CHEMICALS OF LIFE

1. (a) Explain the different physical properties of water as an essential chemical of life. (10 marks)

- Water is a liquid at room temperrature; because of the strong hydrogen bonds between the water molecules that keep the molecules close together;
- Water has a high specific heat capacity; meaning that a relatively large amount of energy is needed to raise the temperature of water, as much of the energy is used to break the strong hydrogen bonds;
- Water has a high latent heat of fusion; meaning that ice requires relatively high amounts of anergy to melt it; and liquid water must lose a relatively large amount of energy to freeze;
- Water has a high latent heat of vapourisation; meaning that a relatively large amount of energy is required to vapourise water because of the strong hydrogen bonds between its molecules;
- Water has a high surface tension; therefore, a very strong film is formed on its surface as a result of the strong cohesion forces between its molecules;
- Water has a low viscosity; that is, water molecules can easily slide past each other;
- Water is a universal solvent; dissolves more substances than any other solvent;
- Ice is less dense than water; that is, it floats on water insulating the water below it;

(b) Explain the significance of the physical properties of water to living organisms. (10 marks)

- Water is a liquid at room temperature; providing a medium for chemical reactions in the cells; and an environment to live in by aquatic organisms;
- Water has a high specific heat capacity; temperature changes within water are minimized, thus enabling aquatic organisms to have a relatively stable temperature; and their biochemical processes to proceed at more constant rates;
- Water has a high latent heat of fusion; making cells contents; and the aquatic environments slow to freeze in cold weather;
- Water has a high latent heat of vaporization; therefore, much heat is lost with minimal loss of water from the body; and evaporation of water during sweating or transpiration causes marked cooling;
- Water has a high surface tension; enabling some organisms like pond skaters to land and move on the water surface without sinking; it also

enables water to form droplets on surfaces and run off for example on feathers of birds;

- Water has a low viscosity; therefore, water can readily flow through narrow capillaries; and can serve as a lubricant e.g. synovial fluid in joints;
- Water is a universal solvent; making it a transport medium as in blood, lymphatic and excretory systems, the alimentary canal, xylem and phloem;
- Ice is less dense than water; ice floats on the water insulating the water below it and thus increasing the chances of survival of aquatic organisms below the ice;
- Water is colourless and transparent; enabling light to penetrate through and thus allowing aquatic plants to photosyn;thesis
- Water is incompressible; providing support in non-woody plants and maintaining the hydrostatic skeleton in some animals e.g. earthworms;
- Water has a high tensile strength; this allows a continuous water column up the xylem of tall trees without splitting;

2. (a) Describe the structure of starch. (08 marks)

Starch is a polymer of α-glucose molecules; starch has two components, amylose; and amylopectin; amylose has a straight chain structure; consisting of thousands of glucose molecules linked by 1,4-glycosidic bonds; which cause the chain to coil helically into a more compact shape; Amylopectin has many branches; caused by 1,6-glycosidic bonds; and in each chain, glucose residues are joined 1,4-glycosidic bonds; which cause the chains to coil helically into a more compact shape;

(b) How is starch suited for its functions? (06 marks)

- Starch is insoluble in; therefore it cannot be lost in solution; and does not affect the osmotic properties of the cell;
- Starch is highly coiled into a compact shape; enabling large amounts of energy to be stored within a small volume of the cell;
- The glycosidic bonds can easily be broken (starch is easily hydrolysed); releasing glucose for oxidation to produce energy;
- Starch is chemically inert under many conditions; and thus it is not used during strorage;

(c) Describe the structure of cellulose. (06 marks)

Cellulose is a polymer of β-glucose molecules; it consists of unbranched straight chains; in which the glucose molecules are linked by 1,4-glycosidic bonds; Hydroxyl groups project from each chain in all directions; and form hydrogen bonds with the neighbouring chains; The chains associate in groups to form microfibrils; which are arranged in larger groups to form macrofibrils;

(d) Explain how the structure of cellulose relates to its function. (06 marks)

- Hydroxyl groups project from each cellulose chain and form hydrogen bonds with neighbouring chains; thus offering great tensile strength;
- The cellulose chains associate in groups to form microfibrils; which are arranged in larger groups to form macrofibrils; which offer greater tensile strength;
- The macrofibrils are arranged in several layers; preventing cells from bursting when water enters them osmotically; cells become turgid thereby providing support to non-woody plants;
- Parallel arrangement of microfibrils; permits full permeability to water, gases and solutes;
- The glycosidic bonds linking the β-glucose molecules can be broken down by enzyme cellulose; to release glucose for oxidation to produce energy;
- The glycosidic bonds are strong; which adds to the molecules' toughness;

3. (a) Compare starch and cellulose. (08 marks)

Similarities

- Both are polymers of glucose;
- Both contain 1,4-glycosidic bonds linking glucose molecules;

Differences

Starch	Cellulose
A polymer of α-glucose;	A polymer of β-glucose;
It is of two forms, amylose and amylopectin;	It is in one form, cellulose;
Amylopectin, one of its components, is branched;	Consists of unbranched straight chains;
Has 1,6-glycosidic bonds which cause branching in amylopectin;	Lacks 1,6-glycosidic bonds;

Chains coil to form a helix;	Chains associate to form microfibrils and macrofibrils;
No hydrogen bonds between the neighbouring chains;	Neighbouring chains are linked by hydrogen bonds;
Glucose molecules in the chain are oriented in the same direction;	Each glucose molecule is rotated at 180^0 to the other;

(b) Describe how a triglyceride is formed. (04 marks)

A triglyceride is from three fatty acids; and glycerol; each of the three hydroxyl groups of glycerol condenses; with the carboxyl group of a fatty acid molecule; forming a triglyceride with formation of an ester bond; and loss of water.

(c) Explain why lipids are better energy storage compounds in animals than carbohydrates. (08 marks)

- Lipids are insoluble in water; therefore they cannot be lost in solution; and can be stored in large concentrations without affecting the osmotic properties of the cells;
- Lipids are much more compact than carbohydrates; therefore larger amounts of energy can be stored within a small volume of the cell as compared to carbohydrates;
- Lipids release much more energy; and metabolic water on oxidation in respiration as compared to the same mass of carbohydrates;
- Lipids can also serve secondary functions like insulation against heat; water proofing; aiding buoyancy; cushioning and cell membrane formation; unlike carbohydrates.

(d) Of what importance is cholesterol to living organisms? (05 marks)

- Cholesterol is a structural component of the cell membrane;
- Cholesterol is a constituent of the myelin sheath;
- It is essential in the synthesis of hormones e.g cortisol, testosterone;
- Essential in the synthesis of bile salts which are involved in digestion of fats;
- Essential in vitamin D synthesis;

4. (a) Explain why lipids;

(i) Have a higher calorific value than carbohydrates. (03 marks)

Lipids contain a higher proportion of hydrogen; and an almost insignificant proportion of oxygen as compared to the carbohydrates; So on oxidation, a given mass of a lipid yields more energy than the same mass of a carbohydrate;

(ii) Are insoluble in water. (03 marks)

Lipids contain fatty acids; with long hydrocarbon tails; which are non-polar(hydrophobic);

(b) A camel stores fat in the hump primarily as a water source rather than as an energy source.

(i) By what metabolic process would water be made available from the fat? (01 mark)

- Respiration.

(ii) What advantage does fat have over carbohydrates as a water source? (02 marks)

- Fat contains more hydrogen than carbohydrate; and thus yields more water than carbohydrate;

(c) Account for the fact that poikilothermic animals store lipids containing unsaturated fatty acids while homeothermic animals do not. (04 marks)

- The body temperature of poikilothermic animals becomes lower in cold environments; The lipids containing unsaturated fatty acids have lower melting points; and generally remain liquid at lower temperatures; unlike those rich in saturated fatty acids; and this may necessary if the lipids are to maintain their functions such as constituents of cell membranes;

5. (a) Account for the fact that carbohydrates are able to form a variety of polysaccharides. (10 marks)

- Both pentoses and hexoses can be used to make polysaccharides; and normally one type of monosaccharide is used in each type of polysaccharide;
- Two types of linkages; 1,4-glycosidic bond and 1,6-glycosidic bond exist between sugar units; and thus branching can occur;
- Existence of alpha and beta forms of monosaccharides; for example alpha glucose in starch and beta glucose in cellulose;
- Sugars may be ketoses or aldoses;
- The high chemical reactivity of sugars;

(b) State the different functions of lipids in living organisms.

(08marks)

- Insulation of the body against heat loss; for example fat beneath the skin(subcutaneous fat) enables the body to retain its heat;
- Source of metabolic water for animals inhabiting water scarce areas like the camels; When oxidised in respiration water is released;
- Protection; fat usually builds around delicate body organs like the kidneys and the heart protecting them against physical damage;
- Buoyance; fats are less dense than water and therefore provide buoyance to aquatic vertebrates like the whales and sharks;
- Structural components in the cell membrane in the form of phospholipids;
- Constituents of the myelin sheath which ensures rapid impulse transmission in myelinated neurons of vertebrates;
- Involved in the transportation of fat-soluble vitamins, A, D, E and K;
- Water-proofing; insects and plants possess a waxy cuticle preventing evaporation of water and reducing transpiration respectively; Animals skins secrete oils which waterproof their bodies;

6. Describe the structure of an amino acid. (05 marks)

- An amino acid consists of a central alpha carbon atom; to which is attached an acidic carboxyl group; a basic amino group; a hydrogen atom; and a varying R-group;

(b) Distinguish between essential and non-essential amino acids.

(02 marks)

- Essential amino acids are those that cannot be synthesized by the animal's body and are instead obtained from diet; while non-essential amino acids are those that are synthesised in the body;

(c) Describe how amino acids function as buffers in the body.

(05 marks)

- In neutral solution, amino acids possess a negatively charged acidic carboxyl group; and a positively charged basic amino group;
- When hydrogen ions are added, they are accepted by the carboxyl group; while the hydroxide ions added are neutralized by accepting a proton from the amino group; and hence keeping the pH constant;

7. Describe how amino acids form a polypeptide. (09 marks)

- A polypeptide is formed by linking several amino acids; The carboxyl group of one amino acid; condenses; with the amino group of another amino acid; forming a dipeptide; with formation of a peptide bond

between the two amino acids; The dipeptide formed has a free amino group at one end; and a free carboxyl group at the other end; and therefore further condensation between the dipeptide and several other amino acids can take place; forming a polypeptide;

(b) Describe the biological functions of amino acids. (05 marks)

- Amino acids are monomers/building blocks during protein synthesis;
- Act as buffers; neutralising hydrogen ions in acidic solution; and hydroxide ions in alkaline solution;
- Act as intermediate metabolites in metabolic pathways; for example in the Krebs cycle to release energy during starvation;

8. (a) Describe the different types of bonds that contribute to protein structure. (10 marks)

- Peptide bond; formed by condensation between the carboxyl group of one amino acid and the amino group of another amino acid;
- Hydrogen bond; formed by the attraction between the hydrogen of the –OH or –NH group and the oxygen of the –C=O or the nitrogen of the – NH group;
- Ionic bond; formed by the attraction between the positively charged basic R groups and the negatively charged acidic R groups;
- Disulphide bond; formed by the oxidation of the neighbouring sulphydryl groups of two cysteine molecules lining up alongside each other;
- Hydrophobic interractions; formed by the interaction between the non-polar R groups of the polypeptide chain;

(b) Explain the different functions of proteins in the body. (10 marks)

- Homeostasis; soluble proteins act as buffers preventing pH changes wherever they occur in the body;
- Transport; cell membrane proteins are involved in the transport of metabolites across the membrane; Haemoglobin transports oxygen and some carbon dioxide;
- Protection; Antibodies defend the body against foreign antigens; fibrinogen and prothrombin are important in blood clotting;
- Support and movement; myosin and actin for muscle contraction; chondrin for structural support in bone and cartilage; collagen gives strength in bone, tendons and connective tissue;

- Enzymes; speed up and control biochemical reactions in the body; digestive enzymes, respiratory enzymes;
- Sensitivity and coordination; hormones act as chemical messengers coordinating and controlling activities in the body e.g insulin and glucagon for glucose regulation; Rhodopsin is a photosensitive pigment in the retina;
- Storage; for example casein in milk;

9. (a) Define protein conformation. (01 mark)

- Refers to the characteristic three-dimensional shape of a protein molecule;

(b) Giving examples, describe the different levels of protein structure. (12 marks)

- Primary structure; refers to the linear sequence of amino acids in a polypeptide; Each protein possesses a primary structure;
- Secondary structure; polypeptide chain is folded into an alpha helix, a beta pleated sheet or a triple helix; for example keratin forms an alpha helix; fibroin forms a beta pleated sheet; and collagen forms a triple helix;
- Tertiary structure; polypeptide chain bends and folds more extensively into a compact globular shape; for example myoglobin in muscles;
- Quaternary structure; more than one polypeptide chain are linked together by ionic bonds, hydrogen bonds and hydrophobic interactions forming a large complex protein molecule; for example haemoglobin which has four polypeptide chains;

(c) State the differences between globular and fibrous proteins. (06 marks)

Globular proteins	**Fibrous proteins**
Soluble;	Insoluble;
Have metabolic functions;	Has support and structural functions;
Polypeptide chains are folded into a spherical shape;	Polypeptide chains form long parallel strands;
Have irregular amino acid sequences;	Have repetitive regular sequences of amino acids;
Amino acid sequence is highly specific and never varies between two examples of the same protein;	Actual sequence may vary between two examples of the same protein;

(d) Explain how the structure of proteins enables them to form body tissues and structures. (04 marks-2011)

- Some proteins are folded into an alpha helix maintained by the many hydrogen bonds; This gives them great stability and tensile strength; for example keratin which forms structures like the nails, hair, wool;
- Some proteins consist of parallel chains held together by many hydrogen bonds forming a beta pleated sheet; making them very stable and rigid; for example silk which forms the cocoon threads in silkworms;
- Some proteins have polypeptide chains wound around each other to form a triple helix that gives them great tensile strength; for example collagen which is a component of tendons, bones and connective tissue;

10. (a) What is protein denaturation? (02 marks)

- Protein denaturation refers to the loss of the specific three-dimensional shape of a protein molecule; leading to the loss of its normal biological function;

(b) Explain how different factors cause protein denaturation. (10 marks)

- Heat or radiation(e.g infra-red or ultra-violet light); these supply kinetic energy to the protein causing its atoms to vibrate violently; so disrupting the weak hydrogen and ionic bonds;
- Strong acids; strong alkalis; and high concentrations of salts; these interact with negatively charged carboxyl groups or positively charged amino groups; thereby disrupting ionic bonds; long term exposure breaks the peptide bonds;
- Heavy metals; Cations of heavy metals form strong bonds with negatively charged carboxyl groups on the R groups of proteins; thereby disrupting ionic bonds;
- Organic solvents and detergents; these form bonds with hydrophobic groups and disrupt hydrophobic interactions; and this in turn disrupts hydrogen bonding;
- Mechanical force; physical movement may break hydrogen bonds;

(c) Explain the significance of the alpha helix in a protein molecule. (04 marks)

- The alpha helix is stable; rigid; with great tensile strength; and this adds to the overall stability of the protein molecule;

11. (a) What is meant by the term an enzyme? (02 marks)

- An enzyme is an organic molecule; protein in nature; that speeds up a chemical reaction in the body; and remains unchanged at the end of the reaction;

(b) Outline the different properties of enzymes (08 marks)

- Are protein in nature;
- Are specific in action, that is, each reaction is catalyzed by a specific enzyme;
- They work efficiently and rapidly; A very small amount of the enzyme turns a large amount of the substrate into products per minute;
- Enzymes are sensitive to pH changes; Each enzyme has its own pH range within which it functions efficiently;
- Enzymes are denatured by excessive heat;
- All enzyme controlled reactions are reversible;
- Enzyme activity is affected by substrate concentration; and enzyme concentration;
- Rate of enzyme activity is reduced by inhibitors;
- Enzymes lower the activation energy of the reactions they catalyse;

(c) Explain the role of enzymes in the body. (08 marks)

- Enzymes speed up chemical reactions in the body; at temperatures suitable for living organisms; Without enzymes, these reactions would be too slow to sustain life;
- Enzymes control metabolism; Many different metabolic reactions occur in a single cell at the same time and therefore there is need for function organization; and this is achieved by each reaction being catalyzed by a specific enzyme; and thus metabolism proceeds in gentle steps in an orderly fashion;

12. Describe the mechanism of enzyme action based on;

(a) The lock and key hypothesis. (10 marks)

- The shape of the active site of the enzyme is complementary to that of the substrate; The substrate with the complementary shape binds and fits into the active site exactly; like the way a key fits into a lock; forming an enzyme-substrate complex; which is maintained by bonds formed between the enzyme and the substrate; At this point, activation energy is lowered; and the reaction occurs forming an enzyme-product complex; Once the product is formed, it no longer fits

into the active site; and escapes into the surrounding medium; leaving the active site free to bind with other substrate molecules;

(b) The induced fit hypothesis. (10 marks)

- The shape of the active site is not complementary to that of the substrate; but the enzyme and its active site are instead physically flexible; As the enzyme interacts with the substrate, the shape of the active site is moulded into a precise shape; into which the substrate fits exactly; forming an enzyme-substrate complex; which is maintained by bonds formed between the enzyme and the substrate; At this point, activation energy is lowered; and the reaction occurs forming an enzyme-product complex; Once the product is formed, it no longer fits into the active site; and escapes into the surrounding medium; leaving the active site free to bind with other substrate molecules;

13. (a) Classify enzymes based on the type of reaction they catalyse. (06 marks)

- Oxidoreductases; catalyse oxidation and reduction reactions; e.g hydrogenases and oxidases;
- Transferases; catalyse the transfer of a chemical group from one molecule to another; e.g transaminases;
- Hydrolases; catalyse hydrolytic reactions in which a large molecule is broken into two products; e.g lipases, peptidases;
- Isomerases; catalyse the rearrangement of groups of atoms within a molecule; e.g mutases;
- Lyases; catalyse non-hydrolytic removal of parts of a molecule; e.g decarboxylases;
- Ligases; catalyse the formation of bonds between two molecules using energy from ATP; e.g synthatases;

(b) How do inhibitors change the rate of enzyme controlled reactions?

- Inhibitors can be competitive inhibitors; or non-competitive inhibitors;
- A competitive inhibitor has a structure which is sufficiently similar to that of the normal substrate; and therefore it binds into the active site of the enzyme preventing the normal substrate from doing so; and thus no enzyme-substrate complex is formed; Rate of the reaction reduces; But increase in concentration of the substrate increases the reaction rate;
- A non-competitive inhibitor has a structure which is different from that of the normal substrate; and binds at any site on the enzyme away from

the active site; It distorts the structure of the enzyme and its active site; an enzyme-substrate complex is not formed; and the rate of the reaction reduces;

14. (a) What is enzyme inhibition? (02 marks)

- This is the decrease in the rate of an enzyme controlled reaction; when small substances called inhibitors bind to the enzyme;

(b) Explain how competitive and non-competitive inhibition of enzymes occur. (08 marks)

- Competitive inhibition occurs when the inhibitor molecule has a structure which is sufficiently similar to that of the normal substrate; The inhibitor binds into the active site of the enzyme; preventing the normal substrate from doing so; that is, the inhibitor molecule and the substrate compete for the active site of the enzyme; An enzyme-substrate complex is not formed; and the rate of the reaction decreases; This can be reversed by increasing the substrate concentration;
- In non-competitive inhibition, the structure of the inhibitor molecule is not similar to that of the substrate; and binds to the enzyme at a site other than the active site; The structure of the enzyme and the shape of the active site are altered; the enzyme-substrate complex is not formed; and the rate of reaction reduces; It can be reversible if the inhibitor binds loosely to the enzyme or irreversible if the inhibitor binds permanently to the enzyme;

(c) What is the importance of enzyme inhibition in enzyme catalyzed reactions? (06 marks)

- Regulation of metabolism; e.g end-product inhibition of allosteric enzymes;
- Applied drugs as a mechanism of action; eg sulphonamides are competitive inhibitors in bacteria;
- Applied in respiratory poisons; e,g cyanide which inhibits cytochrome oxidase;
- Controls enzyme activity;
- Applied in insecticides as a mechanism of action; e.g organophosphates are non-competitive irreversible inhibitors;

15. Explain how the following factors affect enzyme activity.

(a) Substrate concentration. (07 marks)

- At low substrate concentration, the rate of enzyme activity is low; because most of the active sites of the enzymes are unoccupied; Increasing the substrate concentration increases the rate of enzyme

activity; because the enzyme-substrate interactions increase; The rate of enzyme activity increases with increasing substrate concentration up to a certain point beyond which any further increase in substrate concentration produces no significant change in enzyme activity; because at this point all the active sites of the enzymes are saturated; so any extra substrate has to wait until the products are released from the enzyme's active site;

(b) Temperature. **(10 marks)**

Below the optimum temperature, increase in temperature increases enzyme activity; because increase in temperature increases the kinetic energy of the enzyme and substrate molecules; thereby increasing their chances of collision; leading to formation of more enzyme-substrate complexes; and hence products;

Above the optimum temperature, increase in temperature decreases enzyme activity; because the bonds that maintain the 3-dimensional shape of the enzyme are broken; causing the shape of the active site to change; so that substrates no longer fit into; and hence no enzyme-substrate complex can be formed;

(c) pH. **(06 marks)**

- Provided the substrate concentration is maintained at a high level and the temperature is kept constant, an enzyme works efficiently over a particular narrow pH range; When the pH is altered above or below the optimum pH for maximum activity of the enzyme; the rate of enzyme activity decreases; This is because changes in pH alter the ionic charge of the acidic and basic groups of the enzyme; thereby disrupting the ionic bonding; which maintains the three-dimensional shape of the enzyme;

16. (a) Explain how an end-product inhibition in an enzyme controlled reaction is a negative feedback. **(07 marks)**

- The end-product itself acts as an allosteric inhibitor in a given metabolic pathway; When the end-product is in excess; it inhibits one of the enzymes responsible for its own production; by changing the shape of the enzyme such that the substrate no longer fits into the active site; thereby slowing down or stopping the formation of further end-product; hence negative feedback;

(b) Explain the effect of substrate concentration on;

(i) competitive inhibition. (02 marks)

- Increase in substrate concentration increases the rate of the reaction; because the substrate outcompetes the inhibitor for the active site of the enzyme;

(ii) non-competitive inhibition. (02 marks)

- Increase in substrate concentration has no effect on the rate of the reaction; because the substrate and the inhibitor do not compete for the active site of the enzyme;

(c) Explain the role of the active site of an enzyme in enzyme specificity. (02 marks)

- The active site has a precise shape into which only the substrate with the complementary shape fits exactly; preventing other substrates from binding to the enzyme;

17. (a) Define the term enzyme cofactor. (02 marks)

- An enzyme cofactor is a non-protein substance which enables the enzyme to work efficiently;

(b) Giving examples, explain the different types of enzyme cofactors. (09marks)

- Inorganic ions; mould the shape of the enzyme or its active site such that an enzyme-substrate complex can be formed; for example salivary amylase works efficiently in presence of chloride ions;
- Prosthetic group; non-protein organic molecule that binds permanently to the enzyme aiding it's catalytic activity; for example haem, FAD;
- Coenzyme; non-protein molecule which binds loosely to the enzyme aiding its catalytic activity; for example NAD, coenzyme A, ATP;

18. (a) Describe the structure of a nucleotide. (07 marks)

A nucleotide consists of a pentose sugar; a nitrogenous base; and phosphoric acid linked together; The nitrogenous base is linked to carbon atom number 1; and phosphoric acid to carbon atom number 5 of the pentose sugar; The pentose sugar is either ribose or deoxyribose; The nitrogenous base is either adenine, thymine, cytosine, guanine or uracil;

(b) How is a polynucleotide formed from nucleotides?(08 marks)

- The phosphate group of one nucleotide; condenses; with the pentose sugar of another nucleotide; forming a dinucleotide; with formation of a phosphodiester bond; The dinucleotide formed has a free phosphate

group at one end; and a free pentose sugar at the other end; and therefore further condensation can occur between the dinucleotide and several other nucleotides; forming a polynucleotide;

19. (a) Describe the structure of DNA.(10 marks)

DNA consists of two polynucleotide chains; Each chain forms a right-handed helical spiral; and the two chains coil around each other to form a double helix; The two chains run in opposite directions, that is, are anti-parallel; Each chain has a sugar-phosphate backbone; with nitrogenous bases which project from it at right angles; and form hydrogen bonds with complementary bases of the opposite chain; Adenine hydrogen bonds with thymine; while cytosine hydrogen bonds with guanine; The distance between the two sugar-phosphate backbones is constant;

(b) How is DNA suited for its functions?(10 marks)

- Sugar-phosphate backbone is held by strong phosphodiester bonds; giving the molecule stability;
- DNA coils up into a double helix; making it more compact to fit in a small volume of the nucleus;
- The hydrogen bonds between the complementary base pairs are weak; therefore can be broken to separate the two strands during transcription and DNA replication;
- Complementary base-pairing; enables accurate replication and hence ensures that DNA remains in the same form from one generation to another;
- DNA is metabolically stable; therefore it cannot be degraded in the cells allowing it to remain the same throughout the lifetime of an individual until it is inherited;
- DNA is a very long molecule; and thus stores a lot of information.
- The two strands of DNA are antiparallel; which enables the nitrogenous bases to project towards each other for complementary base pairing;
- The sugar-phosphate backbones form a double helix; which protects the bases against any form of damage;

20. (a) DNA replication is a semi-conservative process. What does this mean? (02 marks)

It means that each newly synthesized DNA molecule retains one of the two strands in the parent DNA molecule.

(b) Describe the process of DNA replication. (12 marks)

DNA replication starts with the unwinding of the DNA double helix, catalyzed by enzyme helicase forming single strands of DNA which then act as templates for the synthesis of new DNA double helices. Enzyme DNA polymerase binds to each strand and starts to move along it. Every time it meets the next base on the DNA strand, free nucleotides approach and the one with the correct complementary base hydrogen bonds with the base in the DNA strand. The free nucleotide is held in position by this enzyme until it bonds with the preceding nucleotide. The enzyme continues to move along the strand one base at a time with the new DNA strand growing as it does so. Since the enzyme moves in only the 5′ ——→ 3′ direction, the leading strand is copied/replicated continuously while the lagging strand is copied/replicated discontinuously leaving small gaps in the newly synthesized strand which are closed by enzyme DNA ligase.

21. (a) Distinguish between a codon and genetic code. (04 marks)

A codon is a triplet of bases in a mRNA molecule; that codes for an amino acid in a polypeptide; while genetic code is a triplet of bases in a DNA molecule; that codes for an amino acid in a polypeptide;

(b) Explain the characteristic features of the genetic code. (10 marks)

- It is a triplet code; a sequence of three bases in DNA codes for one amino acid in a polypeptide;
- It is degenerate; an amino acid can be coded for by more than one triplet of bases;
- It is universal; the same triplets of bases code for the same amino acids in all organisms;
- It is non-overlapping; no base of a given triplet code contributes to the adjacent triplet code;
- It is punctuated; it has some triplets of bases that do not code for amino acids and thus mark the end point of a gene; and also has triplets of bases which code for amino acids that initiate a polypeptide chain;

(c)Describe the role of mRNA in protein synthesis. (05 marks)

mRNA carries genetic information for protein synthesis; from the DNA in the nucleus to the ribosome in the cytoplasm; It carries this information in form of a sequence of bases; which is complementary to that of the section of the DNA from which it is transcribed; In the cytoplasm, mRNA

acts as a template for protein synthesis; the sequence of bases in mRNA is translated into a polypeptide chain in the ribosome;

22. (a) Explain what is meant by the following terms.

(i) Transcription. (02 marks)

Transcription is the process by which the base sequence of a section of DNA representing a gene is converted into a complementary base sequence of mRNA.

(ii) Translation. (02 marks)

Translation is the process by which a sequence of bases in a mRNA molecule is converted into a sequence of amino acids in a polypeptide chain.

(b) Describe the series of events leading to formation of mRNA in a cell. (08 marks)

mRNA is formed in a cell by a process called transcription;
In the presence of enzyme RNA polymerase, a section of DNA unwinds by breakage of hydrogen bonds between complementary base pairs exposing single strands of DNA in that region. One of the strands is selected as the template for the formation of mRNA. Free nucleotides line up opposite the complementary bases on the template DNA strand. AS RNA polymerase moves along the DNA strand, it links these free nucleotides forming mRNA. Once formed, the mRNA molecule peels off its DNA template and moves out of the nucleus through the nuclear pores. RNA polymerase leaves DNA and the unzipped section of DNA zips up again.

23. Compare:

(a) DNA and RNA. (10 marks)

Similarities:

- Both contain nucleotides as building blocks.
- Both are involved in protein synthesis.

Differences:

DNA	RNA
Double stranded polynucleotide;	Single stranded polynucleotide;
Contains deoxyribose;	Contains ribose;
Contains pyrimidine base thymine;	Contains pyrimidine base uracil;
Chemically very stable;	Chemically less stable;
Found in the nucleus;	Found mainly in the cytoplasm;
Has larger molecular mass;	Has smaller molecular;
Exists in one form;	Exists in three forms: tRNA, mRNA, and rRNA;
Ratio of purines to pyrimidines is constant;	Ratio of purines to pyrimidines varies;

(b) Transcription and translation. (07 marks)

Similarities:

- Both involve mRNA;
- Both processes are required in protein synthesis;

Differences:

Transcription	Translation
Leads to formation of mRNA;	Leads to formation of a polypeptide chain;
Occurs in the nucleus;	Occurs in the cytoplasm;
Involves only mRNA;	Involves all the three forms of RNA; tRNA, rRNA and Mrna;
Information is copied from DNA;	Information is copied from mRNA;

24. (a) Describe how mRNA is translated into a polypeptide chain. (09 marks)

mRNA is translated into a polypeptide chain on a ribosome; The first two codons in mRNA enter the ribosome; The first codon binds with the aminoacyl-tRNA molecule having the complementary anticodon and carrying the first amino acid; The second codon then also binds with another aminoacyl-tRNA molecule having the complementary anticodon; The ribosome holds the mRNA, tRNA and the associated enzymes in position until a peptide bond is formed between the adjacent amino acids; Once a new amino acid has been added to the growing polypeptide chain, the ribosome moves one codon along mRNA; The first tRNA molecule attached to the polypeptide now leaves the ribosome and passes back into the cytoplasm to bind with its specific amino acid again; The ribosome continues to read and translate the mRNA code until it meets the stop codons; At this point, the polypeptide chain is terminated and it leaves the ribosome; It can then assume secondary, tertiary or quaternary structure.

(b) Explain the evidences which show that DNA is a hereditary material. (10 marks)

- Metabolic stability of DNA; DNA undergoes little or no alteration in structure and this is important for a material transferring information from one generation to another because if altered, imperfect copies of DNA would be made affecting future generations.

- Constancy of DNA within a cell; the amount of DNA remains constant for all body cells; since the amount of DNA doubles before mitosis.
- Correlation between mutagens and their effects on DNA; mutagens alter the structure of DNA and the characteristics of an organism that can be inherited are also altered.
- Evidence from bacterial transformation; the characteristics of a given bacterial strain can change if it takes up a free DNA molecule from the environment and incorporates it into its DNA; this shows that the new characteristics that the bacterium has acquired are determined by the DNA it took up from the environment.
- Evidence from transduction experiments; Viruses can be used as vectors to transfer a piece of DNA from one bacterium to another; The infected bacterium can acquire characteristics of the donor; indicating that DNA is responsible for these changes.

!11NICE READING!!!