

CELL BIOLOGY

- Start with the topic and competency

a). **Chemicals of life;**

Properties and functions of chemical compounds of mammals

- Water- Structure(polarity), Solvent properties, interaction of water with polar and non-polar compounds, functions in living organisms
- Proteins-Structure of an amino acid, formation of a protein(peptide bond), Types(Globular, fibrous and intermediate), Structural categories(primary, secondary, tertiary and quaternary)
- Lipids- structure, types, properties, functions in living organisms(structural and physiological)

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- Research; **Sources of lipids**
- Enzymes- Properties, mechanisms (lock & key), Inhibition (competitive & non-competitive), factors that affect enzyme activity.

b). Microscopy

Microscope structure & function with all the properties

- Preparation of a slide and use of a microscope

- Drawings

- Electron microscope; properties & uses

c). **Ultra structure of a plant, animal and bacterial cell**

- Prokaryotes- bacteria cell; structure, classification
- Eukaryotes; ultra-structure of a plant & animal cell.
- Comparison; plant vs animal cell, Prokaryotic vs Eukaryotic
- Plasma membrane (fluid mosaic); functions, fluidity, make a model

d). Diversity of tissues(Histology);

- i) Plants; Parenchyma, Collenchyma, Sclerenchyma, xylem & phloem
- ii) Animals; (most focus to be put here); epithelial, cardiac, areolar, fibrous & skeletal tissues

N.B; Structure, location & functions

- Levels of organization of tissues; cell, tissue, organ
- Debate; Unicellular vs multicellular

CELL BIOLOGY

Competency: The learner evaluates cells and tissues, by analyzing and relating their structure to function, as a basis for medical research in order to improve health.

SUB TOPICS

- 1. Chemicals of life
- 2. Microscopy
- 3. Ultrastructure of plant, animal and Bacterial cells
- 4. Diversity of tissues

Sub-topic 1; chemicals of life

- Learning outcome.
- Analyse the properties and functions of chemicals compounds(water, lipids,proteins,including enzymes from mammals) in a cell, focusing on their roles in maintaining cellular structure and metabolic processes in living organisms(Thermal properties of water not required)

Water

- Describe water molecule; its interaction with polar and non-polar substances.
- Properties of water (physical and chemical)-exclude thermal properties.
- Functions of water; relate with properties.
- Role of water in maintaining cellular structure (e.g turgidity, plasmolysis e.t.c) and metabolic process (e.g its role in digestion, homeostasis, excretion e.t.c) in living organisms.

Lipids

- - Describe lipids; compositions - Properties of lipids; for simple and conjugated lipids. - Explain the functions of simple and conjugated lipids; give relevant examples
- Role or functions of lipids in maintaining cellular structure (e.g as a part of cell membrane) and metabolic process (e.g its role in transport; homeostasis (insulation), energy production e.t.c) in living organisms- relate properties to functions
- Distinguish between fats and oils; justify the ones best to be used in cooking at home. Give relevant examples; visit supermarkets; check nutritional information indicated and come with relevant choices. - Relate the properties of lipids to their functions.

Proteins

- Describe proteins; compositions
- Structural categories of protein; primary, secondary and tertiary; and their properties and functions
- relate properties to functions
- Role of proteins in maintaining cellular structure (e.g as a part of cell membrane) and metabolic process (e.g its role in nutrition as enzymes, transport, growth e.t.c) in living organisms.
- General functions of proteins with relevant examples
- Relate the properties of proteins to their functions

Enzymes

- Define enzymes;
- Explain their properties
- Mechanisms of enzyme action; lock and key and induced hypothesis - Different types of inhibition
- Commercial application of enzyme inhibition

Introduction

- All living organisms are made up of chemicals which constitute the protoplasm of their cells. These are known as the chemicals of life i.e. the chemicals which keep the cells alive. The study of the chemicals of life and the chemical reactions in which they take place is known as bio-chemistry. These chemicals of life are divided into two categories; organic and inorganic chemicals of life

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- The organic chemicals of life are all derived from carbon and include; carbohydrates, proteins, lipids, nucleic acids (DNA and RNA), waxes and steroids as well as vitamins.
- The inorganic chemicals of life include, 1. Water, 2.mineral salts, 3.lipids 4.proteins, WATER a)
- Structure All inorganic and organic chemicals of life must be supplied in appropriate quantities in the diet except nucleic acids and a few vitamins.
- Therefore there is need for a balanced diet to keep the cells alive.

WATER

- a) Structure All inorganic and organic chemicals of life must be supplied in appropriate quantities in the diet except nucleic acids and a few vitamins. Therefore there is need for a balanced diet to keep the cells alive. Water is formed when two hydrogen atoms combine with an oxygen atom by sharing electrons. The result is a stable molecule, which is relatively unreactive. The shape of the water molecule is triangular rather than linear (figure 1) and the angle between the nuclei of the atoms is approximately 105°. Overall the molecule is electrically neutral, but in both of the oxygen-hydrogen bonds, the oxygen draws electrons away from the hydrogen nucleus.

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- Thus there is a net negative charge on the oxygen atom and a net positive charge on the hydrogen atom.
- A molecule that carries an equal distribution of electrical charge (figure 2) is called a Polar molecule.
- Polarity is uneven charge distribution within the molecule. In water one part or pole of the molecule is slightly negatively charged and the other slightly positive, this is known as dipole.
- This occurs because the oxygen atom has a greater electron attracting power (electronegativity) than the hydrogen atom

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- As a result, the oxygen atom pulls the bonding electrons more towards itself than towards hydrogen.
- These attractions are not as strong as normal ionic or Figure 2 covalent bonds and are called Hydrogen bonds.
- They are constantly formed, broken and reformed in water although individually weak their collective effect is responsible for the unusual properties of water.
- Because of this charge separation, water is an overall neutral molecule. Water molecules form relatively weak hydrogen bonds with other water molecules. Hydrogen bonds are also formed with any charged particles that dissolve in water, and charged surfaces in contact with water. Hydrogen bonds account for the unique properties of water

b) Properties of water

- Water is biologically important as shown by each of its properties.

1. Solvent properties

- It is a universal solvent for polar substances (charged or ionisable substances) e.g. salt and it is also a solvent for non polar substances e.g. sugar. It is able to attract other polar substances, forming Hydrogen bonds with them, thereby dissolving them.
- Polar molecules such as salts, sugars and amino acids dissolve readily in water and so are called hydrophilic ("water loving"). Uncharged or non-polar molecules such as lipids do not dissolve so well in water and are called hydrophobic ("water hating"). Most non-polar substances such as lipids are immiscible in water and serve to separate aqueous solutions into compartments.

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- This property enables water to carry out the following functions;
 - i. It is a lubricant e.g. in the joints where it forms the synovial fluid which enables protection against damages.
 - ii. It acts as a transport medium as blood, lymph, in the expiratory system as well as in the alimentary canal where it transports materials from one point to another.
 - iii. It is an important constituent of the excretory waste products, by which toxic materials are removed from the body.
 - iv. It is the largest constituent of the protozoan protoplasm of all cells where it contributes up to 60%.

Density and freezing properties

- The density of water decreases below 4°C and ice therefore floats on relatively warmer water below.
- Water below 4 °C tends to rise which maintains the circulation in large water bodies therefore this property is important because;
- It makes water an important factor in the cycling of nutrients needed by living things.
- It makes water a suitable habitat for many aquatic organisms, both plants and animals.

High surface tension and cohesion

Cohesion is the force of attraction between molecules of the same kind. At the surface of the liquid a force called surface tension exists between the molecules due to the cohesive forces between the molecules.

This causes the water surface to occupy the least possible surface area. Water has a higher surface tension than any other liquid. As a reagent, water is an essential metabolite i.e. it participate

This property is important as follows;

- ❖ The high cohesion of water molecules enables the movement of water through the xylem to the leaves.
- ❖ Surface tension enables small organisms to settle on water or skate on the water surface.
- ❖ It enables the water to participate in the absorption of mineral salts from the soil.

Water as a reagent

This property is significant in the following ways;

- a. Water is a raw material of most bio-chemical reactions taking place such as photosynthesis, respiration, and digestion.
- b. Water is a medium in which most bio-chemical reactions take place.
- c. Water is a pre-requisite for fertilization, where fertilization involves mobile gametes e.g. external fertilization in lower plants, fish, amphibians, and internal fertilization in higher vertebrates and plants.

Incompressibility

This property enables water to carry out the following functions;

- a. It forms the hydro-static skeleton of animals such as earthworms.
- b. It provides support to the non woody plants e.g. herbaceous plants by maintaining turgidity of the cells.
- c. Water provides stomata movement, movement of leaves, opening and closing the flowers e.t.c. to take place through changes in the turgidity of the cells.

High tensile strength

Water can be lifted by forces applied at the top as seen in movement of water to the xylem of tall trees due to strong cohesive forces between water and the walls of the conducting vessels.

Water is transparent

It is important because it enables light to penetrate the water bodies to allow photosynthesis of aquatic plants and also to allow vision to the aquatic animals.

Water is denser than air

Water supports organisms as large as whales.

It also supports and disperses reproductive structures such as larvae and large fruits e.g. coconuts.

pH

- Water itself is partially ionized so it is a source of protons (H^+ ions), and indeed many biochemical reactions are sensitive to pH ($-\log [H^+]$).
- Pure water cannot buffer changes in H^+ concentration, so it is not a buffer and can easily be any pH, but the cytoplasm and tissue fluids of living organisms are usually well buffered at about neutral pH (pH 7-8).

Water has a low viscosity

This is a measure of how resistant a liquid is to flowing.

The lower the viscosity the easier the liquid flows.

Water has a viscosity that is lower than that of ethanol.

The ease with which water flows is important in the transport system of living organisms e.g. in blood as it flows through vessels.

The significance of this property is that water can easily be pumped and moved in the small tubes of the body.

- Water also forms a medium within which swimming is made easy.
- Water can flow freely through narrow vessels.
- Watery solutions can act as a lubricant.

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- If too much water is lost from the body, then the viscosity of blood increases, flow slows and transport is less efficient.
- Plants rely on the flow of water in the xylem and phloem vessels to transport substances around their bodies.
- Aquatic organisms too are able to swim in water because of the relatively low viscosity of water.

BIOLOGICAL IMPORTANCE OF WATER TO ALL ORGANISMS

Metabolic role of water

Hydrolysis. Water is used to hydrolyse many substances like proteins to amino acids, fats to fatty acids and glycerol, starch to maltose,

- Medium for chemical reactions. All biochemical reactions take place in aqueous medium provided by water.

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- Diffusion and Osmosis. It is essential for the diffusion of materials across surfaces such as the lungs or the alimentary canal e.g. diffusion of food materials into the blood stream since such surfaces are moist to facilitate diffusion and the moisture is provided by water. Photosynthetic substrate
- Water is a raw material for photosynthesis

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Water as a solvent

It dissolves other substances and is therefore used in the following ways;

- **Transport.** The solvent properties of water mean that it is a transport medium, as it is in blood plasma, tissue fluid, and lymph, in mammals and Xylem and Phloem in plants. They are all made up of water and dissolve a number of substances which can then be easily transported.
- **Excretion.** Metabolic wastes like ammonia, urea, excess salts require water to be removed from the body in solution form

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- Secretion.

They are transported from their place of secretion in solution form (aqueous form) e.g. most digestive juices have enzymes in solution, tears mainly consist of water, snake venoms have toxins in suspension composed of water.

Water as a lubricant.

Water's properties especially its viscosity makes it a useful lubricant. Lubricating fluids that have a component of water include;

- Mucus which externally facilitates movement in organisms like the snail and earthworm or internally in the walls of the gut and vagina
- Synovial fluid which lubricates movements in the joints of vertebrates.
- Pleural fluid which lubricates movements of the lungs during breathing

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- Pericardial fluid which lubricates movements of the heart Supporting role of water.
- Peri visceral fluid which lubricates movements of internal organs like peristaltic movement of the alimentary canal

Supporting role of water

With its large cohesive forces, water molecules lie close together due to the hydrogen bonds between them and therefore not easily compressed, making it a useful means of supporting organisms.

i. Hydrostatic skeleton

Animals like earthworms are supported by the pressure of the aqueous medium within them. ii) Turgor pressure Herbaceous plants and herbaceous parts of woody plants are supported by osmotic influx of water into their cells.

ii). Humours of the eye

Aqueous and vitreous humours give the shape of the eye and they are mainly made up of water.

iv. Amniotic fluid

- It supports and protects the mammalian foetus during development and is mainly made up of water.

v. Erection of the penis

The pressure of blood which is mainly made up of water makes the penis erect for copulation to take place.

iv. Habitat

Water supports organisms that live in it. Very large organisms like whales return to water as their sizes make movement on land very difficult.

Other biological functions of water include

- Water enables dispersal of seeds and fruits such as coconut as well as dispersal of the gametes and larval forms of aquatic organism. Medium of dispersal i.e. seed dispersal, gametes and larvae stages of some aquatic organisms
- Seed germination
- Osmoregulation
- Migration of aquatic organisms

- Fertilization, by transporting gametes
- Hearing and balance. The watery endolymph and perilymph in the mammalian ear plays a significant role in hearing and balancing
- It breaks the testa of seeds to allow embryo growth during germination.

LIPIDS

- They are larger groups of organic compounds like carbohydrates. They contain carbon, hydrogen and oxygen but the proportion of oxygen in lipids is small.
- Lipids include natural fats which are solid at room temperature and oils (liquid at room temperature).
- They are insoluble in water but soluble in organic solvents.

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- The solubility is from the fact that they have a low oxygen content. i.e. the number of polar OH groups are few.
 - It is those that normally confer solubility in water to the carbohydrates.
 - They are made up of glycerol molecule onto which 3 fatty acid molecules are combined in a condensation reaction.
 - The combination forms a triglyceride (lipid molecule) as well as 3 water molecules.

CONSTITUENTS OF LIPIDS

- Lipids are made up of esters called fatty acids and an alcohol of which glycerol is the most common. Glycerol has three hydroxyl groups (OH) and each of these may combine - with separate fatty acids forming triglyceride.
- This combination occurs by condensation reaction in which three water molecules are formed and therefore the hydrolysis of the triglyceride will again yield glycerol and 3 fatty acids.

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- Fatty acids have a general formula of $C_nH_{2n}O_2$. Their structural formula can be summarized as below $R(CH_2)_nCOOH$.
- Where n is any even number between 4 and 24. R can be CH_3CH_2 , $CH_3CH_2CH_2$ e.t.c.

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- Fatty acids can be classified as unsaturated if they contain one or more double bonds e.g. oleic acid. Fatty acids lacking double bonds are said to be saturated e.g. stearic acid.
- Unsaturated fatty acids melt at a much lower temperature than saturated fatty acids.
- Consequently, saturated fatty acids are normally found in fats while unsaturated fatty acids are commonly found in oils. Lipids vary due to the presence of many fatty acids.

Characteristics of lipids.

- They are made up of carbon, hydrogen and oxygen. They are composed of 3 fatty acids and glycerol (3 -CH₃ groups).

The general formula of glycerol is **C₃H₈O₃**. The fatty acids contain the carboxylic acid carboxyl group (**-COOH**) and a hydrocarbon group.

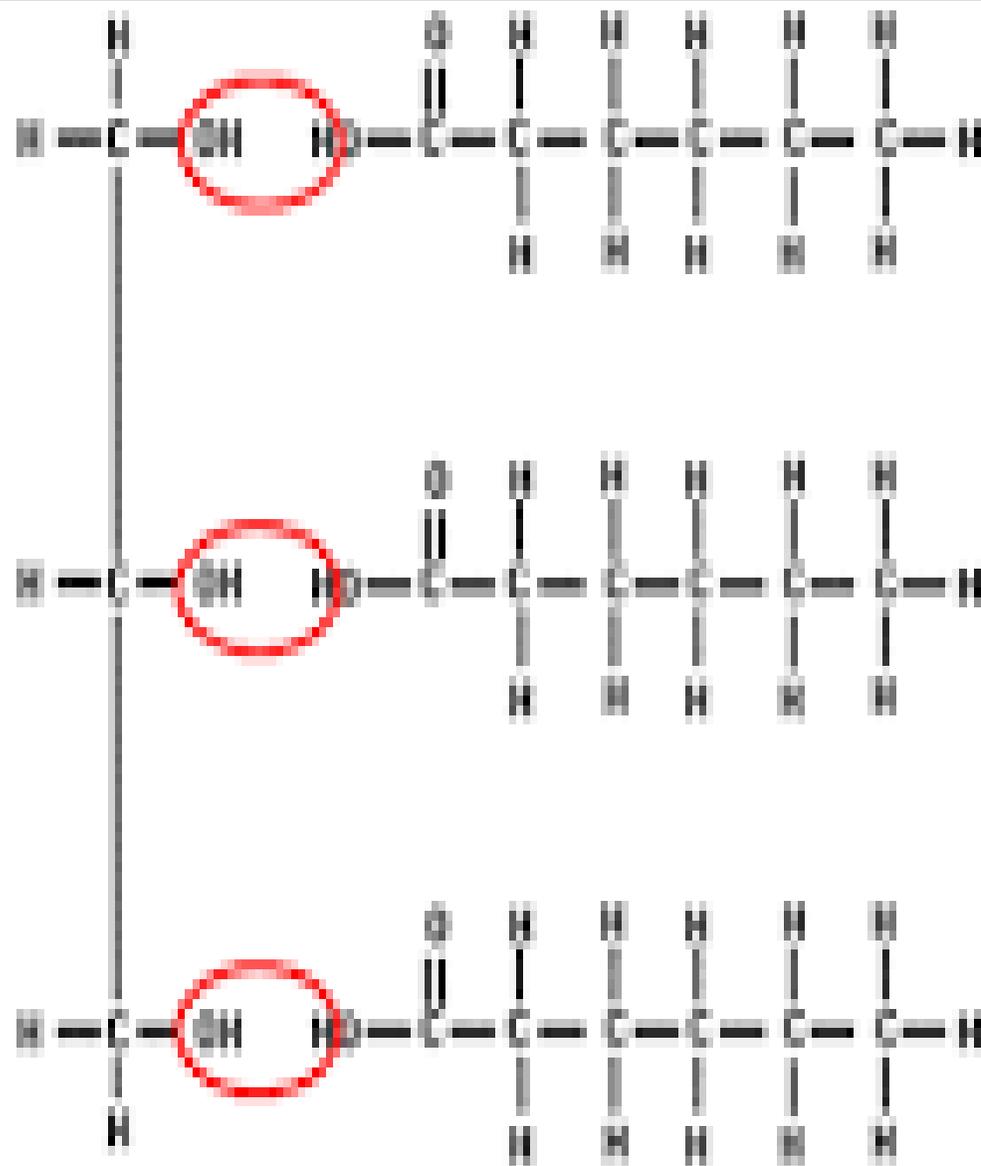
- They have a high proportion of hydrocarbon groups in their molecules.
- They are insoluble in H₂O but soluble in organic solvents e.g. benzene and chloroform, alcohol. This is because lipids have a low O₂ and the numbers of polar hydroxyl groups are few and this decreases their solubility in H₂O.

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- They are either solids (fats) or liquids (oils) at room temperature.
- The higher the proportion of unsaturated fatty acids, the lower will be their melting points.
- They are non-polar and this makes them effective storage materials.
- They are less dense than H₂O and this helps the aquatic organism to float on H₂O. 7.
- They have a functional group -COOH composed of fatty acids glycerol.

FORMATION OF LIPIDS

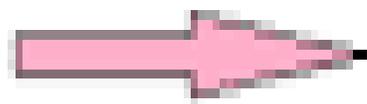
- In the formation of lipids, 3 fatty acids and one glycerol molecule combine to form a triglyceride accompanied by removal of 3 H₂O molecules and formation of 3 ester bonds.
- The fat or oil formed depends on the fatty acid involved i.e. they could be saturated or unsaturated as shown below.



Glycerol

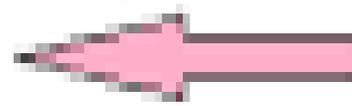
Fatty Acids

Condensation

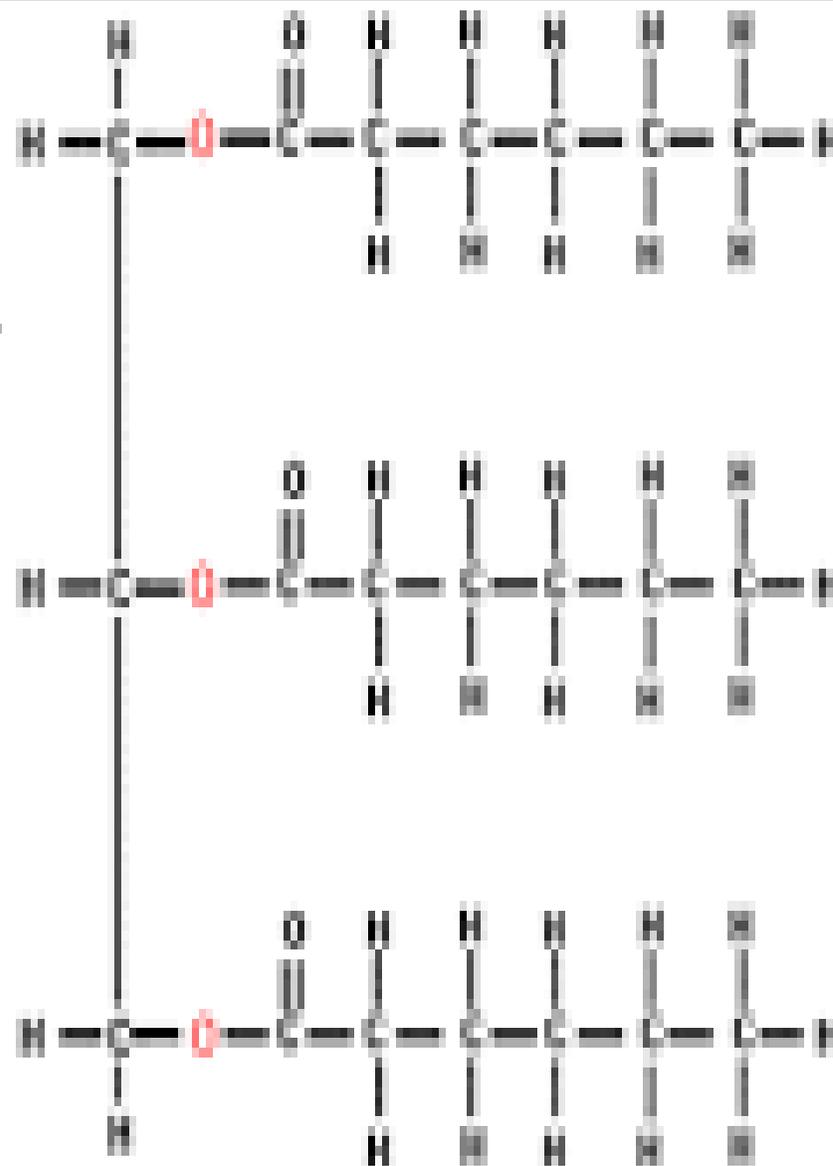


+ 3 H₂O

Hydrolysis



+ 3 H₂O



Triglyceride Molecule

Lipids are better storage compounds than carbohydrate because;

- More energy is produced when they are oxidized i.e. they have a high calorific value.
- Relatively more stable than carbohydrates.
- Compact hence taking little space
- Insoluble in water and so do not dissolve away
- They are light (have low density) which minimizes weight especially of aquatic animals. This contributes to buoyancy of aquatic organisms like whales and seals.

FATTY ACIDS

- Fatty acids occur as saturated or unsaturated

Unsaturated fatty acids are ones where the hydrocarbon part contains one or more double bonds like in linoleic acid and oleic acid.

The saturated don't contain double bonds. The saturated fatty acids have a high boiling or melting points compared to the unsaturated of the same molecular mass.

Read and make notes about the different examples of fatty acids; in your research include; formula, saturation and source

LIPIDS AND THE DIET

- There are two groups of fatty acids;

a) Essential fatty acids

They cannot be synthesized in the body. Therefore, they have to be obtained from the diet. Their deficiency results into retarded growth, reproductive deficiency and kidney failure. These are alpha-linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid).

b) Non-essential fatty acids

The body synthesizes some fatty acids and they are synthesized from compounds of protein and carbohydrate metabolism.

N.B

1. Carboxylic acids have two ends; the alpha end (-COOH) and the Omega end (CH₃) and so Omega -3 fatty acids have a double bond on carbon number 3 and omega 6 have the double bond on carbon number 6.
2. Gram per gram, fat stores more energy than glycogen. The C - H bonds of fatty acids make them a richer source of chemical energy than glycogen, because glycogen has many C - OH bonds. i.e. glycogen has more Oxygen molecules than fat. Therefore, nearly all animals use fat in preference to glycogen for long-term energy storage.

FUNCTIONS/ IMPORTANCES OF LIPIDS

Physiological functions

- i) They are energy sources and stores and so they yield a lot of energy when oxidized. i.e. they have a higher calorific value than carbohydrates of similar molecular mass. i.e. 1g of lipids yields 38kJ (9k) calories 1g of carbohydrates yields 17kJ (4 k Cal.)
- ii) They provide a lot of metabolic water to desert animals when oxidized e.g. in camels where they are heavily deposited in the hump and also developing birds and reptiles while enclosed in their shells.

Structural functions

- i) Lipids are insulators since they are poor conductors of heat. In animals, they are found below the skin. They are mostly found in animals living in cold climates and aquatic mammals with very thick subcutaneous fat (also called BLUBBER in seals and whales)
- ii) They are constituents of the plasma membrane when they combine with phosphoric acids to form phospholipids.
- iii) iii) They form a component of the waxy cuticle of plants and arthropods hence water proofing the organisms and thus reducing water loss since they are insoluble in water

Protection

- i) They cushion delicate body organs and protect them from physical damage. They also absorb shock since they are packaged around these organs. Other functions
- vii) Buoyancy function in that they help the aquatic organism to float and the oils on bird feathers help the aquatic varieties to float.
- viii) Formation of plant scents for attracting insects for pollination
- ix) Formation of bee wax for constructing and repairing honey combs
- x) Storage of fat-soluble vitamins (A, D, E and K)

LIPID DERIVATIVES

a. **WAXES:** These are made of ester bonds by linking one fatty acid+ a long chain of alcohol instead of glycerol.

Waxes are used as water proof material by plants and animals. They are also used as additional protective layers on the surface or epidermis of some plant organs like leaves.

They make exoskeletons of arthropods and bee wax is a constituent of the honeycomb of bees.

b. PHOSPHOLIPIDS (LIPIDS WITH PHOSPHATE).

- They are components of the cell membrane. They are made up of two molecules of fatty acids linked to a molecule of glycerol as in fats. But the third position is occupied by a phosphate group.

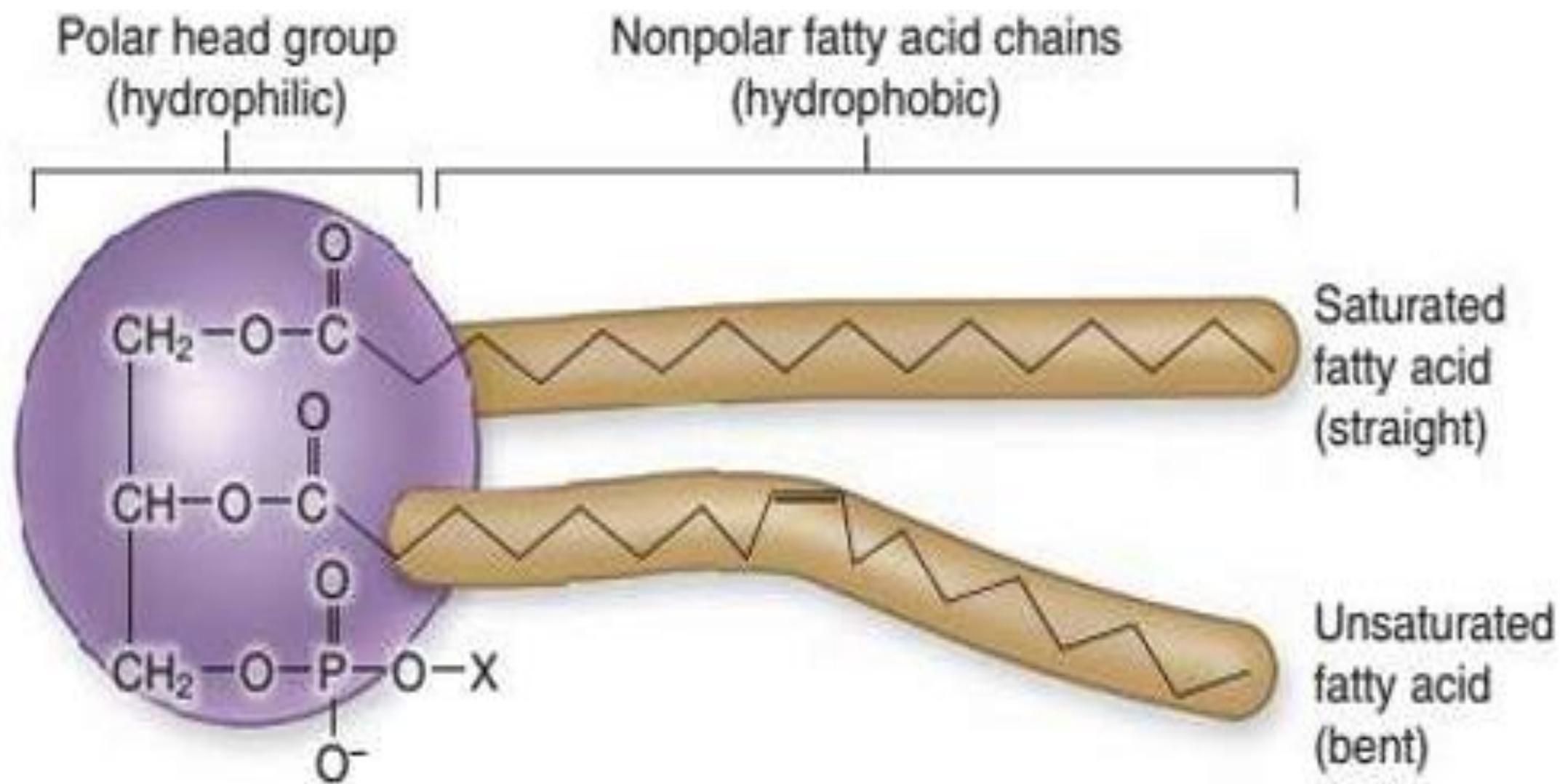


Figure 30: A Phospholipid Molecule

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- The molecules consist of a phosphate head and two hydrocarbon tails (fatty acids). The polar ends of the molecule being soluble enter the water while the insoluble hydrocarbon chain project out wards at right angles to the surface. This property of the phospholipids is important in determining the structure and functions of the cell membrane.

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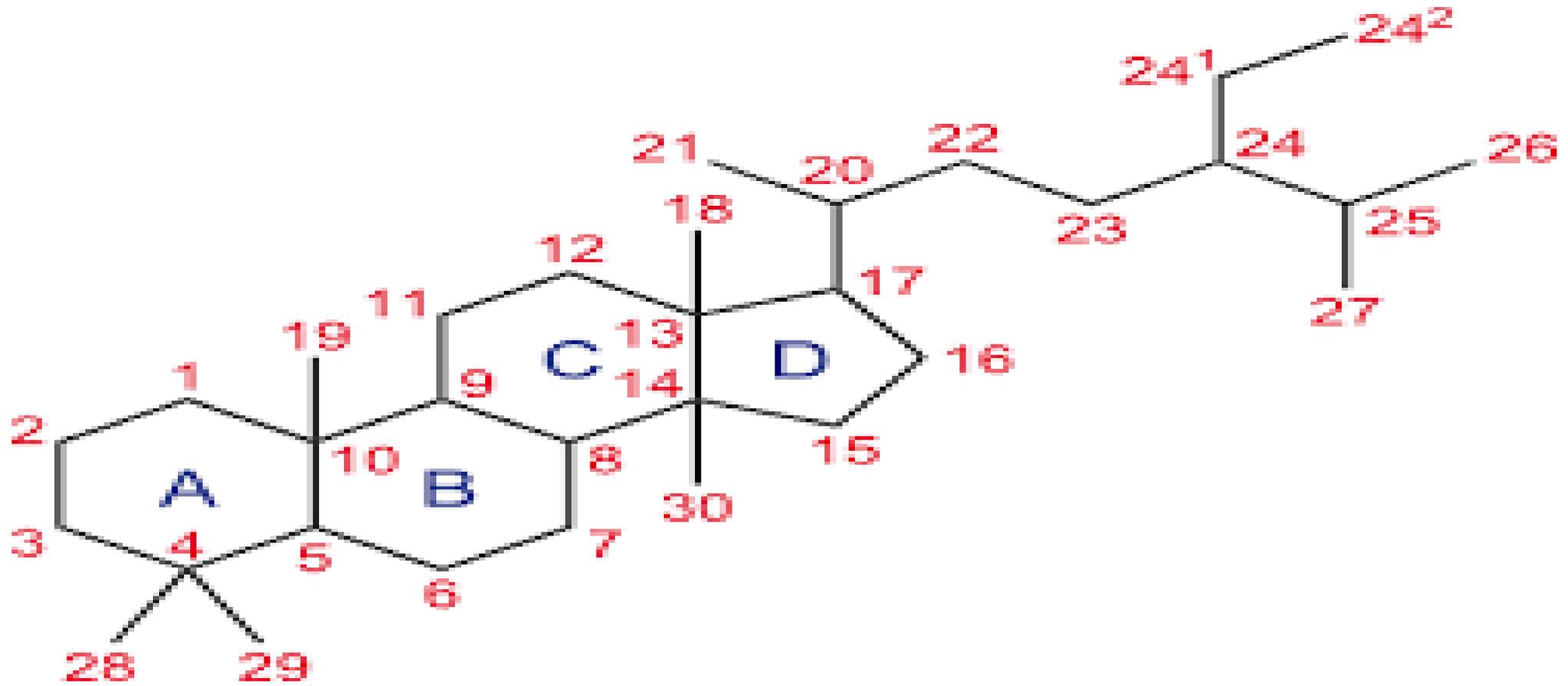
C. GLYCOLIPIDS. They are lipids with a carbohydrate attached by a glycosidic bond. Their role is to serve as markers for cellular recognition. The carbohydrates are found on the outer surface of all eukaryotic cell membranes

D. LIPOPROTEINS. This forms part of the cell membranes and it is the chemical form in which lipids are transported.

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E. STEROIDS. These are lipids whose molecules contain 4 rings of Carbon and Hydrogen atoms. Three of the rings are six numbered and one of them is five numbered. All together there are 17 carbon atoms, six of which are shared between the rings and they are saturated hydrocarbons. They cannot be hydrolyzed. Some are formed by the smooth ER of cell membranes

Structure of steroid

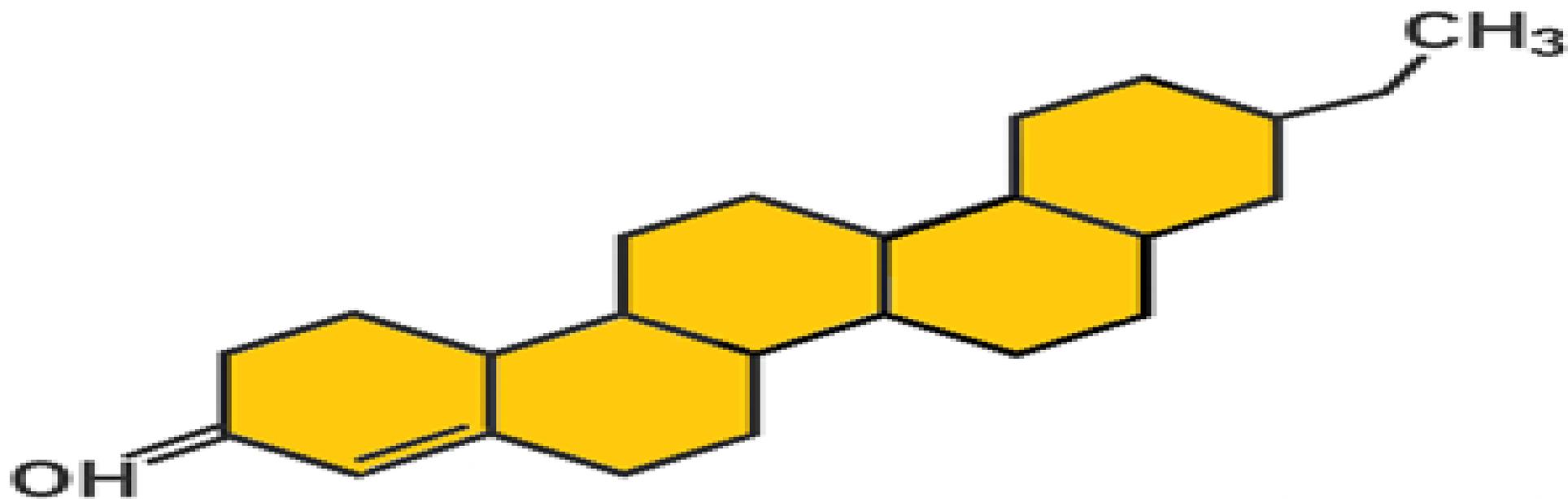


Examples of steroids

Category	Common Examples	Primary Function/Use
Corticosteroids	Prednisone, Hydrocortisone, Dexamethasone, Fluticasone	Reduces inflammation; treats asthma, allergies, and skin rashes.
Anabolic Steroids	Testosterone, Oxandrolone (Anavar), Stanozolol (Winstrol)	Mimics testosterone; builds muscle mass and treats hormone deficiencies.
Sex Hormones	Estrogen (Estradiol), Progesterone, Testosterone	Regulates reproduction, puberty, and secondary sexual characteristics.
Biological Steroids	Cholesterol, Bile Acids, Vitamin D	Builds cell membranes, aids digestion, and supports bone health.

The structure of cholesterol

CHOLESTEROL



**To be
continued.....**

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