LIPIDS

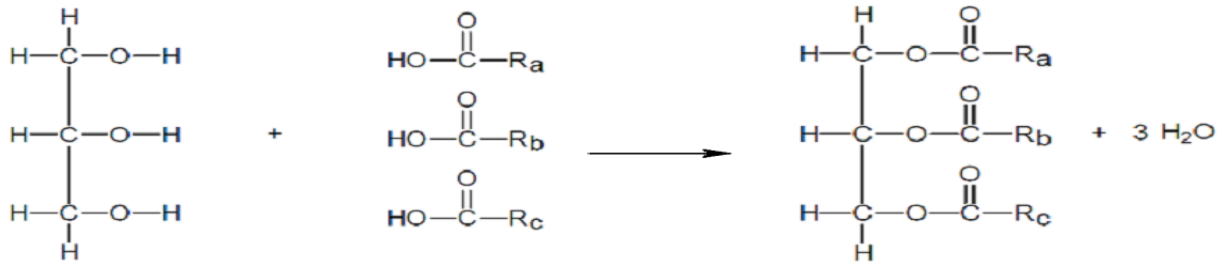
These are organic compounds containing carbon, hydrogen and oxygen but the proportion of oxygen is smaller than in carbohydrates hence they are more reduced than the carbohydrates.

Lipids are insoluble in water.

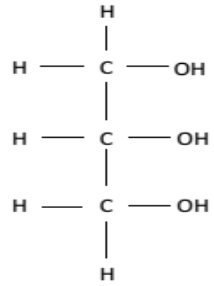
They are of two types i.e. fats and oils. Fats are solid at room temperature while oils are liquids at room temperature.

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.

Formation of a triglyceride



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.

(Leave 8 lines for the answer)

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.

The chain may possess one or more double bonds 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. Serotic acid	$C_{25}H_{51}COOH$	Saturated	Wood oil
6. Arachidic acid	$C_{19}H_{39}COOH$	Saturated	P.nut oil

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

The hydrocarbon chains of the fatty acid may be very long forming long tails which extend from the glycerol molecules. These tails are hydrophobic (water repelling) hence making lipids insoluble in water.

PHOSPHOLIPIDS

These are lipids in which one of the fatty acid groups is replaced by phosphoric acid.

CH_2O-OC-fatty acid

CHO-OC-fatty acid

CH_2O- phosphoric acid

Phosphoric acid is hydrophilic in contrast to the remainder of the molecule, having an end attracting water while the other end repelling it, ie hydrophobic. This gives the phospholipid its characteristics as one the components of the cell membrane.

Explain the suitability of phospholipids as a component of the cell membrane.

WAXES

These are formed by combination of fatty acids with an alcohol other than glycerol. Their major function is water proofing in plants and animals. They are also storage compounds in seeds e.g. castor oil seeds.

STEROIDS

These are related to lipids ie they are lipid derrivatives. e.g. cholesterol in animals used to synthesize sex hormones. Other steroids include vitamin B and bile acids.

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 components 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) The emulsion test:

The reagents used are ethanol and water.

Procedure	Observation	Deduction
To 1 cc of food solution, add 1 cc of ethanol followed by 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	Lipids absent.

	solution.	

b) 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 carbon, hydrogen and Oxygen, they always contain Nitrogen, usually Sulphur and sometimes Phosphorus.

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.

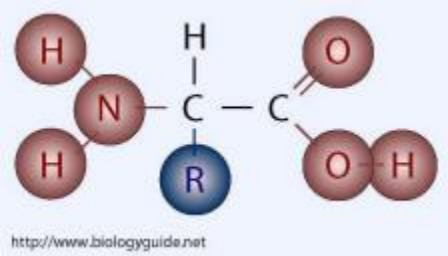
Proteins are not stored in the organism except in eggs and seeds where they are used to form new tissues.

Their building blocks are the amino acids.

AMINO ACIDS

These are about 20 amino acids occuring 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 an amino acid

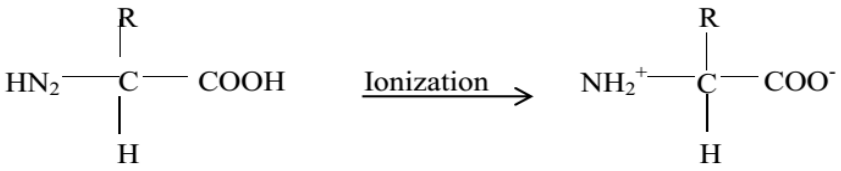


Where R is a variable

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

The carboxyl end (COOH) of the amino acid is acidic in nature. It ionizes in water to give the hydrogen ion making one end negatively charged.

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



Zwitterion (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 showing both basic and acidic properties, hence it is 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 zwitterion. This pH is called the **isoelectric point** of an amino acid.

(**leave 8 lines**)

If the pH falls below the isoelectric point i.e. the solution becomes more acidic, hydrogen ions are taken up by the carboxyl ion. This reduces the concentration of hydrogen ions in solution making the solution less acidic and the amino acid gains an overall positive charge.

If the pH rises above the isoelectric point i.e. it becomes less acidic or more alkaline, hydrogen ions are lost by the amino group. This increases the concentration of free hydrogen ions 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:H*ow do amino acids act as buffer solutions?*

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
- Proline
- Phenylalanine
- Valine
- Arginine
- lysine
- Methionine
- Tryptophan

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
- 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 acids.

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 bonds which occur between the various amino acids in the chain. These bonds include:

1. Disulphide bonds formed between sulphur containing groups on any two cysteine molecules.
2. Ionic bonds formed between the amino ions (NH_3^+) and carboxyl ions (COO^-).
3. Hydrophobic interactions which are interactions between non polar R groups which cause the proteins to fold as hydrophobic side groups.

The polypeptide chain showing 3 types of bonding

(Leave 8 lines)

PROTEIN STRUCTURES

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

Primary structure

It is a sequence of amino acids in a polypeptide chain. The sequence dictates the biological role of the protein. It is strictly determined by the sequence of bases in the DNA molecule.

Secondary structure

It refers to the helical coiling of the polypeptide chains. It is maintained by many hydrogen bonds formed between the oxygen and hydrogen atoms of the neighbouring COO^- and NH_3^+ groups.

Such structures are found in hair, wool, vertebrate skins, horns, nails, claws, beaks and feathers.

Its hardness and stretch ability vary with a degree of cross linkage between di sulphide bridges and neighbouring chains. They are joined together by hydrogen bonds between adjacent chains.

Tertiary structures

It refers to the way in which the helically coiled chains are folded. This is determined by interactions between R groups, rather than interactions between backbone constituents. The polypeptide chains bend and fold extensively forming a precise, compact globular shape. These interactions between R groups include hydrogen bonds, ionic bonds, hydrophobic interactions, and van der Waals interactions. Strong covalent bonds called disulfide bridges may reinforce the protein's conformation.

The hydrophobic interactions are quantitatively the most important and occur when a protein folds so as 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 held together and associate with non-protein parts to form complex conjugated proteins e.g. in haemoglobin.

TYPES OF PROTEINS

a) Classification according to structure

1. Fibrous proteins

These form long parallel unbranched polypeptide chains crosslinked at intervals forming long fibres or sheets.

They are physically tough and insoluble in water.

The secondary structure is the most important with little or no tertiary structure.

They perform structural functions in cells of organisms eg collagen (in tendons, bone, connective tissues), myosin (in muscles), keratin (in hair, nails, feathers, horns) and silk (in spider webs)

2. Globular proteins

Their polypeptide chains are tightly folded to form a spherical shape.

They have a highly irregular sequence of amino acids in their polypeptide chains

They are easily soluble in water and compact.

The tertiary structure is very important.

They have metabolic roles ie they form enzymes eg maltase, antibodies and some hormons like insulin.

3. Intermediate proteins

They are fibrous but soluble eg fibrinogen that forms insoluble fibrin during blood clotting.

Comparison of globular and fibrous proteins

Globular proteins	Fibrous proteins
Soluble in water	Insoluble in water
Have a tertiary structure	Have a secondary structure
No cross linkages	Have cross linkages between adjuscent polypeptide chains
Polypeptide chains are folded in to a spherical shape	Polypeptide chains form long parallel sheets / strands
Have metabolic roles	Have structural roles

Have irregular amino acid sequences	Have repetitive regular sequences of amino acids
Relatively unstable structure	Stable structure
Length of the chain is always identical in two examples of the same protein	Length of the chain may vary in two examples of the same protein

b) Classification according to composition

1. Simple proteins

These are proteins with only amino acids in their structure.

2. Conjugated proteins

These are complex compounds consisting of globular proteins and tightly bound to non protein material, called prosthetic group which 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
Nucleoprotein	Ribosomes	Nucleic acid
Lipo protein	Membranes	Lipids

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

i) Some proteins have structural functions. 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 sugar levels in blood.
iv) Some proteins functions as respiratory pigments. These are globular proteins soluble in water 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, soluble in water 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, soluble in water e.g. antibodies, fibrinogen and thrombin.
vii) Some proteins are contractile. They are fibrous, insoluble in water 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. These are fibrous with a secondary structure and insoluble in water eg albumin in eggwhite. Some are conjugated proteins eg casein in milk.
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.

DENATURATION OF PROTEINS

It is the loss of the three dimensional shape of a protein molecule. The change may be temporary or permanent but the amino acid sequence of the protein (primary structure) remains unaffected. During denaturation, the weak ionic and hydrogen bonds are broken leading to loss of the three dimensional shape. The molecule unfolds and can nolonger perform its biological functions.

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 when boiled. It becomes more fibrous and less soluble.
2. Acids	Additional hydrogen ions in acids combine with COO^- of amino acids and form COOH hence breaking the ionic bonds.	Souring of milk by acid produced by bacteria, lowering the pH, making casein insoluble.
3. Alkalis	Reduced number of hydrogen ions causes NH_3^+ group to loose H^+ to form NH_2 therefore ionic bonds broken.	Souring of milk by alkalis.
4. 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 metal ions
5. Organic chemicals	Organic solvents alter the hydrogen bonds with a protein.	Alcohol denatures certain bacterial proteins hence used as a disinfectant during sterilization.
6. Mechanical force	Physical movement breaks the hydrogen bonds.	On stretching a hair, the hydrogen bonds in the keratin helix is extended and hair stretches.

Renaturation of proteins

This is when a protein spontaneously refolds in to its original structure after denaturation provided conditions are suitable.

Functions of proteins

VITAL ACTIVITY	PROTEIN EXAMPLE	FUNCTION
1. Nutrition	• Digestive enzymes e.g. trypsin, amylase, etc. • Fibrous proteins in granal lamellae • Mucin • Casein • Ovalbumin	• Catalyse hydrolytic reactions in digestion • Arrange chlorophyll molecules to receive unlimited light. • Assists in trapping of food in filter feeders. • Storage of proteins in milk. • Storagr protein in egg white
2. Respiration and transport.	• Haemoglobin. • Myoglobin • Prothrombin and fibrinogen • Antibodies. • Mucin	• Transport of oxygen. • Stores oxygen in muscles. • Required for blood clotting. • Essential for defense. • Keeps respiratory surfaces moist
3. Growth	Hormones e.g. thyroxine	Controls growth and metabolism.
4. Excretion	Enzymes e.g. urease	Catalyze reactions in ornithine cycle and helps in protein break down and urea formation
5. Support and movement	Actin and myosin	Needed for muscle contraction.
	Collagen	Gives strength with flexibility in tendons and cartilage.
	Keratin	Tough for protection e.g. in scales, claws, nails, hooves, etc.
	Scleratin	Provide strength in insect exo-skeleton
6. Sensitivity and co-ordination.	Hormones e.g. insulin and glucagon	Control of blood sugars
	Vasopressin	Control of blood pressure
	Rhodopsin	Visual pigments in retina.
	Phytochromes	Plant pigment important in controlling flowering, germination, etc
7. Reproduction	Hormones e.g. prolactin	Induces milk production in mammals.
	Chromatin	Gives structural support to chromosomes.
		Storage of proteins in seeds which nourishes the embryo.

	Keratin	Forms horns and anthers which are used for sexual display.

ENZYMES

Enzymes are organic catalysts made up of globular proteins, and speed up the rate of chemical reactions but remain unchanged at the end of the reaction.

Classification of enzymes

Enzymes are classified depending on the type of reaction they catalyze ie

1) **Isomerases**
   These reorganize groups within a molecule eg mutases.
2) **Oxidoreductases**
   These transfer oxygen and hydrogen atoms between substances eg oxidases, hydrogenases and dehydrogenases.
3) **Transferases**
   These transfer a chemical group from one substance to another eg transaminases and phosphorylases.
4) **Hydrolases**
   These cause breakdown of substances by addition of water eg peptidases and lipases.
5) **Lyases**
   These catalyse the breakdown of substances without using water eg decarboxylases.
6) **Ligases**
   These form bonds between two molecules using energy in form of Adenosine Tri Phosphate eg synthetases.

Enzyme can also be described as being **intracellular** or **extracellular.** Intracellular enzymes are those which catalyze reactions inside the cells producing them, e.g. all enzymes involved in respiration and photosynthesis.
Extracellular enzymes are those produced by a cell to catalyze reactions outside that cell eg all digestive enzymes in man are extracellular.

Importance of enzymes

The rate at which some reactions occur in the body without enzymes is too slow to sustain life. Enzymes therefore

1. speed up the rate of the reaction without changing the product formed and the nature of reaction
2. They also control metabolic processes hence promoting normal body functions.

NB: The sum / total of all chemical reactions occurring in cells is known as **metabolism.**

Types of metabolism

1. **Catabolism**

These are chemical reactions that involve breakdown of molecules and usually release energy.

2. Anabolism

These are chemical reactions that involve the synthesis of molecules and usually require energy.

ENZYMES AND ACTIVATION ENERGY

Activation energy is the little energy that must be put in to get the reaction started. It is also the energy needed to make substances react.

Enzymes lower the activation energy required for a reaction to take place. They therefore speed up the overall rate of reaction.

A graph showing the activation energy of an enzyme catalyzed reaction

(Get graph from Biological Science pg 117**)**

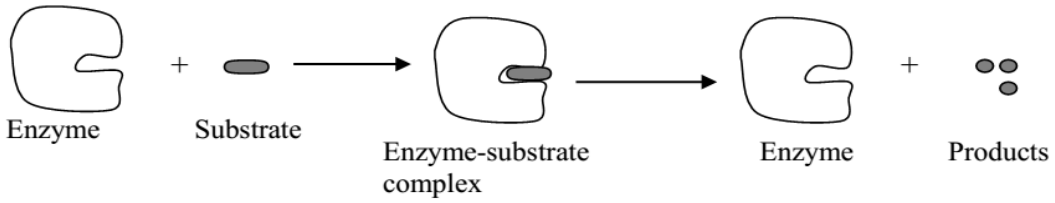
Mechanism of Enzyme action

Enzymes are specific in action. Each enzyme has active sites on their surface membrane in to which the substrate fits to form an enzyme substrate complex.

The substrate has a surface configuration complementary to the active sites of the enzymes enabling it to fit in to the enzyme the way a key fits in to the lock thus the lock and key mechanism of enzyme action.

Once the enzyme substrate complex is formed, the substrate then breaks down in to products that leave the active sites of the enzyme making the enzyme free to catalyse another reaction.

Diagram showing the lock and key mechanism



It is believed that when a substrate combines with the enzyme, it causes a small change to occur in the shape of the enzyme's active sites thereby enabling the substrate to fit more in the active sites of the enzymes. This is known as induced fit.

Enzyme inhibition

Enzymes are inactivated by substrates called inhibitors which interfere with catalytic processes reducing the rate of enzyme catalyzed reactions.

Types of enzyme Inhibition

1. **Competitive inhibition**

It occurs when a compound has a structure that is sufficiently similar to that of the normal substrate and fits in to the active site of the enzyme forming an enzyme inhibitor complex. It prevents the true substrate from fitting in to the active sites of the enzymes thus the genuine substrate and the inhibitor competes for a position in the active site.
When the substrate concentration is increased, the rate of reaction increases.
(Leave 10 lines for a drawing from understanding Biology pg 39)

2. Non competitive Inhibition

This occurs when the inhibitor with no structural similarity to the substrate combines with the enzyme at a point other than the active site. This alters the shape of the enzyme molecule in a way that the active site can nolonger allow the substrate to fit properly.
Since the substarte and inhibitor attach at different parts of the enzyme, they are not competing for the same active sites hence non competitive inhibition.
An increase in substrate concentration will not reduce the effect of the inhibitor.
Non competitive inhibition can be reversible if the enzyme attains its original shape after the inhibitor has left the enzyme molecule, or can be irreversible if the enzyme remains with the distorted shape since the inhibitor doesn't leave the enzyme.
Leave 10 lines for a drawing from understanding Biology)

Allosteric enzymes

These are enzymes that occur in two forms, i.e. active and inactive. They change shape. They are regulated by compounds which bind to the the enzyme's specific sites called allosteric sites, away from the active sites. These compounds modify the enzyme's activity by causing a reversible change in the structure of the enzyme's active sites. This in turn affects the ability of the substrate to bind to the enzymes. Inhibitors of this nature are called allosteric inhibitors.
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.

End-product inhibition (**negative feedback inhibition**).

This is the type of inhibition where the end-product of the reaction pathway inhibits some of the enzymes in the whole process. The end product of a metabolic pathway accumulates and allosterically inhibits some of the enzyme controlling the first step of the pathway. Therefore, the product switches off its own production as it builds up. As the product is used up, its production is switched back on again. This is an example of a **negative feedback** mechanism.

Ilustration of end-product inhibition

(Leave 8 lines for diagram from Biological science page 125)

Application of enzyme inhibition

1. Inhibitors can be used as drugs to reduce the rate at which undesirable reactions occur in the human body. Inhibiting such reactions is one of the ways of treating some forms of cancer.

Enzyme Co-factors

A co factor is a non protein substance which is essential for enzymes to function efficiently. They are of three types ie

1. Activators

These are inorganic ions that mould either the enzyme or substrate to have a shape that allows the enzyme substrate complex to be formed. eg thrombokinase which converts prothrombin to thrombin during blood clotting is activated by calcium ions.

Salivary amylase requires the presence of chloride ions to effectively catalyse the breakdown of starch to maltose.

2. Co-enzymes

These are non protein organic substances essential for proper functioning of some enzymes but are not bound to the enzyme eg Nicotinamide Adenine Dinucleotide (NAD) is a coenzyme to hydrogenases since it is a hydrogen acceptor. Others include FAD.

3. Prosthetic groups

These are organic molecules that are essential for proper functioning of some enzymes but are bound to the enzyme itself. eg haem containing iron is a prosthetic group for cytochrome oxidase.

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.
7) They are inactivated by low temperatures.
8) They work best in narrow temperature ranges.
9) They are inhibited by inhibitor chemicals (poisons e.g. cyanide).
10) Their activity can be enhanced by enzyme activators e.g. chloride ions activate amylase.
11) They work at a specific PH.
12) Their reactions are reversible.

FACTORS AFFECTING ENZYME ACTIVITIES

i) Temperature
ii) Substrate concentration

iii) PH of the medium
iv) Presence of activators
v) Presence of inhibitors
vi) Enzyme concentration

1. Concentration of substrate:

A substrate is a substance (food) acted upon by the enzyme to form simpler products.

The rate of enzyme reaction increases with increase in substrate concentration up to a point when further increase in substrate concentration causes no significant change in the reaction rate. This is because at high substrate concentration, all the active sites of the enzymes are saturated. At this point, the enzyme concentration is the limiting factor.

A graph showing how the rate of reaction varies with substrate concentration

Leave 9 lines for a graph from Understanding Biology pg 38

2. Enzyme concentration:

Provided the substrate concentration is maintained at a high level, the rate of reaction increases with increase in enzyme concentration.

A graph showing how the rate of reaction varies with enzyme concentration

Leave 9 lines for a graph from Understanding Biology pg 37

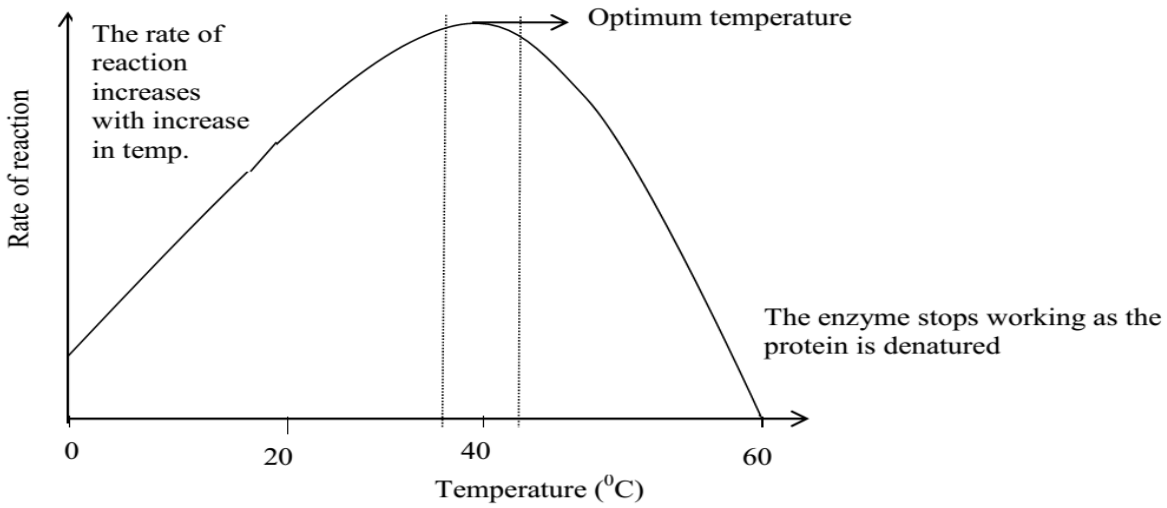
NB: The number of substrate molecules which an enzyme can act upon in a given time is called its ***Turn Over Number.***

3. Temperature:

Enzymes work best at optimum temperature. At very low temperatures, the rate of enzyme reaction is very slow because the enzyme is inactive.

As the temperatures increase, the rate of reaction also increases gradually until it attains a peak where it has maximum activity and this always corresponds to optimum temperatures. An optimum temperature is which promotes maximum enzyme activity. However with further increase in temperature, the rate of reaction decreases rapidly since at high temperatures, the enzymes are denatured ie the active sites of the enzyme which is protein in nature, are altered or changed.

A graph showing the variation of enzyme activity with temperature



4. PH of the medium.

Every enzyme functions most efficiently over a particular pH range. Some work best in a low pH (acidic) while others in a neutral pH and others in a high pH (Alkaline)

A graph showing variation of different enzyme activity with PH

Leave 9 lines for a graph from Understanding Biology pg 39

5. Presence of enzyme inhibitors

Enzyme activities decrease in presence of enzyme inhibitors and increase in their absence.

6. Presence of activators

Enzyme activities increase with presence of enzyme activators and decrease with absence of enzyme activators.

Commercial application of enzymes

1. Used in biological washing powders. The powders usually contain proteases which remove food stains such as food, blood, allergens and bacteria.
2. Used in meat tenderizers to soften meat.
3. α-amylase is used in baking industry.
4. Used in sweeteners. Glucose isomerase is used to make the soft drinks and cakes taste sweet.
5. Many are used in industry to make cheese and other dairy products.
6. Used in photographic industry. Protease is used to digest the protein coat on the film when developing the image.
7. Used in paper in paper industry. Amylase is used to remove starch from the raw materials.

NUCLEIC ACIDS

These are made up of chains of individual units called nucleotides. There are two types of nucleic acids i.e.

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

The Nucleic Acid structure

Each Nucleic acid is made up of repeating sub units of nucleotides. Each nucleotide is made up of three subunits ie

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

1. NITROGENOUS BASES

These are organic bases having rings containing both carbon and nitrogen atoms.

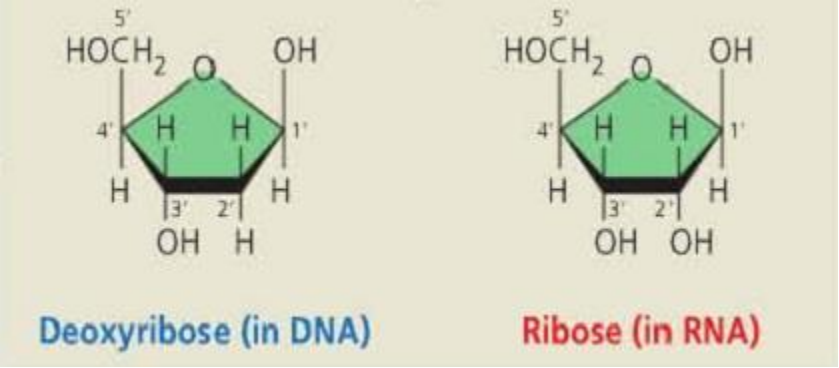
The purines i.e. Adenine (A) and Guanine (G) are made up of two interconnecting rings while the pyrimidines i.e. Uracil (U), Cytosine (C) and Thymine (T) possess a single ring.

Structure of a pyrimidine Structure of a purine

(Leave 8 lines)

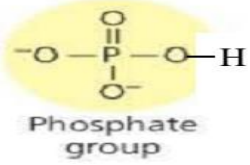
2. THE PENTOSE SUGAR UNITS

These include ribose and deoxyribose. They differ in that ribose sugars contain an additional oxygen atom.

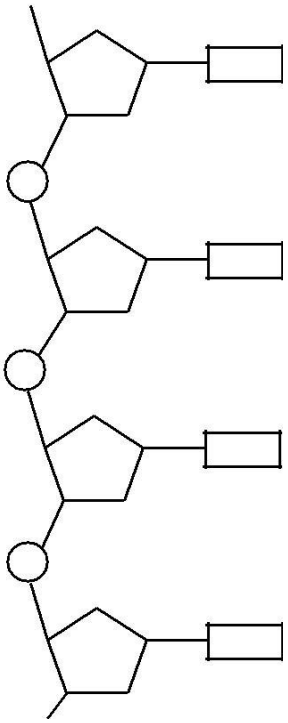


3. PHOSPHATE UNITS

These are alpha links between one sugar group and the next.



The three groups are linked together in a specific way to make a nucleotide. Several 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 uracil (pyrimidines).

The base uracil is found exclusively in RNA. RNA chains exist as single strands.

Types of RNA

i) Messenger RNA (mRNA)

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

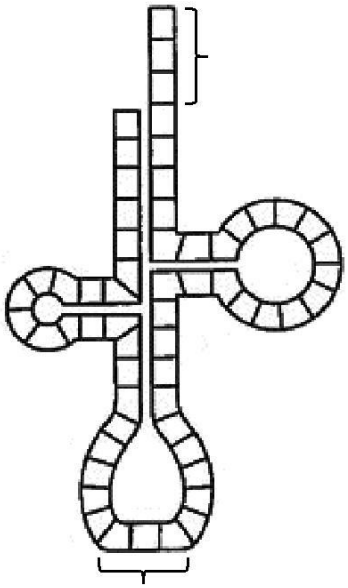
It is single stranded and forms 3-5% of the total RNA in the cell. mRNA is synthesized in the nucleus from a DNA template, a process called transcription. After synthesis, the mRNA strand then moves through the nuclear pores of the nuclear membrane to the cytoplasm.

ii) Transfer RNA (tRNA)

It forms about 15% of the total RNA. There is about 20 types of tRNA each coding for a particular amino acid. Its function is to pick up amino acids from the amino acid pool and deliver them to the site of protein synthesis i.e. on the ribosomes for alignment into polypeptides.

A tRNA molecule has a trifoliate leaf shape with the site of attachment of the amino acid at one end and anticodons at the other end. The anticodons determine the type of amino acid carried by the tRNA.

Structure of tRNA



iii) Ribosomal RNA (rRNA)

It is the most abundant in the cell forming 80% of the total RNA. It is associated with ribosomes in the cytoplasm. It translates the sequence of amino acids into a polypeptide chain in the cytoplasm.

DEOXYRIBO NUCLEIC ACID

It is made up of long chains of nucleotides with deoxyribose as the pentose sugar and bases ie Adenine and Guanine (purines) with Cytosine and thymine (pyrimidines). It has a very high molecular weight because its chains are double stranded being linked 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 links with a pyrimidine. In this case, adenine bonds with thymine while guanine bonds with cytosine.

DNA is of one type and found in the nucleus.

Structure of the DNA according to Watson and Crick

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.

Each chain has a sugar – phosphate back bone with bases which project at right angles and the hydrogen bonds between the bases of the opposite chains across the double helix.

The chains run in opposite directions ie they are anti parallel.

The width between the backbones is constant and equal to the width of a base pair ie width of a purine and a pyrimidine.

A purine of one chain links with a pyrimidine of another chain ie Adenine links with Thymine while guanine links with Cytosine.

(Leave ¾ a page for drawings from Biological Science page 109)

Phosphorylated nucleotides

These are nucleotides with additional phosphate groups. The addition of a phosphate group to an organic molecule increases the reactivity of that molecule. eg Adenosine Tri Phosphate (ATP) which has two extra phosphate groups linked to the molecule by high energy bonds hence an energy carrier during several reactions.

Structure of ATP

(leave 6 lines for a drawing from Biological Science page 127**)**

Other important nucleotides

1. Nicotinamide Adenine Dinucleotide (NAD): It is a hydrogen carrier during respiration.
2. Flavine Adenine Dinucleotide (FAD): It is also a hydrogen carrier in respiration.
3. Co-enzyme A: It is an acetyl carrier during respiration.

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.

Differences between RNA and DNA

RNA	DNA
It is a single polynucleotide chain	It is a double polynucleotide chain
Smaller molecular mass	Larger molecular mass
May have a single or double helix	Always a double helix
Pentose sugar is ribose	Pentose sugar is deoxyribose

Organic bases present are Adenine, Guanine, Cytosine and Uracil	Organic bases present are Adenine, Guanine, Cytosine and Thymine
The ratio of Adenine and Uracil to Cytosine and Guanine varies	The ratio of Adenine and Thymine to Cytosine and Guanine is one
Manufactured in the nucleus but found throughout the cell	Found almost entirely in the nucleus
Amount varies from cell to cell (and within the cell according to metabolic activity)	Amount is constant for all cells of a species (except gametes and spores)
Chemically less stable	Chemically very stable
May be temporary existing for a short period only	It is permanent
Three basic forms ie messenger, transfer and ribosomal	Only one basic form but with an infinite variety within that form

PROTEIN SYNTHESIS

This is the process by which proteins are manufactured within the cells of an organism.It requires the supply of amino acids, energy and information. It occurs in three stages i.e.

1. Transcription
2. Amino acid Activation
3. Translation

Transcription

It is a process by which the base sequence of a section of DNA representing a gene (cistron) is converted in to a complementary base sequence of mRNA and transferred to the cytoplasm. It occurs in the nucleus.

The process is initiated by RNA polymerase enzyme attaching at the start codon of the coding strand of the DNA molecule.

This causes the hydrogen bonds between the DNA strands in the region to be coded to break and the DNA double helix unwinds.

One DNA strand ie the template / coding strand is coded as RNA polymerase enzyme moves along it, catalyzing the synthesis of messenger RNA with a base sequence complementary to that of the DNA coding strand, until the enzyme reaches the stop codon.

Once formed, Messenger RNA strips off the DNA strand and passes out of the nucleus through the nuclear pores of the nuclear membrane to the cytoplasm.

The DNA molecule then winds up again reforming a double helix.

Amino acid activation

It occurs in the cytoplasm of the cell.

Amino acids bind to specific tRNA molecules using energy from ATP hydrolysis in presence of Aminoacyl synthetase enzyme forming a tRNA – amino acid complex with a specific anticodon.

(Leave 7 lines for an illustration)

Translation

This is the mechanism by which the sequence of mRNA molecules is converted in to a sequence of amino acids in a polypeptide chain. It occurs on the ribosomes.

The first two mRNA codons enter in to the ribosomes. The first (initiator) codon then binds to the anticodon of the tRNA amino acid complex carrying the first amino acid of the polypeptide chain.

The second codon attracts the second tRNA amino acid complex carrying a complementary amino acid anticodon. A dipeptide bond is then formed between the two adjacent amino acids, along the mRNA.

The ribosome thus provides a frame work holding in position mRNA, tRNA amino acid complex and associated enzymes.

The tRNA molecule which was previously attached to the polypeptide chain strips off, leaves the ribosome and passes back to the cytoplasm for further activation.

The ribosome moves along the mRNA attracting the next amino acid to be added to the polypeptide chain.

This process continues until the stop or terminator codon is reached. The polypeptide chain then leaves the ribosome to the cytoplasm.

Many ribosomes attach on a single mRNA molecule, forming a polysome. This allows several polypeptides to be synthesized at the same time from a single mRNA molecule.

The polypeptide chains are then constructed in to proteins.

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 from one mRNA molecule.

Questions:

1. *How does DNA regulate the synthesis of proteins in a cell?*
2. *Outline the role played by the different types of RNA in protein synthesis.*
3. *Describe the process by which proteins are synthesized in a cell.*

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 features that can improve lineage 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.
vi) It should not be metabolically active.

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, they are metabolically active and not self-replicating.

Friedrich later eliminated proteins as the best candidates 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

1. 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.The gamete nuclei contain half the quantity as expected.
2. DNA remains stable and intact as a large molecule.
3. DNA is not metabolized at any stage.
4. DNA has the capacity to mutate. Mutagens like U.V. light bring about changes in the DNA molecule which form a basis for new material of inheritance. Mutation is however limited and does not change the whole organism.
5. Presence of DNA in chromosomes which are the materials of hereditary.
6. Ability of DNA to self replicate.

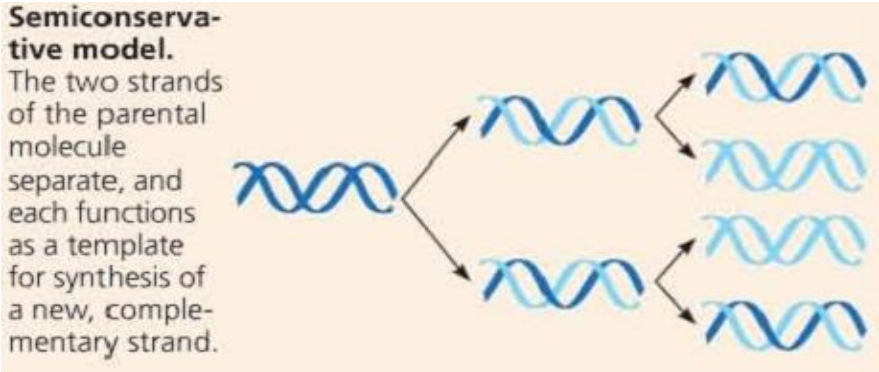
DNA REPLICATION

It is a process by which DNA molecule makes exact copies of its own. It brings about an increase in the amount of DNA before cell division. There are three hypotheses put forward to explain the process of DNA replication ie

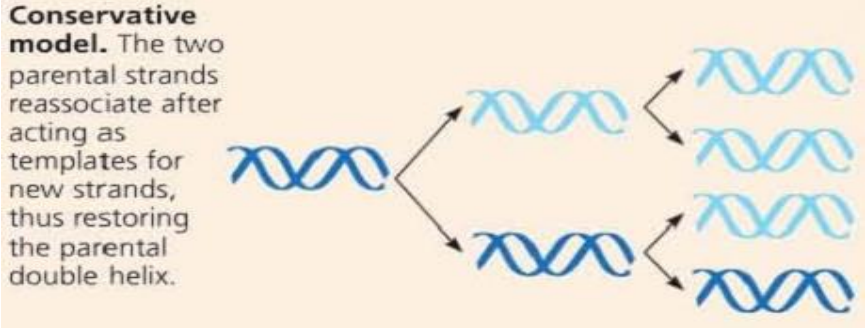
1. The semi-conservative hypothesis

The DNA double helix unwinds in presence of DNA helicase enzyme, and forms two DNA strands. Therefore the parent molecule is a template where by each strand is used to manufacture another complementary strand alongside the parental strand thus one strand is directly conserved and only one new strand is manufactured.
(Leave 10 lines for a diagram illustrating this)

Replication by semi conservative would be too slow due to the length of the DNA chain. Therefore, DNA opens up many replication folks so that replication occurs at all the folks almost concurrently to avoid the slow speed.



2. **The conservative hypothesis**
   No unwinding occurs but the DNA molecule acts as a stimulant to direct the reaction. A new DNA molecule is formed alongside the parental DNA double helix and they are directly similar but not complementary.This hypothesis has not received any scientific backing and appears impractical.



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.

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 ie not enclosed in a nuclear membrane. Simple chromosomes are also found in chloroplasts and 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 these chromosomes is known as nucleoprotein or chromatin.

Proteins in a chromosome

They are called **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.

The genetic code

This refers to the way genetic information is encoded or arranged on the DNA strand. Alot 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 proteins, enzymes, hormones, etc, the code must be read and interpreted correctly and the secret information released and transformed into products.

Reading the code

The DNA with the code is 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 reading and transfer of information from the nucleus to the cytoplasm is done by messenger RNA.

The code dictionary

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 on its own codes for an amino acid, only four amino acids would be coded.If the bases code in pairs, only 16 amino acids would be coded. In both cases, 20 amino acids are not arrived at. Therefore 3 bases are required for coding an amino acid. Hence each amino acid is determined by a triplet base pair. The three base pair hypothesis means that to code for the 20 amino acids occurring in the body, 64 possible combinations exist. Out of the 44 remaining combinations, some are degenerate while others are nonsense codons /stop codons.

General characteristics of the genetic code

1. The code is universal ie same codons are used to specify the same amino acids in all living organisms.
2. The code is degenerate i.e. more than one codon can code for the same amino acid. However, 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.
3. The code is non-ambiguous i.e. not more than one amino acid can be coded for by the same codon.
4. The genetic code is triplet i.e. it has three bases.
5. It is collinear because the sequence of codons on the mRNA corresponds to that of the amino acids in the polypeptide chain.
6. The genetic code is non-over lapping except in some viruses.
7. Some triplets do not code for any amino acids i.e. they punctuate the process of protein synthesis.
8. The genetic code has initiator or start codons and terminator or stop codons.

Gene

It is a basic unit of hereditary located at a gene locus on the chromosome. Genes which code for polypeptides are of two types ie

1) **Structural genes:** These code for functional proteins e.g. enzymes, hormones, antibodies, etc.
2) **Regulatory genes:** These 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.

Question: Explain the one gene one enzyme hypothesis.

END