiary structure
4. Quaternary structure

The structure of a protein depends upon the spatial arrangement of polypeptide chains present in proteins. Since three spatial arrangements are possible, proteins have the following four structures.

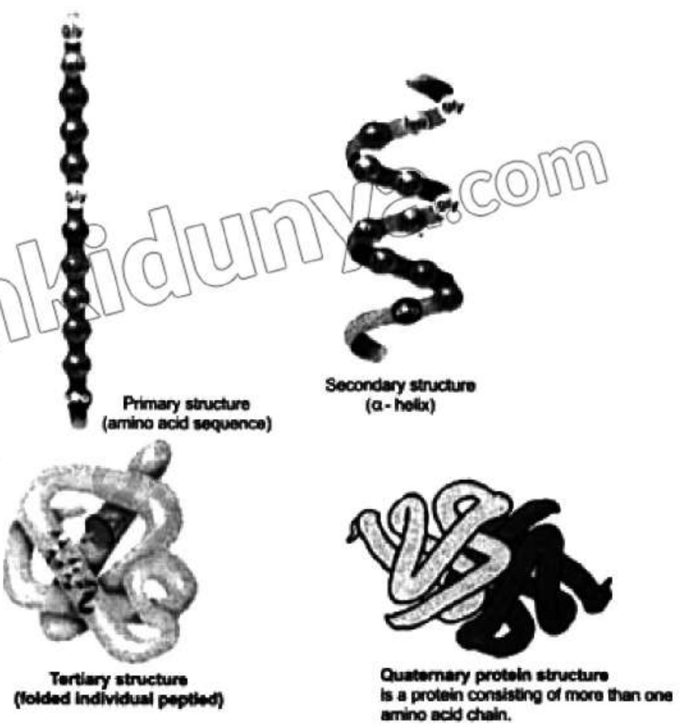


Fig 15.1

a) The Primary Structure of Proteins

The sequence of amino acids in a peptide chain is called primary structure. Amino acids are linked with one another through peptide bonds. The arrangement of these acids is called primary structure.

b) The Secondary Structure of Proteins

Peptide chains may acquire a spiral shape or may be present in a zig-zag manner. This coiling or zig-zagging of a polypeptide is called the secondary structure of a protein. It is due to H-Bond. For example, collagen.

c) The Tertiary Structure of Proteins

The twisting or folding of polypeptide chains represents a tertiary structure of proteins. For example, myoglobin.

d) Quaternary Proteins

Quaternary means four. This is the fourth phase in the creation of a protein.

Quaternary protein is the arrangement of multiple folded protein or coiling protein molecules in a multi-subunit complex. Different types of bonding interactions including hydrogen bonding, salt bridges, and disulfide bonds hold the various chains into a particular geometry. For example, haemoglobin.

15.2.2 Classification of Proteins based on Constitution

On the basis of constitution proteins are classified into three groups:

1. Simple Proteins
2. Compound or Conjugated Proteins
3. Derived Proteins

Simple Proteins

Proteins which on complete hydrolysis produce only the amino acids from which they are formed are called simple proteins. For example, albumins, globulins, collagens, etc.

Composite or Conjugated Proteins

Proteins composed of simple proteins (apoproteins) and non-protein groups called prosthetic groups are called composite or conjugated proteins. For example, lipoproteins, glycoproteins, phosphoproteins, nucleoproteins, hemoproteins, etc.

Derived proteins

Proteins consisting of simple or conjugated proteins partially hydrolyzed by acids, bases, or enzymes. For example, peptones. Peptides, proteoses, proteans, etc.

15.2.3 Classification of Proteins based on Shapes

Proteins are classified into two groups on the basis of their shapes.

1. Fibrous proteins
2. Globular proteins

Fibrous proteins

Proteins that are made up of elongated or fibrous polypeptide chains are called fibrous proteins. They form fibers of large sheets. Examples of fibrous proteins include keratins, collagens, myosins, and elastins. Hair and the outer layer of skin are composed of keratin. Connective tissues contain collagen. Myosins are muscle proteins and are capable of contraction and extension.

Globular proteins

Proteins that are water-soluble and possess a shape like a sphere or a globe upon folding are called globular proteins. These proteins are usually soluble in acids, water, alcohol, and bases—for example, albumin of eggs and haemoglobin.

15.2.4 Classification of Proteins on the basis of Functions

They can be classified based on their functions into several categories.

1. Enzymes:

Protein that facilitates the biochemical reactions. For example, lactase that breaks down lactose into glucose and galactose. Catalase catalyzes the decomposition of hydrogen peroxide into water and oxygen.

2. Structural Proteins:

Proteins that provide support and shape to cells and tissues. For example, Collagen which is found in connective tissues, provides strength and elasticity.

3. Transport Proteins:

Protein that facilitates the movement of substances across membranes. For example, haemoglobin carries oxygen in red blood cells.

4. Storage Proteins:

Proteins that store nutrients and ions. For example, ferritin. It stores iron in the liver and spleen. The casein stores calcium in milk.

5. Hormonal Proteins:

Proteins regulate physiological processes and serve as signalling molecules.
For example, insulin regulates glucose metabolism. Thyroid Hormones that control metabolism and growth.

6. Defensive Proteins:

Proteins that protect the organism against pathogens are called defensive proteins. For example, antibodies. They bind to and neutralize foreign substances like bacteria or viruses.

7. Receptor Proteins:

Proteins that bind to specific molecules and transmit signals into the cell are called receptor proteins. For example, insulin receptor that binds insulin and initiates cellular responses.

8. G Protein-Coupled Receptors (GPCRs):

Proteins that respond to various signaling molecules are called G protein-coupled receptors.

9. Contractile Proteins:

Proteins that enable muscle contraction and movement are called contractile proteins. For example, actin and myosin.

10. Regulatory Proteins:

Proteins that control the activity of other proteins.
For example, transcription factors that regulate gene expression. Cycling regulates the cell cycle.

15.1.5 Structure- Function relationship of Proteins

The primary structure is the amino acid sequence of a protein. For example, insulin. The secondary structure describes how the peptide backbone segments orient into a homogeneous sequence. For example, collagen. The tertiary protein structure describes how the whole protein molecule coils into a three-dimensional arrangement. For example, myoglobin. Quaternary structure describes the arrangement of multiple folded protein or coiling protein molecules in a multi-subunit complex. Different types of bonding interactions including hydrogen bonding, salt bridges, and disulfide bonds hold the various chains into a particular geometry. For example, hemoglobin.

15.2.6 Key roles of proteins in maintaining body function

Proteins are essential macromolecules that play a crucial role in the structure, function, and regulation of the body's tissues and organs. It's important to consume an adequate amount of protein through the diet to support these essential functions in the body. Good dietary sources of protein include meat, poultry, fish, eggs, dairy products, legumes, nuts, and seeds. They are made up of amino acids, which are the building blocks of life. The nutritional importance of proteins can be summarized as follows.

- Proteins play an important role in the formation of protoplasm. Protoplasm is the essence of all forms of life.
- Proteins like collagen and elastin provide structural support to tissues, tendons, ligaments, and skin. Enzymes act as biological catalysts, facilitating and speeding up chemical reactions in the body. They are involved in digestion, metabolism, and the synthesis of various molecules.
- Proteins such as insulin and growth hormones act as chemical messengers that regulate various physiological processes, including metabolism, growth, and development.
- Proteins like hemoglobin transport oxygen in the blood, while others facilitate the movement of nutrients, ions, and molecules across cell membranes.
- Proteins like actin and myosin are essential for muscle contraction, allowing for movement and locomotion.
- Antibodies are proteins produced by the immune system to identify and neutralize pathogens such as bacteria and viruses, playing a critical role in immune defense.
- Receptor proteins on cell surfaces interact with signaling molecules, enabling cells to respond to external stimuli and coordinate various physiological responses.
- Certain proteins act as enzyme inhibitors.
- Proteins store essential nutrients such as amino acids and metal ions for future use, ensuring a constant supply for the body's needs.

CONCEPT ASSESSMENT EXERCISE 15.2

1. What are proteins? Give its simple classifications.
2. Differentiate primary, secondary, and tertiary structure of Proteins.
3. What are polypeptides?

15.2.7 Fibrous Proteins for structure and support

Fibrous proteins are specialized proteins that play a structural or supportive role in our bodies. They are like building blocks, providing strength to different parts.

Silk fiber:

Silk is not only a material for clothing; It is composed of fibrous proteins. These proteins form long, strong structures that make silk fibers durable and flexible.

Keratin (in nails and hair):

Have you ever wondered why hair and nails are so strong? This is due to a protein called keratin. Keratin gives our hair and nails structure and strength and makes them elastic.

Myosin (in muscle cells):

Myosin is a special protein found in our muscles. It helps muscles contract and relax so we can move our bodies.

Fibrin (in blood clots):

Fibrin is like a superhero in our blood. When we get a cut, fibrin helps in forming of a clot to stop bleeding. It forms a mesh to seal the wound and protect us.

Insulin also signals other body systems, such as how cells absorb amino acids. It has other positive effects on the body. Doctors use insulin to treat certain types of diabetes.

15.3 Precipitation of Milk Proteins

Acid precipitation is the process of reducing the pH (acidity) of milk by adding acidic substances such as lemon juice. The main proteins precipitated in the liquid are milk proteins (casein and whey). The casein proteins in milk are micelles (small clusters of proteins). The phosphate groups on the casein micelles cause them to be negatively charged. This leads to electrostatic repulsion between the micelles and the casein proteins. The lower the pH of milk, the less electrostatic repulsion the micelles have. The addition of lemon juice lowers the pH of milk. As a result, the micelles can move closer together and form large aggregates. This results in the milk coagulating or coagulating when the pH drops.

15.4 Enzymes

(Greek word En means in and Zyme means yeast)

Enzymes are biocatalysts that alter the speed of metabolic activities in living bodies. Enzymes are complex protein molecules that are quite specific in action and sensitive to temperature and pH.

15.4.1 Role of Enzymes as a Biocatalyst

Metabolism refers to a series of chemical reactions that take place in living organisms in order to maintain life. These reactions enable organisms to grow, reproduce, maintain their structures, and respond to environmental conditions. Metabolism involves two main types of processes: anabolic and catabolic. Anabolic reactions involve the synthesis of larger molecules, while catabolic reactions involve the breakdown of larger molecules. Generally, enzymes are released in anabolic reactions and used in catabolic reactions. As a result, these biochemical reactions are essentially energy transfers. In metabolism, chemicals are converted from one state to another by enzymes. These enzymes play a critical role in metabolism, as they catalyze (i.e., accelerate) biochemical reactions and regulate metabolic pathways. The molecules on which the enzymes act are referred to as substrates. The enzymes convert these substrates into various molecules known as products.

How does Enzyme work?

When an enzyme attaches to a substrate, a temporary Enzyme-Substrate Complex (ES) is formed. The ES complex then breaks down the enzyme product.

$$E + S \rightarrow ES\ Complex \rightarrow E + P$$

In 1894, German chemist Emil Fischer proposed the lock and key model to explain how enzymes work. In this model, enzymes and substrates have specific shapes that fit together perfectly. This model describes the specificity of enzymes.

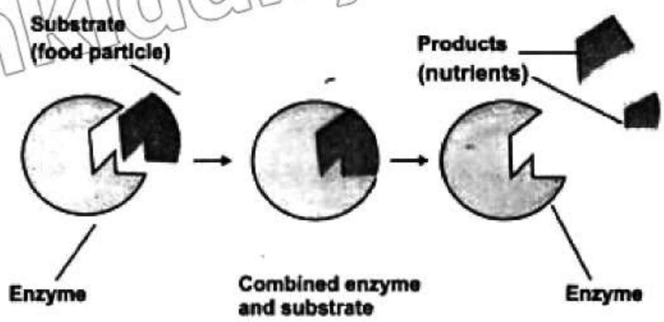


Fig 15.2 Lock and Key Model

In 1958, Daniel Koshland, an American biologist, proposed the induced-fit model to explain enzyme action. According to Koshland's model, active sites are not rigid structures but rather are moulded into the desired shape to perform their function. The "Induced fit model" is more acceptable than the "lock and key" model.

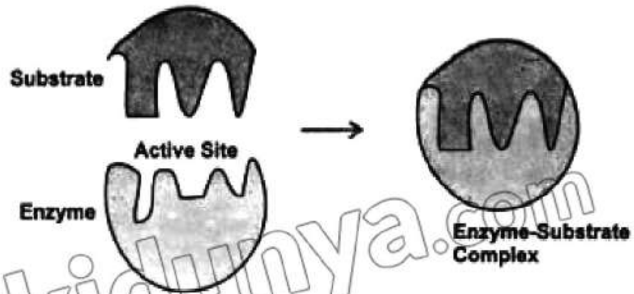


Fig 15.3 Induced Fit Model

15.4.2 Factors Affecting Enzyme Activity

Enzymes are very sensitive to the environment in which they work. Any factor that can change the chemistry or shape of an enzyme molecule can affect its function. Here are some factors that can affect how fast enzymes work.

i) Temperature

Enzymes work at their maximum speed at a specific temperature called optimum temperature. For example, an animal enzyme works at 37 °C, a plant enzyme acts at 60 °C, etc. When the temperature increases, the activation energy increases and kinetic energy is added to the reaction, which speeds up the reaction. However, when the temperature is increased too much, the vibration of enzyme atoms increases, and the enzyme's globular structure is lost, resulting in enzyme denaturation, which slows down the enzyme's activity and can block it completely.

ii) Substrate concentration

When there are sufficient enzyme molecules for the reaction to take place, increasing the substrate concentration will increase the rate of reaction. However, if the enzyme concentration remains constant and the substrate concentration increases, there is a point at which the addition of substrate does not increase the reaction rate at all. If all the active sites are occupied (high amounts of substrate) of enzymes, no substrate molecule will find any free active sites. This type of saturation is known as the active site state and the reaction rate does not increase.

iii) pH

All enzymes operate at maximum activity within a specific range of pH. This range is known as the optimum pH, and a small change in the pH of an enzyme either slows or stops the enzyme's activity. Each enzyme has its optimum pH value. For instance, the enzyme pepsin works in the stomach and is active in acidic environments (pH = 2) while the enzyme trypsin works in the small intestine and is active in alkaline conditions (pH = 8 to 9)

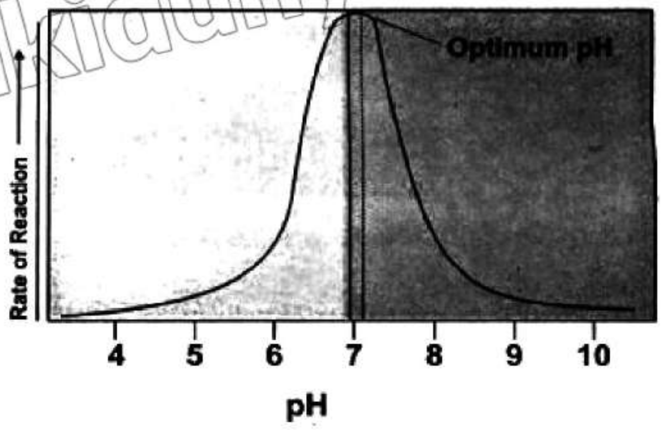


Fig 15.4: Effect of pH on Enzyme Activity

15.4.3 Role of Inhibitors in Enzyme Catalyzed Reactions

Inhibitors play a crucial role in regulating enzyme-catalyzed reactions by modulating the activity of enzymes. Inhibitors can be classified into two main types: competitive inhibitors and non-competitive inhibitors.

Competitive Inhibitors:

A competitive inhibitor is a molecule that is similar to the substrate and competes with it for the active site on the enzyme. It binds to the active site and prevents the substrate from attaching to the enzyme. For example, sarin, a nerve gas, acts as a competitive inhibitor to acetylcholine, a neurotransmitter. Sarin mimics acetylcholine's structure and competes for its active site, causing acetylcholine to build up in the synapses. Malonic acid is another example of a similar molecule. Malonic acid has a similar structure to succinic acid. Succinic acid is converted into fumaric acid on the succinate dehydrogenase enzyme, so malonic acid does not bind to the active sites on the substrate and therefore does not form a product.

Non-competitive Inhibitors:

Non-competitive inhibitors don't compete directly with the active site for the substrate but rather change the shape and form of the enzyme, reducing its ability to convert substrates to products. For example, mercury ions bind to the enzyme's thiol groups and change the shape and activity of the enzyme.

CONCEPT ASSESSMENT EXERCISE 15.3

1. What are enzymes? Why are they called biocatalysts?
2. How does enzyme work?
3. Differentiate between competitive and non-competitive enzymes inhibition.

15.5 Lipids

Lipids are naturally occurring heterogeneous groups of organic compounds of animals and plants origin, which are soluble in organic solvents. These include fats, waxes, oils, hormones and some membrane components. They function as energy-storing molecules and chemical messengers.

Lipids are the main constituents of cell membranes (cell walls), food storage molecules, and cholesterol.

All lipids are water insoluble, that's the one property they have in common.

15.5.1 Classification of Lipids

Classification of Lipids

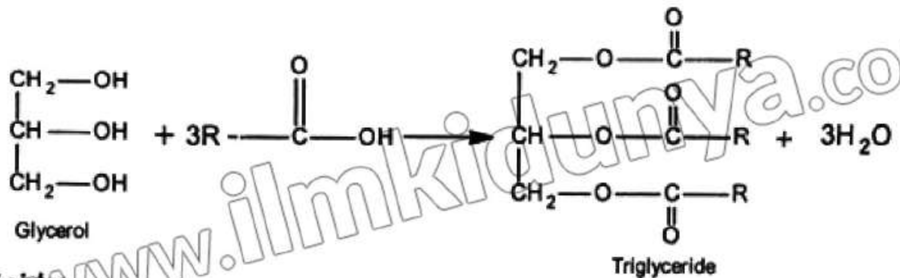
- **Structure-function based**
  - Triglycerides
  - Phospholipids
  - Steroids
  - Waxes
  - Terpenes
- **Chemical structure based**
  - Simple lipids
  - Phospholipids
  - Derivative lipids
- **Function based**
  - Energy-storing lipids
  - Structural lipids
  - Signaling lipids
  - Protective lipids
- **Physical characteristics based**
  - Saturated Glycerides
  - Unsaturated Glycerides

Lipids can be classified into the following classes. These categories highlight the structure-function relationships of lipids.

1. Triglycerides:

Fats and oils are made from two kinds of molecules, glycerol and three fatty acid. Since they contain three fatty acid units, they are called triglycerides. Fatty acids contain long hydrocarbon chains containing 12 to 22 carbon atoms and a carboxylic acid group at one end. They are the building blocks of most lipids. Examples include palmitic acid, oleic acid, and linoleic acid.

They are found in oils, butter, and adipose tissue. If the fatty acids are saturated, they form fats that are solid at room temperature, like butter. If they are unsaturated, they form oils which are liquid at room temperature, like olive oil, sunflower oil, cotton seed oil, etc.



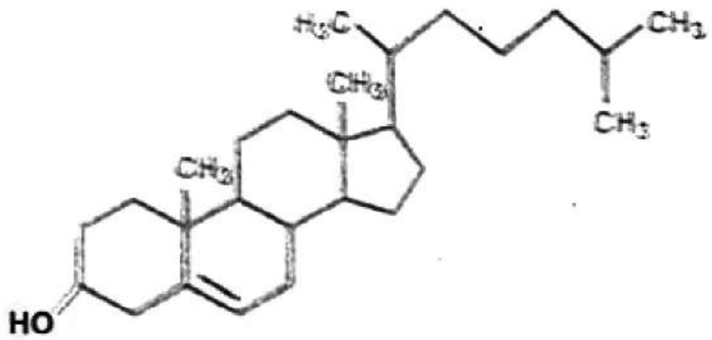
2. Phospholipids:

They are esters of glycerol, two fatty acids, and a phosphate group(PO_4^{3-}).

They are an integral part of cell membranes.

3. Steroids:

Steroids are organic compounds with a typical molecular structure containing four fused rings of carbon atoms (three six-membered and one five-membered). They function as structural components of cell membranes and are the precursors of various hormones. Examples: cholesterol, testosterone, estrogen.



Cholesterol

4. Waxes:

Waxes consist of long-chain fatty acids esterified to long-chain alcohols. They often act as a protective cover for plants and animals. Examples: lanoline, beeswax, carnauba wax, whale oil, etc.

5. Isoprenoids or Terpenes:

Lipids containing isoprene units (five-carbon units) are called terpenes or isoprenoids. They have various functions, including pigmentation in plants (carotenoids) and an electron carrier in cellular respiration (ubiquinone). Examples: pinene, camphor, menthol. Chlorophyll, and vitamin A.

15.5.2 Classification of lipids based on chemical structure

Based on chemical structure lipids are classified into the following groups

> **DO YOU KNOW?**
>
> Lanoline serve as a protective coating for hair and skin, so it is used in skin creams and ointments. Carnauba wax is used automobile polish.

1. Simple lipids: These are composed of fatty acids and glycerol molecules. For examples;

Triglycerides: Found in fats and oils, which act as the main energy store for organisms.

Waxes: Provide protection and water resistance to plants and animals.

Compound lipids: Contain additional components such as phosphoric acid, nitrogenous bases or proteins.

2. Phospholipids: These are essential components of cell membranes with a hydrophobic tail and a hydrophilic head.

Glycolipids: They participate in cell recognition and attachment, contain part of carbohydrates.

3. **Derivative lipids:** They are formed by hydrolysis of simple, or complex lipids. For example;
   (i) **Steroids:** Contain cholesterol, which is important for cell membrane structure, and hormones such as testoste.one and estrogen.
   (ii) **Prostaglandins:** Act as local hormones that influence inflammation, circulation and other physiological processes.

15.5.3 Classification of lipids on the bases of function:

Based on functions lipids are classified into the following classes

1. **Energy-storing lipids:**

Triglycerides: Stores energy in adipose tissue for future use.

2. **Structural lipids:**

Phospholipids: Form the basic structure of cell membranes.

Glycolipids: Promote membrane stability and cell recognition.

3. **Signaling lipids:**

Eicosanoids: Contain prostaglandins and leukotrienes that affect inflammation and the immune response.

4. **Protective lipids:**

Waxes: form a protective coating on plant and animal surfaces.

15.5.4 Classification of lipids on the basis of Physical Characteristics:

Based on physical characteristics lipids are classified into the following classes.

Saturated Glycerides: Fatty acids that contain only single bonds between carbon atoms are called saturated glycerides. They exist as solids at room temperature. Some examples of foods that contain high concentrations of saturated fats include butter, cheese, lard, and some fatty meats.

Unsaturated Glycerides: Fatty acids that contain at least one carbon-carbon double bond are called unsaturated glycerides. Oils are unsaturated glycerides. They exist in a liquid state at room temperature. Foods that contain higher concentrations of unsaturated fats include nuts, avocado, and vegetable oils such as canola oil and olive oil.

15.5.5 Nutritional and Biological Importance of Lipid

Lipids play three important biochemical roles:

1. As a storehouse of metabolic energy (Triglycerides)
2. As components of membranes
3. As messengers (Prostaglandins and Steroid Hormones)

One of the primary nutritional roles of lipids is to provide energy. For example, saturated, unsaturated, and trans fats provide approximately 9 calories per gram, compared to 4 calories per gram for carbohydrates and protein. Although fats are high in calories, they do not necessarily lead to weight gain if you track your total intake. Fats are also required for the absorption of essential nutrients such as fat-soluble vitamins A, D, and E.

15.5.6 Essential Lipids

Lipids that are not produced by the body and enter the body through food are known as essential lipids. Polyunsaturated fatty acids (PFA) are the most important lipids and are found in the form of polyunsaturated fats (Omega-6 and Omega-3 fats). These fats are essential for hormone synthesis, cell membrane structure, brain, and vision health, and can help lower blood cholesterol levels. Omega-6 fatty acids are found in vegetable oils and nuts, while omega-3 fatty acids can be found in flax seeds, walnuts, and fatty fish.

15.5.7 Non-Essential Lipids

Monounsaturated fats are not required in the diet because the body can synthesize them from amino acids. However, they reduce the risk of cardiovascular disease. Non-essential lipids are present in olive oil, peanuts, and avocado. Saturated fats, trans fats, and cholesterol are found in the diet and increase the bad cholesterol levels in the blood. Trans fats come from processed and fried foods, while cholesterol comes from fatty animal foods.

Cholesterol is a building block of hormones. Our bodies use cholesterol to produce some important hormones. These hormones act like messengers, delivering important signals to different parts of our bodies. For example, cholesterol is essential to produce sex hormones such as estrogen and testosterone. These hormones play an important role in the development of secondary sexual characteristics and the regulation of the reproductive system.

Some hormones actually consist of amino acids linked together and are called peptide hormones. These hormones also act as messengers, but perform different tasks than hormones made from cholesterol. For example, insulin.

Insulin is a protein hormone produced by the pancreas and consists of two parts, the alpha chain (21 amino acids) and the beta chain (30 amino acids), connected by a bridge. Its molecular weight is 5,808 g/mol. When we eat, our body releases insulin, which helps cells absorb sugar for energy.

Its main function is to control the body's use of sugar and fat. It tells the liver, muscles, and fat cells to absorb sugar from the blood. Sugar is stored as glycogen in the liver and muscles and as triglycerides in adipose tissues.

Insulin prevents the body from using fat for energy. When blood sugar levels are low, the body uses stored sugar through glycogenolysis. Insulin deficiency leads to a condition called diabetes mellitus. Diabetes mellitus is a disorder in which the body does not produce enough or respond normally to insulin, causing blood sugar (glucose) levels to be abnormally high.

Hibernation is a process that occurs in many species, including polar bears, reptiles, and amphibians. Under favourable conditions, their body accumulates large amounts of fat. Due to the unbearable cold, the bodies of hibernating animals sleep longer than they would otherwise be able to survive. Animals undergo various physical changes during hibernation. Breathing becomes very slow. Also, body temperature decreases depending on the surrounding temperature. During hibernation, their metabolism slows down and they become less active. They often hide in secluded caves and caves so that no one disturbs their peaceful sleep and they are not hunted. During this time, stored fat is used to meet energy needs.

CONCEPT ASSESSMENT EXERCISE 15.4

1. What are triglycerides? Draw its structure

15.10 Nucleic Acids

Naturally occurring biomolecules that serve as the primary information-carrying molecules in cells are called nucleic acids.

Types of Nucleic Acids:

There are two types of nucleic acids.

1) Deoxyribonucleic acids (DNA)

2) Ribonucleic acid (RNA)

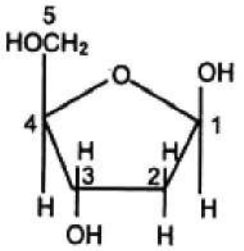
15.10.1 Structural Components of DNA and RNA

DNA consists of large polymeric molecules. Its monomers are called nucleotides. Four types of nucleotides are involved in the structure of DNA strands, which differ only from the base attached to carbon number 1 of the pentose sugar.

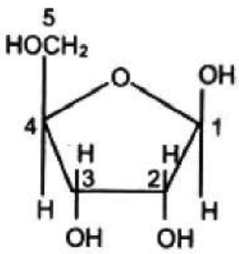
Components of Nucleotide

Each nucleotide consists of three components.

1) Pentose sugar or five-carbon sugar: In RNA pentose sugar is called ribose and in DNA it is called deoxyribose. In deoxyribose, the hydroxyl group at carbon number 2 of ribose is replaced by a hydrogen atom



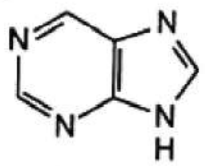
deoxyribose

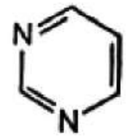


Ribose

1) **Nitrogenous base:** Four different types of nitrogenous bases are found in DNA: adenine (A), thymine (T), cytosine (C), and guanine (G). RNA, the thymine is replaced by uracil (U)

Adenine and guanine are called purines which contain two-carbon nitrogen ring bases. While cytosine, thymine, and uracil are called pyrimidines which contain one-carbon nitrogen ring bases.

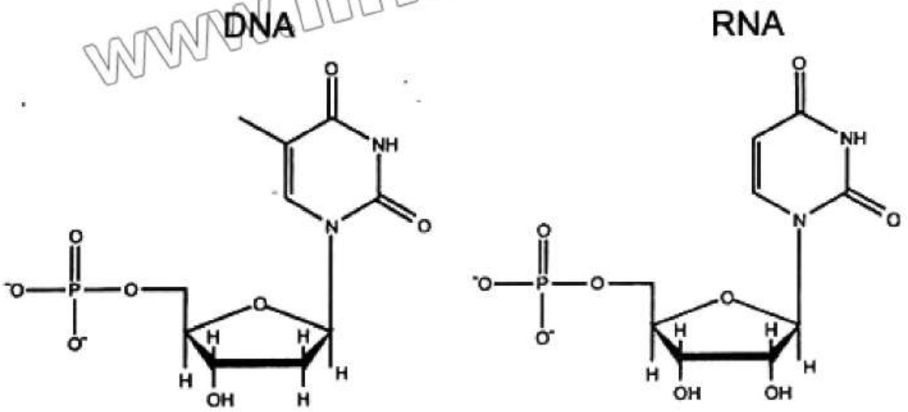




Pyrimidine

3) Phosphate unit: It is linked to C-5 of deoxyribose sugar in DNA and ribose sugar in RNA.

A simple structure of nucleotides is



15.10.2 Difference between RNA and DNA

1. RNA contains ribose sugar while DNA contains deoxyribose sugar.
2. Nitrogenous bases in DNA are cytosine, thymine, adenine, and guanine while in RNA thymine is replaced by uracil.
3. DNA is double-stranded while RNA is single-stranded, but the chain can fold back to itself to form a helical loop. The two strands in DNA are twisted into a double helix and are held in position by hydrogen bonds between complementary pairs of bases. The two stands are antiparallel i.e. they run in opposite directions.

DNA can store and transmit all the genetic information needed to build organisms. For instance, in human beings, the single fertilized egg cell carries the information for making legs, hands, head, liver, heart, kidneys, etc. DNA is found primarily in the cell nucleus.

Structure of DNA was discovered by J. Watson and Francis Crick in 1953. They were awarded the 1962 Nobel Prize for their work. This discovery initiated the field of molecular biology. Cancer research involves an extensive study of nucleic acids.

15.10.3 Structure of DNA

DNA exists in the spiral structure of a double helix, where two strands spiral around each other. The strands are joined together by hydrogen bonding between the bases of the two strands. The sequence of base pairs in a single strand is a genetic code that stores information needed to make proteins.

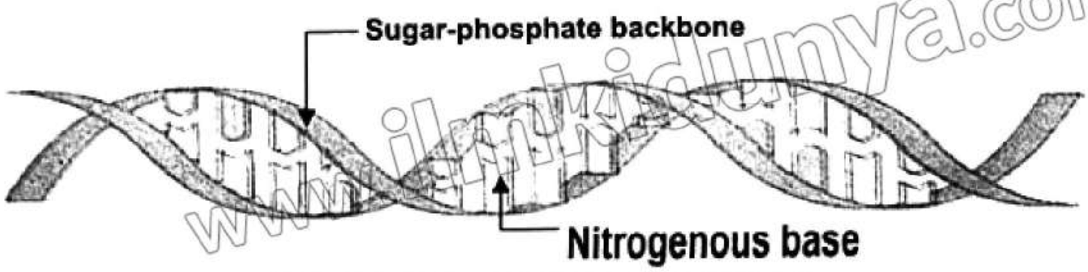


Figure 15.5 Structure of DNA

The double-stranded structure of DNA is the key to storing genetic information and transferring it from one generation to the next. The part of DNA that carries this genetic information is called genes. DNA is self-replicating. It copies the genetic information before a cell divides, so each daughter cell carries a copy of the correct genetic code can organism passed on to its offspring.

15.10.4 Structure of Ribonucleic Acid (RNA)

RNA exists as a single-stranded. It is created by DNA to carry genetic information. It is responsible for controlling the synthesis of new proteins by receiving, reading, decoding, and using the genetic information from DNA. DNA copies the genetic code in messenger RNA. The messenger RNA carries these copies into the cytoplasm to be synthesized into a protein. The genetic information in the mRNA is then translated with the aid of transfer RNA or ribosomal RNA which is used for protein synthesis. The resulting chain of amino acids called the polypeptide, is then sent to the Golgi Bodies to be processed and transformed into a protein.

Fig 15.6 Structure of RNA

Science Titbits (Chemistry in action)

The variation in DNA of individuals forms the basis of a method for identifying a person from samples of their hair, skin cells, or body fluid. Because DNA sequences like fingerprints are unique for each individual, this method is called DNA fingerprinting. Only a tiny sample is needed. The pattern is compared with the DNA of a sample from a known individual. If the DNA fingerprints are identical, it can be stated with a high degree of chemistry that the DNA in the known sample is from the individual.

CONCEPT ASSESSMENT EXERCISE 15.5

1. Write the names of structural components of DNA and RNA.
2. Which type of sugar is present in DNA?
3. What is the sugar unit in DNA?

15.11 Minerals of Biological Significance

Minerals are a type of nutrient that exists in the body. They are just as important as our oxygen to support life. They are also found in food in both organic and inorganic forms. Only 5% of the human body is made up of minerals. They are essential for every mental and physical process. They are also the most important factor in maintaining all physiological processes.

Types of nutrients

What are macronutrients and micronutrients?

- *Macronutrients* are those nutrients that your body needs in large amounts. For example calcium, phosphorus, magnesium, and sulphur.
- Micronutrients are nutrients that your body does not need in large quantities. For example, iron, zinc, copper, and iodine.

15.11.1 Sources of I nportant Minerals

- Sources of Iron: Red meat, egg yolk, whole wheat, fish, spinach mustard etc.
- Sources of Calcium: Milk, cheese, egg yolk, beans, nuts, cabbage and green leafy vegetables.
- Sources of phosphorous: Egg yolk, cheese, milk, cabbage etc.
- Sources of Zinc: Oyster, red meat, chicken, beans, nuts, dairy products and some sea foods.

15.11.2 Role of important Minerals in nutrition

Role of Iron

Iron is an important mineral that helps maintain healthy blood. A lack of iron is called iron-deficiency anaemia, causing extreme fatigue and lightheadedness. It affects all ages, with children, women who are pregnant or menstruating, and people receiving kidney dialysis among those at the highest risk for this condition.

Iron is an important component of hemoglobin which is a protein in the red blood cells. Hemoglobin carries oxygen from the lungs to every part of the body. When iron levels are low, the red blood cells do not have enough oxygen transport, resulting in fatigue. Iron is also a component of myoglobin which carries and stores oxygen, especially in muscle tissue. Iron is essential for the development and growth of the brain in children. It is also necessary for the normal generation and functioning of different cells and hormones in the body. Iron deficiency anaemia is a condition in which iron levels are low. It can lead to extreme tiredness, dizziness, and other symptoms. It is most common in children and women who are pregnant, menstruating, or on dialysis.

Role of Calcium

Calcium is one of the most abundant minerals in the body. Calcium is associated with healthy bones and teeth. About 99% of the body's calcium is stored in bones, and the remaining 1% is found in blood, muscle, and other tissues.

Calcium is an essential component that plays an important role in blood coagulation. It also plays an important role in helping muscles to contract and regulating normal heart rhythms and nerve functions.

System integrity is determined by vitamin D status. Vitamin D deficiency leads to a decrease in the amount of ionized calcium in the body. This in turn leads to a reduction in the amount of calcium in the body's blood and tissues. Vitamin D deficiency causes rickets, osteomalacia, and osteoporosis.

Role of Phosphorus

Phosphorus is a mineral found naturally in most foods and available in supplements. Phosphorus plays a variety of roles in your body. It plays a key role in the structure of your bones, teeth, and cell membranes, activating enzymes and maintaining your blood's pH level. Phosphorus plays a vital role in the proper functioning of your nerves and muscles (including your heart), as well as in the building blocks of your genes, DNA, RNA, and ATP (which are your body's primary sources of energy).

Role of Zinc

Zinc is the most important of all trace elements involved in humans. Your body contains about 2 gm of zinc. Zinc supports many functions in the human body. In addition to supporting the immune system, it enables the production of proteins and DNA, promotes wound healing, and influences child growth and development. The body needs zinc for the immune system to function properly. Low zinc levels can increase the risk of infections such as pneumonia. Zinc plays a role in maintaining healthy skin. It also plays an important role in promoting prostate health and testosterone levels.

CONCEPT ASSESSMENT EXERCISE 15.6

1. What is the biological significance of minerals?
2. What problems are caused by a deficiency of calcium and Phosphorus?
3. Give importance to zinc mineral.

KEY POINTS

- Carbohydrates have the general formula $C_x(H_2O)_y$.
- All carbohydrates contain an aldehyde or keto group and a hydroxyl group.
- Monosaccharides contain 3 to 6 carbon atoms.
- Carbohydrates which upon hydrolysis from 2 to 10 molecules of monosaccharides or simple sugars are called oligosaccharides.
- The Carbohydrates upon hydrolysis form hundreds to thousands of units of simple sugars are called polysaccharides.
- Glycogen is a type of stored glucose molecule made up of a large number of connected glucose molecules.
- Proteins are complex nitrogenous substances that produce amino acids on complete hydrolysis
- Enzymes are biocatalysts that alter the speed of metabolic activities in living bodies.
- Lipids are naturally occurring heterogeneous groups of organic compounds of animal and plant origin, which are soluble in organic solvents.
- Cholesterol is a building block of hormones.
- Naturally occurring biomolecules that serve as the primary information-carrying molecules in cells are called nucleic acids.
- Nucleic acids are present in every living cell as well as in viruses. They can reproduce, store and transmit genetic information. They are of two types of DNA and RNA.

Nucleotide is the structural unit of DNA and consists of one sugar, one nitrogenous base and at least one phosphate.

- Minerals are nutrients and are as necessary as oxygen for life. They are constituents of teeth, bones, tissues, blood, muscles, and nerve tissues.
- Minerals are classified as major and trace minerals i.e. those required in appreciable quantity are major and those needed in low quantity are trace.

EXERCISE

1. Multiple Choice Questions (MCQs)

i. Which carbohydrate is the primary source of quick energy in the body?
a) Starch b) Cellulose c) Glucose d) Glycogen

ii. What is the main structural component of plant cell walls?
a) Starch b) Cellulose c) Glycogen d) Chitin

ii. Which amino acid cannot be synthesized by the human body?
a) Glycine b) Glutamine c) Lysine d) Alanine

iv. Enzymes are primarily composed of:
a) Carbohydrates b) Lipids c) Proteins d) Nucleic acids

v. Which lipid is a major component of cell membranes?
a) Triglyceride b) Steroid c) Phospholipid d) Cholesterol

vi. RNA differs from DNA in that RNA:
a) Is double-stranded b) Contains thymine
c) Contains uracil d) Has a deoxyribose sugar

vii. What mineral is essential for oxygen transport in the blood?
a) Calcium b) Iron
c) Phosphorus d) Zinc

viii. Competitive inhibitors of enzymes:
a) Bind to the allosteric site b) Bind to the active site
c) Denature the enzyme d) Increase enzyme activity

ix. What is TRUE about enzymes?
a) They make biochemical reactions to proceed spontaneously
b) They lower the activation energy of a reaction
c) They are not very specific in their choice of substrates
d) They are needed in large quantities

x. The number of Carbon atoms in Hexose is:
a) One b) Four
c) Six d) Ten

2. Short Answer Questions

i. Describe the primary structure of a protein.
ii. What is the role of dietary fiber in health?
iii. Explain how temperature affects enzyme activity.
iv. What is the function of hemoglobin?
v. Differentiate between saturated and unsaturated fatty acids.
vi. What is the main function of RNA
vii. Describe one function of cholesterol in the body.
viii. How do enzymes lower activation energy?
ix. Describe the lock and key mechanism of enzyme action.
x. Identify the nutritional importance of carbohydrates and their role as energy storage.
xi. Identify the differences between fibrous proteins and globular proteins?
xii. What role do antibodies play in the immune system?
xiii. What is the optimal pH for most human enzymes?
xiv. What happens to an enzyme when it becomes denatured?
xv. How does a non-competitive inhibitor differ from a competitive inhibitor?
xvi. How is glycogen used during exercise?
xvii. Identify the sources of minerals such as iron, calcium, phosphorous, and zinc.
xviii. How does insulin regulate blood glucose levels?

3. Long Answer Questions

i. Explain the role of proteins in the body and their nutritional importance, including examples.
ii. Describe the factors affecting enzyme activity and provide examples of how these factors can alter enzymatic reactions in the human body.
iii. Detail the classification of lipids and discuss their nutritional and biological importance.
iv. Describe the structure of DNA and RNA and explain how these structures relate to their functions in genetic information storage and transfer.
v. How would you categorize various carbohydrates based on their chemical structures, and what functions do these classifications suggest in biological systems?
vi. Describe the role of iron, calcium, phosphorus, and zinc in nutrition.
vii. Compare and contrast the effectiveness of glycogen and fat as energy storage molecules during prolonged physical activity.
viii. Analyze the mechanisms by which competitive and non-competitive inhibitors affect enzyme activity.
ix. Examine the role of proteins in maintaining body functions.
x. How would you treat a patient with a deficiency in one of these minerals, considering dietary and supplemental interventions?
xi. Identify how milk proteins can be precipitated by lowering the pH using lemon juice. How would you apply this principle to develop a new method for producing cheese?