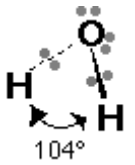
CHEMICALS OF LIFE

These are compounds needed to maintain life of living organisms. They are divided into two groups, i.e.

i) Inorganic compounds e.g. water, vitamins, salts, acids and roughages.
ii) Organic compounds e.g. carbohydrates, lipids, proteins and nucleic acids.

WATER

It is the most important inorganic compound in life and most abundant within living organism.
A human cell contains about 80% water and the whole body has over 60% water.
Water is formed when two hydrogen atoms combine with an oxygen atom by sharing electrons. The shape of a water molecule is triangular and the angle between the nuclei of atoms is approximately 105^0
Water molecules form weak hydrogen bonds with other water molecules nearby and its bonds give it the unique properties.



Properties of water

i) It is liquid at room temperature.
ii) It has a high heat capacity therefore much energy is used to raise its temperature because it is used to break the hydrogen bonds which restrict the mobility of the molecules. As a result water is relatively slow to heat up or to cool down thus a high heat capacity.
iii) Water expands as it freezes unlike other liquids which contract on cooling.
iv) Water reaches its maximum density above its freezing point at 4^oC hence when water freezes, the ice formed is less dense than the water and hence floats on top of the surface. In this way, ice insulates water below making it less dense and able to float hence the water will be warmer than the air above.
v) Water has a high surface tension. Surface tension is the force that causes the surface of a liquid to contract so that it occupies the least area. It is high due to the fact that molecules are oriented so that most hydrogen bonds point inwards towards other water molecules.
vi) It has a high latent heat of fusion i.e. much heat must be removed before freezing occurs.
vii) It has high adhesive and cohesive properties preventing it from breaking under tension.
viii) It is colourless and transparent.
ix) It has a low viscosity i.e. water molecules slide over each other very easily.
x) It dissolves more substances than any other liquid i.e. it is a universal solvent.

Functions of water

- It is a component of cells
- It is a solvent and a medium of transport
- It is a reagent in hydrolysis
- It enables fertilization by swimming gametes
- It enables dispersal of seeds, fruits, gametes and larvae stages in aquatic organisms.
- It is important in transpiration in plants.
- It is important in translocation in plants.
- It enables germination to proceed by activating enzymes, transporting hydrolyzed stored food, swelling and breaking open the testa.
- It is involved in Osmo-regulation in animals
- It enables cooling by evaporation as a result of sweating and panting.
- It is a component of lubricants at joints e.g. the synovial fluid.

- It offers support in hydrostatic skeleton.
- It offers protection as a component of mucus and tears.
- It enables migration to occur as a result of river flow or ocean currents.

QUESTION: ***HOW DO THE PROPERTIES OF WATER RELATE TO ITS BIOLOGICAL ROLE?***

1) Water is transparent and this allows light penetration in aquatic habitats to enable photosynthesis of aquatic autotrophs and visibility of aquatic animals.
2) Water has a low viscosity and this allows for smooth flow of water and other dissolved substances in an aquatic medium for easy transport.
3) It has a high surface tension providing support to aquatic organisms and allowing movement of living organisms on water surface.
4) Has a high latent heat of vaporization hence a cooling effect on the body surface since evaporation of water from the body of an organism draws out excess heat.
5) It has a high boiling point thus provides a stable habitat and medium since a lot of heat which is not normally provided in the natural environment is needed to boil the water.
6) It has a high latent heat of fusion and hence a low freezing point thus providing a wide range of temperature for survival of aquatic organisms since it prevents freezing of cells and cellular components.
7) It has a high specific heat capacity which minimizes drastic temperature changes in biological systems and provides a constant external environment for many plant cells and aquatic organisms.
8) It has a maximum density at 4^{o} C hence ice floats on top of water insulating the water below hence increasing the chances of survival of aquatic organisms below the ice.
9) Water is liquid at room temperature providing a liquid medium for living organisms and metabolic reactions and a medium of transport.
10) It has high adhesive and cohesive forces creating enough capillarity forces for transport in narrow tubes of biological systems.
11) It is a universal solvent hence providing a medium for biochemical reactions.
12) Water is a polar molecule allowing solubility of polar substances, ionization or dissociation of biochemical substances.
13) Water is incompressible thus providing support in hydrostatic skeleton and herbaceous stems.
14) Water is neutral hence does not alter the pH of cellular components on their environment.
15) A water molecule is relatively small for easy and fast transport across a membrane.

QUESTION: ***OUTLINE THE ROLE OF MINERALS AND IONS IN BIOLOGICAL SYSTEMS.***

1) They are components of smaller molecules e.g. phosphorus is contained in ATP and iodine is contained in thyroxin, etc.
2) They are constituents of large molecules e.g. proteins contain nitrogen and sulphur, phospholipids contain phosphorus, nucleic acids contain nitrogen and phosphorus, etc.
3) They are components of pigments e.g. haemoglobin and cytochromes which contain ion, chlorophyll contain magnesium, etc.
4) They are metabolic activators e.g. activates glucose before it is broken down in cell respiration, calcium ions activate ATPase enzyme during muscle contraction.
5) They determine the anion, cation balance e.g. Na^{+}, K^{+} and Ca^{+} are important in transmission of impulses and muscle contraction.
6) They determine the osmotic pressure and water potential so that it does not fluctuate beyond narrow limits e.g. Na^{+}, K^{+} and Cl^{-} are involved in water balance in the kidneys.
7) They are constituents of structures in cell membranes, cell walls, bones, enamel and shells.

CARBOHYDRATES

These comprise of a large group of organic compounds which contain C,H and O. they have a general formula $C_X(H_2O)_Y$ though some do not conform to it e.g. deoxyribose $C_5H_{10}O_4$.

Main functions of carbohydrates

- They are a primary source of energy being oxidized in the body to release energy.
- They are structured components of cells e.g. cellulose making up the cell wall.
- They are determinants of osmotic potential of body fluids therefore maintain blood pressure.
- They are recognized units on the surface of body cells, i.e. they are component structures of the surface cell membranes recognized by antibodies.

Types of carbohydrates

1. Monosaccharides (single unit sugars)
2. Disaccharides (double unit sugars)
3. Polysaccharides (several unit sugars)

MONOSACCHARIDES

Monosaccharides (mono=one, saccharide= sugar) are substances consisting of one molecule of sugar. They are also known as simple sugars.

Properties of monosaccharides

- They have a sweet taste
- They dissolve in water
- They form crystals
- They have a low molecular mass
- Can pass through a selectively permeable membrane.
- They change the colour of benedict's solution from blue to orange when boiled with the solution thus they are known as ***reducing sugars.***

Monosaccharides are named using a suffix 'ose'. They contain either an aldehyde group (CHO) and are called aldoses or they contain a ketone group (C=O) and are called ketones. Monosaccharides have a general formula $(CH_2O)_n$ where:

- n=3 (triose sugar)
- n=5 (pentose sugar)
- n=6 (hexose sugar)
- n=7 (heptose), etc.

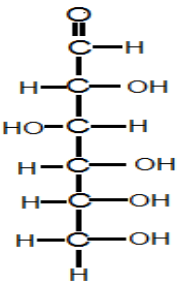
The most frequent monosaccharides are the hexose sugars; glucose, fructose and galactose.

HEXOSE SUGARS

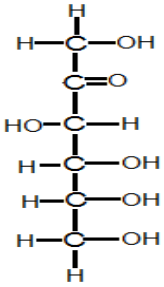
These are sugars with molecular formula $C_6H_{12}O_6$ and structural formulae as shown below:

Glucose (aldose)

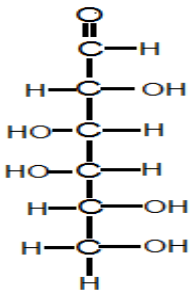
Glucose



Fructose

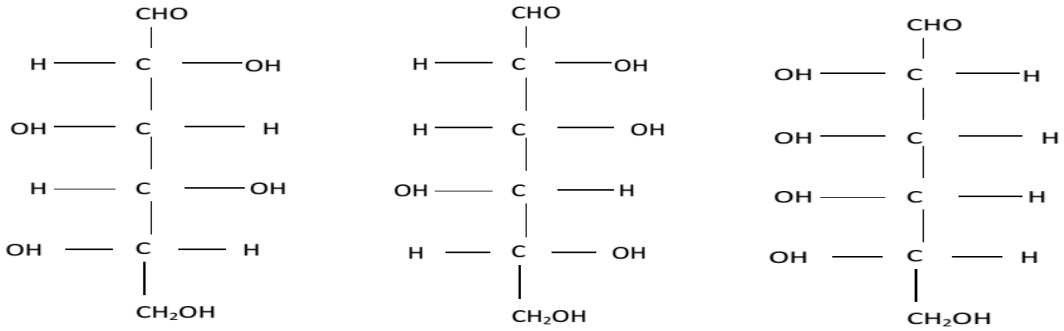


Galactose

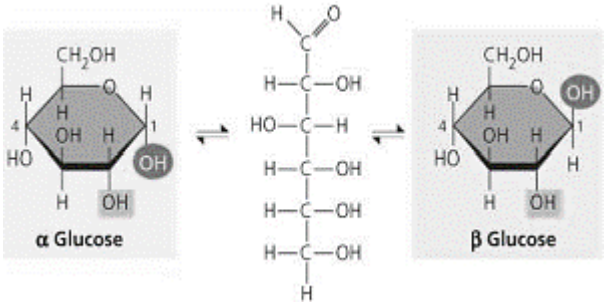


Glucose can exist in a number of isomers where it has different structural formulae remaining with the same molecular formulae.

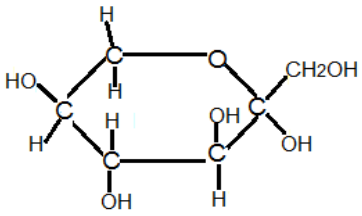
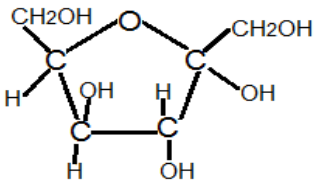
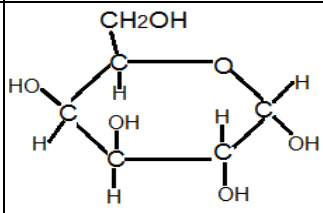
Isomers of glucose



The hexose sugars can exist in straight or chain form as shown above or in ring form as shown below:

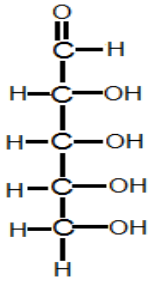
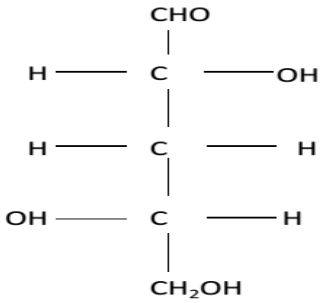
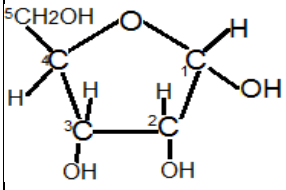
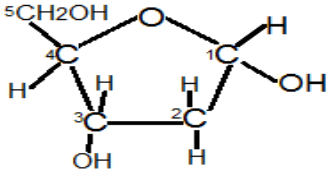


Fructose exist in rings which are either 5 sided or 6 sided. The six sided are also known as pyranoses while the 5 sided are also known as furanoses.

Fructose (pyranose)	Fructose (furanose)	Galactose
		

PENTOSE SUGARS

They have 5 carbon atoms. They are found in nature as ribose and deoxyribose. They exist in straight and ring forms.

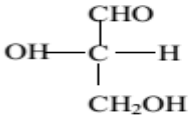
Straight forms		Ring forms	
Ribose	Deoxyribose	Ribose	Deoxyribose
			

Ribose occurs in co-enzymes, adenosine triphosphate (ATP) and ribonucleic acid (RNA). Deoxyribose occurs in DNA (Deoxyribo Nucleic Acid).

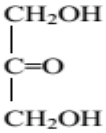
TRIOSE SUGARS

They contain 3 carbon atoms. The two occurring trioses are glyceraldehyde and dehydroxyacetone. Both of them are found in plant and animal cells playing a role in carbohydrate metabolism.

Glyceraldehyde

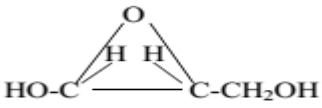


Dehydroxyacetone

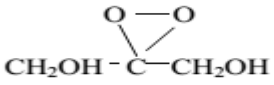


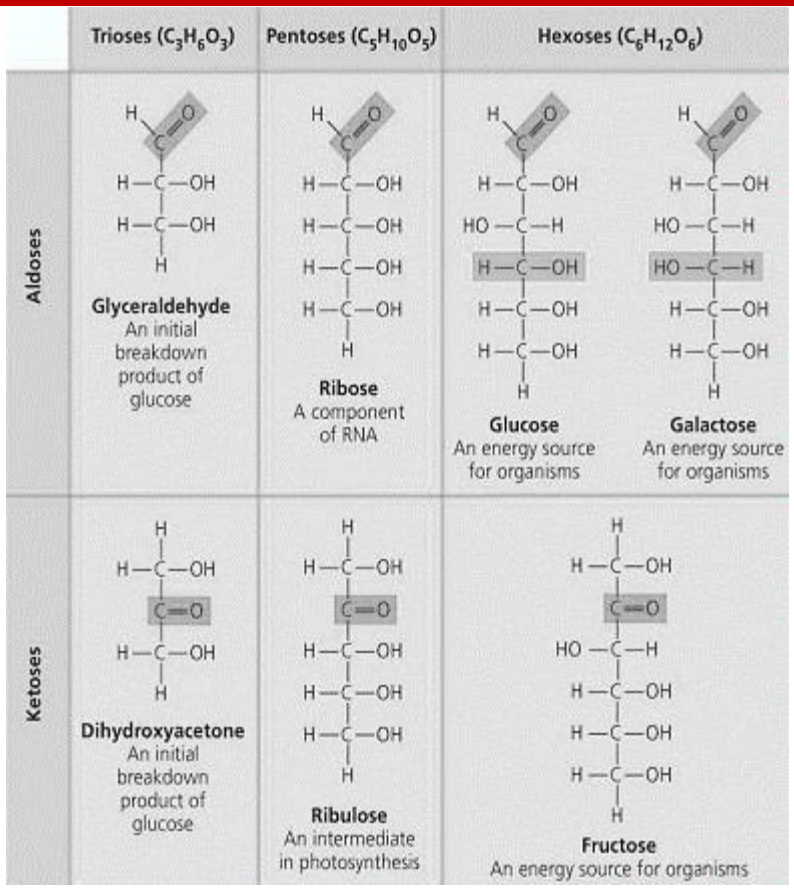
Ringed forms

Glyceraldehyde



Dehydroxyacetone





DISACCHARIDES

Monosaccharides combine together in pairs to form disaccharides. This union involves loss of a water molecule and therefore the reaction is a condensation reaction. The bond formed is a glycosidic bond. The most common disaccharides are:

1. Maltose formed from linkage of two glucose molecules. It is common in most germinating seeds and cereals.
2. Sucrose from union of glucose and fructose. It is the main form in stems of sugar canes and roots of sugar beets which are sources of commercial sugars.
3. Lactose resulting from the union of glucose and galactose and found in milk.

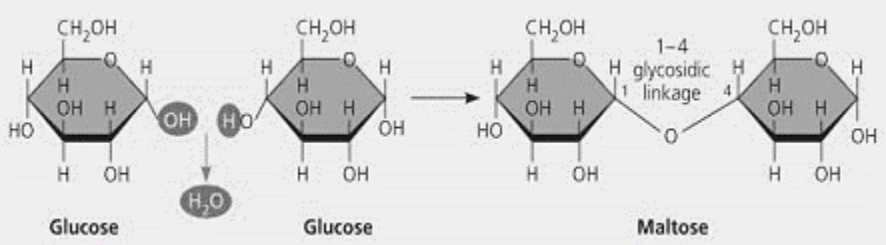
The disaccharides have the following properties:

i) They are sweeter than monosaccharides
ii) They can be crystallized
iii) They are soluble in water
iv) Do not change the colour of Benedict's solution when heated with it (apart from maltose)- they are known as non-reducing sugars
v) Can be broken down into simple sugars by dilute mineral acids and enzymes

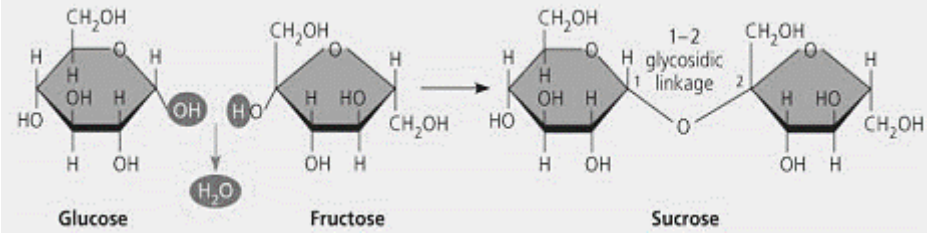
Note: Maltose can also be formed as a product of starch hydrolysis.

Formation of maltose

$C_6H_{12}O + C_6H_{12}O$ -------- $C_{12}H_{22}O + H_2O$



Formation of sucrose



POLYSACCHARIDES

Many monosaccharides may combine by condensation reactions to form polysaccharides. A number of monosaccharides which combine may be variable and the chain can be branched or unbranched.

Properties of polysaccharides include:

- ✓ Are not sweet
- ✓ Do not dissolve in water
- ✓ Cannot be crystallized
- ✓ They have a high molecular mass.
- ✓ They are non-reducing sugars

The chains may be folded to make them compact which are ideal for storage. Such a large size of the molecules makes them insoluble in water and suitable for storage as they exert no osmotic influence and do not easily diffuse out of the cell.

Starch is the main storage material in green plants while glycogen is for animals.

Upon hydrolysis, polysaccharides are broken down into their constituent monosaccharides.

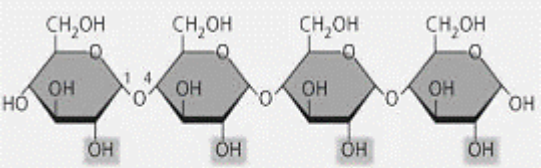
Not all polysaccharides are used for storage e.g. cellulose is a structural polysaccharide giving support and strength to the cell walls.

STARCH

It is found in plant parts in form of granules. It is a reserve food formed from any excess glucose during photosynthesis. It is common in seeds e.g. maize where it is the main food supply during germination.

Structure:

It is a polymer of α-glucose molecules which are held by glycosidic bonds forming chains of α-glucose units which get folded or coiled into a helix.



) **Starch: 1–4 linkage of α glucose monomers.** All monomers are in the same orientation. Compare the positions of the —OH groups highlighted in yellow with those in cellulose (c).

Starch has two components i.e. amylose and amylopectin, that is, 20% amylose, 79% amylopectin and 1% other substances e.g. phosphates and fatty acids.

Amylose stains deep blue with iodine while amylopectin stains red to purple with iodine.

Amylose is structurally unbranched while amylopectin is branched.

Differences between amylose and amylopectin

Amylose	Amylopectin
-Consists of unbranched chains.	-consists of branched chains
-Comprises of only 1,4 glycosidic bonds	-comprises of both 1,4 and 1,6 glycosidic bonds.
-Gives a blue-black colour with iodine solution	-Gives a red-violet colour on addition of iodine solution.
-Has a lower RFM	-larger RFM
-Has less glucose units.	-Has more glucose units.

QUESTION: ***HOW DOES THE STRUCTURE OF STARCH RELATE TO ITS ROLES?***

- ❖ It is a polymer of α-glucose molecules hence a large molecule making it relatively insoluble in water hence an ideal storage molecule.
- ❖ The α-glucose molecules are held by glycosidic bonds which can be broken down to free glucose molecules from the stored starch for ATP synthesis during respiration.
- ❖ The starch molecule is coiled into a helix with a hydroxide group projecting interiorly making it insoluble in water hence exerts no osmotic effects in cells and is ideal for storage.
- ❖ It is insoluble in water implying that it cannot be lost from the storage cells and tissues in solution form.
- ❖ It is insoluble in water hence it does not affect the osmotic properties of the cells.
- ❖ It is highly coiled into a helix making it compact implying that a lot of it can be stored in a limited space.

GLYCOGEN

It is a major polysaccharide storage material in animals. It stored mainly in the liver and muscles. It is also made up of α-glucose molecules and exists as granules. However its chains are shorter (10-20 glucose units) and is more branched. Glycogen is more soluble than starch.

CELLULOSE

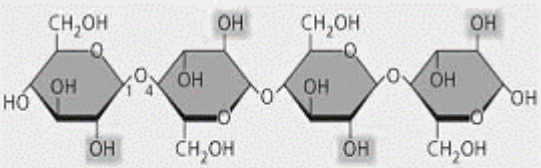
It comprises up to 50% of a plant cell wall and in cotton it makes up to 90%.

It is a polymer of about 10000 β-glucose molecules forming long unbranched chains which are parallel to each other with cross linkages between them which give it its stability and a good structural material.

Structure:

It is a polymer with straight chains of β-glucose units held by glycosidic bonds with the OH group projecting out wards from each chain forming cross linkages of hydrogen bonds with adjacent chains.

The cross linking binds the chains together which associate to form micro fibrils that are arranged in larger bundles to form macro fibrils.



) **Cellulose: 1–4 linkage of β glucose monomers.** In cellulose, every other β glucose monomer is upside down with respect to its neighbors.

Note: starch lacks the structural properties possessed by cellulose because it lacks cross linkages.

The stability of cellulose makes it difficult to digest and therefore not a good source of food to animals except those which have cellulase producing microorganisms which live in them in a symbiotic way e.g. in the rumen of cattle, goats, sheep, etc.

Uses of cellulose

- Rayon produced form cellulose extracted from wood is used in the manufacture of tyre cords.
- Cotton is used in the manufacture of fibres and closes.
- Cellophane used in packaging is produced from cellulose.
- Paper is a product of cellulose.
- Celluloid used in photographic films is also a derivative of cellulose.

Enzymes that digest starch by hydrolyzing its α linkages are unable to hydrolyze the β linkages of cellulose because of the distinctly different shapes of these two molecules. In fact, few organisms possess enzymes that can digest cellulose. Humans do not; the cellulose in our food passes through the digestive tract and is eliminated with the feces. Along the way, the cellulose abrades the wall of the digestive tract and stimulates the lining to secrete mucus, which aids in the smooth passage of food through the tract. Thus, although cellulose is not a nutrient for humans, it is an important part of a healthful diet. Most fresh fruits, vegetables, and whole grains are rich in cellulose. On food packages, "insoluble fiber" refers mainly to cellulose.

Some prokaryotes can digest cellulose, breaking it down into glucose monomers. A cow harbors cellulose-digesting prokaryotes in its rumen, the first compartment in its stomach (Figure 5.9). The prokaryotes hydrolyze the cellulose of hay and grass and convert the glucose to other nutrients that nourish the cow. Similarly, a termite, which is unable to digest cellulose by itself, has prokaryotes living in its gut that can make a meal of wood. Some fungi can also digest cellulose, thereby helping recycle chemical elements within Earth's ecosystems.

QUESTION: ***how does the structure of cellulose relate to its roles?***

i) The cross linking binds the chains together offering much tensile strength.
ii) The micro fibrils in cell walls are arranged in several layers offering protection to the plant cell preventing it from bursting when water enters by osmosis.
iii) The arrangement of micro fibrils in cell walls contributes to turgidity hence offering support.
iv) The parallel layers of cellulose are fully permeable to water and solutes.
v) The arrangement of micro fibrils determines the shape of the cells and hence plant organs since it determines the direction in which cells expand as they grow.
vi) The glycosidic bonds holding the β-glucose units in cellulose can be broken down in presence of enzyme cellulase so that a free glucose molecule can be respired.

Differences between cellulose and starch

Cellulose	Starch
• Consists of a straight chain of beta glucose. • It's a structural polysaccharide in plant cell walls. • Hydroxyl groups project in all directions of the chain. • Consists of unbranched chains. • Neighboring chains form cross linkages. • It is not easily hydrolysed into constituent monosaccharides and disaccharides. • The polysaccharide chains are straight and parallel.	• Consists of long chains of 1-4 linked alpha glucose. • It's a storage polysaccharide. • Hydroxyl groups in the polysaccharide chain project into the interior. • Consists of branched chains in amylopectin. • Does not form linkages between neighboring chains. • It is easily hydrolysed into constituent monosaccharides and disaccharides. • The polysaccharide forms are coiled to form helices.

OTHER POLYSACCHARIDES

1. **Chitin:**
   Chemically and structurally, chitin resembles cellulose but differs in possessing an acetyl group ($NH\text{-}OCH_3$) instead of one of the OH groups. Like cellulose, it has a structural function and is a major component of exoskeleton of insects and crustacea. It is also found in fungal cell walls.
2. **Inulin:**
   It is a polymer of fructose and found as a storage carbohydrate in some plants.
3. **Mucopolysaccharides:**
   These are carbohydrate derivatives derived from a combination of sugar molecules and amino acids in a condensation reaction. This group includes hyaruronic acid which forms part of the matrix of vertebrae connecting tissue.
   Heparin, an anti-coagulant also contains mucopolysaccharides. They contain amino sugars and are found in;
   (i) The basement membrane of epithelium
   (ii) The matrix of connective tissues
   (iii) Synovial fluid in joints of vertebrates
   (iv) Matrix of bone and cartilage.
   (v) vitreous humor of the eye

Reasons why carbohydrates form a variety of polysaccharides

- They form both 1, 4 and 1, 6 glycosidic bonds. This increases the variety of polysaccharides since branching can occur e.g cellulose has only 1, 4 while glycogen and starch have both 1, 4 and 1, 6 glycosidic bonds.
- They use both pentoses and hexoses to form polysaccharides. In some cases one monosaccharide is used while in other cases, two or more different monosaccharides are used in alternating sequences.
- The difference in the level of branching shown by carbohydrate polymers, leads to the formation of different polysaccharides e.g glycogen is more branched than starch.
- The existence of both alpha and beta forms of certain monomers increases the variety of polysaccharides. This causes the difference between starch and cellulose.
- The high chemical reactivity of monomers makes them combine with other groups to form related monomer units. These combine to form different polysaccharides e.g cellulose differs from chitin.
- The existence of both ketoses and aldoses which form both five numbered and 6 numbered rings. This causes the difference in certain polysaccharides e.g insulin is different from starch.

FOOD TESTS ON CARBOHYDRATES

1. **Test for reducing sugars**

The reagent used is Benedict's solution (blue) or Fehling's solution (blue). Boiling is required.

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 1 cm^3 of Benedict's solution and boil.	Colourless or turbid solution turned to a blue solution, then to a green solution, to a yellow precipitate, to orange precipitate and to a brown precipitate on boiling.	Too much; reducing sugars present.
	Colourless or turbid solution turned to a blue solution which persists on boiling.	Reducing sugars absent.

If Fehling's solution is used, the change is from blue solution to orange precipitate if reducing sugars are present. It remains a blue solution if they are absent.

Examples of reducing sugars include:

1) Glucose (present in grapes)
2) Fructose (present in many edible fruits)
3) Galactose and lactose (present in milk)
4) Maltose (present in germinating seeds)

The conclusions based on colour changes are according to the following observations:

Blue ***solution***- no sugars

Green ***solution***- little sugars present

Yellow ***precipitate***- moderate sugars present

Orange ***precipitate***- much sugars present

Brown ***precipitate***- too much reducing sugars present

2. Test for non-reducing sugars

procedure	Observation	conclusion
To 1 cm^3 of food solution add 1 cm^3 of dilute hydrochloric acid and boil, cool under water then add 1 cm^3 of sodium hydroxide solution, followed by 1 cm^3 of Benedict's solution and boil.	Colourless or turbid solution turned to a blue solution, then to a green solution, to a yellow precipitate and to a brown precipitate on boiling.	Little or Moderate or Much or Too much; non-reducing sugars present.
	Colourless or turbid solution turned to a blue solution which persists on boiling.	Non-reducing sugars absent.

Note:

i) When boiled with dilute HCl, the non- reducing sugars breaks down into the reducing sugars.
ii) Sodium hydroxide solution or sodium hydrogen carbonate powder is added to neutralize the acid so that Benedict's solution can work.

An example of non-reducing sugars is Sucrose (present in sugar cane)

3. Test for starch:

The reagent used is iodine which is a brown or yellow solution).

Procedure	Observation	Conclusion
To 1 cm^3 of food solution, add 3 drops of iodine solution.	Colourless or turbid solution turned to a black or blue-black or blue solution or brown solution with black specks.	Much or moderate or little starch present.
	Colourless or turbid solution turned to a yellow or brown solution.	Starch absent.

LIPIDS

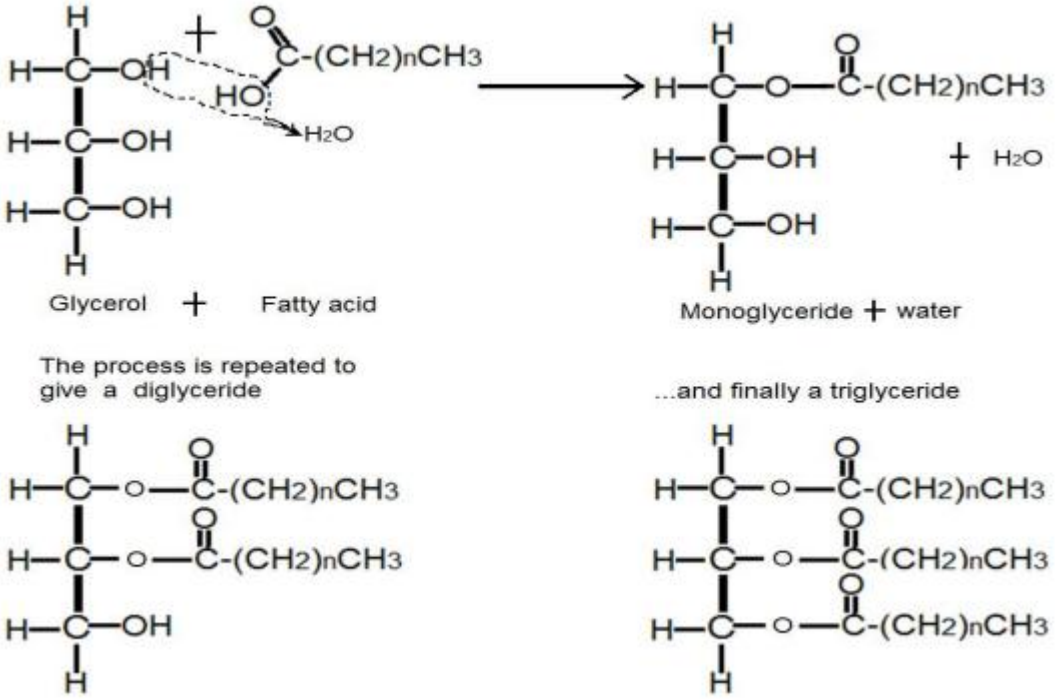
These are large group of organic compounds. Like carbohydrates, they contain carbon, hydrogen and oxygen but the proportion of oxygen is smaller than in carbohydrates hence they are more reduced than the carbohydrates.
Lipids are insoluble in water.
They are of two types i.e. fats and oils. Fats are solid at room temperature while oils are liquids at room temperature.

Properties of lipids

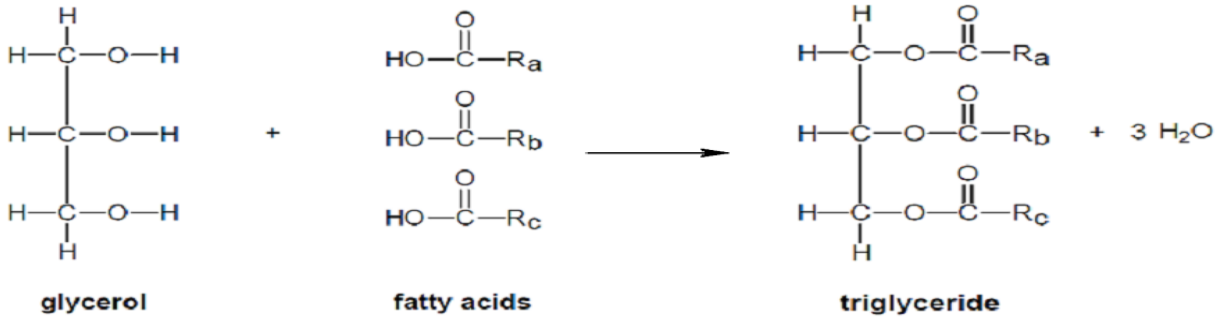
- They are insoluble in water but soluble in non-polar solvents like benzene, chloroform, diethyl ether, etc. The low solubility is due to the low oxygen content which results into a small number of polar hydroxyl groups in lipids hence very few hydrogen bonds.
- They have a high proportion of hydrogen in their molecules.
- They are non-polar compounds.
- They are less dense than water.
- They can be solids or liquids at room temperature.
- Their melting point increases with increase in saturation.
- They undergo high oxidation in respiration to yield large amounts of energy.
- They are poor conductors of heat.

Formation of triglycerides

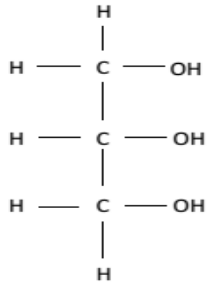
Lipids are made of fatty acids and glycerol. Glycerol has 3 OH groups and each combines with a separate fatty acid to form a lipid chemically known as a triglyceride. This is a condensation reaction that leads to liberation of 3 water molecules.
Metabolic water is formed and an ester bond is formed between the glycerol and fatty acid. Since the glycerol possesses 3 hydroxyl groups to which 3 fatty acids attach themselves, 3 water molecules are formed. In this reaction, the fatty acids may all be the same or different, saturated or unsaturated.



For example



Question: ***using the structural formula:***



For glycerol, and molecular formula $CH_3(CH_2)_nCOOH$ for a fatty acid, show the formation of a triglyceride from fatty acids and glycerol.

FATTY ACIDS

All occurring lipids have glycerol and therefore it is the nature of the fatty acids which determines the characteristics of any particular lipid. All fatty acids have a carboxyl group (COOH), the reminder of the molecule being a hydro carbon chain of varying length.

These chains may possess one or more double bond in which case it is said to be unsaturated. If it possesses no double bonds, it is said to be saturated.

Nature of fatty acid	General formula	Saturated/unsaturated	Occurrence
1. Butyric acid	C_3H_7COOH	Saturated	Butter fat
2. Linoleic acid	$C_{17}H_{31}COOH$	Unsaturated	Seed oil
3. Oleic acid	$C_{17}H_{33}COOH$	Unsaturated	All fats
4. Palmitic acid	$C_{15}H_{31}COOH$	Saturated	Animal & veg fat
5. Selotic acid	$C_{25}H_{51}COOH$	Saturated	Wood oil
6. Arachidic acid	$C_{19}H_{39}COOH$	Saturated	P.nut oil

From the table, it is seen that the hydrocarbon chains may be very long forming long tails which extend from the glycerol molecules. These trails are hydrophobic (water repelling) which makes the lipids insoluble in water.

Saturated and unsaturated fatty acids

In saturated fatty acids all the available bonds in carbon atoms are used and there are a maximum possible number of hydrogen atoms. Saturated fatty acids lack double bonds in the hydrocarbon tail.

Unsaturated fatty acids do not contain the maximum number of hydrogen atoms, they have one or more double bonds between some of the carbon atoms in the hydrocarbon chain.

Saturated fatty acids have high melting points and are therefore found in fats while in unsaturated fatty acids, the presence of the double bonds lowers the melting point and are therefore found in oils.

Since there are many types of fatty acids but one type of glycerol, lipids (fats and oils) vary due to the fatty acids.

Essential fatty acids

These are fatty acids which cannot be synthesized by the body and must be supplied in the diet.

Common sources of essential fatty acids are; vegetables and seed oils. A deficiency of these fatty acids results in retarded growth, reproductive disorders and kidney failure.

Non-essential fatty acids

These are fatty acids that can be synthesized by the body from metabolism of other compounds like proteins and carbohydrates.

How cholesterol causes arthesclerosis

Cholesterol is produced by the liver and is used as the starting point for the synthesis of other steroid molecules. The major source of cholesterol is diet and many dairy products are rich in cholesterol or fatty acids from which cholesterol can be synthesized. Thyroxin stimulates cholesterol production in the liver and also increases the rate of excretion of bile. Excessive amounts of cholesterol in blood can be harmful. It can be deposited in walls of arteries leading to arthesclerosis and increased risk of formation of a blood clot which may block blood vessels, a condition known as thrombosis. This is often fatal if it occurs in the coronary artery in the wall of the heart (coronary thrombosis or heart attack) or brain (cerebral thrombosis). Although cholesterol is harmful in excess, it is essential to have some in the diet for reasons stated.

Question: ***explain why lipids are insoluble in water?***

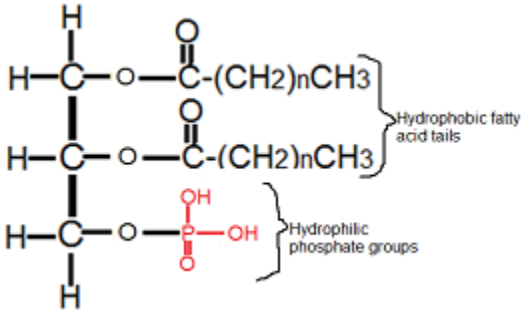
LIPID DERIVATIVES

1. **Waxes;** these are composed of one fatty acid and a long chained alcohol other than glycerol. They are used as water proof substances by plants and animals. In plants they occur in the cuticle of the leaves, meristems, fruits and seeds of some plants. In animals they are a constituent of the exoskeleton of insects, arthropods. They also form the combs of bees.
2. **Glycolipids;** these are a combination of a carbohydrate and a liquid. They are found in the cell membrane where they have a structural function and they are important in transportation of materials across the cell membrane.
3. **Phospholipids;** these are lipids containing a phosphate group. In the formation of a phospholipid, a phosphate group is added to the third carbon atom in the position of the hydroxyl group. The other two hydroxyl groups of the glycerol react with fatty acids.

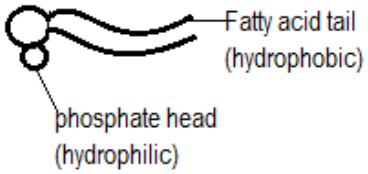
   A phospholipid therefore has a phosphate group and two fatty acid chains. The phosphate group carries an electric charge and hence contributes to the polarity of the phospholipid molecule. The phosphate group forms the polar end i.e water soluble hydrophilic head while the fatty acid hydrocarbon chains form the nonpolar water-insoluble hydrophobic end of the phospholipid molecule.

   Phospholipids are able to dissolve in both water and non-polar solvents. This property is important in determining the structure and function of the plasma membrane.

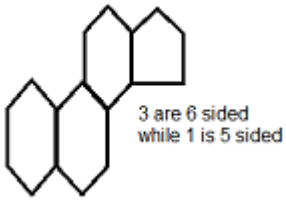
Structure of the phospholipid



A phospholipid can be simply represented as



4. **Steroids;** these are biologically important substances in both plants and animals. The skeleton of a steroid molecule consists of four complex rings of carbon atoms. Three of these are six sided while one is 5 sided.
   The various steroids differ in the side groups attached to the carbon atoms of the skeleton. Like lipids, they contain hydrogen atoms and oxygen atoms but do not contain any fatty acid. They have a general skeleton shown below



Examples of steroids include;

Cholesterol which is a component of the plasma membrane and a raw material for many other steroids like bile acids.
Bile acids e.g glycolic acid and taurochloric acid used in the emulsification of fats during digestion.
Vitamin D (calciferol) which promotes phosphorous and calcium absorption and metabolism.
Sex hormones e.g testosterone and oestrogen.
Hormones from adrenal cortex i.e are referred to as corticosteroids.

FUNCTIONS OF LIPIDS

Structural:

i) They are components of the plasma/cell membrane.
ii) They form subcutaneous fat in the dermis of the skin hence insulating the body since they are poor conductors of heat.
iii) They are components of the waxy cuticle in plants and insects there by preventing water loss (desiccation).
iv) They form a component of the myelin sheath of nerves hence playing a role in the transmission of impulses.
v) They protect delicate organs e.g. the heart and kidney from injury.
vi) They coat on fur of animals enabling it to repel water which would otherwise wet the organism.
vii) They are component of adipose tissue.

Physiological:

i) They provide energy through oxidation.
ii) They are solvents for fat soluble vitamins (ADEK).
iii) They are a good source of metabolic water to desert animals, young birds and reptiles while still in their shells.
iv) They are a constituent of the brown adipose tissue which provides heat for temperature regulation (thermogenesis).

Other functions:

i) Some lipids provide a scent in plants which attracts insects for pollination.
ii) Wax is used by bees to construct honey combs.
iii) Wax from bees is used in the manufacture of candles.

QUESTION: *WHAT PROPERTIES DO LIPIDS POSSES AS STORAGE COMPOUNDS?*

i) They are compact taking up little space.

ii) They are insoluble in water hence cannot be lost in solution.
iii) They are light to keep the weight to a minimum and allow buoyancy.
iv) They have a high calorific energy value.
v) They have a high hydrogen-oxygen content hence can yield a lot of water on oxidation.

TESTS FOR LIPIDS

They are tested for using the emulsion test or the grease spot (translucent spot) test.

a) Sudan III test:

Procedure	Observation	Deduction
To 1 cc of food solution, add 1 cc of Sudan III and shake.	A turbid solution turns a red emulsion.	Lipids present.
	Turbid or colourless solution remains a turbid or colourless solution.	Lipids absent.

b) The emulsion test:

The reagents used are ethanol and water.

Procedure	Observation	Deduction
To 1 cc of food solution, add 1 cc of ethanol and shake. Then add 5 drops of water and shake.	A turbid solution turns to a cream emulsion	Lipids present.
	Turbid or colourless solution remains a turbid or colourless solution.	Lipids absent.

c) Translucent spot test:

Procedure	Observation	Conclusion
Add 2 drops of test solution on a piece of filter paper.	A translucent spot or patch is left on the paper.	Lipids present
Allow to dry and observe under light.	No translucent spot is formed on the paper.	Lipids absent.

PROTEINS

These are organic compounds of large molecular mass and insoluble in water. In addition to C, H and O, they always contain N, usually S and sometimes P.

Whereas there are few carbohydrates and fats, the number of proteins is limitless e.g. a single bacterium may have around 800 types of proteins while man has 10,000 types. This is because there are several amino acids which may join in different patterns hence forming the various types of proteins.

Proteins are specific to each species hence determine the character of the species.

Proteins are not stored in the organism except in eggs and seeds where they are used to form new tissues.

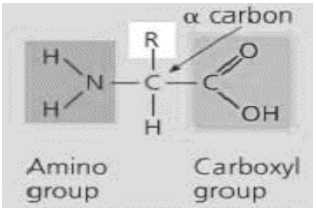
Proteins form the structural basis of all living cells.

Their building blocks are the amino acids.

AMINO ACIDS

These are groups of many chemicals of which around 20 occur in proteins. They contain an amino group (NH_2) and a carboxyl group (COOH). Most amino acids have one of each and are therefore neutral but a few have more amino groups than carboxyl making them alkaline or may have more carboxyl than amino groups making them acidic.

Structure of amino acids

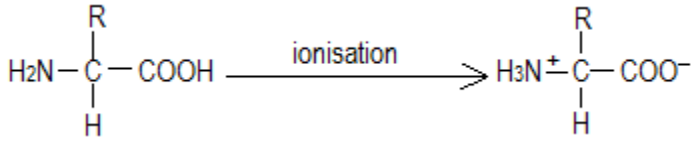


Where R is a variable

Amino acids are soluble in water and ionize to form ions.

The carboxyl end of the amino acid is acidic in nature. It will ionize in water to give H^+. This will make the COOH group negatively charged.

The amino end (NH_2) is basic in nature. It attracts the H^+ in solution making it positively charged. The ion is now dipolar i.e. having a negative and a positive pole. Such ions are called zwitter ions i.e. the negative and positive charges exactly balance and the amino acid ion has no overall charge i.e.



Zwitter ion (no overall charge)

Therefore in acidic solutions, an amino acid acts like a base and in alkaline solutions, it acts as an acid. In neutral conditions found in the cytoplasm of most living organisms, the amino acid acts as both.

Amino acids therefore show both acidic and basic properties i.e. they are amphoteric.

The overall charge of the amino acid depends on the pH of the solution.

At some characteristic pH, the amino acid has no overall electric charge i.e. it exists as a zwitter ion. This pH is called the isoelectric point of an amino acid.

If the pH falls below the iso-electric point i.e. the solution becomes more acidic, H^+ are taken up by the carboxyl ion. This reduces the concentration of the H^+ in solution making the solution less acidic and the amino acid gains an overall positive charge.

If the pH rises above the iso-electric point i.e. it becomes less acidic or more alkaline, hydrogen ions are lost by the amino group. This increases the concentration of free H^+ in the solution making it more acidic and the amino acid gains an overall negative charge. Therefore being amphoteric, amino acids are buffers.

NOTE: a buffer solution is one which resists the tendency to alter its pH even when small amounts of acid or base are added to it.

Questions: ***how do amino acids act as buffer solutions?***

Amino acids make the proteins serve as buffers. The amphoteric nature of amino acids is useful biologically as it means that they serve as buffers in solution resisting changes in PH. The buffer action depends on concentration of hydrogen ions. When an acid is i.e more hydrogen ions(H+), the hydrogen ions(H+) are accepted by the amino acids making them positively charged hence reducing the H+ concentration of the solution. When a base is added, or a decrease in H+ concentration of the solution, the amino acid releases H+ to the solution.

Types of amino acids	
1. Essential Amino acids These are amino acids that cannot be synthesized by the body and therefore got from the diet that the organism feeds on. They include: • Histidine • Isoleucine • Leucine	**2. Non-Essential amino acids** These are amino acids that are synthesized by the body through a process called transamination. They include: • Tyrosine • Alanine • Glycine • Serine

• Proline • Phenylalanine • Valine • Arginine • lysine • Methionine • Tryptophan	• Theonine • Cystine • Cystein • Aspartic acid • Glutamic acid • Asparagine
Proteins can be classified into: **first class proteins** which contain all the essential amino acids e.g. from beans and **second class proteins** which are deficient of one or more essential amino acid.	

Formation of polypeptides

They are formed as a result of condensation reaction between the amino group of one amino acid and the carboxyl group of another amino acid to form a dipeptide.

Further combinations of this type extend the length of the chain to form a polypeptide which usually contains many amino acids.

The shape of the polypeptide molecule is due to four types of bonding which occur between the various amino acids in the chain. These bonds include:

Formation of cross linkages in polypeptide chain(s)

The polypeptide chains in a protein are joined together by bonds of different types. The bonds are formed between the amino acids in the chains due to their different properties i.e acidic, basic, hydrophobic, etc. these bonds include;

Ionic bonds:

These are formed between basic and acidic groups of some amino acids forming a strong interaction. These bonds are formed between acidic amino acids and basic amino acids e.g between aspartic acid and lysine.

Disulphide bonds:

These occur between amino acids that have sulphur. These amino acids contain the sulphurdyl group (-SH) in their R groups. If two molecules of cystein line up alongside each other, the neighboring sulphurdyl groups are oxidized to form a disulphide bond.

Disulphide bonds may be formed between different chains of amino acids or between different parts of the same polypeptide chain. These are the strongest bonds and are not easily broken.

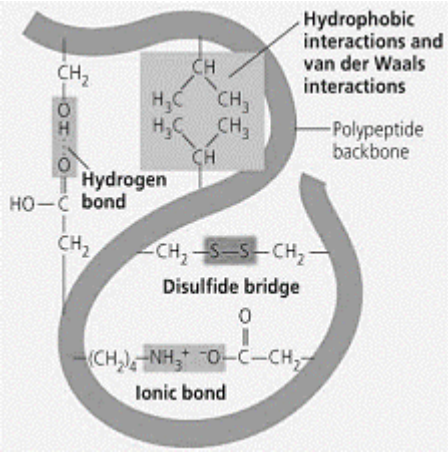
Hydrogen bonds:

These are weak bonds formed between hydrogen atom in one amino acid and a highly electronegative element in another amino acid. Though they are weak, their occurrence is frequent and their total effect makes a considerable contribution to the stability of the protein molecule.

Hydrophobic bonds/interactions:

These are as a result of non-polar R groups of amino acids in polypeptide chains. They are weak forces of attraction and point inward to the protein. If a polypeptide chain has hydrophobic groups and is in an aqueous environment, the chain folds because of the attraction between the hydrophobic groups. The hydrophobic groups come into close contact and exude water, hence pointing inwards. On the other hand, the hydrophilic groups point outwards.

The polypeptide chain showing 3 types of bonding



Protein structures

There are 3 main protein structures i.e. primary structure, secondary structure and tertiary structure.

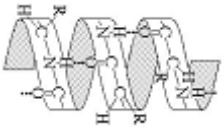
1. Primary structure:

It is a sequence of amino acids in a polypeptide chain. It is made up of 2 polypeptide chains held together by di-sulphide bridges. The sequences of amino acids of a protein dictate its biological functions. Examples of primary structures are insulin and lysosomes.

2. Secondary structure:

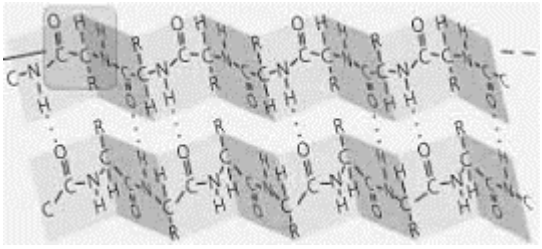
This involves folding or twisting of the polypeptide chains into a spiral shape or beta-pleated shape. It is maintained by many ionic bonds which are formed between neighbouring COO^- and NH_3^+ groups.

(i) **Spiral shape**; proteins in this shape take the form of an alpha helix. They are hard but stretchable. The helical structure is maintained by hydrogen bonds. Examples of such proteins include; keratin, collagen, etc. keratin is found in hair, beaks, nails, feathers, claws, horns, etc.



(i) Beta pleated sheets:

These result from the folding of two or more adjacently joined parallel polypeptide chains which are stabilized by hydrogen bonds. They then get arranged into sheets. Proteins with this structure are very stable and rigid (unstretchable) e.g fibroin protein found in silk. Beta pleated sheets have a flat zig zag structure. They commonly occur in insoluble structural proteins but also in parts of some soluble proteins.



Tertiary structures

The polypeptide chain coils extensively forming a compact globular shape. This structure is maintained by interaction of the four types of bonds i.e. ionic, hydrogen, di sulphide bonds and hydrophobic interactions.

The hydrophobic interactions are quantitatively the most important and occur when a protein folds to shield the hydrophobic side groups from the aqueous surrounding and at the same time exposing hydrophobic side chains.

Quaternary structure

It is a combination of several polypeptide chains clumped together and associate with non-protein parts to form complex proteins e.g. in haemoglobin.

Types of proteins

1. **Fibrous proteins (**plays structural roles**)**

These form long chains which may run parallel to one another being linked by cross bridges. They are very stable molecules and have structural roles within the organism e.g. collagen in made of such proteins.

It has a primary structure which is a repeat of tri peptide sequence (glycine, proline and alanine) and forms a long unbranched chain.

2. **Globular proteins (**plays metabolic roles**)**

They have a highly irregular sequence of amino acids in their polypeptide chains. Their shape is compact and globular. All enzymes are globular proteins. Others include hormones and haemoglobin.

3. **Conjugated proteins**

These are proteins which incorporate other chemicals within their structure. The non-protein part is the prosthetic group and plays a virtual role in the functioning of the proteins e.g.

Name of protein	Where it is found	Prosthetic group
Haemoglobin	Blood	Haem (iron)
Mucin	Saliva	Carbohydrate
Casein	Milk	Phosphoric acid
Cytochrome oxidase	Electron carrier path way	Copper
Nucleoplasm	Ribosomes	Nucleic acid

QUESTION: ***HOW DOES THE MOLECULAR STRUCTURE OF PROTEINS RELATE TO THEIR ROLES?***

i) Some proteins have a structural function, these are fibrous proteins with a secondary structure insoluble in water and physically tough e.g. collagen in connective tissues, bone, tendons and cartilage. Other structural proteins include keratin in feathers, nails, hair, horns, beaks and skin.

ii) Some proteins function as enzymes. These have a globular structure and are soluble in water e.g. digestive enzymes like pepsin, respiratory and photosynthetic enzymes.

iii) Some proteins function as hormones regulating metabolic processes. These are globular and soluble in water e.g. insulin which regulates metabolic activity.

iv) Some proteins functions as respiratory pigment. These are globular proteins with a quaternary structure that increases their surface area for transport or storage of respiratory gases e.g. haemoglobin which transports oxygen in blood and myoglobin that stores oxygen in muscles.

v) Some proteins are involved in transport and are globular with primary or tertiary structures e.g. serum albumen that transports fatty acids and lipids in blood.

vi) Some proteins are involved in immunological responses hence protecting the body. These are globular e.g. antibodies, fibrinogen and thrombin.

vii) Some proteins are contractile e.g. they are fibrous with a secondary structure e.g. myosin and actin filaments in muscles.

viii) Storage proteins are toxins and soluble and water with a globular structure e.g. snake venom, bacteria toxins, etc.

ix) Some proteins are insoluble in water e.g. ovalbumin that occurs in egg white, casein in milk, etc.

x) Globular proteins form colloidal suspensions that hold molecules in position within cells e.g. proteins in the cytoplasm of most cells where they are soluble in water and have a large surface area.

xi) Globular proteins in blood are buffers since they are soluble in water.

Differences between globular and fibrous proteins

Globular	Fibrous
• Soluble in water • Easily denatured by very high temperature • Functional in nature • Tertiary proteins • Non identical polypeptide chain length • Consist of compact and spherical molecules.	• Insoluble in water • Not easily denatured by high temperature • Structural in nature • Secondary proteins • Identical polypeptide chain length • Consist of long fibrous molecules.

Denaturation of proteins

The dimensional structure of the protein is due to weak ionic and hydrogen bonds. Any agent which breaks these bonds causes the three dimensional shape to be changed to a more fibrous form. This process is known as denaturation.

In case the actual sequence of the amino acid is not altered but only the overall shape of the molecule is changed.

Factors causing protein denaturation

Factor	Explanation	Example
1. Heat	Causes the atoms of the protein to vibrate more thus breaking the hydrogen and ionic bond.	Coagulation of albumen (egg white becomes more fibrous).
2. pH	When the pH is adjusted to the normal isoelectric point for protein, its net charge will be zero (zwitterion). If the pH is lowered far below the isoelectric point, the protein will lose its negative charge and contain only positive charges. The like charges will repel each other and prevent the protein from aggregating as readily, preventing formation of amine bonds.	
3. Acids	Addition of hydrogen ions in acids combine with COO^- of amino acids and form COOH ionic bonds are hence broken.	Souring of milk by acid and lowering pH of casein making it insoluble.
4. Alkalis	Reduced number of H^+ cause NH^+ group to loose H^+ to form NH_2 therefore ionic bonds broken.	Souring of milk by alkalis.
5. Inorganic chemicals	Ions of heavy metals e.g. mercury and silver combine with COO^- groups destructing the ionic bonds.	Enzymes are inhibited by being destructed in presence of ions e.g. cytochrome oxidase.
6. Organic chemicals	Organic solvents alter hydrogen bonding with a protein.	Alcohol denatures certain bacterial proteins. This is what makes it useful for sterilization.
7. Mechanical force	Physical movement can break hydrogen bonds.	On stretching a hair, the hydrogen bonds in the keratin helix is extended and hair stretches.

Functions of proteins

VITAL ACTIVITY	PROTEIN EXAMPLE	FUNCTION
1. Nutrition	• Digestive enzymes e.g. trypsin, amylase, etc. • Fibrous proteins in grana lamellae • casein	• catalyses, hydrolysis of proteins to peptides. • Helps to arrange chlorophyll molecules to receive unlimited light. • Assists in transporting of food in filter feeder. • Storage of proteins in milk.
2. Respiration and transport.	• Haemoglobin. • Myoglobin • Prothrombin/fibrinogen • Antibodies.	• Transport of oxygen. • Stores oxygen in muscles. • Required for blood clotting. • Essential for defense.
3. Growth	Hormones e.g. thyroxine	Controls growth and metabolism.
4. Excretion	Enzymes e.g. urease	Catalyzes reaction in ornithine cycle and helps in protein break down and urea formation
5. Support and movement	Actin/myosin	Makes it easy for muscle contraction.
	Collagen	Gives strength with flexibility in tendons and cartilage.
	Keratin	Tough for protection e.g. in scales, claws, nails, hooves, etc.
	Sceleratin	Provide strength in insect exo-skeleton
6. Sensitivity and co-ordination.	Hormones e.g. insulin	Control of blood sugars
	Vasopressin	Control of blood pressure
	Rhodopsin	Visual pigments in retina.
8. Reproduction	Hormones e.g. prolactin	Induces milk production in mammals.
	Chromatin	Gives structural support to chromosomes.
	Chitin	Storage of proteins in seeds which nourishes the embryo.
	Keratin	Forms horns and anthers which are used for sexual display.

ENZYMES

Enzymes are biochemical catalysts made up of globular proteins. An enzyme is always associated with a non-protein component known as co-factor which is tightly bonded to the enzyme.

Enzymes are organic compounds protein in nature that speed up the rate of biochemical reactions in the body of an organism and remains unchanged at the end of the reaction.

Importance of enzymes

The rate at which some reactions occur in the body without enzymes is too slow to sustain life. Enzymes therefore ***speed up the rate of the reaction without changing the product formed and the nature of reaction*** i.e. an enzyme cannot make a reaction that would not occur to take place and it cannot make an endothermic reaction exothermic but only ensures that products are formed in the shortest time possible.

They also control metabolic processes hence promoting normal body functions.

Mechanism of enzyme action

Each enzyme has a unique surface structure which provides a precise position known as active site, at which the substrate can join the enzyme molecules to form an enzyme substrate complex.

This infinite contact is maintained until the reaction is complete. The precise and specific fit between enzyme and substrate is sometimes compared with the lock and key mechanisms. There are two theories put forward to describe the mechanism of enzyme action i.e.

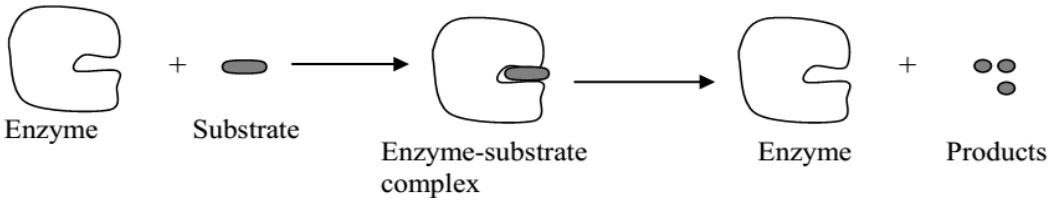
(i) Lock and key hypothesis
(ii) Induced fit hypothesis

The lock and key mechanism

The widely accepted mechanism by which enzymes are known to work is the "**key and lock" theory**.

The theory suggests that the enzyme has a specific region known as the active site where the substrate fits like a key fits in a lock. The substrate must have a complementary shape to the active site of the enzyme. In this theory the key is analogous to the substrate and the lock to the enzyme. When the substrate combines with the enzyme, an enzyme- substrate complex is formed. This breaks down to release the products and the enzyme, which can pick other substrates.

Illustration



Advantages of the lock and key hypothesis

1. It explains why enzymes are specific in action i.e. only substrates with complementary shapes to the active site fit into the active sites and are converted to products.
2. It explains why the rate of enzyme controlled reaction is affected by substrate concentration. If all the active sites are in use, no more substrates a can fit or occupy the active site hence the rate is constant.
3. It explains why and enzymes can be inhibited.
4. It explains why enzymes are able to lower the activation energy in a chemical reaction.

The induced fit theory

The bonds between the amino acids of the active site of the enzyme are relatively flexible. When the substrate combines with an enzyme, the active site may mould into the shape of the substrate.

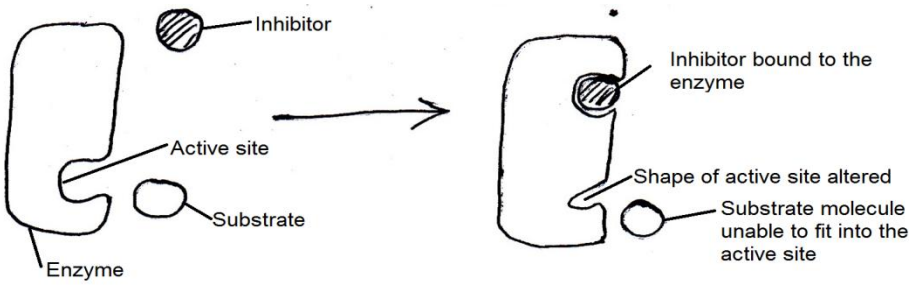
The theory says that when the substrate molecule enters the active site, it causes the enzyme to change its shape so that the two molecules fit together more tightly. The induced fit hypothesis is believed to make the substrate molecules more active because as the active site changes shape, it presses on the substrate molecule exposing the weak bonds.

Enzyme inhibitors

Enzymes may be inactivated by substrates called inhibitors which interfere with catalytic processes. This effect may be produced in several ways.

1. Active sites at the enzyme may be blocked by the formation of the enzyme inhibitor complex. This is known as ***competitive inhibition*** and occurs when inhibitor molecule is structurally similar to the usual substrate of the enzyme. The reaction can be reversed if the substrate concentration is increased.
2. The inhibitor may react irreversibly with the enzyme to form an inactive non-enzymatic end product. A small concentration of heavy metal ions combine permanently with the enzyme and completely inhibit it.
3. The inhibitor may alter the shape of the enzyme at its point of activity so that the enzyme substrate complexes cannot form. This is known as **non-competitive enzyme inhibition**. These attach themselves not to the active site of the enzyme but elsewhere on the enzyme molecule. These cause breakage of some bonds in the enzyme molecule leading to alteration of the 3 dimensional structure and hence the shape of the enzyme molecule.

Change in the shape of the enzyme molecule leads to change of the shape of the active site. Therefore the substrate can no longer fit in the active site.



An increase in the substrate concentration does not change the rate of reaction. This is because the inhibitor alters/changes the shape of the enzyme and that of the active site permanently whenever it comes into contact with the enzyme hence it leaves the active site non complementary.

Non competitive inhibitors are mostly non reversible inhibitors. Non competitive inhibitors include; heavy metals (mercury, lead, silver, etc), cyanide, nerve gas, insecticides, herbicides, etc.

Importance of inhibitors

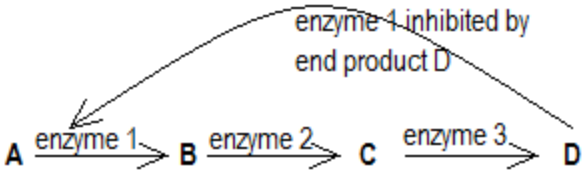
(i) They can be used in medicine and agriculture

(ii) They control metabolic pathways by regulating the different stages in them

(iii) They provide important information about the shapes and properties of enzymes.

4. End product inhibition

This takes place in some metabolic pathways when the end product combines with the first enzyme controlling the first step of the pathway for its production so that further formation of the end product is slowed or stopped. This is an example of negative feedback which is important in regulation of body processes. The end product acts as an allosteric inhibitor.



Allosteric enzymes

These are enzymes that occur in two forms, i.e. active and inactive.

The inactive form is shaped in such a way that the substrate will not fit into its active sites. Therefore for such enzymes to work, it must be transformed into the active form.

Allosteric enzymes can be inhibited by molecules which do not combine with the active site but with the other parts of the enzyme. In this case, the inhibitor prevents the enzymes from changing into the active form, and substrates which bring about this are known as allosteric inhibitors.

Co-factors

Co-factors are non-protein components required by enzymes for their efficient functioning.

In some instances an enzyme must be associated with smaller molecule in order to function properly. There are three types of co-factors:

i) **Inorganic ions**; e.g salivary amylase activity is increased by the presence of chloride ions.

ii) **Prosthetic groups**; these are non-protein organic molecules tightly bound to the active site e.g. FAD, haem, etc.

iii) **Coenzymes;** non-protein organic groups loosely associated with the enzyme, NAD and ATP.

Prosthetic groups and coenzymes act as carriers of groups of atoms.

Classification of enzymes

Each enzyme is given two names; a synthetic name based on the six classification groups. The trivial names are derived by the following;

(i) Start with the name of the substrate on which the enzyme acts e.g. Succinate.
(ii) Add the name of the type of reaction which is catalysed e.g. dehydrogenation.
(iii) Convert the end of the last word to an …"ase" suffix e.g. Succinate Dehydrogenase.

Enzyme group	Type of reaction catalysed	Examples of enzymes
1. Oxidoreductases	Oxidation and reduction reaction	Dehydrogenase and oxidase
2. Transferases	Transfer of chemical groups	Transaminase and phosphorylase
3. Hydrolases	Hydrolysis reactions	Maltase, amylases, lipase, peptidase
4. Lyases	Addition or removal of a chemical group by hydrolysis	decarboxylase
5. Isomerases	Arrangement of groups within the molecule	Isomerases, mutases
6. Ligases	Formation of bonds between two molecules using energy derived from the breakdown of ATP	synthetases

Enzymes are classified depending on the type of reaction they catalyze. The following are some of the classes of enzymes.

1) **Isomerase;** these catalyze reactions involving isomerism
2) **Phosphorylases**; these catalyze reactions involving addition of a phosphate
3) **Hydrogenases;** these catalyze reactions involving addition of hydrogen.
4) **Dehydrogenase;** these catalyze reactions involving removal of hydrogen.
5) **Kinases;** these catalyze reactions involving movement of molecules from one area to another.
6) **Carboxylases;** these catalyze reactions involving addition of Carbon dioxide.

Nomenclature of enzymes

Enzymes are named by adding a suffix "ase" to their substrates. A substrate is a substance, which the enzyme acts upon, or simply it is the raw material for the enzyme.

Examples of enzymes and their substrates

Enzyme	Substrate
Peptidase	Peptides
Lipase	Lipids
Maltase	Maltose
Sucrase	Sucrose
Lactase	Lactose
Cellulase	Cellulose

Some enzymes however retained their names they had before this convention. Such enzymes include pepsin and trypsin.

Sometimes the enzymes digesting carbohydrates are generally called carbohydrases and those digesting proteins as proteases.

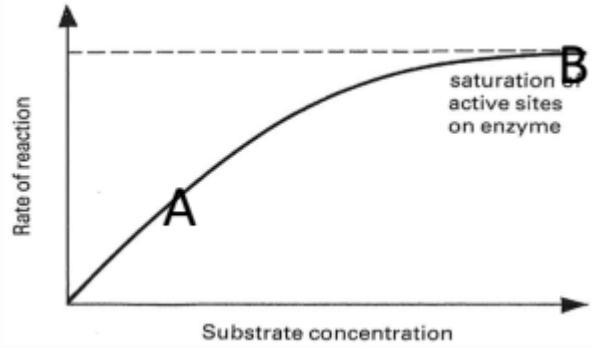
PROPERTIES OF ENZYMES

1) They are all protein in nature.
2) They are specific in their action i.e. they catalyze specific food i.e. Maltase on Maltose.
3) They speed up the rate of chemical reactions (they are catalysts).
4) They are effective even in small amounts.
5) They remain unchanged at the end of the reaction.
6) They are denatured by high temperatures since they are protein in nature and are inactivated by low temperatures.
7) They are inactivated by inhibitor chemicals (poisons e.g. cyanide).
8) They work at a specific PH. (either acidic or alkaline).
9) Their reactions are reversible.
10) Their activity can be enhanced by enzyme activators e.g. chloride ions activate amylase.

FACTORS AFFECTING THE RATE OF ENZYME CONTROLLED REACTIONS

1. Substrate concentration;

The rate of enzyme controlled reaction increases with increase in substrate concentration until all the active sites of the enzyme are occupied by the substrate molecule. At this point the rate of reaction can only be increased by increasing the enzyme concentration.



A: The rate of reaction increases with enzyme concentration because there are free active sites into which more substrates fit increasing the rate of product formation

B: The rate of reaction is constant because all the enzyme active sites are occupied by substrates. Any more substrate molecules added will have no active sites to be occupied hence constant rate of reaction. The limiting factor at this point is the low enzyme concentration.

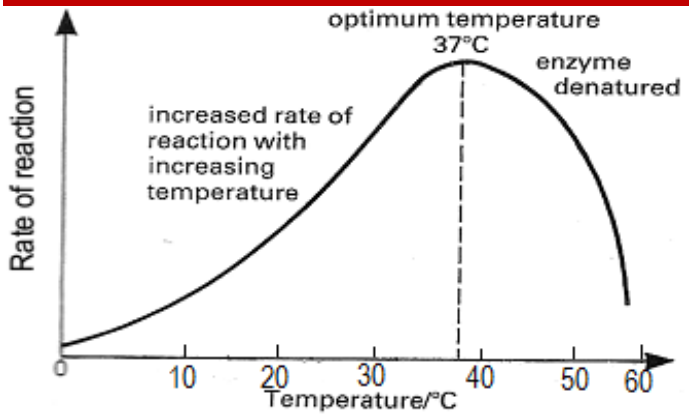
2. Temperature;

Within the physiological range (4^0c-40^0c) the rate of the enzyme controlled reaction increases with increase in temperature. This is because temperature increases the kinetic energy of reacting molecules leading to more collisions between the enzyme and substrate molecules.

Beyond 40^0c, the rate of the reaction decreases with increase in temperature due to Denaturation of the enzyme molecules.

Very high temperatures lead to breakage of some bonds that maintain the enzyme structure. As a result, the 3 dimensional structure of the enzyme is altered leading to a change in the shape of the active site.

The shape of the active site at this point can no longer fit in it hence no enzyme reaction.



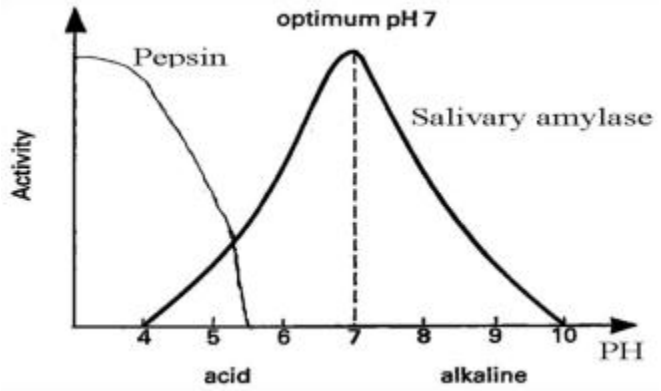
3. Enzyme concentration;

Provided there is an excess of substrate molecules, the rate of an enzyme controlled reaction increases with increase in enzyme concentration. This is because the number of active sites increases which leads to increase in number of substrate molecules that fit into and occupy the active sites hence increase in the rate of product formation.

4. PH of the medium;

All enzymes work efficiently within a particular PH range. However there is an optimum PH for each enzyme. Any deviation from the optimum PH results in Denaturation of the enzyme hence decrease in the rate of reaction.

Enzyme	Optimum PH
Pepsin	2.00
Sucrase	4.50
Enterokinase	5.59
Salivary amylase	4.80
Catalase	7.60
Chymotrypsin	7.00-8.00
Pancreatic lipase	9.00



5. Enzyme inhibitors;

These lower the rate of enzyme controlled reactions or they may stop enzyme action altogether.

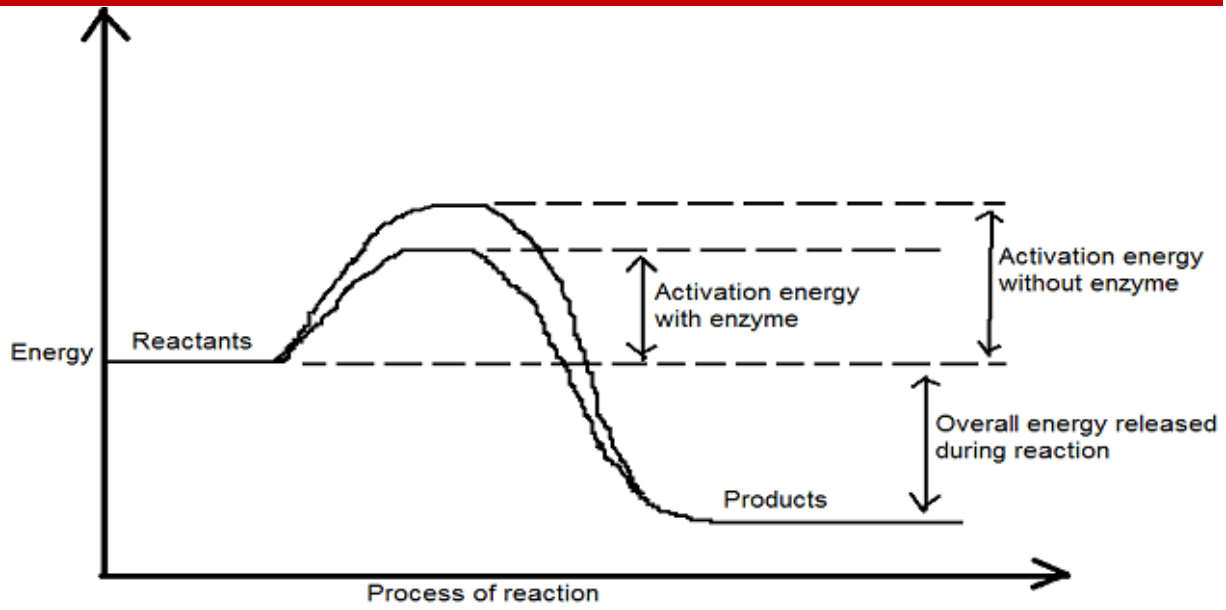
6. Presence of cofactors;

For some enzymes, the rate of enzyme controlled reaction depends on cofactors.

How enzymes work

Enzymes work by lowering the activation energy to allow the reaction to take place. Activation energy is the energy barrier that has to be overcome before a reaction takes place. Since heat is usually the source of energy, enzymes make it possible for reactions to take place at low temperature.

For enzymes to work, they lower the activation energy so that there is easy conversion of reactants to products.



NUCLEIC ACIDS

These are made up of chains of individual units called nucleotides. Nucleic acids carry the genetic code that determines the order of amino acids in proteins. Genetic material stores information, can be replicated, and undergoes mutations. They differ from proteins as it has phosphorus and **NO** sulphur.

There are two types of nucleic acids i.e.

i) DNA (Deoxyribo Nucleic Acid)
ii) RNA (Ribo Nucleic Acid)

Both types of nucleic acids are present in the nucleus of the cell.
DNA is found only within the nucleus while RNA is found within the nucleus (nucleolus) and in the cytoplasm.
RNA is usually associated with ribosomes and responsible for protein synthesis.
RNA is one stranded while DNA is double stranded hence having a higher molecular mass than that of RNA.

The nucleic acid structure

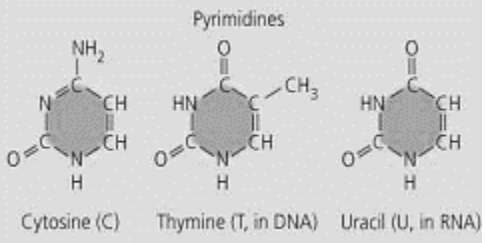
These are big molecules built from 3 types repeating sub-units i.e.

i) Nitrogenous bases (purines and pyrimidines)
ii) Pentose sugars
iii) Phosphate units.

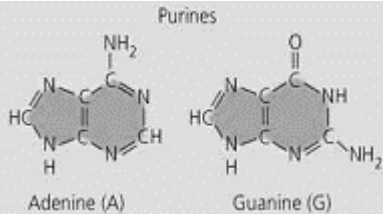
1. PURINES AND PYRIMIDINES (NITROGENOUS BASES)

These are organic bases which belong to a series of related compounds in which the rings contain both carbon and nitrogen atoms.

The ***purines*** i.e. Adenine (A) and Guanine (G) are made up of two interconnecting rings while the *pyrimidines* i.e. Uracil (U). Cytosine (C) and Thymine (T) possess a single ring.



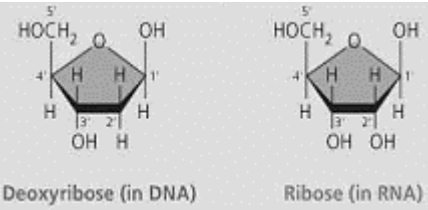
Note: They have single carbons and nitrogen rings



Note: they have double carbons and nitrogen rings

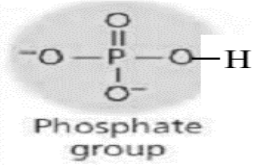
2. THE PENTOSE SUGAR UNITS

The pentose sugars are found in nucleic acids and are of two types i.e. ribose and deoxyribose. They differ only in that ribose sugars contain an additional oxygen atom.

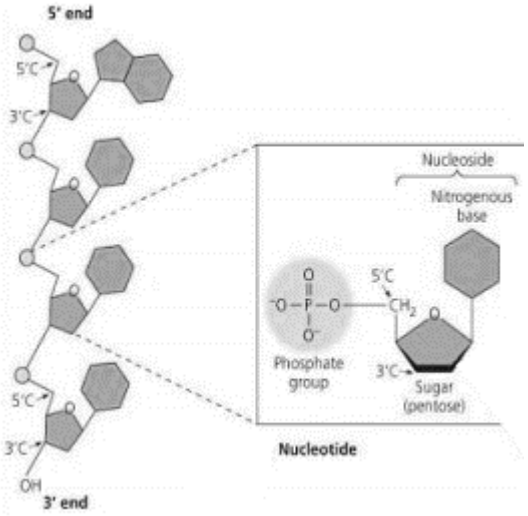


3. PHOSPHATE UNITS

These act as alpha links between one sugar group and the next.



In nucleic acids, these 3 groups are linked together in a specific way to make a larger group as a nucleotide.



Many nucleotides are then joined by condensation to form a long chain known as a nucleic acid.

RIBONUCLEIC ACID (RNA)

The RNA molecule is made up of long chains of nucleotides incorporating the pentose sugar ribose and any of the four bases i.e. adenine and guanine (purines) or cytosine and thymine (pyrimidines).

The base uracil is found exclusively in RNA while the other bases also occur in DNA. RNA chains exist as single strands.

RNA exists in 3 types, i.e.

i) Messenger RNA (mRNA)

It forms an intermediate link between the nucleus and cytoplasm to facilitate the transfer of genetic information from the nucleus to the cytoplasm.

It is single stranded and forms 3-5% of the total RNA in the cell. mRNA is synthesized in the nucleus, a process known as transcription. It is synthesized of a DNA template after DNA has unzipped. Once completed, the mRNA strand then moves through the nuclear pore to the cytoplasm.

ii) Transfer RNA (tRNA)

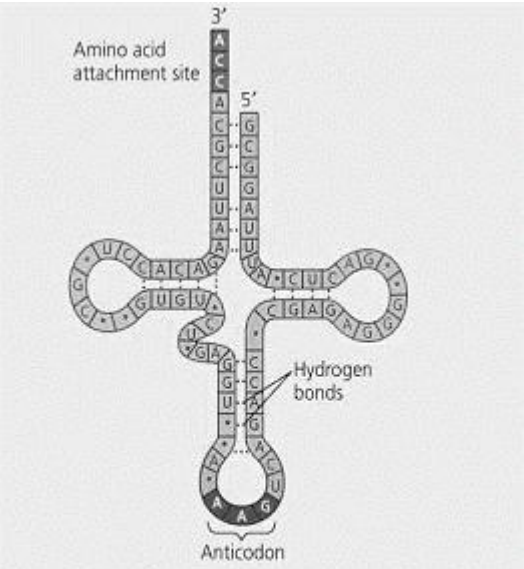
There is about 20 types of tRNA each coding for a particular amino acid. The function of tRNA is to pick up amino acids from the amino acid pool and delivering them to the site of protein synthesis i.e. on the ribosomes for alignment into polypeptides.

iii) Ribosomal RNA (rRNA)

It is the most abundant in the cell forming 80% of the total RNA. It is found in the cytoplasm where it is associated with the protein molecules which together form the ribosomes that are assembling sites during protein synthesis.

rRNA plays an important role in translating the sequence of amino acids into a polypeptide chain in the cytoplasm.

Structure of tRNA



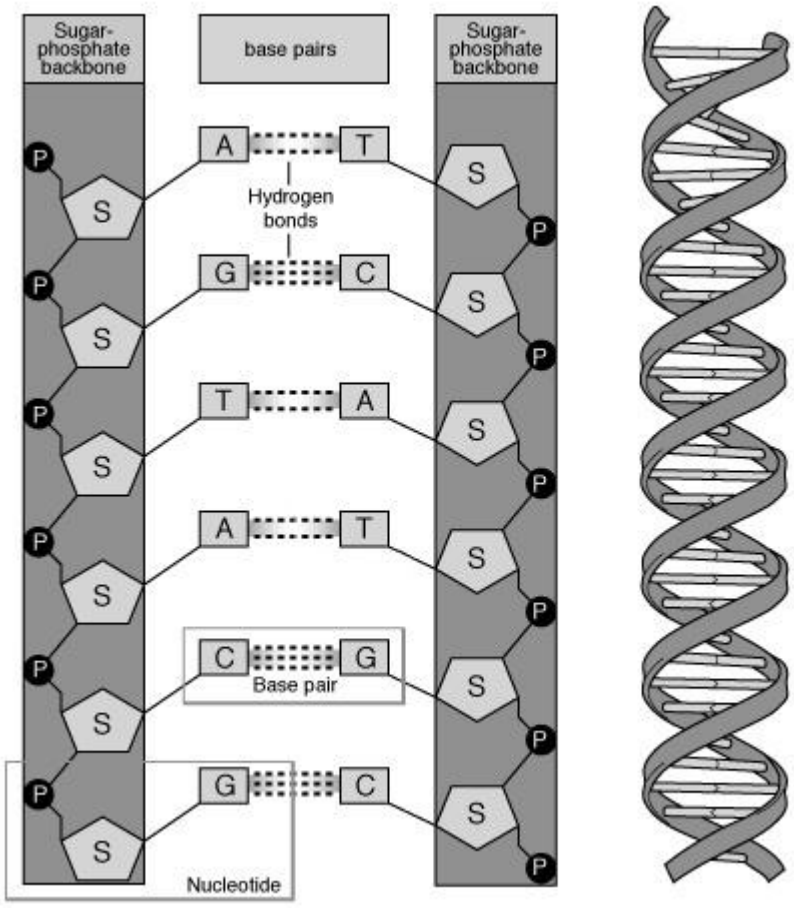
Two-dimensional structure. The four base-paired regions and three loops are characteristic of all tRNAs, as is the base sequence of the amino acid attachment site at the 3' end. The anticodon triplet is unique to each tRNA type, as are some sequences in the other two loops. (The asterisks mark bases that have been chemically modified, a characteristic of tRNA.)

DEOXYRIBO NUCLEIC ACID

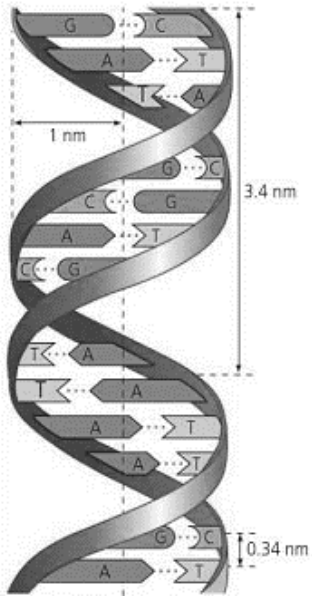
This has a very high molecular weight and its structure is more complex than that of RNA. It is similarly made up of long chains of nucleotides but in this case, the sugar unit is a pentose deoxyribose and the pyrimidine base uracil is replaced by thymine.

DNA chains do not occur singly but paired together by weak hydrogen bonds across the bases to form ladder like constrictions. These bases can only link in a specific way where a purine must always link with a pyrimidine. In this case, adenine bonds with thymine while guanine bonds with cytosine.

Structure of the DNA double helix



The partial chemical structure of DNA



Phosphorylated nucleotides

The addition of a phosphate group to an organic molecule has the effect of increasing the reactivity of that molecule. Nucleotides may also require additional phosphate groups with an increase in reactivity. An example of this is Adenosine tri phosphate (ATP) which has two extra phosphate groups linked to the molecule by high energy bonds. This molecule acts as an energy carrier during several reactions.

Other important nucleotides

Many nucleotide derivatives act as co-enzymes acting in conjugation with other specific enzymes as carrier molecules by transferring a group of atoms from one molecule to another.

Nicotinamide adenine dinucleotide (NAD) is a phosphorylated derivative and Flavine adenine dinucleotide (FAD) both act as hydrogen carriers.

Co-enzyme A, also a nucleotide derivative acts as an acetyl carrier molecule.

Similarities between RNA and DNA

- Both contain guanine, cytosine and adenine.
- Both are found in the nucleus.

- Both are made of long chains of nucleotides.
- Both are made up of a base, sugar and a phosphate group.
- They both form the genetic material.
- Both of them contain four bases and two of them are derived from purines and the others from pyrimidines.

Differences between RNA and DNA

DNA	RNA
Contains thymine	Contains uracil
Made up many nucleotide chains	Made up of a single nucleotide chain
Double stranded	Single stranded
High molecular weight	Has a low molecular weight
Has got hydrogen bonds	Lacks the hydrogen bonds
Found exclusively in the nucleus	Found in the nucleus and cytoplasm
It is of one type.	It is of three types i.e. mRNA, rRNA and tRNA.

PROTEIN SYNTHESIS

Protein synthesis requires the supply of amino acids, energy and information. When these are grouped or brought together, proteins are synthesized in 3 types, i.e. Transcription, Activation and Translation.

Transcription

This is the process of transferring part of the coded information of DNA in the nucleus to the ribosome in the cytoplasm. It involves a nucleic acid molecule made of RNA, known as mRNA, which is a single stranded molecule manufactured in the nucleus from one strand of DNA double helix referred to as coding strand.

The enzyme catalyzing the reaction of transcription is known as RNA polymerase. The beginning of protein synthesis starts by RNA polymerase attaching itself to the DNA double helix and the hydrogen bonds are broken down in the region of DNA to be coded (copied) and the DNA strand unwinds.

One DNA strand is then coded by base pairing of ribo-nucleotides, which are condensed together to form a strand of mRNA. The base sequence of mRNA is complementary to the coding strand of DNA. Once formed, the mRNA passes out into the cytoplasm and becomes attached to the ribosome.

Amino acid activation

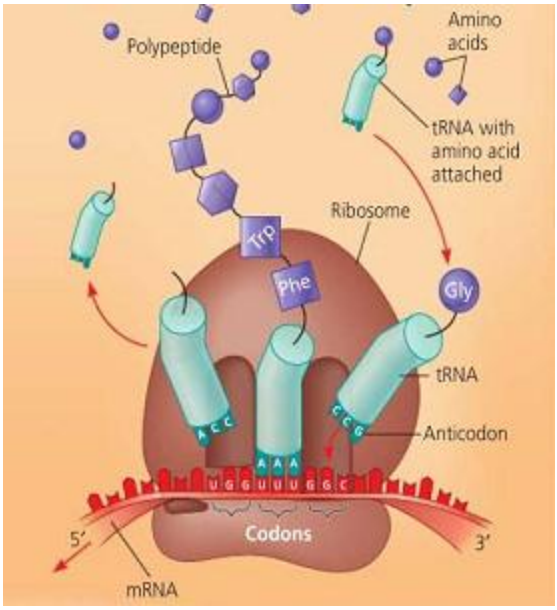
Amino acids are activated for protein synthesis by combining with a short length of RNA known as transfer RNA (tRNA). The activation process involves ATP for provision of energy.

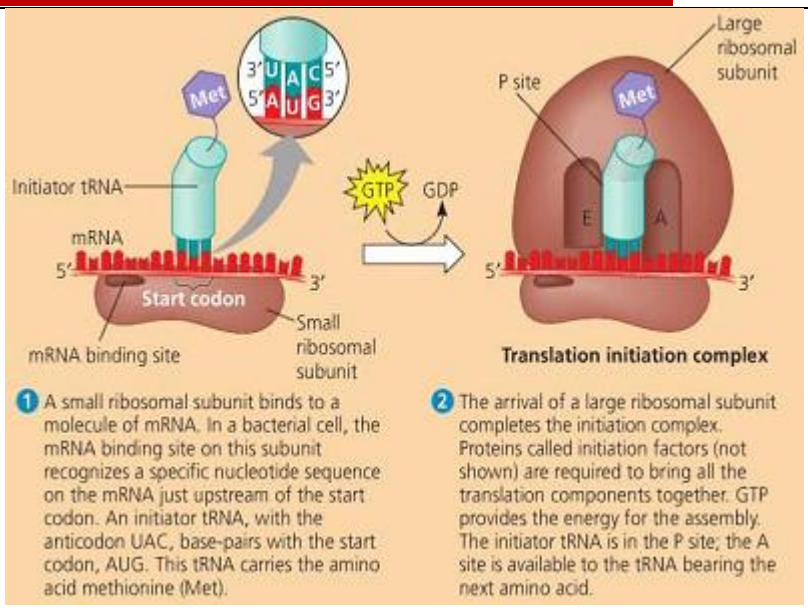
There are more than 20 amino acids coded for in all proteins. All tRNA have a globally leaf shape but differ in sequence of bases known as anticodon which is exposed on one of the leaves. This anticodon is complementary to the codon of mRNA.

Each type of tRNA binds with a specific amino acid. The amino acid molecules join to the free ends of tRNA molecules. The tRNA amino acid complexes now move to the ribosomes.

Translation

This process occurs in the ribosomes. It is mainly placing of the activated tRNA anticodon to the right mRNA codon by the ribosome in order to make a polypeptide chain.





Ribosomes move along the length of the mRNA strand reading the codon from the start codon starting at one end of the mRNA molecule. A ribosome works its way along the mRNA positioning the anticodons of the tRNA on the complementary codon of the mRNA strand.

In the ribosome, complementary anticodons of amino acids, tRNA complexes are held in place by hydrogen bonds.

The amino acids are then joined by peptide bonds therefore meaning that the ribosome is acting as a supporting frame work, holding the mRNA and two amino acids.

tRNA complexes together and enables and enzyme to catalyze the formation of a polypeptide bond between the adjacent amino acids.

The ribosomes move along the mRNA and as it does it positions two activated tRNA having one amino acid at the same time.

The ribosome has two sides, A and P sides. At the starting codon, the side A is attached to the first tRNA which the P side is empty.

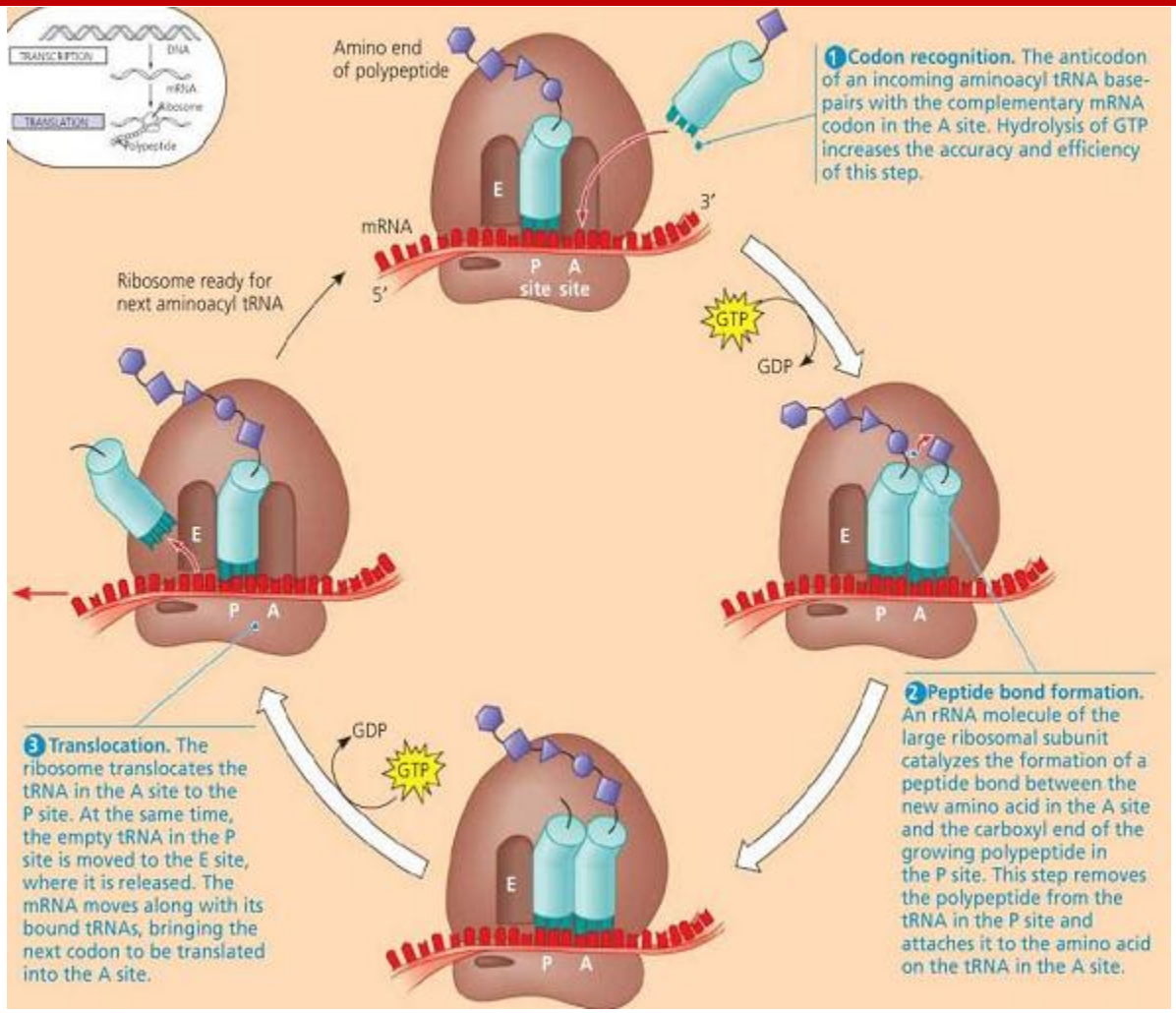
When it continues to move, a second tRNA attracts itself to the empty side corresponding to the second codon of mRNA.

The presence of the second amino acids on the second tRNA stimulates the formation of a polypeptide bond between the amino acids.

This makes the earlier tRNA to loose contact from the mRNA and its amino acids making it free going back to the cytoplasm.

For further activation, the ribosome continues to move along the codons of the mRNA, placing the activated tRNA in their right positions, together with their amino acids in the process forming a polypeptide chain which is released into the cytoplasm when the ribosome reaches the stop codon.

The protein structures are determined by the amino acids sequences.

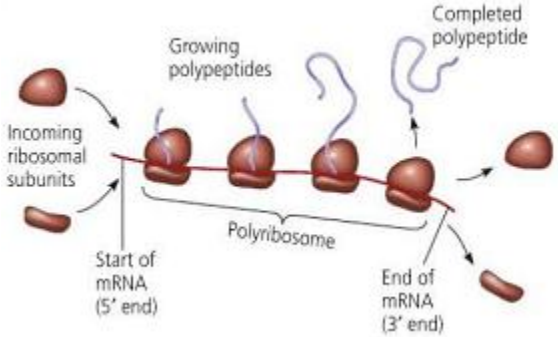


Polysomes/polyribosomes

These are groups of ribosomes, connected by a common strand of mRNA and synthesizing different types of polypeptide chains simultaneously. This arrangement means that several polypeptide chains are made at the same time, on one mRNA molecule.

When synthesis is completed, the polypeptides are moved from the ribosome to the cytoplasm and constructed into the proteins for internal use by the cell or for secretion.

Diagram illustrating synthesis of proteins by polysomes



Questions:

1. *How does DNA regulate the synthesis of proteins? (protein synthesis but focus on DNA)*
2. *Outline the role played by the different types of RNA in protein synthesis.*

THE GENETIC MATERIAL

This is the material that is responsible for the transmission of hereditary traits or characteristics form one generation to another.

Characteristics of a hereditary material

i) It should be able to carry out self-replication i.e. make exact copies of itself for the onward transmission of its features to the off springs.
ii) It should be stable in structure i.e. it should not change erratically losing its structure during transmission.
iii) It should have the capacity to change i.e. to provide new material for creation of a new inheritance feature that can improve linkage of off springs. This can be done through mutation.
iv) It should have the capacity to store information correctly preferably in a code which can be read and interpreted at an appropriate time.
v) It should be strategically located in the part of the body where it can be protected against metabolic reactions but have the ease to transmit information to all body parts e.g. in the nucleus.

Evidence of DNA as a hereditary material

Early researchers scrutinized many molecules in the body to find out which ones could have characteristics that fit the hereditary material. Proteins were seen as the best candidates since they were versatile in nature and were dominant in body parts. Proteins however are unstable as they constantly change and they are metabolically active and even not self-replicating.

Friedrich later eliminated proteins as the best candidate and identified a macro molecule he named 'nuclein' which appeared to satisfy most of the essential characteristics. Nuclein was later renamed DNA.

Characteristics of DNA as a genetic material

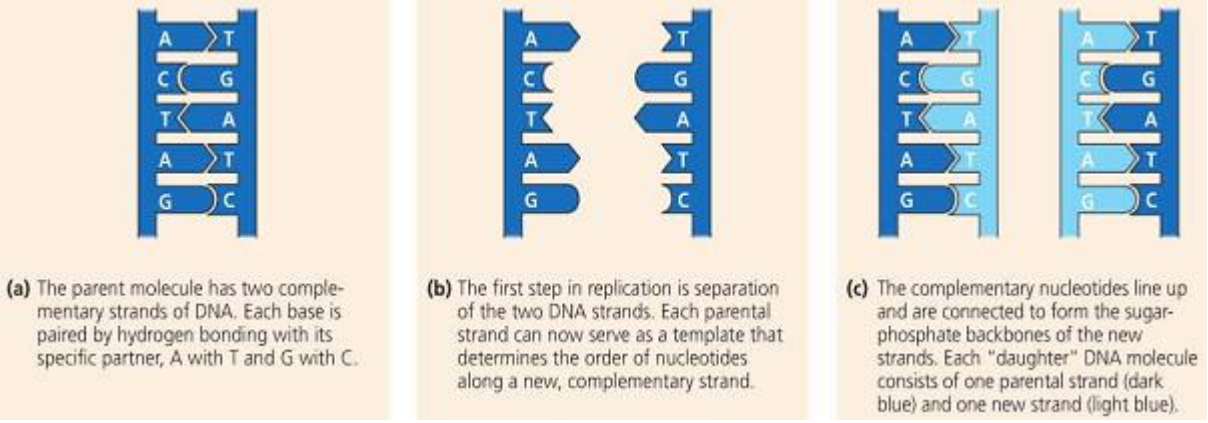
i) Consistency of DNA content in the nucleus. Diploid nuclei from cells in any species and at different stages of mitosis all contain the same quantity of DNA.
ii) The gamete nuclei contain half the quantity as expected.
iii) Unlike other cell components, DNA remains stable and intact as a large molecule.
iv) DNA is not metabolized at any stage.
v) DNA has the capacity to mutate. Mutagens like U.V. light bring about changes in the DNA molecule which acts as a basis for new material of inheritance. Mutation is however limited and does not change the whole organism.
vi) Presence of DNA in chromosomes which are the materials of hereditary.
vii) Ability of DNA to replicate.

DNA REPLICATION

One of the most attractive features of DNA is that it can increase in amount before a cell divides. In order for DNA replication to occur, the two strands should be capable of unwinding. The process of DNA replication is catalyzed by enzymes.

A model for DNA replication (the basic concept)

In this simplified illustration, a short segment of DNA has been untwisted into a structure that resembles a ladder. The rails of the ladder are the sugar-phosphate backbones of the two DNA strands; the rungs are the pairs of nitrogenous bases. Simple shapes symbolize the four kinds of bases. Dark blue represents DNA strands present in the parent molecule; light blue represents newly synthesized DNA.



(a) The parent molecule has two complementary strands of DNA. Each base is paired by hydrogen bonding with its specific partner, A with T and G with C.

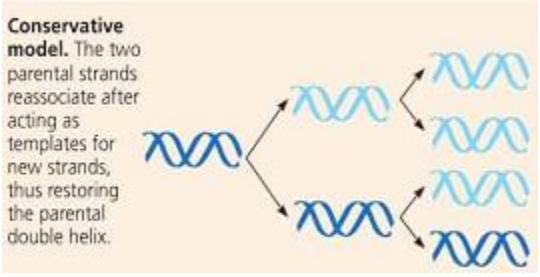
(b) The first step in replication is separation of the two DNA strands. Each parental strand can now serve as a template that determines the order of nucleotides along a new, complementary strand.

(c) The complementary nucleotides line up and are connected to form the sugar-phosphate backbones of the new strands. Each "daughter" DNA molecule consists of one parental strand (dark blue) and one new strand (light blue).

There are three hypotheses put forward to explain the process of DNA replication:

1) **The conservative hypothesis**

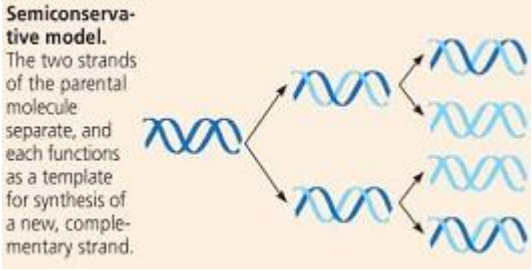
Here, no unwinding occurs but the DNA molecule acts as a stimulant to direct the reaction. All the DNA strands formed are directly similar but not complementary to the parental strands. This hypothesis has not received any scientific backing and appears impractical.



Conservative model. The two parental strands reassociate after acting as templates for new strands, thus restoring the parental double helix.

2) **The semi-conservative hypothesis**

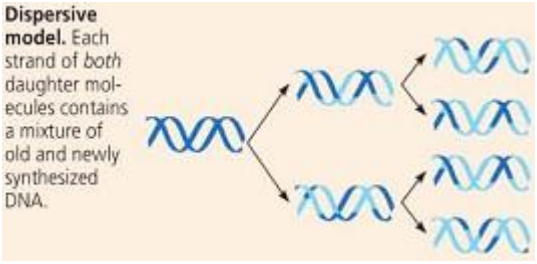
The DNA double helix unwinds and produces two DNA strands. Therefore the parent molecule act as a template where by each strand is used to manufacture another complementary strand thus one strand is directly conserved and only one new strand is manufactured.



Semiconservative model. The two strands of the parental molecule separate, and each functions as a template for synthesis of a new, complementary strand.

3) **Dispersive hypothesis**

According to the hypothesis, DNA initially disintegrates and then re-assembles alongside with the new complementary nucleotides adding to form new helices.



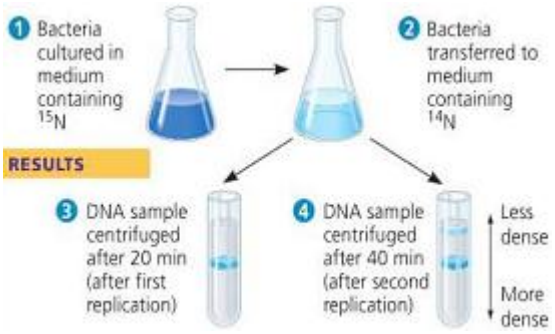
Dispersive model. Each strand of *both* daughter molecules contains a mixture of old and newly synthesized DNA.

Note: Meselson and Stahl performed an experiment to find out whether DNA replication follows the conservative, semiconservative or dispersive model. They cultured E. coli for several generations in a medium containing nucleotide precursors labeled with a heavy isotope of nitrogen, ^{15}N. They then transferred the bacteria to a medium with only ^{14}N, a lighter isotope. Two samples were taken from this flask, one at 20 minutes and one at 40 minutes, after the first and second replications, respectively. They could distinguish DNA or different densities by centrifuging DNA extracted from the bacteria.

They then compared their results to those predicted by each of the three models.

The first replication in the ^{14}N medium produced a band of hybrid (^{15}N- ^{14}N) DNA. This result eliminated the conservative model.

The second replication produced both light and hybrid DNA, a result that refuted the dispersive model and supported the semiconservative model. They therefore concluded that DNA replication is semiconservative.



DNA AND THE CHROMOSOME STRUCTURE

The chromosome structure depends upon the complexity of an organism. There are two levels of complexity and two types of chromosomes:

i) **Prokaryotic chromosomes:**
Prokaryotes have simple chromosomes but with a naked structure. Simple chromosomes are also found in chloroplasts, mitochondria of higher plants, blue green algae (cyanophyta).

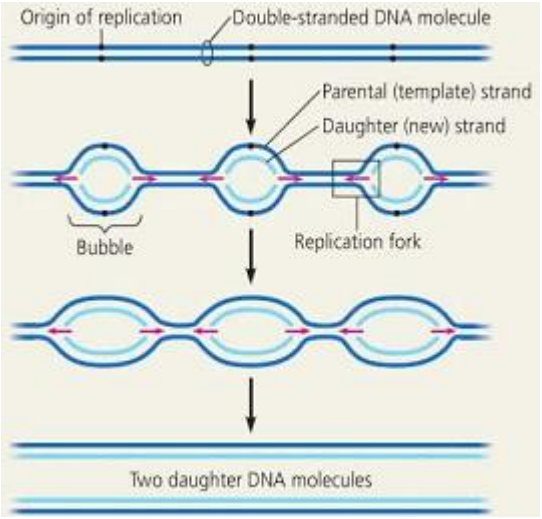
ii) **Eukaryotic chromosomes:**
They are in higher plants and animals. Each cell contains several pairs of chromosomes. The chromosomes are large and they change their form and structural organization at different stages of the cell cycle.
Each chromosome is made up DNA and an equal quantity of protein weight by weight. The DNA protein complex found in chromosomes is known as nucleoprotein or chromatin.

Proteins in a chromosome

There are two types:

1) **Histones:**
These are basic or non-acidic proteins that form the back bone structure of a chromosome on which the DNA is wrapped. The back bone structure of the chromosome on which the DNA is wrapped is called **octamer.** The types of histones are H_1, H_2A, H_2B, H_3 and H_4.

2) **DNA:**
Eukaryotic chromosomes contain double helical DNA in large quantities. Replication of DNA in eukaryotic chromosomes occurs by the semiconservative method but would be very slow due to its length taking about 16 days to manufacture one strand.
To avoid the slow speed, DNA opens up as many as 6000 ***replication forks***. Replication takes place at all the forks almost concurrently and the cycle is completed in 3-4 minutes.



DNA AND GENES

The genetic code

This refers to the way genetic information is encoded or arranged on the DNA strand. It is a known fact that a lot of genetic information is stored and transmitted by the DNA molecule.

Such information is arranged in form of a code of base pairs on the DNA strand. To be able to utilize this information e.g. during the manufacture of amino acids, proteins, enzymes, hormones, etc. the code must be read and interpreted correctly and the secret information released and transformed into products.

Reading the code

A code (DNA) is usually located in the nucleus yet the products of reading it are found in the cytoplasm. Therefore, information has to be transferred from the nucleus to the cytoplasm in order to make the products. Both transfer and utilization of information is done through a special molecule called RNA. This is a nucleic acid that has the capacity to move out of the nucleus therefore transfer information.

What is a gene?

It is a unit of hereditary located on the positions called gene loci on the chromosome. Genes who code for polypeptides are of two groups:

1) **Structural genes:** these code for function of proteins e.g. enzymes, hormones, antibodies, etc.
2) **Regulatory genes:** these serve to control the activity of other genes.

The DNA strand has two regions;

i) The split gene area, which is the coded area and made up of coding sequences known as exons.
ii) The non-coding area is made up of redundant DNA and is composed of non-coding sequences called introns. The function of introns is unknown.

The code dictionary/genetic code

The genetic code is a set of rules by which information encoded within genetic material is translated into proteins by living cells. There are four bases on the DNA strand that are used for coding of amino acids. Their combination ought to give a coding total of 20 amino acids found in the body. If each base was on its own codes for an amino acid, only four amino acids would be coded. If the bases acted in pairs only 16 amino acids would be coded. In both cases, 20 amino acids are not arrived at it. It therefore appears reasonable to theorize that 3 base pairs are required for coding an amino acid.

Second mRNA base

First mRNA base (5` end of codon)	U	C	A	G	Third mRNA base (3` end of codon)
U	UUU, UUC: Phe UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr UAA: Stop UAG: Stop	UGU, UGC: Cys UGA: Stop UGG: Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile AUG: Met	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn AAA, AAG: Lys	AGU, AGC: Ser AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Having established that each amino acid is determined by a triplet base pair, it has been used to establish and read the code dictionary. The three base pair hypothesis means that to code for the 20 amino acids occurring in the body, 64 possible combinations exist. The 44 combinations are not used in amino acid coding and are referred to as degenerate or nonsense codons/stop codons. Because of this, more than one but nearly similar triplet can code for an amino acid.

The three bases of an mRNA codon are designated here as the first, second, and third bases, reading in the 5` to 3` direction along the mRNA. () the codon AUG not only stands for the amino acid methionine (met) but also functions as a "start" signal for ribosomes to begin translating the mRNA at that point. Three of the 64 codons function as "stop" signals, marking the end of a genetic message.

General characteristics of the genetic code

i) ***Universal:*** This means that the same codons are used to specify the same amino acids in all forms of life.

ii) The code is ***degenerate*** i.e. more than one codon can code for one amino acid. Some amino acids like methionine and tryptophan are coded by only one codon but many others are coded by several codons. Therefore, a code has excess codons. These codons are known as synonymous.

iii) The code is ***non-ambiguous*** i.e. no one codon can code for more than one amino acid.

iv) The genetic code is ***triplet*** i.e. it has got three bases.

v) The principle of ***co-linearity:*** It is ***collinear*** because the sequence of codons on the mRNA corresponds to that of the amino acid on the polypeptide chain. The linear order of nucleotides in DNA determines the linear order of codons in mRNA.

vi) ***Non-over lapping*** except in some viruses. From the starting of mRNA the sequence of bases read in blocks of three, correspond to the sequence of amino acids, without any overlapping of bases. For example if the bases from the starting are AUGCCAAUC the sequence of codons is AUG/CCA/AUC and not AUG/GCC/CAA/AUG. No single base in a sequence takes part in the formation of more than one codon.

vii) ***Non sense/termination codons:*** Some triplets do not code for any amino acids i.e. they punctuate the process of protein synthesis. They include UAA, UAG and UGA.

viii) The genetic code has ***initiation or start codons***. AUG specifies methionine, AUG when present at the first position of the mRNA, acts as a start signal thus called start codon. It means all polypeptides begin with the first amino acid as methionine which is later removed enzymatically. If AUG appears in the middle of mRNA, it simply codes for methionine.

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"Whatever the mind of man can conceive and believe, it can achieve" (Napoleon Hill, 1983).