HUMAN DIGESTIVE SYSTEM

Digestion — Is the breaking of food into small particles.
Nutrition — means feeding.
Food — any substance that a plant or animal can take into its body to help it to grow and
be healthy.
Nutrients — are substances that are found in food.

6. Nutrients found in food

- Carbohydrates
- Proteins
- Lipids
- Vitamins
- Mineral salts
- Water

THE CHEMICAL COMPOSITION OF THE MAIN FOOD SUBSTANCE

1. CARBOHYDRATES

- contain carbon, Hydrogen and Oxygen
- The ratio of Hydrogen to Oxygen in their molecules is 2: 1

i.e. (i) Glucose $C_6H_{12}O_6$
(ii) Maltose $C_{12}H_{22}O_{11}$

- Carbohydrates may be classified into three groups as regards to increasing number of carbon atoms.
- These include
  (i) Monosaccharides
  (ii) Disaccharides
  (iii) Polysaccharides

(I) MONOSACCHARIDES

- These are called simple sugars.
- Complex carbohydrates, proteins as well as fats are made from simple sugars.

Characteristics of Monosaccharides

- Are soluble in water
- Are sweet
- can react with O_2 to release energy

Examples of Monosaccharides are: glucose, fructose and galactose.

(II) DISACCHARIDES

- also called double sugars

- are formed in living cells when two molecules of monosaccharides combine by help of
  enzymes.
- the process of formation of a large molecule of a substance by combining small
  molecules is called **CONDENSATION.**
- After formation of one disaccharide molecule from two molecules of simple sugars, a
  simple molecule of water is released.

Examples of Disaccharides are

Maltose, sucrose and lactose.

- All disaccharides have 12 carbon atoms that is why they are called Double sugars.
- The process of condensation is summarized by the

Chemical Equation.

$C_6H_{12}O_6 + C_6H_{12}O_6 \xrightarrow{\text{enzymes}} C_{12}H_{22}O_{11} + H_2O$

Word Equation

Glucose + Glucose $\xrightarrow{\text{enzymes}}$ Maltose + Water

Characteristics of Disaccharides

- are soluble in water
- are sweeter than simple sugars
- can be hydrolysed into simple sugars

HYDROLYSIS

- the process of converting a large molecule of organic compound into smaller compounds.
- The equation below summarizes the process of hydrolysis of Sucrose and Maltose.

(I) SUCROSE

WORD EQUATION

Sucrose + water $\xrightarrow{\text{enzymes}}$ glucose + fructose

CHEMICAL EQUATION

$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{enzymes}} C_6H_{12}O_6 + C_6H_{12}O_6$

(II) MALTOSE

WORD EQUATION

Maltose + Water $\xrightarrow{\text{enzymes}}$ Glucose + Glucose

CHEMICAL EQUATION

$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{enzymes}} C_6H_{12}O_6 + C_6H_{12}O_6$

NB: Disaccharides can also be hydrolyzed in the laboratory by boiling them with acid.

(III) POLYSACCHARIDES

- These are complex carbohydrates with many monosaccharide molecules joined together
to form one molecule in the process called **CONDENSATION**.

Examples of Polysaccharides

Starch, cellulose and glycogen.

CHARACTERISTICS

- are insoluble in cold water
- are not sweet (sweet less)
- can be crystallized

FUNCTIONS OF CARBOHYDRATES

- they provide energy
- they are used in synthesis of proteins and lipids
- they act as food reserves e.g. starch in plants and glycogen in animals.

2. LIPIDS

- These contain carbon, hydrogen and oxygen elements in their molecules.
- The proportion of oxygen to hydrogen is much smaller than in a molecule of carbohydrates.

TYPES OF LIPIDS

Fats and oils

- Fats are solid and oils are liquid at room temperature.

Examples of Lipids are:

- Natural fats e.g. beef fats and mutton fats with a chemical formula $C_{57}H_{11}O_6$
- Oils e.g. Kazinga, covo e.t.c

NB: Lipids can be splitted into glycerol and fatty acids when acted upon by enzymes as shown:

Lipids + Water $\xrightarrow{\text{enzymes}}$ fatty acids and Glycerol

- The chemical formular for glycerol is $C_3H_8O_3$

Characteristics of Lipids

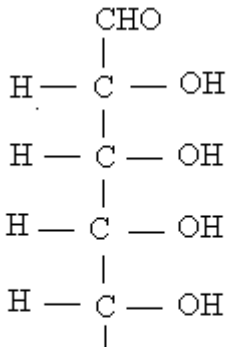
- they are insoluble in water
- they are soluble in alcohol or benzene
- they are a high energy content e.g. 1g of fats gives out 39 kj of energy while 1g of carbohydrates yield 17.6 kj when completely oxidized.
- they make a permanent translucent spot on paper.

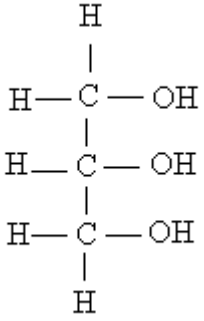
Functions of Lipids

- they make part of protoplasm
- they are food reserves in form of oils e.g. castor oil

Molecular structure of carbohydrates (glucose) and lipids (Glycerol) compared

Glucose ($C_6H_{12}O_6$) and **Glycerol ($C_3H_8O_3$)**





3. PROTEINS

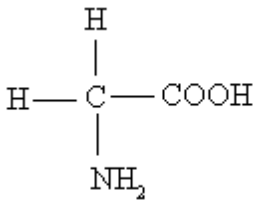
These are also complex compounds which differ from carbohydrates and lipids in that they contain nitrogen in addition to carbon, hydrogen and oxygen found in all other organic compounds. In some proteins sulphur or phosphorus is added.

FORMATION OF PROTEINS

- Proteins are made from **amino acids**.
- Amino acids combine together to form peptides. Peptides combine together to form
  polypeptides, again combine together to form proteins.
- In nature, there are few amino acids out of which a vast number of proteins are formed
  due to:

  - different combinations of amino acids
  - different arrangement of amino acids
  - different quantities of amino acids

- The human body can synthesise amino acids, still it requires other amino acids from
  either plants or animals.
- These additional amino acids are called **ESSENTIAL AMINO ACIDS** because they
  must be present for normal body repair.
- The amino acids consists of two parts:
  - The amino group (-NH2)
  - The acid group (-COOH)
- The chemical formular of the simplest amino acid is CH_2 NH_2 COOH and its molecular formula is



PROPERTIES OF PROTEINS

- do not dissolve in water
- cannot diffuse across cell-membrane because they are large in size.

NB. Only amino acids are soluble in water and are easily used by cells after diffusing
across cell membrane.

FUNCTIONS OF PROTEINS

- used for building up new cell material.
- supply energy during a period of starvation.

FOOD TESTS

1. Starch Test

- Add few drops of diluted iodine solution to the food sample.

Results

The food turns blue-black if it contains starch. If the food does not contain starch it shows brown colour.

2. Test for Sugars

(a) REDUCING SUGAR (Monosaccharides)

- Take small amounts of food samples and dissolve it.
- Take a few cubic centimeters of food solution and add few drops of Benedicts solution
  or (Fehlings A followed by Fehlings B)
- Heat gently for a few minutes.

Results

- The mixture shows a yellow (or orange or brick red) colour if it contains reducing
  sugars.
- If it doesnt contain reducing sugars blue colour of reagent is maintained.

(b) NON — REDUCING SUGARS (Disaccharides)

- Take few cm^3 of the food solution and add a few drops of hydrochloric acid.
- Boil the mixture for a few minutes to hydrolise the disaccharides.
- Add few drops of sodium hydroxide solution to neutralize hydrochloric acid.
- Add few cm^3 of Benedict solution.
- Heat the mixture gently for few minutes.

Results

- The mixture shows yellow or orange or brick red colour if it contains non-reducing sugars.

TEST FOR PROTEINS

- Take few cm^3 of the food solution and mix well with few cm^3 of sodium hydroxide.
- Add few drops of copper sulphate solution and mix well.

Results

- If the food sample has proteins, violet (purple) colour is seen.

NB: Biuret solution or milons reagent can be used instead of the mixture of sodium hydroxide and copper sulphate.

TEST FOR LIPIDS

- Rub the food sample on a piece of filter paper.
- Allow it to dry.

Results

- A translucent permanent spot on the paper is seen if the food sample contains lipids.

Or

- Take few drops of the food sample shake with about $5cm^3$ of ethanol in a dry test tube

until it dissolves.
- Add few cm^3 of water and shake.

Results

- A cloudy white emulsion is formed.

4. VITAMINS

- These are accessory food factors required by the body in small quantities for a variety of
metabolic processes.
- Vitamins have no energy value.
- Most vitamins are acquired by animals from plants.
- some can be synthesized by animals i.e.
(i) Vitamin D (calceferol) is synthesized in the skin by being activated by ultraviolet
rays.
(ii) Vitamin K (menequinone) is synthesized by bacteria in the colon.

The following are some vitamins with their source and functions.

Vitamins	Sources	Functions
A (Retinol) is fat soluble	Eggs, milk, liver, butter, carrots, tomatoes, mangoes etc	- prevents night blindness - protects against softening and ulceration of cornea (prevents total blindness)
B_1, Thiamine (is water soluble)	Whole grain, cereals, peas, beans, fruits, vegetables, milk, nuts, cheese	- catalyses formation of energy rich molecules. - prevents Beriberi if deficient affects nervous system.
B_2. Riboflavin (water soluble)	Liver, milk, eggs, green vegetables	- for cell respiration - prevents eye disorder

B_{12}. (water soluble Cobalamin)	- animal food i.e. liver, dry beans, rape	- for red blood cell formation. Deficiency causes extreme anaemia.
Niacin, Nicotinic Acid (water soluble)	Meat, fish, whole grain cereals, beans and peas.	- Catalyses cell respiration - prevents development of pellagra.
C. Ascorbic Acid (water soluble)	Citrus fruits (i.e. oranges, lemons, tangerines), cabbage, tomato, onions, guavas.	- prevents scurvy - helps the body to resist infections - builds up the living cells of the body e.g. inside the mouth and blood vessels.
D. Calciferol (fat soluble)	Milk, butter, eggs, fish, liver oil, fats in the skin converted by ultraviolet radiation to vitamin D	- Catalyses cell respiration - helps the body to make use of calcium to prevent rickets in young children and osteomalacia in adults.
E. (Tocopherol) is fat Soluble	Green vegetables, seed embryos	- necessary for normal reproduction in rats and other animals except man.
K. (Phylloquinone) (fat soluble)	Cabbages, peas	Needed for blood clotting

5. MINERALS

A. Nitrogen

Sources : Lean meat, fish, eggs, milk, beans, peas e.t.c.

Functions : (a) for formation of muscles, hairs, skin and blood
(b) for protein synthesis. Deficiency leads to kwashiorkor.

B. Phosphorus

Sources : Lean meat, fish, eggs, milk, beans, peas e.tc.

Functions :
- Necessary for protein synthesis
- for bone and teeth formation and all tissues above
- Deficiency leads to muscle weakness and bone pains

C. IODINE

Sources : sea fish, cheese, iodized salts

Functions : Helps in formation of thyroxine in the thyroid glands. Deficiency causes
Goiter and reduction in growth.

D. IRON

Sources : Liver, green vegetables, yeast, eggs, kidney.

Functions : - Helps in formation of haemoglobin in red blood cells. Deficiency leads
to anemia with resulting in tiredness and lack of energy.
- Formation of chlorophyll in green plants.

E. CALCIUM

Sources : Milk, cheese, green vegetables, bones of small fish

Functions : - Necessary for muscle contraction
- Necessary for blood clotting
- Formation of bones and teeth

Deficiency of calcium leads to rickets and all orthopedic conditions.

F. SODIUM AND CHLORINE

Sources : Table salts, green vegetables.

Functions : - transmission of nerve impulses
- necessary for body fluids i.e. blood and lymph.
- shortage leads to dehydration and muscle cramp
- too much leads to high blood pressure

G. POTASSIUM

Sources : Potatoes, mushroom, cauliflower, beef, liver, fish.
Functions : - helps in protein synthesis
- helps in nerve impulse transmission

H. FLOURINE

Sources : Drinking water

Functions : prevents dental cavities

6. WATER

- Water has no nutrient value, it contains some minerals. It is taken either as a drink or a component of food.
- It is essential that enough water should be taken for transporting the products of digestion round the body.
- Removal of waste products out of the body.
- Regulating body temperature i.e. water loss through the skin helps to cool the body.
- Encourages chemical reactions in the body since the substances are always in solution form.
- Transporting important chemicals around the body such as oxygen.

7. ROUGHAGES (Dietary Fibre)

Roughages have no nutritional value; however, they are essential part of the diet for the following reasons.

- They stimulate peristalsis in the alimentary canal since they give the food the right consistency.
- They prevent constipation.

NB. Green leafy vegetable are high in fibre content.

A BALANCED DIET

Is the food that provides all food substances in right quantities for good health.

THE HUMAN ALIMENTARY CANAL (GIT)

The alimentary canal is a long hollow muscular tube that runs from the mouth to anus.

FUNCTIONS OF THE ALIMENTARY CANAL

- it is where food is digested.
- it is responsible for absorption of food substances into the blood stream.

GENERAL FEATURES OF THE ALIMENTARY CANAL

- It is supplied with blood and held in position by the **Mesentery vessels**.
- It is controlled by the **autonomic nervous system.**
- It is associated with glands that produce digestive juices containing

enzymes.
- There is wavelike movement along it due to contraction and relaxation of its walls called **peristalsis.**
  - Peristalsis helps in pushing food along the alimentary canal.
- It is lubricated with mucus produced in goblet cells along the alimentary canal.
- The mucus helps the food to slide easily down the canal.

The alimentary canal and the digestive glands form the Digestive system.

DIGESTION

- begins in the mouth and ends in the small intestines.

TWO TYPES OF DIGESTION

A. PHYSICAL DIGESTION

- is the breaking down of large pieces of food into smaller particles by exerting external physical forces.
- this takes place in the mouth by teeth and in the stomach as well as the small intestine (Jejunum where bile mixes with fats) and emulsifies into smaller droplets.
  - The breaking down of large drops of fats into smaller fat droplets is called **EMULSIFICATION.**

ADVANTAGES OF PHYSICAL DIGESTION

(i) makes the food to be in a form which can be easily swallowed.
(ii) increases the surface area of food on which enzymes can act during chemical digestion.

CHEMICAL DIGESTION

This is the breakdown of large food molecules in new and smaller molecules through the action of enzymes.

IMPORTANCE OF CHEMICAL DIGESTION

- Makes food to be in smaller molecules which can be absorbed easily into the blood stream for body use.

The table below summarizes the chemical digestion which takes place in

different regions of the Alimentary canal.

Region of Alimentary Canal	Digestive Gland	Digestive juice produced	Enzymes in the juice	Class of food acted upon	Substances produced
Mouth	Salivary gland	saliva	Salivary amylase (ptyalin)	Cooked starch	Maltose
Stomach	Gastric gland	Gastric juice	Pepsin	proteins	Polypeptides
			Renin	Milk protein	Insoluble casein
Small intestine (i) Duodenum	Pancreas	Pancreatic juice	Trypsin	Polypeptides	Peptides
			Pancreatic amylase	Uncooked cassava/ starch	Maltose
			Lipase	Fats	Fatty acids and Glycerol
(ii) Ileum	Walls of small intestine	Intestinal juice	Maltase	maltose	Glucose
			Sucrase	Sucrose	Glucose and fructose
			Lactase	Lactose (Milk sugar)	Glucose and galactose
			Peptidase	Peptides	Amino Acids

Bile which is produced by the liver is used to breakdown fats into small droplets; emulsification, to increase the surface area for lipase to act on. It is stored in the gall bladder and passes into the duodenum thru the bile duct.

NB. In addition to the digestive enzymes, the digestive juices also contain other substances as listed below.

(a) The saliva - has water and mucus. Water lubricates food while mucus helps to form
the bolus.

(b) The Gastric Juice - contains hydrochloric acid which

- Kills most bacteria, which are swallowed together with food.
- Softens any bone which is swallowed together with food.
- Provides acidic medium for pepsin to work properly.

(c) The walls of the stomach - produces a lot of mucus which protects the stomach from

being damaged by the hydrochloric acid.

ENZYMES

- are biological catalysts which are responsible for chemical reactions in the body.

PROPERTIES OF ENZYMES

- they work best at a certain pH i.e. either acidic or alkaline
- they work best at optimum temperature
- are specific i.e. they work on one type of food only
- all enzymes are proteins or (are protein in nature)

N.B. Digestive enzymes are generally named according to the food they work on. e.g.

(i) Those which catalyse the breakdown of lipids are called **Lipase.**
(ii) Those that act on starch are called **amylases**.
(iii) Those acting on proteins are **proteinases** e.g. pepsin, trypsin e.t.c.
(iv) They are destroyed (denatured) by heating, since they are proteins.
(v) They always form the same end — product or products.

ABSORPTION (in the ileum)

- The absorption of nearly all digested food takes place in the **ileum** by simple **diffusion**
and sometimes by **Active transport**.

ADAPTATION OF SMALL INTESTINES FOR EFFICIENT ABSORPTION

a. it is fairly long — this gives a large surface area for food to be absorbed.
b. they are highly folded; the folds slow down the rate of movement creating more
chance for absorption. Folds give a large surface area on which food is absorbed.
c. in its internal surface there are many finger like projections called villi. These provide
large surface area on which food is absorbed.

Villus structure.

d. Each villus has a dense network of blood capillaries that provide efficient transport of
the absorbed food.

e. the lining epithelium of the villi is very thin. This allows fluids to pass through rapidly.

N.B. A lot of water and mineral salts are absorbed in the colon. Alcohol is absorbed in
the stomach.

PROBLEMS ASSOCIATED WITH THE DIGESTIVE SYSTEM

1. DIARRHOEA

- caused by germs (bacteria and viruses) which irritates the lining of the alimentary canal.

Treatment

- Give Thanzi ORS to patients to replace the lost water, sugar and salts in the body.
- Give antibiotics (e.g. Tetracycline) to the patient

2. CONSTIPATION

- caused by persistent suppression of the reflex defaecation.
- eating over-refined foods which do not have enough fibres.

Prevention

- Eat food with enough roughage to stimulate peristalsis.

3. ULCERS

- caused by too much acid in the stomach.

Prevention

Take anti-acid tablets or drink enough water to neutralise the acid.

4. APPENDICITIS (severe inflammation of appendix)

- caused by germs
- cured by removing the appendix in an operation.

EXPERIMENT

VISKING TUBING AS A MODEL OF PART OF THE SMALL INTESTINE

SMALL INTESTINE

IS VISKING TUBING PERMEABLE TO MOLECULES OF DIFFERENT SIZES?

Procedure

- Take a beaker of water and heat it to 37˚C
- Tie with a thread around one end of a length of visking tubing to seal it.
- Into the visking tubing pipette the solution of starch and glucose, close the end with a paper clip.
- Place the visking tubing in a large test tube containing enough tap water at 37˚C to cover the tubing.
- Test the water for glucose with Benedict solution or Fehlings solution.
- After about 20 minutes repeat the tests on the water in contact with the visking tubing.

RESULTS

Time of test	Results with iodine solution	Benedicts solution
At start	Brown	Blue
After 20 min	Brown	Yellow, Brick red

CONCLUSION

- At the start, tap water had no starch or glucose
- After 20 minutes tap water showed that there is no presence of starch but there was presence of glucose (yellow/brick red/orange shows that there is sugars)

This shows that the visking tubing was permeable to glucose alone that is why there is presence of glucose in the tap water.
Starch molecules did not diffuse because they are large in size compared to molecules of glucose.

The permeability of the visking tubing is illustrating what happens during the absorption of food in the small intestines.
Smaller molecules of glucose, amino acids, fatty acids diffuse while bigger particles do not diffuse into the bloodstream in the small intestines.

FUNCTIONS OF LARGE INTESTINES

- Absorption of mineral salts and water
- Preparing faeces for egestion

FATE OF DIGESTED FOOD

(A) USES OF GLUCOSE

- During respiration in the protoplasm, glucose is oxidized to carbon dioxide and water.

This process releases energy to drive the many chemical processes in the cells.

(B) USES OF LIPIDS (fatty acids and glycerol)

1. for oxidation to release energy.
2. for insulation under the skin to prevent heat loss from the body during cold conditions
   i.e. lipids help to keep our body warm.
3. as solvents for some Vitamins i.e. A, D, E and K.
4. to form important components of the cell membrane.

(C) USES OF PROTEINS (amino acids)

1. for growth and repair
   - structural proteins are used for growth and repairing damaged tissues (parts)
2. for formation of blood proteins i.e. antibodies, haemoglobin
3. formation of cell membranes and other components of the protoplasm.
4. for respiration to produce energy after deamination.

FUNCTIONS OF THE LIVER RELATED TO DIGESTION

The liver is a large, reddish — brown organ which lies just below the diaphragm and partly overlaps the stomach. (The liver has a great many important functions.)

1. Regulates blood sugar

- The liver converts glucose, amino acids to an insoluble carbohydrate called **glycogen.**
- The liver stores about 100g of glycogen.
- If the concentration of glucose in the blood falls below 80mg/100 cm^3 of blood, the stored glycogen is converted to **glucose**.

NB: If the concentration rises above 160mg/100cm^3, glucose is excreted by the kidneys. This only takes place in a diabetic patient where the level of insulin is ↓.
If blood glucose level falls below 40mg/100cm^3 it affects the brain cells adversely causing convulsions and coma.

The liver helps keep the glucose concentration between 80 and 150 mg and prevents the effects of hypo or hyperglyceamia.

2. Formation of bile

- Red blood cells break down into green and yellow pigments. These pigments are removed from the blood by the liver and excreted in bile.
- The liver also produces bile salts which help in the emulsification of fats; the breakdown of fats into small droplets to ↑ the surface area for lipase to act on.
- Bile is produced continuously by the liver cells, but stored in the gall bladder.

3. Storage of iron

- When red blood cells break up their decomposition is completed in the liver and iron from the haemoglobin is stored. This is the reason why the liver is a rich source of iron.

4. Deamination

- Excess amino acids are not stored in the body. They are deaminated (broken down) into carbohydrates (by removal from the molecule of the amino group $-NH_2$) and urea.
- Urea is excreted (eliminated by the kidneys) in the form of urine.

5. Manufacture of plasma proteins

- The liver makes most of the protein found in blood plasma including fibrinogen which helps in the clotting of blood. Fibrinogen is converted into insoluble fibrin which then forms a mesh of fibres over the wound in which blood cells are trapped thus forming a clot.

6. Use of fats in the body

- Some fats stored in the body are oxidized in the liver to substances which can be oxidized to release energy.

7. Detoxification

- Poisonous compounds, produced by bacteria in the large intestines enter the blood and are converted to harmless substances in the liver.

8. Storage of Vitamins

- Fat soluble Vitamins A and D are stored in the liver. This makes the animal liver a valuable source of these vitamins in the diet.

- The liver also stores a product of Vitamin B_{12} which is necessary for normal production of red cells in the bone marrow.

THE HUMAN CIRCULATORY SYSTEM

Functions of the circulatory system

- Blood has the following functions in the body.

(1) transportation of food from the small intestines to body tissues.
(2) to transport oxygen from lungs to body tissues.
(3) to transport wastes such as CO_2 and urea from the body tissues to excretory organs
such as the lungs and kidneys.
(4) to transport hormones from the endocrine glands to target organs.
(5) to provide defence to the body against infection.
(6) to regulate body temperature.

The human circulation

- The arrows show the direction of blood.
- From the lungs blood flow into the left hand side of the heart from where it is pumped
  to all parts of the body.
- It is brought back to the right hand side of the heart before going back to the lungs.
  This is called **double circulatory system** because the blood travels through the heart
  twice on one completion journey around.

The main parts of the Blood system

- Three main parts form transport system in blood circulation
  (a) blood vessels
  (b) the heart
  (c) the blood

(a) Blood vessels

- are the passage of blood.

TYPES OF BLOOD VESSELS

(i) Arteries (ii) veins (iii) capillaries

A. ARTERIES

- carry away blood from the heart to the rest of the body
- they have thick elastic walls
- the thick walls pressure back against the blood as it flows through them
- the thick and elastic walls are therefore the adaptation of the arteries to withstand the
  high pressure of the blood due to pumping force of the heart.

- Arteries have narrow lumen (cavities)

Cross section of an artery

- Arteries have no valves at intervals.
- Blood flows in arteries with high pressure because of the force exerted by the pumping
  action of the heart.
- Arteries carry oxygenated blood, except the pulmonary artery. The blood in arteries is
  bright red because it is oxygenated.
- the aorta is the largest artery.

B. <u>VEINS</u>

- are vessels that carry blood from the rest of the body to the heart.
- have thin walls and wide lumens.

Cross section of a vein

- the wider lumens of veins makes the volume of blood in the veins greater than in
  arteries since wider lumens create more room for blood.
- Veins have valves at intervals. The valves help to prevent blood from flowing back.

Valves in a vein

- they have blood flowing with low pressure since the pumping effect of the heart is not
  felt because they are further from the heart.
- carry deoxygenated blood, except the pulmonary vein therefore the blood carried by the
  vein is dark red since it is deoxygenated.
- the vena cava is the largest vein in the body.

C. CAPILLARIES

(i) are the smallest blood vessels. They have the narrowest lumens. This makes the
volume of blood in them to be smallest.
(ii) are the shortest blood vessels. As a result, the volume of blood in them is the smallest
at any time.
(iii) have very thin walls consisting of a single layer of flattened cells. This enables
useful substances i.e. glucose and oxygen, and wastes i.e. CO_2 to diffuse through
them easily.

- This makes capillaries places of exchange of substances in the body by diffusion.

Narrow lumen, thin wall and short length of a capillary.

(iv) form a bridge between veins and arteries.

A capillary bed

- Each organ of the body, except the lungs is supplied with oxygenated blood from an artery. Deoxygenated blood is taken away by a vein.
- The artery and the vein are named according to the organ they are connected with i.e. kidney blood vessels are renal artery and vein.
- The liver has hepatic artery and vein. All arteries except the pulmonary artery branch from the Aorta. All veins, except the pulmonary vein join the Vena cava.
- The liver has two blood vessels supplying it with blood
  (1) the hepatic artery (Oxygen)
  (2) the hepatic portal vein (supplies food from the small intestines)

THE HEART

- it is made up of cardiac muscle.
- the muscle contracts and relaxes regularly throughout life because it never tires.
- the main function of the heart is to pump blood around the body.

IMPORTANT FACTS ABOUT THE HEART

a. The muscles of the heart are supplied with blood by the coronary arteries. The blood
contains oxygen and nutrients (glucose) for the heart muscles.
b. The heart is surrounded by the pericardial cavity, which is filled with a cushioning
fluid called **the pericardial fluid.**

- The pericardial fluid prevents friction between the heart and the chest cavity.

THE HEART

- The heart has four chambers, the two upper chambers are the **ATRIA** or **AURICLES.**

The two bottom chambers are the **VENTRICLES.**

- The left hand side of the heart is completely separated from the right hand side by the muscle called **Septum.**
- The left hand side of the heart carries oxygenated blood while the right hand side carries deoxygenated blood.
- Inside the heart the aorta and the pulmonary artery have valves called **semi-lunar valves.**

- The atria receive blood only, therefore they have thin walls since they dont need to
  exert force on the blood.
- The Ventricles pump blood so they have thick walls so that they exert enough pressure
  on the blood when they contract to push it.
- The right Ventricle pumps blood to the lungs, which are very close to the heart.
    - The left Ventricles pumps blood to all parts of the body. As a result, the left Ventricles has thicker wall than the right Ventricle as it needs to exert greater pressure on the blood to push it over a longer distance.

BLOOD FLOW THROUGH THE HEART

Blood enters the auricles from the body by the vena cava and the pulmonary vein and begins to pass through the open valves into the **ventricles.**

- the **auricles** contract and force the rest of the blood into the ventricles.
- the ventricles then contract. As the blood is pushed up against the **bicuspid (mitral)**
  and tricuspid valves, it closes them and then is forced out into the aorta and
  pulmonary artery.
- when the ventricles relax the pressure of the blood falling back in the arteries closes the
  semi-lunar valves so that no blood reenters the heart.

BLOOD PRESSURE

- when the ventricles contract the heart becomes smaller squeezing blood out. This is
  called **systole** and the pressure exerted is called **SYSTOLIC PRESSURE.**
- when ventricles relax the heart becomes bigger allowing blood to flow into the atria and
  ventricles. This is called **diastole** and the sucking pressure is created is called the
  DIASTOLIC PRESSURE.
- if a person has systolic pressure like this of 120 mm Hg and diastolic pressure of
  80 mm Hg he is described as having a blood pressure of 120/80 mm Hg.
- Blood pressure increases with age. A pressure of 120/80 mm Hg is an average figure
  for a young adult.
- If pressure drops too low, food and oxygen are not circulated sufficiently quickly, the
  person often faints and may die.
- if blood pressure is higher than normal for long periods, damage may be done to the

kidney, heart and other organs of the body.
- people with high blood pressure are more likely to have heart attacks and strokes than
people with average blood pressure.
- people who often live in the stressful conditions of large cities often suffer from high
blood pressure or **hypertension.**

BLOOD

- Blood consists of blood cells and plasma.

PLASMA

- Is a liquid composed of water and dissolved substances e.g. glucose, amino acids, salts,
hormones and blood proteins.

FUNCTIONS OF PLASMA

(a) transports dissolved foods i.e. glucose, amino acids, vitamins to body tissues where
they are used for different purposes.
(b) to transport hormones from endocrine glands to target organs.
(c) to transport antibodies to tissues where they provide defence against infections.
(d) to transport wastes i.e. urea and CO_2 from tissues to excretory organs. The carbon
dioxide is transported in the form of hydrogen carbonate ions (HCO_3^-)

BLOOD CELLS

There are two types of blood cells.
(1) red blood cells
(2) white blood cells

RED BLOOD CELLS (ERYTHROCYTES)

- they are produced in the borne marrow of short bones i.e. ribs, vertebrae and sternum.
- Bone marrow is a fatty substance found in hallow bones.
- Red blood cells are red because they contain Haemoglobin which is made up of a
protein molecule and iron.

- Red blood cells are biconcave in shape and has no nuclei.

FUNCTIONS OF RED BLOOD CELLS

(a) to transport oxygen in the body. They have two adaptations for the transportation of
oxygen.
(i) they have haemoglobin on their surfaces. The haemoglobin has high affinity for
oxygen so that the oxygen that diffuses into the blood from the alveoli of the lungs
is attracted and transported by the haemoglobin on the red blood cells.
- when O_2 combines with haemoglobin they form a compound called oxyhaemoglobin.
(ii) they have biconcave shape. This shape increases the surface area of red blood cells
so that more O_2 is attracted and transported.

Cross section of a red blood cells.

(b) to transport antigens. These are proteins found on the surface of red blood cells.
Antigens stimulate the production of antibodies in the body.

WHITE BLOOD CELLS (LEUCOCYTES)

- they have irregular shape.
- they have nuclei
- are fewer in number than red blood cells.

FUNCTION OF WHITE BLOOD CELLS

- they provide body defence against infection.
- when the white blood cells arrive at the scene of infection they squeeze between the
endothelial cells, a process called **diapedesis.**

TWO TYPES OF WHITE BLOOD CELLS

(a) Phagocytes

- are produced in bone marrow.
- they have lobed nucleus. They defend the body against infection by engulfing and digesting germs i.e. bacteria.

- the process of engulfing and digesting germs by phagocytes is called **Phagocytosis.**

Two kinds of phagocytes

- Neutrophils
- Monocytes

NEUTROPHILS

- are more abundant white blood cells.
- are usually the first to arrive at the site of infection by amoebic movement.
- while some germs are engulfed and digested by the neutrophils, some neutrophils are killed and form part of pus.

MONOCYTES

- in addition to engulfing and digesting germs monocytes engulf and digest dead cells and
dead neutrophils.

- While the neutrophils are the "1st line troops," the monocytes are like "mop up crew"
- Monocytes that take up residence in connective tissues are referred to as **macrophages**. These cells remain like watchful soldiers.

(b) Lymphocytes

- most of them are produced and exists outside blood system.
- they are produced in lymphoid organ i.e. lymph nodes and spleen.

- they produce proteins called antibodies which provide defence against infection in the
following ways.

(i) some neutralize toxins produced by germs. These are the **Antitoxins.**
(ii) **Lysins** kill germs by dissolving them.
(iii) **Agglutinins** clump the germs so that they cannot penetrate most cells or they cannot reproduce properly.
(iv) **Opsonins** combine with antigens — they surround the outer surface of germs

(c) Platelets

- These are tiny cells produced in the red bone marrow by a large cell called **MEGAKARYOCYTE.**
- Platelets have no nuclei.

FUNCTION OF PLATELETS

- help in the clotting of blood on a wound.

A clot at the site of a wound has two important functions.
(a) stops bleeding
(b) minimizes entry of germs into the body through the wound.

HOW CLOTS ON THE WOUND IS FORMED

- Platelets and damaged cells on a wound release a chemical called **thromboplastin.**
- Thromboplastin converts a plasma enzyme called **prothrombin** produced by the liver
  into active form called **thrombin**. The thrombin converts **fibrinogen** into **fibrin,** an
  insoluble protein that forms long branching fibres across the wound.
- Blood cells and platelets get caught in the fibres, forming a clot.

Note: Blood does not clot in our bodies because our blood vessels contain substances
  called **anticoagulants** that prevent clotting.

A sample of blood seen under a microscope.

BLOOD TRANSFUSION

- Is the transfer of blood from an external source into the body of a person. It is done to a
  person who has lost a lot of blood due to accidents or disease, which may lead to heart

failure.

BLOOD GROUPS

There are four blood groups A, B, AB and O.
- when certain blood groups are mixed, the red corpuscles (blood cells) stick together
(agglutinate) and block the blood vessels.
- This is because certain proteins on the surface of the red cells of a person donating
blood reacts with other proteins (antigens) in the plasma of the person receiving the
blood.

Blood Group	Type of Agglutinating Proteins (Antigen) on the red blood cells	Type of Agglutinating Proteins (Antibodies) in the Plasma
A	A	b
B	B	a
AB	A, B	none
O	none	a, b

- Group O has no agglutinating protein on their red blood cells, therefore no reaction
occurs when the blood is donated to someone.
- people with group O can give blood to anyone, so they are known as **Universal Donors**.
- people with group AB have no agglutinating proteins in their plasma. So they can
receive blood from anyone. They are called **Universal Recipient**.
- Group A people can only receive blood from group A or group O. The b agglutinating
protein in their plasma will react with the B protein in both group B and group AB
blood. They can give to A and AB.
- Group B people can give blood B groups and AB. They can also receive blood from
other B and O.

NB. An adult who is fit and well can very easily spare half a litre of blood to give to
someone in an emergency.
- A drink afterward restores the amount of fluid in the circulatory system and the
donor is given iron tablets to help him rapidly make some more red blood

cells.

The Rh Factor (Rhesus Factor)

- Apart from the A — antigens and B — antigens on the surface of the red blood cells there is also a Rhesus Factor substance. It is called Rhesus because it was discovered in a type of monkey called Rhesus monkey.
- people with Rhesus factor in their blood are described as Rhesus positive (Rh+), those who do not have are Rhesus negative (Rh-).
- If Rh+ is donated to Rh- agglutination occurs.
- The Rh factor may have a harmful effect on a newly born baby. A Rh+ child may be born to an Rh- mother.
- Before the child is born the Rh+ red blood cells from the babys body may enter the Rh- mothers blood stream by diffusing across the placenta.
- mothers blood will then begin to produce antibodies to destroy these Rh+ red blood cells.
- the antibodies attack the Rh+ cells that enter the body as if they were harmful to mothers body.

- If the Rh+ antibodies enter the babys blood stream after diffusing across the placenta they destroy the babys Rh+ red blood cells. If too many red cells are destroyed the unborn baby (foetus) may die.
- If a woman with Rh- is accidentally given a transfusion of Rh+ blood, she then produces a lot of antibodies and all her children may be still born.

LYMPHATIC SYSTEM

- is the second circulatory system in the body which is responsible for circulating fluids.
- some fluids leak out of the capillaries into which they branch and become tissue fluids.
- this is achieved due to the high blood pressure in the arteries.

Contents of the tissue fluid

Water, glucose, fatty acids, glycerols, amino acids, vitamins, hormones and some white blood cells (lymphocytes)

- at the venous end of capillaries blood pressure is low and so some of the tissue fluids
  passes back into the blood stream and some enters the **lymph vessels** of the lymphatic
  system.
- **LYMPH** is therefore blood without red blood cells or any of the large protein molecules such as fibrinogen, which is forced out of the capillaries.
- the tubules of the Lymphatic system gradually join to form larger vessels.
- like blood in the veins, the lymph is squeezed along the lymph vessels when muscles of
  the rest of the body contract and relax.
- like the vein, lymph vessels have valves in them to prevent the lymph from flowing
  backwards.

The circulation of fluids in the Body

FUNCTIONS OF TISSUE FLUIDS

(a) to supply oxygen to tissue cells.
(b) to supply nutrients i.e. glucose to tissue cells.
(c) to carry CO_2 and other wastes away from tissue cells to the blood for excretion.
(d) to cleanse dirt e.g. dead tissue cells around the tissue cells and pour them into lymph
vessels which are more permeable than capillaries.
- Thus the Lymphatic system is referred to as the **drainage system of the body.**

LYMPH FLOW

- There is no pumping action in the lymphatic system. Lymph moves along the Lymphatic vessels because of

(a) Force of gravity

- the lymph in the upper part of the body i.e. arms, head, is moved along the lymphatic
vessels by gravity.

(b) Contraction of skeletal muscles

- contraction of skeletal muscles during activities such as breathing, walking, pushes
the lymph along the lymphatic vessels.

(c) Valves

- Lymphatic vessels have valves at intervals that help the Lymph to move forward.
- just like veins, Lymphatic vessels have thin walls
- Along the Lymphatic vessels there are Lymph glands or Lymph nodes.
- Each Lymph node has tiny spaces in which the Lymph is filtered before it goes to blood
stream.
- The Lymph nodes produce Lymphocytes that produce antibodies.

Differences between Blood and Tissue Fluid

Blood	Tissue Fluid
red blood cells	no red blood cells
contain fibrinogen	no fibrinogen
more oxygen and glucose	less O_2 and glucose
less CO_2	more CO_2
less water	more water

Note: Lymph vessels are similar to veins because

(a) both have valves at intervals
(b) both have thin walls

Lymph Nodes in Human Beings

PROBLEMS ASSOCIATED WITH THE CIRCULATORY SYSTEM.

(a) high blood pressure (hypertension)
(b) heart attack

HOW TO PREVENT THESE PROBLEMS

(a) doing physical exercises
(b) keep the body weight at a reasonable level
(c) avoid smoking

EXCRETION

Is a process which gets rid of unwanted products produced during metabolic processes in the body of a plant or an animal.

EXCRETORY PRODUCTS IN PLANTS

(a) Carbon dioxide

- produced during respiration. During the day this CO_2 is used by the same plant as a raw material for photosynthesis.
- at night when there is no sunlight, the plants excrete CO_2 into the atmosphere through the stomata by diffusion.

(b) Oxygen

- during photosynthesis during the day O_2 is produced by green plants.
- Some is used in the plants for respiration.
- Most of the O_2 is excreted through the stomata by diffusion. This is because the rate of respiration which uses O_2 is lower than the rate of photosynthesis which produces O_2.

EXCRETORY PRODUCTS IN ANIMALS

- In large animals, the excretory system gets the excretory products.

Excretory organ	The Excretory product
The skin	Sweat (water and salt)
The kidney	Urea, water and salt
The lungs	Carbon dioxide
The liver	Bilirubin

FORMATION AND EXCRETION OF UREA IN HUMAN BEINGS

- when amino acids are absorbed in the villi of the small intestines, they are carried by the
  blood through the hepatic vein to the liver.
- required amount is released by the liver into the blood stream to be circulated.
- Excess amino acids are deaminated by the liver.
- the amino group of each amino acid molecule is changed to ammonia (NH_3) which
  reacts with CO_2 to form urea.

The urea is sent to the kidneys for excretion. Urea contains nitrogen and so it is

called **nitrogenous excretory product.**

- The rest of each amino acid molecule is converted into glycogen and stored by and in the liver.
- It is reconverted and used when there is not enough glucose in the blood stream.

Deamination and Urea formation.

KIDNEYS

- A human being has 2 kidneys.
- Kidneys are red — brown, bean shaped organ enclosed in a transparent membrane and attached to the back of the abdominal cavity.
  - The kidneys are supplied with oxygenated blood by the renal artery.
    - The renal vein takes away the deoxygenated blood to the vena cava.

- The tube called ureter, runs from each kidney to the bladder.
- The kidneys produce a water liquid called **urine** which contains substances i.e. urea coming from the liver.
- The urine trickles down the ureters to the bladder which gradually expands like a balloon as more urine collects in it.
- The top of the urethra is surrounded by a ring of muscles called the sphincter muscle.
- This muscle tightly contract and prevents urine from coming out of the bladder.
- Urine is forced out of the bladder through the urethra when the sphincter muscle relaxes and the muscles in the wall of the bladder contract. This is called **urination.**

Diagram of the position of kidneys in the body.

INSIDE THE KIDNEY

- The kidney is divided into two areas.
  (a) a dark outer area — cortex
  (b) a light inner area — medulla
- the medulla is connected to the ureter.

Longitudinal section of the kidney.

- Inside the kidney there are numerous microscopic structures called **nephrons**.
- Each nephron consist of cup — like capsule called the **Bowmans capsule** which is
  connected to a narrow tubule.
- The tubule twists and turns, doubles back on itself and leads to a collecting duct.
- About 12 nephrons share the same collecting duct.
- All collecting ducts open into the ureter.
- The tubule consists of three regions
  (i) first convolution 1st coil after the Bowmans capsule
  (ii) the u-shaped Loop of Henle
  (iii) 2nd coil leading to collecting duct, second convolution.

- A branch of renal artery supplies blood to the nephrons.
- This enters the Bowmans capsule and splits up into a little bunch of capillaries called the **glomerulus.**

- These then join up again to form a blood vessel which leaves the capsule and splits up
  into further capillaries which wraps round the tubule.
- These then join up to form blood vessel leading to renal vein.

The structure of the Nephron

MECHANISM OF EXCRETION IN THE KIDNEYS

- Urine formation in the kidney occurs in the nephron.
- The blood vessel which brings blood to the glomerulus is wider than the capillaries of the glomerulus. This creates resistance to the flow of blood, so that pressure is set up.
- This pressure causes fluid to filter out through the capillary walls and collect in the Bowmans capsule.
- The filter fluid, (called glomerular filtrate) contains a solution of glucose, salts, amino acids and urea, while fibrinogen and other proteins remain in the capillaries and proceed with blood.
- As the filtered serum passes down the renal tubule, all the glucose and amino acid, some salts and much of the water are reabsorbed into the network capillaries surrounding the tubule.
- This selective reabsorption prevents loss of useful substances from the blood serum.
- The remaining liquid now called **urine**, contains only the waste products i.e. inactive hormones, urea, excess salt and water.
- This liquid passes down the collecting tubule where more water is reabsorbed and the concentration of the blood is regulated.
- If the blood is too dilute e.g. after drinking a lot of water, less water is absorbed back into the blood and the urine is dilute. If the blood is too concentrated e.g. after sweating profusely, more water is reabsorbed from the collecting duet, making urine more concentrated.
- From the collecting ducts, the urine enters the pelvis of the kidney where it collects and continues down the ureter to the bladder as a result of peristalsis in the ureter.
- The capillaries from the glomeruli and renal tubules unite to form the renal vein.

- It is the cells of the tubule which selectively reabsorb substances from the glomerular filtrate.
- This is done against diffusion gradient using energy supplied by respiration within the cells.
- So blood leaving the kidneys in the renal vein contains less oxygen and glucose, more carbon dioxide and as s result of excretion, less water and nitrogenous waste.

Main Nitrogenous substances removed from the blood by the kidney.

Nitrogenous compounds in blood %		Nitrogenous compounds in urine %
Protein	7 — 9	0
Urea	0.03	2
Uric acid	0.005	0.05
Ammonia compounds	0.0001	0.05
Water	90 - 93	95

The role of ADH in Osmo — regulation

WATER BALANCE AND OSMOREGULATION

- water is lost from the body in urine, faeces, sweat and exhaled breath.
- It is gained by eating and drinking.
- These losses and gains produce corresponding changes in the blood.
- Changes in the concentration of blood are detected by the hypothalamus of the brain.
- If the blood passing through the brain is too concentrated, the hypothalamus stimulates the pituitary gland beneath it to secrete into the blood a hormone called anti-diuretic hormone (ADH).
- The ADH causes the kidney tubules to absorb more water from the glomerular filtrate back into the blood.
- Thus the urine becomes more concentrated and loss of water from blood is reduced.

- If blood passing through the hypothalamus is too dilute production of ADH from the pituitary gland is suppressed and less H_2O is absorbed from the filtrate.

HOMEOSTASIS

- Means stating the same.
- The kidneys play a part in the homeostasis of the body. They help to regulate the composition of the internal environment.

KIDNEY FAILURE

- If one kidney fails to function the person can still lead a normal life using the other
  kidney.
- if both kidneys fail, the individual will die if not treated promptly.
- the treatment can take two forms
  (i) kidney transplant or
  (ii) a kidney dialysis

HOW A DIALYSIS MACHINE WORKS

- Blood is drawn from an artery in the arm and passed through a tubing inside a dialysis
  machine.
- This tubing has partially permeable walls and is bathed in a specially controlled **dialysis**
  fluid which has similar composition to blood plasma but does not contain any waste
  products. This means that

(1) waste products i.e urea are more concentrated in blood than in the dialysis fluid so
they diffuse out of the blood and into the dialysis fluid.
(2) Useful substances i.e. glucose and salts do not diffuse out of the blood because the
concentration of these substances in the dialysis fluid and the blood are the same.
(3) Large molecules i.e. blood proteins and red blood cells are too large to pass through
the dialysis tube wall.
- the patients blood is then returned into the vein in the arm.
- Blood has to pass through the dialysis machine many times to be cleaned properly so
  the dialysis takes up to ten hours and is needed every few days.

NB:

- The tubing inside the dialysis machine is long and narrow, providing large surface area for diffusion.
- The dialysis fluid is warmed close to blood temperature, which increases the rate of diffusion and makes sure that the patients blood is not cooled down by its passage through the machine.

TRANSPLANTS

- These are tissues or organs from one body to another in order to replace the one that
  does not work.

SOME FORMS OF TRANSPLANTS

(a) Cornel Transplant

- This is the most successful because of the absence of blood circulatory system in the
  cornea.

(b) Skin Transplant

- Is done to replace burnt or damaged skin.
- The skin is taken from another part of the body of the same person i.e. buttocks.
- If another persons skin is used, the one to be given the transplant is given drugs to
  stop the formation of antibodies so that the foreign protein in the transplant is not
  rejected.

(c) Kidney Transplant

- A healthy kidney is surgically inserted to replace the damaged one in the body.

(d) Heart Transplant

- A healthy heart is surgically inserted to replace the damaged one.

FACTORS TO CONSIDER BEFORE AN ORGAN TRANSPLANT

(i) Level of difficulty of carrying out some transplant to serve the life of the recipient

e.g. heart transplant.

(ii) The blood group of the donor and recipient of the transplant must be the same.

(iii) Some laboratory tests are done and also antibodies are given for fear of transferring some diseases.

(iv) The recipients antibody system must be suppressed by drugs for the rest of recipients life if it is different from that of the donors transplant i.e. a kidney transplant.

GROWTH AND REPRODUCTION

GROWTH - Is the result of increase in the number of cells, increase in the size of cells or both at once.

- This always occurs by CELL — DIVISION, every cell in existence has been formed by the division of a pre — existing nucleus.
- Firstly, the nucleus divides into two and then the whole cell divides, separating each nucleus in a unit of cytoplasm, so that two cells exist where previously there was only one.
- Both cells may then enlarge to the size of the parent cell. Such cell division and enlargement give rise to growth.

GROWTH IN A ROOT TIP

DIAGRAMS SHOWING CELLS OBTAINED FROM DIFFERENT REGIONS OF A ROOT TIP.

1. THE ROOT CAP

- Is a mass of loose unspecialized cells fitting over the region that is actively dividing.
- This cap is protective in function.

2. REGION OF CELL DIVISION (APICAL MERISTERMS)

- Occurs at tips of stems and roots. This a region of active cell division from which permanent tissues are derived.
  - **AMERISTERM** is a region of active cell division from which permanent tissue is derived. Meristerms also occur between Xylems and Phloems in veins (cambium), just inside the outer layer of the bark (cork cambium), in young leaves and the bases of internodes.

3. THE REGION OF ELONGATION

- Lies behind the apical meristerm. Here the root is actively lengthening, mainly by

the enlargement of its cells.

4. THE REGION OF DIFFERENTIATION

- As the cells get order, they become specialized to carry our different functions e.g.
  - Some become vascular cells, some protective cells e.t.c.
  - So they differ in size and shape.

- The nucleus in a cell contains thread-like structures called **CHROMOSOMES.**
- **CHROMOSOMES** are bodies which contain the chemical information controlling the cells activities, development and heredity.
- The information concerned is recorded on a huge molecule called DNA (Deoxyribonucleic acid)
- DNA in the nucleus contains all the information necessary to produce all the enzyme which direct all the metabolic reactions of respiration, photosynthesis and synthesis of all the chemicals in the cell.
- A reaction chain of enzymes in a cell is called **METABOLIC PATHWAY.**

1. MITOSIS

- Is a type of division by which all cells of the body (or soma) are produced.
- It is sometimes called **SOMATIC CELL DIVISION**.
- The nucleus is the centre of cell activity. It contains information that is passed on from one generation to another (inherited) and by containing instructions for the synthesis of many enzymes, directs the development and activity of the cells.
- Mitosis is the process that ensures that every cell in an organ has the same DNA.
- Mitosis is a continuous process from beginning to end; but for purposes of discussion, it is often convenient to divide it into four main stages.

FOUR STAGES OF MITOSIS

1. PROPHASE : Chromosomes can be stained easily, but it is difficult to see that each one is already duplicated.

2. METAPHASE: The duplication is easy to see as the duplicates begin to separate.

3. ANAPHASE: The duplicated chromosomes separate completely.

4. TELOPHASE: Two new cells are formed each with the same number of chromosomes as the original cell.

THE CHROMOSOMES NUMBER OF SOME SELECTED ORGANISMS

Organisms	Latin name	Number of chromosomes in ordinary cells
Man	Homo sapiens	46
Mosquito	Culex pipiens	6
Rabbits	Oryctolagus cuniculus	44
Guinea Pig	Cava cabaya	64
Housefly	Musca domestica	12
Cucumber	Cucumis sativus	14
Cotton	Gossypium hirsutum	52
Bean	Phaseolus vulgaris	22
Tobacco	Nicotiana tabaccum	48
tomato	Lycopersicum esculentum	24

DEVELOPMENT IN VERTEBRATES

- In vertebrates such as fish and amphibians, fertilization takes place **externally.**
- In reptiles, birds and mammals, fertilization occurs **internally**.
- The egg (ovum) is non-motile and relatively large, with a store of yolk to supply nutrients for the embryo after fertilization.
- The sperm is small and motile, and can swim towards an egg using its tail.
- The sizes of the eggs vary from one group of vertebrates to another. In mammals the eggs are microscopic; fish eggs are smaller than those of amphibians, while those of birds and reptiles are quite large.
- After fertilization cells not only divide and expand, they also differentiate into different types of cells, so that specialized tissues and organs develop.

2. MEIOSIS AND FERTILIZATION

The production of sperm and ova is the result of a special nuclear division which

reduces
to half, the number of chromosomes in the cells.

- This division is called **MEIOSIS** or **REDUCTION DIVISION.**
- Meiosis occurs in all animals and higher plants in the tissue in which sex cells are
  produced.
- In some non-flowering plants it occurs during the production of **spores.**
- In flowering plants it occurs in the **anthers** and **ovaries**, in animals in the **testes** and
  ovaries.
- Ordinary cells with full chromosome number are called **DIPLOID NUMBER**. A
  Diploid cell has chromosomes existing in pairs e.g. Human beings have 46
  chromosomes, Houseflies have 12 e.t.c
- In the anthers, ovaries and testes diploid cells undergo meiotic division during which
  their chromosome pairs recombine and then separate into different new cells.
- The resulting **DAUGHTER CELLS** are **HAPLOID CELLS**. **HAPLOID CELLS**
  contain half the chromosome number.
- The number of chromosomes in a haploid cell is called the **HAPLOID NUMBER** e.g.
  a human beings is 23, Housefly is 6 e.t.c.
- When fertilization occurs, the chromosomes from the two sex-cells group together. So
  fertilized human egg contains 46 chromosomes i.e. 23 chromosomes form sperm and
  23 chromosomes form ovum.
- This shows that the chromosomes number is restored to normal during fertilization
  when the nuclei of two sex-cells fuse e.g.

MITOSIS AND MEIOSIS COMPARED

MITOSIS	MEIOSIS
Produces genetically identified cells	Produces genetically difference cells
Chromosomes number of parent cell retained in the daughter cells	Chromosome number of parent cell halved in daughter cells
Two daughter cells produced	Four daughter cells produced
Occurs in ordinary body cells	Occurs in certain cells in reproductive organs

REPRODUCTION

- Is the formation of a new organism from the already existing one.

Reproduction is important to living things in the following ways:

(i) it maintains existence of species of organisms on earth.
(ii) It leads to the arising of new species of organisms.

TWO TYPES OF REPRODUCTION

(A) ASEXUAL REPRODUCTION

This is the formation of new organisms from a single parent. Examples of asexual reproduction are **budding** in hydra and yeast, **binary** fission in amoeba and **regeneration** in earthworms.

(B) SEXUAL REPRODUCTION

- This is the formation of new organisms from male and female parents.
- Flowering plants and many multi-cellular animals such as mammals reproduce by
sexual reproduction.

THE HUMAN REPRODUCTIVE SYSTEM

Men and women have different reproductive systems. Both systems need to produce gametes but the male system needs to have, in addition, a mechanism

for transferring sperm to the female.

- The female, in addition to a mechanism for producing ova, needs to have a system in
  which a baby can develop if she becomes pregnant.

(A) THE MALE REPRODUCTIVE SYSTEM

1. TESTES - these are two oval — shaped in male. They produce the male gametes — sperm.

2. SCROTAL SACS (SECROTUM) — Is a sac containing testicles between the thighs.

- These are pouch — like extensions of the skin that lie outside the body cavity because sperm need to develop at a temperature of less than 37˚C.

3. SPERMATIC CORD — These are at the upper end of each testicle which

contain
blood vessels.

4. EPIDIDYMIS — These are narrow, much-coiled tubes which store sperm from the
testis before entering the sperm ducts.

5. SPERM DUCT OR VASDEFERENS — These are tubes from each testicle which pass into the abdominal cavity.
- They provide a passage for the sperm.

6. THE SEMINAL VESICLE, PROSTATE GLANDS AND COWPERS GLAND
- Secrete fluid, rich in the sugar fructose, into the vas deferens.
- The mixture of fluid and sperm is called **SEMEN.**
- The fluid in the semen contains nutrients and enzymes that nourish the sperm so that
they begin to swim actively.

7. URETHRA — Is a tube that passes through the centre of this penis to the exterior.
- Semen and urine do not pass through urethra at the same time.

8. PENIS — This is the organ of copulation that is used during mating.
- The penis becomes erect to facilitate easy entry into the vagina of the cow.

THE DIAGRAMS SHOWING STRUCTURES OF HUMAN SPERM AND THAT OF A HUMAN OVUM.

(A) HUMAN SPERM

ACROSOME — contains **HYDROLYTIC ENZYMES** which break down part of the egg membrane so that the sperm can penetrate during fertilization.

The sperm has the following structural adaptations for movement.

(i) It has a tail/flagellum that it uses for swimming by flapping it.
(ii) It has a lot of mitochondria in the middle piece where a lot of energy is produced during respiration, and is used for movement.
- The middle piece of the sperm is referred to as the **power house of the sperm** since it produces a lot of energy during respiration in the mitochondria, which the sperm uses for movement.
(iii) It has a streamlined shape that minimizes drag so that the sperm swims easily in the semen.

(B) HUMAN OVUM

STRUCTURAL DIFFERENCES BETWEEN A SPERM AND AN OVUM

SPERM	OVUM
Has a tail	Has no tail
Has a head	Has no head
Has a neck	Has no neck
Has no jelly-like coat	Has jelly-like coat
Is small	Large because it has large cytoplasm containing a lot of yolk that provides food to the developing embryo in its early stage.

STRUCTURAL SIMILARITIES BETWEEN A SPERM AND AN OVUM

1. Both have cytoplasm
2. Both have cell membranes
3. Both have nuclei

(B) THE FEMALE REPRODUCTIVE SYSTEM

- This is where human development begins after the sperm has been deposited in the female reproductive organ and has fused with the ovum.

- The following diagram shows the female reproductive organ of a human being.

1. VAGINA - Its a passage for penis.
- It leads sperms to uterus during intercourse

2. OVIDUCT — Its a passage for ovum from ovary.
- Its a place for fertilization
- Its lining has cilia that pushes the ovum along the oviduct by their beating effect.
- There are rhythmic contractions and relaxation (peristaltic movements) along the oviduct that also help in pushing the ovum along the oviduct.

3. OVARY — Stores and releases ova, one ovum every 28 days. There are right and left ovaries that release the ova alternatively.

4. UTERUS — Place for the implantation and development of embryo.
- Its walls help in giving birth through their strong rhythmic contractions that push the baby out.
- It is thick walled for easy implantation of the developing embryo

and to
exert enough force in pushing the baby out during birth.

OVA PRODUCTION

- Between the ages of 10 and 14 years of a female, when the girl reaches sexual maturity
or puberty the ova starts to ripen and are released one at a time about every 28 days
from alternative ovaries.
- As each ovum matures the cells round it divide rapidly and produce a liquid filled sac
called the **GRAAFIAN FOLLICLE**.
- The Graafian follicle produces Oestrogen that initiates the rapid growing of cells living
the uterus and develops a dense network of blood vessels.
- When mature, the follicle bursts and releases the ovum into the funnel of the oviduct.
- The release of an ovum by the ovary is called **OVULATION.**
- The Graafian follicle from which the ovum has been released becomes a **yellow solid**
called the **CORPUS LUTEUM**, which produces a hormone called
PROGESTERONE.
- This hormone keeps the uterus living thick and with dense network of blood vessels.
No more Oestrogen is produced this time.
- The development of thick muscular walls and a dense network of blood vessels in the
uterus are in preparation for the reception of any fertilized ovum.
- If the ovum is not fertilized within three days after ovulation it dies upon reaching the
uterus.
- This is followed by a slow disintegration of the thickened lining of the uterus, because
the Corpus Luteum disappears and about 12 to 14 days after ovulation the dead ovum
together with the uterus lining and a quantity of blood from the disintegrating uterus
lining are passed out of the body through the vagina.
- The shedding off of the thickened uterus wall, in the absence of fertilization is called
MENSTRUATION. This lasts for 5 days.
- Counting the onset of menstruation as day 1, ovulation usually occur on about day 14,

but sometimes it may occur on day 13 or day 15.

DIAGRAM SHOWING MENSTRUATION CYCLE OF A HUMAN BEING

NB: Between the ages of 42 and 55 the ovaries lose their ability to release ova. As a result, the woman of this age loses her fertility.

- The loss of fertility in a woman due to old age is called **MENOPAUSE.**
- At this stage ovulation stops and the reproductive organ decreases in size.

THE PROCESS OF FERTILIZATION AND CONCEPTION

- The fusion of the male and female gametes to form a zygote is called **FERTILIZATION.**
- Once a zygote is formed it develops into an **EMBRYO.**
- When the embryo reaches the uterus it releases enzymes that help it to digest its way into the thick wall of the uterus. The embryo becomes firmly embedded i.e. implanted in the uterus wall.

DIAGRAM SHOWING OVULATION, FERTILIZATION AND EMBRYO IMPLANTATION

THE ROLE OF THE FOLLOWING HORMONES IN THE MENSTRUAL CYCLE

1. FOLLICLE STIMULATING HORMONE — (FSH)

- It stimulates the growth of follicles
- It stimulates the development of the ovaries.

2. OESTROGEN

- After menstruation, it causes repair and growth of the uterine lining which becomes thick, with many blood vessels.
- A high concentration of Oestrogen in the blood inhibits FSH production, preventing the ripening and growth of more follicles.
- It stimulates the pituitary gland to secrete lutenising hormone (LH)

3. LUTENISING HORMONE (LH)

- It causes ovulation
- it influences the formation of the corpus luteum, which secretes Progesterone and Oestrogen

4. PROGESTERONE

- Keeps the uterine lining thick and well supplied with blood, preparing it for the implantation of an embryo.
- Inhibits both FSH and LH production.

HUMAN DEVELOPMENT

PREGNANCY — This is the period between implantation and the birth of an organism.

It is about 38 weeks in humans.

- As the embryo is implanted onto the wall of the uterus it continues to grow and produces new cells, which form tissues and organs.
- When all organs are formed the embryo is now called the **FOETUS.**
- One of the first organs to form is the heart which pumps blood around the body of the embryo.
- After the implantation, a membrane called the **AMNION** enclose the embryo in a fluid-filled space known as the **AMNIONITIC CAVITY.**

Amniotic fluid has the following functions:

(i) It is a shock absorbs, protecting the developing foetus against mechanical injury.
(ii) It supports the foetus and allows it to move freely during growth.
(iii) During birth, it lubricates and reduces friction in the vagina.

DIAGRAM SHOWING THE FOETUS ENCLOSED BY AMNION

UMBILICAL CORD

(i) Carries blood vessels, a vein and an artery from the embryo to the placenta.
(ii) Forms a passage for the materials from mothers blood to the embryos blood and vice
versa.

DIFFERENCES BETWEEN BLOOD FLOWING IN THE ARTERY AND BLOOD FLOWING IN THE VEIN OF THE UMBILICAL CORD.

BLOOD IN THE ARTERY	BLOOD IN THE VEIN
Lower oxygen concentration	Higher Oxygen concentration
Higher CO_2 concentration	Lower CO_2 concentration
Lower amino acids concentration	Higher amino acids concentration
Lower glucose concentration	Higher glucose concentration
Higher Urea concentration	Lower Urea concentration
Dark red in colour	Bright red in colour

PLACENTA

This is the structure that is closely attacked to the lining of the uterus on one side and closely to the blood capillaries from the blood vessels of umbilical cord on the other side.

DIAGRAM SHOWING THE STRUCTURE OF THE PLACENTA AND UMBILICAL CORD

N.B. SINUSES — Is the blood filled space.
- It keeps to surround the babys villi.

FUNCTIONS OF THE PLACENTA

(a) Forms a barrier separating the embryos blood system and the mothers blood system

This function is important in the following ways:

(i) It prevents the mothers high blood pressure from damaging the embryos delicate blood vessels.
(ii) It minimizes the entry of harmful material e.g. germs such as plasmodia from the mothers blood into the embryos blood.
(iii) When the embryos and the mothers blood groups are incompatible there could be agglutination which could result in death of both the mother and the embryo if there was mixing of the embryos blood and the mothers blood.

(b) Place for exchange of material between the mothers blood and the embryos blood
e.g.

Into the blood of the embryo	Oxygen, glucose, water, salts, amino acids, antibodies
Carbon dioxide and Urea	Into the mothers blood

The placenta is adapted for its function as a place for exchange of materials by the process of diffusion in the following ways:

(i) It is in close contact with a network of blood capillaries. This ensures sufficient supply of blood to take away and bring in materials for exchange by diffusion, thus it

ensures efficient diffusion.
(ii) It has finger-like projections called **VILLI,** which stick into the blood spaces in the
walls of the uterus.
- The villi increase the surface area of the placenta on which a lot of diffusion occurs.
(iii) It is folded. The folds increase the surface area of the placenta on which a lot of
diffusion occurs.
(iv) It has a thin membrane so that materials diffuse faster than easier.

(c) The placenta produces the hormone Progesterone, which prevents menstruation and
prevents any further Ovulation.
- The hormone also stimulates further thickening of the lining of uterus.

THE PROCESS OF BIRTH

- The hormone called **OXYTOCIN** brings about rhythmic muscular contractors of uterus
walls.
- At about this time the amnion bursts and amniotic fluid escapes from the vagina.
- Soon afterwards the uterus starts contracting powerfully and the cervix opens up i.e.
dilates. As a result the baby is pushed through the vagina and comes out head first.
- The baby cries soon after birth because it experiences a sudden change in temperature
of its surroundings.

TWINS AND MULTIPLE BIRTH

There are two types of twins:

(A) NON-IDENTICAL OR FRATERNAL TWINS

- These arise when two ova are released from the ovaries at the same time and are both
fertilized by two different sperms.
- The two babies born do not have the same genes since they are coming from two
different ova and sperms so that they will be no more alike than brothers or sisters.
- Fraternal twins can be of the same or different sex.

(B) IDENTICAL TWINS

- They arise when a single ovum is released from one ovary and is fertilized by the sperm.
- The zygote formed then splits into two cells, Zygotes, each of which develops into an embryo.
- The two embryos have exactly the same genes since they are formed from the same ovum and the same sperm so that the two babies will be exactly alike and will be of the same sex either brothers or sisters.
- Sometimes in identical twins the zygote splits but the zygotes formed do not completely separate so that the two embryos are joined at some point.
- Such jointed identical twins are called **SIAMESE TWINS.**
- These Siamese twins can be separated through operation after birth.

BREAST FEEDING

Babies can either be fed on breast milk or bottled milk. Both produce healthy babies although breast-feeding has certain advantages over bottled-feeding.

SOME OF ADVANTAGES OF BREAST — FEEDING OVER BOTTLED-FEEDING

- The baby is able to obtain antibodies from colostrum which help to fight against diseases.
- Mothers milk is free from bacteria.
- The baby develops a sense of closeness to the mother while feeding.
- Breast-milk is cheap and is available always.
- Breast-milk is digested more quickly and more easily than bottled milk.
- Breast milk is at the right temperature i.e. the normal body temperature.

CONTRACEPTION

Is the prevention of fertilization when sexual intercourse takes place. This is an important method of family planning.

METHODS OF CONTRACEPTION

1. **ABSTENANCE** — total avoidance of sexual intercourse.

2. SHEATH/CONDOMS — wearing condoms on the penis which prevents sperm from entering the vagina.

3. (IUD) INTRA — UTERINE DEVICE — A small plastic loop or coil that is inserted in the uterus.
- This interferes with and prevents the implantation of the fertilized ovum.

4. DIAPHRAGM — A dome- shaped rubber structure designed to fit over the cervix. The woman inserts the diaphragm into the vagina before sexual intercourse and removes it eight hours after intercourse.

5. CONTRACEPTIVE PILLS — A pack of tablets taken regularly, one a day, for three weeks by women and sopped for a week during which menstruation occurs.
- The pills contain hormones that prevent ovulation.

6. SPERMICIDAL CREAM — Creams applied inside the vagina before sexual intercourse. The creams kill the sperms.

7. STERILIZATION — In men, is done by cutting the sperm ducts and tying them through surgical operation. This is called **Vasectomy.**
- In women, is done by cutting the fallopian tubes and tying them through surgical operation. This is called **Ligation.**
- This method is suitable to a couple which has enough children because once it is done it cannot be reversed.

8. COITUS INTERRUPTUS — Withdrawal of the penis from the vagina before ejaculation.

9. RHYTHMIC METHOD — Having sexual intercourse during safe periods only.

10. NORPLANT — Norplant consists of six capsules, each 34 millimetres long. Each capsule contain 38 milligrams of synthetic progesterone. This hormone thickens the mucus produced by the cervix and

inhibits
the production of Lutenising Hormone (LH)
- The contraceptive capsules are inserted under the skin through an
incision on the inside of the upper arm.

PROBLEMS ASSOCIATED WITH REPRODUCTION

- Sterility
- STDs
- Maternal mortality

REPRODUCTION IN FISH

- In many animals which live in water, the female sheds her unfertilized eggs into the
water and the male releases sperms over them.
- The eggs are fertilized outside the body of the female and so the process is called
EXTERNAL FERTILIZATION.
- For fertilization to be successful, the eggs and sperms must be released at the same time
and close to each other.
- This results usually in behaviour pattern in which the male and female are first attracted
towards each other and then stimulate each other to produce gametes.
- This behaviour is called **COURTSHIP BEHAVIOUR IN FISH**.

DIAGRAM SHOWING COURTSHIP BEHAVIOUR IN THREE – SPINED STICKLEBACK.

- The male stickleback, in the breeding season, develops a red belly and blue eyes.
- These colour changes helps it (i) To keep other males at bay
(ii) To attract the female.

ACTIVITIES OF A MALE STICKLEBACK THAT LEAD TO FERTILIZATION

1. The male digs a small hole and roofs it over with pieces of vegetation (a Nest)
2. The male attracts the female with its bright colours.
3. The male lead the female to the nest.
4. The male "points" to the nest entrance (shows the nest)
5. The male tremble — thrust — stimulates the female to lay eggs.
6. The male fertilizes the eggs.

ACTIVITIES OF A FEMALE STICKLEBACK THAT LEAD TO FERTILIZATION

1. It attracts the male stickleback by displaying its swollen abdomen.
2. It follows the male to the nest.
3. It spawns (lays) eggs in the nest.

PHYSICAL DIFFERENCES BETWEEN A MALE AND A FEMALE STICKLEBACK

1. The abdomen of a female is swollen because it contains eggs while that of the male is
not swollen.
2. The male is shorter and smaller while the female is longer and bigger.

LOCOMOTION

The movement of organisms from one place to another.

THE SKELETON

- Is the framework of the body of the organisms.
- It is present in both plants and animals.

TYPES OF SKELETON

1. HYDRO STATIC SKELETON

This is a kind of skeleton in which a liquid is contained inside cells and spaces inside
the body of soft — bodied animals e.g. caterpillars and earthworms.

2. EXOSKELETON

This is the hard material found outside the body of an animal.

- It found in both plants and animals.
- Example of animals are spiders, grasshoppers and crabs.
- The shedding of the exoskeleton in animals is called **MOULTING OR ECDYSIS.**

ADVANTAGES

- It provides complete protection to an organism since it covers the body.

DISADVANTAGES

- Growth is restricted i.e. organisms are small in size.
- Restrict the speed of animals.

3. ENDOSKELETON

This is the hard material found inside the body of the animal.

-Vertebrate such as fish, goats, lizards and human beings have endoskeleton.

ADVANTAGES

- It allows free growth of organisms since it does not cover the body of the organism.
- Speed of organism (movement) is not restricted.

DISADVANTAGES

- It provides little protection to the body of the organism from external physical forces.

THE HUMAN SKELETON

The human skeleton has three regions:

1. THE AXIAL SKELETON

This consists of skull, the vertebral column, ribs and sternum.

2. THE APPENDICULAR SKELETON

Made up of bones of the limbs.

3. THE LIMB GIRDLES

Made up of the Pectoral (shoulder) bones and the Pelvic (hip) bones.

DIAGRAM SHOWING THE HUMAN SKELETON

GENERAL FUNCTIONS OF HUMAN SKELETON

The following are the general functions of a human skeleton.

(a) It brings about movement.
- Many bones act as levers, when muscles pull on these levers they produce movement
e.g chewing action, breathing movements of ribs e.t.c.

(b) It protects the delicate importance organs in the body e.g. the skull protects eyes and
the brain, the rib cage protects the liver, the lungs and the heart.

(c) It supports the body.
- The skeleton supports the body thereby giving it shape and form. Without it the
whole body would collapse.

(d) It produces blood cells.
- Red blood cells, white blood cells and platelets are produced in bone marrow.

(e) It helps in breathing.
- The ribs help in respiration.

(f) It is used in sound production i.e. the ear ossicles.

(g) It is used for digestion.
- Teeth break food particles into small particles.

THE STRUCTURE OF A BONE

The bone is a live; it contains living cells that are supplied with food and oxygen by blood cells.

COMPACT BONE — Is the hardest part of the bones.
SPONGY BONE — has spaces in it which stop it from being heavy.
MARROW CAVITY — is a hollow that contains bone marrow.
THE BONE MARROW — Is a very soft material and has a good supply of blood. It is found in the marrow cavity.

- Red blood cells, white blood cells and platelets are made in the bone marrow.

COMPOSITION OF THE BONE

There are two components of a bone namely.
(i) organic component
(ii) inorganic component

- The organic component is made of protein called **COLLAGEN.**
- This component is elastic or flexible or rubbery.

- The inorganic component is made of **calcium**, **phosphate** and **calcium carbonate**.
- This component is hard due to the presence of calcium.

EXPERIMENT:

TO INVESTIGATE THE COMPOSITION OF ABOVE.

PROCEDURE

1. Take small pieces of flesh bones of a chicken. Weigh them and try to bend them.
2. Place them in a test tube and cover them with hydrochloric acid.
3. Fix a delivery tube from this test tube to another test tube containing limewater, as follows:

4. Leave the apparatus in a safe place for about two days.
5. After two days observe and record any colour change in the lime water.
6. Rinse the bones and try to bend them.
7. Dry bones in the sun and reweigh them.

EXPECTED RESULTS

1. After two days the limewater turns milky. This means that the mixture of hydrochloric
acid and bones in the test tube produce carbon dioxide. This carbon dioxide was
released from calcium carbonate.
2. The mass of the bones decrease. This means that part of the bones dissolves in the
hydrochloric acid.
3. The bones are hard before soaking in the acid. But after soaking in the acid for two
days they become rubbery.
- Thus the hard inorganic component (calcium) dissolves in the hydrochloric acid
leaving the organic component (collagen) which is flexible (rubbery)

THE VERTEBRAL COLUMN

The vertebral column consists of 33 bones (individual vertebrae). The column can be divided into five regions namely: the cervical, thoracic, lumbar, sacral and caudal.

- The vertebral are built on the same general plan and there is no abrupt change in
structure from one region to another.

DIAGRAM OF A GENERALIZED VERTEBRA

1. THE NEURAL SPINE — are used for muscle and ligament attachment.
- are long and point backwards to prevent backwards movement.
2. THE TRANSVERSE PROCESS — these are used for ligament and muscle attachment.
3. CENTRUM — this structure resists compression and produces red blood cells.
4. NEURAL CANAL — a passage of the spinal cord.

All the vertebrae have two main functions:

1. To provide a tough, hard but flexible pillar on which the body is built.
2. To provide a canal through which the spinal cord passes.
3. To protect the spinal cord from external physical forces.

GROUPING OF VERTEBRAE

1. CERVICAL VERTEBRAE
These form the neck, support the head and are 7 in number. The top most cervical
vertebrae are called the atlas and the one reset to it is called the **axis**.

- Cervical vertebrae have the following characteristics:

(i) They have small neural spine.
(ii) They have transverse processes each of which has a central hole through which an artery passes on each side of the vertebra.
(iii) Each has special articulating surfaces called **FACETS**.

- The atlas forms a special joint with the skull, which allows nodding movement up and down.
- It different from the other cervical vertebrae in the sense that:
(i) it has broad and flat transverse processes.
(ii) it has two deep hollow surfaces in front of it which fit the two rounded swellings in the base of the skull.
(iii) It has no Centrum.

DIAGRAM SHOWING ATLAS

- The Axis has a broad Centrum with stout projection called the **ODONTOID PEG** (process), which fits into the atlas.
- This forms a pivot joint, which allows head rotation.

DIAGRAM SHOWING THE AXIS

2. THORACIC VERTEBRA

The main function of the thoracic vertebrae is to hold the ribs firmly which allowing
for their movement in breathing.
- They have long neural spine which prevent the backward movement.
- They have two large processes to which ribs are attached.

DIAGRAM SHOWING THORACIC VERTEBRA

3. LUMBAR VERTEBRA

- There are 5 lumbar vertebrae that form the lumbar region.
- These vertebrae protect and support the heavy but delicate organs in the abdominal
cavity (region)
- They also provide attachment for the powerful back muscles.
- Much of the bodys weight of the human being is exerted on this region of the spine.
- Due to the stresses exerted by muscle attachment their transverse processes are
thicker.

DIAGRAM SHOWING THE VERTEBRA

4. SACRAL VERTEBRAE

There are five sacral vertebrae that are fused together at the base of the spine to form
the sacrum.

5. COCCYGEAL VERTEBRAE (TALC BONES)

There are 4 coccygeal vertebrae which are fused together to form a small pieces of
bone called the coccyx.
- This is a representation of a tail in human beings.

JOINTS

A joint is a place where bones meet.

A TYPICAL JOINT

PARTS AND FUNCTIONS

1. **CARTILAGE** — prevent the rubbing of the bones at a joint.
2. **SYNOVIAL MEMBRANE —** produces synovial fluid.
3. **SYNOVIAL FLUID** — Lubricates the joints thereby preventing friction during movement.
4. **CAPSULE OF JOINT OR LIGAMENTS —** these help to hold bones together at a joint.

GROUPS OF JOINTS

Main groups of joints are

1. IMMOVEABLE JOINTS.

These are joints which do not move e.g. sutures of the skull.

2. MOVEABLE JOINTS

Moveable joints are described according to the type of movement they allow.

TYPES OF MOVEABLE

1. SLIDING JOINTS

These are joints that occur where bones meet at flat surfaces and glide over each other,

e.g. ankle and wrist joints.

e.g wrist joint

2. HINGE JOINTS

These are joints that work like a hinge, allowing movement in one plane only thus giving a maximum of 180˚ angle of movement. e.g. elbow and knee joint.

Elbow joint

3. BALL AND SOCKET JOINT

These joints have the greatest flexibility allowing a maximum of 360˚ angle of movement.

MUSCLES

- Are the flesh parts of the body.
- All movements in the body are caused by muscle contracting or shortening.

KINDS OF MUSCLES

There are three kinds of muscle cells:

1. SMOOTH OR UNSTRIATED OR UNSTRIPED MUSCLES

They are also called **INVOLUNTARY MUSCLE** because they are not under our control/will.

- Examples include walls of intestine, Blood vessels and iris of the eye.
- The muscles are capable of remaining contracted for along period of time i.e. cannot get tired easily.

2. SKELETAL OR STRIATED OR STRIPED MUSCLES

- These are also called **VOLUNTARY MUSCLES** because they are under our control/will.
- They are striated
- They are strong and contract fast
- They easily get tired
- Examples in the body are Biceps and triceps muscles of the upper arm, quadriceps femoris and Biceps femoris of the upper leg (thigh)

N.B. Muscles that work in pairs are called **ANTAGONISTIC MUSCLE.**

- When the muscle on one side contracts the other one on the other side relaxes e.g.
Biceps and triceps muscles.

DIAGRAM SHOWING THE BICEPS AND TRICEPS IN THE UPPER ARM

ACTION OF RUNNING IN MAN

The complete action of running consists of a **Power stroke** and a **Recovery stroke.**

During the power stroke — the leg is straightened and the foot exerts a backward force on the ground.
- The equal and opposite force of reaction exerted by the ground on the food is the force
  that causes forward motion.
- During the Recovery stroke — the leg is bent. This is necessary not only to raise the foot
  above the ground, but also to allow the leg to be moved forward as rapidly as possible.

DIAGRAMS SHOWING ACTION OF RUNNING IN MAN

DIAGRAM SHOWING MUSCLES OF THE LEG

LEVERS

- A lever is a bar which is turned about a fixed point.
- The fixed point where a bar is turned is called **FULCRUM (F).**
- Weight or mass lifted by a lever is called the **LOAD (L).**
- The force applied to lift the load is called **EFFORT (E).**

There are three main types of levers, called **ORDERS OF LEVERS.**

These types of levers are:

1. FIRST ORDER (CLASS) LEVER

This is a lever in which the Load (L) is at one end, the effort (E) at the other end and fulcrum (F) in the middle.

An example of first class lever in the body is the nodding of a head.

DIAGRAM SHOWING NODDING OF A HEAD

2. SECOND ORDER LEVER

This is a lever in which the Load (L) is between the effort (E) and the fulcrum (F).

An example of second order levers in the body is when one stands erect on the toes.

DIAGRAM SHOWING ON STANDING ERECT ON THE TOES

3. THIRD ORDER LEVER

This is the lever in which the effort (E) is between the fulcrum (F) and the Load (L)

An example of third class lever in the body is the lifting of a load in the hand (Elbow joint in the fulcrum)

DIAGRAM SHOWING ONE LIFTING AN OBJECT

PROBLEMS ASSOCIATED WITH LOCOMOTION

1. DISEASES

In Malawi these include Tuberculosis, Poliomylitis and Rickets.

2. FRACTURES — A fracture is a break in a bone .

These are

(a) SIMPLE FRACTURE — Is when a fracture is closed, that is, without causing an open wound.

(B) COMPOUND FRACTURE — An open wound is caused when part of the broken bone tears through the flesh and protrudes.

3. OTHER INJURIES

(A) SPRAINS — are injuries to the soft tissues surrounding joints e.g. when ligaments, tendons and blood vessels are overstretched and occasionally torn or partially torn without the bones being affected.

(B) DISLOCATION - Is a displacement of the end of a bone from the joint.
- This is usually caused by a twist or severe blow, which forces the bones out of place and also tears the ligaments.

(C) STRAINS — are injuries to muscles because of being exerted too heavily.
- The muscle fibres become overstretched and sometimes partially torn.

LOCOMOTION IN BIRDS

- All birds can walk and nearly all can fly except the **ostrich**, the **kiwi** and the **penguin**, which are flightless birds.
- In addition some birds can swim, for example, ducks and penguins.
- Birds in flight faces the following problems
  (i) Drag due to friction and turbulence.
  (ii) Gravitational force i.e. downward pull.

HOW DOES THE BIRD OVERCOME THESE PROBLEMS

1. WING DESIGN — The curves are slightly different on the upper and lower surface.

- This curve of the wing has the effect of making the air flow differently across the two surfaces as the bird is moving forwards.
- The flow of air on the upper surface of the wing reduces the pressure there, and this tends to lift the bird — overcoming the gravitational force.
- The large surface area of the wing also helps in supporting the bird — overcoming the

gravitational force.
- The problems of lift and drag are thorns solved by the shape of the wing.

2. FEATHER DESIGN — Birds have streamlined bodies covered with feathers which
overlap backwards. This reduces friction and drag.

HOW DOES A BIRD FLY

- Movement of the wings in the bird is brought about by the action of powerful **PECTORAL** (breast) muscles.
- During the downward beat the wings beat forwards and downwards. The fully extended
wings provide a large solid flat surface against air.
- This movement of the wings brings about forward motion and the shape of the wing
gives the bird upward lift.
- During the upward beat the wings move upwards and backwards.
- As the wings move upwards air passes between the quill feathers. This reduces the air
resistance against the wings as they return to the starting position again ready for the
next flap.
- During flight the tail steers the bird and is also used a brake.

TYPES OF FEATHERS

- Feathers that are attached to the wing are called **FLIGHT FEATHERS,** since they help
in the flight of birds.
- Feathers that cover the rest of the bird are called **DOWN FEATHER.**

DIAGRAM SHOWING FLIGHT FEATHER

DOWN FEATHER

STRUCTURAL DIFFERENCES BETWEEN FLIGHT (QUILL) FEATHER AND DOWN FEATHER

FLIGHT FEATHER	DOWN FEATHER
Large and strong shaft	Small and weak shaft
Large quill	Small quill
Even margin	Uneven margin
Generally large	Generally smaller

ADAPTATIONS FOR FLIGHT IN BIRDS

(a) They have bodies that are streamlined.
- This reduces drag so that it is easy for them to fly through the air.

(b) They have wings that are streamlined. This shape creates air currents at the upper and
lower surfaces of the wings to provide the birds.

(c) They are light so that they are easily overcome force of gravity.

- The birds are light because

(i) Their skeletons are made of hollow bones.
(ii) Their flight feathers provide a large surface are onto the wing and the feathers in general trap a lot of air in between them.
- This reduces the average density of the birds.
(iii) They have air sacs which when filled with air reduce the average density of

the birds.

(d) They have strong and powerful breast (Pectoral) muscles for producing sufficient
energy for flight so that they provide enough lift to overcome force of gravity, and
keep the bird moving through the air.
(e) They have feathers that provide sufficient insulation to the bird by trapping a lot of air
in between them.
- This air forms a layer of insulation that protects the bird from the cold environment
at high altitudes.

LOCOMOTION IN FISH

- Movement in fish is mainly brought about by powerful muscles of the tail.
- The powerful muscles on both sides contract alternatively, making the body move from
side to side and this makes the water to be pushed backwards and in turn the water
pushes the fish forward.
- The water that enters the mouth of the fish provides a forward push to the fish as it is
expelled through the gill cover.
- In some fish, the fins contribute to propulsive forces that make the fish move.
- But the main function of fins is to control stability and direction of the fish e.g. the
dorsal and ventral fins, control the rolling and yawning(zig-zag mvts) movements presented to the water.
- The paired fins e.g. the Pectoral and Pelvic fins act as hydroplanes and control the pitch
of the fish causing it to swim downwards or upwards according to the angle to the water
at which they are held by the muscles.

DIAGRAM SHOWING EXTERNAL FEATURES OF THE FISH

ADAPTATIONS OF FISH FOR LOCOMOTION

- The body of fish is streamlined to reduce drag as it moves through the water.
- Scales overlap backwards, to reduce drag as it moves through the water.
- Some fish have long air filled sacs called **SWIM BLADDERS,** which help in changing
the depth i.e. when full of air allow the fish to rise since the average density of the fish
decreases, and when empty allows the fish to sink.
-Paired fins
-Caudal/tail fin
-Dorsal and anal fins

N.B. Fish have Lateral line to detect movements and vibrations in water.

LOCOMOTION IN INSECTS

Locomotion in birds is brought about by flying using wings or by walking using limbs.

(1) WALKING IN INSECTS

- The legs, which are used for walking have joints.
- Many of the joints are **Peg** and **Socket** type. They permit movement in one plane
only, like hinge joints, but there are several such joints in one leg each operating in
a different direction so that the leg as a whole can describe fairly free

directional
movement.

DIAGRAM OF THE LEG SHOWING JOINTS.

DIAGRAM OF AN INSECTS LEG SHOWING ANTAGONISTIC MUSCLES.

Muscles that bring about movement in an insect work antagonistically.
When extensor muscles contracts the flexor muscles relax.

2. FLYING IN INSECTS

- Most insects have two pairs of wings, which they use for flying.
- The wings are attached to the second segments of their thorax.
- During flying insects use two pairs of antagonistic muscles that raise and lower their

wings by contracting and relaxing.
- The muscles that raise (elevate) the wings through their contraction to make the insect gain height are called **Elevator muscles.**
- These muscles are attached to the roof and bottom of the thorax and are in pairs.

DIAGRAM SHOWING THE THORAX OF AN INSECT WHEN GAINING HEIGHT.

Elevator muscles : contracted, fatter and shorter.
Depressor muscles : relaxed, thinner and longer.

The wings are raised and insect gains height.

- The muscles whose contraction lower (depress) the wings to make the insect lose height are called **Depressor muscles**.
- The Depressor muscles are attached to the sides i.e. ventral plates of the thorax and are in a pair.
- When depressor muscles contract they become short and fatter, they pull the ventral plates and lower the wings to make the insect lose height.

DIAGRAM SHOWING THE THORAX OF AN INSECT WHEN LOSING HEIGHT

Elevator muscles : relaxed, thinner and longer.
Depressor muscles : contracted, fatter and shorter.

The wings are lowered and insect loses height.