**BIOLOGY NOTES FORM TWO**

**EXCRETION AND HOMEOSTASIS**

**Excretion**-Process by which living organisms separate and eliminate waste products formed during metabolic processes from the body. They include; carbon IV oxide, excess water and mineral salts, nitrogenous wastes etc. accumulation of these substances may become toxic to cells.

**Homeostasis**-This is the maintenance of internal environment of cells under constant conditions E.g. temperature, osmotic pressure, blood sugar and chemical constituents.

**Egestion**. - This is the removal of undigested and indigestible materials from the alimentary Canal of animals.

**Secretion**. - This is the release of certain useful substances produced by cells e.g. hormones, Enzymes, sebum, saliva and mucus.

**Excretion in Plants**

* Plants do not have complex organs for excretion because;
1. There is very little accumulation of toxic wastes such as nitrogenous wastes.
2. Some waste products are re-used in the same plant such as Co2, oxygen and water.
3. Some of these gases are removed by simple diffusion through the stomata and lenticels.
4. Some plants store wastes in their tissues in non-toxic forms such as nicotine, caffeine, tannins, resins, quinine, morphine etc.

**Economic Importance of Plant Excretory Products**

1. *Tannins* – They are deposited in dead tissues of wood and barks of trees e.g. in acacia and wattle tree. Tannin is used to treat leather.
2. *Caffeine* – it is stored in coffee berries and tea leaves. It is used as a stimulant.
3. *Quinine* – it is stored in the leaves of aloe and bark of *cinchona* tree. It is used in the treatment of malaria.
4. *Cocaine* – it is obtained from the leaves of coca plant and is used as an anesthetic.
5. *Cannabis* – found in the leaves and flowers of *Cannabis sativa* (bhang). It is used to manufacture some drugs.
6. *Nicotine* – found in leaves of tobacco plant and is used in the manufacture of insecticides and narcotic drugs. It also manufactures cigarettes.
7. *Rubber* – it is made from latex of rubber plant. It is used in shoe industry and manufacture of chewing gum.
8. *Colchicines* – it is used in plant breeding and treating of cancer.
9. *Pappain*- it is obtained from raw paw paw and it is used as a meat tenderizer.
10. *Khat/miraa* – it’s chewed and acts as a mild stimulant.

**Excretion and Homeostasis in Unicellular Organisms**

* Most simple organisms such as the protozoa (amoeba and paramecium) live in aquatic environment.
* They depend mainly on diffusion as the means of excretion.
* Their bodies have a large surface area to volume ratio providing a large surface area for gaseous exchange and excretion to take place by simple diffusion.
* Waste products diffuse from the cytoplasm where they are highly concentrated across the cell membrane into the surrounding water where their concentration is low.
* The organisms also use the contractile vacuole to achieve excretion.
* Amoeba and paramecium live in an aquatic environment that is hypotonic to their body fluids. Water therefore tends to move into their cytoplasm by osmosis.
* The excess water and dissolved chemicals accumulate in the contractile vacuole which releases them to the surrounding water.

**Diagram**

**Excretion in Mammals**

* Mammals have an elaborate excretory system since their bodies are complex.
* The main excretory organs in mammals include; lungs, skin, kidneys and the liver.

**A Structure and Function of the Mammalian Skin**

* Skin is the largest body organ covering the whole body surface.
* **It has the following functions.**
1. Protection of the underlying tissues from entry of micro-organisms, physical damage and ultra violet rays from the sun.
2. Regulation of body temperature.
3. Excretion of salts, excess water and traces of urea.
4. Reception of stimuli such as heat, cold, pain, touch and pressure.
5. Synthesis of vitamin D.
6. Storage of fats.

**Diagram**

* The skin is made up of two layers;
1. Epidermis (upper and outer layer)
2. The dermis (inner layer)

a) **Epidermis (upper and outer layer)**

* It is made up of three other layers;
1. Cornfield layer.
2. Granular layer.
3. Malphigian layer.
4. **Cornifield layer**
* The Cornifield layer of the epidermis consist of dead cells which form a tough outer coat; that protects the skin against mechanical damage, bacterial infection and water loss;
1. **Granular layer**
* It’s the middle layer of the epidermis and is made up of living cells that give rise to the Cornifield layer.
1. **Malphigian layer**
* Malphigian layer consists of actively dividing cells that contain fine granules of melanin; that prevents the skin against ultraviolet light rays from the sun; melanin gives the skin its colour.
1. **The Dermis** (**inner layer**)
* It is thicker than the epidermis and consists of the following structures;
1. *Sebaceous glands* produce an oily secretion sebum which give hair its water repelling property; that keeps the epidermis supple and prevents it from dying

Sebum also prevents bacterial attack due to its antiseptic property;

1. *Has blood vessels;* that dilate and contract;

In hot conditions, they dilate; increasing blood flow near the skin surface enhancing blood flow near the skin surface; minimizing heat loss;

Blood vessels supply nutrients and oxygen to skin tissues and also remove waste products and carbon IV oxide.

1. *Has Hair follicle* ;hairs stand during cold weather thus trapping a layer of air which prevents heat loss; In hot weather they lie close to the skin surface; to enhance heat loss to the atmosphere.
2. *Have many sensory neurons* which detects environmental changes; increasing sensitivity of the skins.
3. *Has subcutaneous layer*; contains fat which acts as a heat-insulating layer and a fuel storage.
4. *Lymphatic vessels*; they drain excess tissue fluid.
5. *Sweat glands*; are involved in temperature regulation through loss of excess heat by the evaporating water.

Sweat also excretes excess water, mineral salts, urea and lactic acid.

**B The Lungs**

* They are involved with the removal of carbon VI oxide which is released by cells during their metabolism.
* Carbon IV oxide would be toxic if it was left to accumulate in the tissues.

**C Structure and Function of the Kidney**

***Diagram fig. 4.3; generalized urinary system of a mammal (page 88 KLB)***

* Mammals have a pair of kidneys which are bean shaped and dark red in colour.
* The kidneys are surrounded by a layer of fat which cushions them against mechanical injury.
* Above each kidney are the adrenal glands which secrete hormones.
* Renal artery supplies blood to the kidneys and the renal vein removes the blood.
* Ureter transports urine from the kidney to the bladder which temporarily stores the urine.
* The mammalian kidney has three distinct regions; cortex, medulla and pelvis.

***Diagram fig. 4.4(a) and 4.4(b) (page 89 KLB)***

**Cortex**

* It is the outermost region and is dark red in colour.

**Medulla**

* It is red in colour and extends to form conical structures called pyramids.
* Pyramids open up into the pelvis.

**Pelvis**

* It’s white in colour and narrows down to form the Ureter.
* The human kidney contains urinary tubules called the nephrons.

**Nephron**

* It is the basic functional unit of the kidney. Each nephron is made up two main parts;
* Renal tubule
* Glomerulus.

***Diagram fig. 4.6. The structure of the kidney nephron***

**X**

**B**

**A**

**C**

**D**

**C**

The renal tubule has 5 main parts.

1. Bowman’s capsule
2. Proximal convoluted tubule
3. Loop of Henle
4. Distal convoluted tubule
5. Collecting tubule
6. **Bowman’s capsule**
* It is a thin walled and cup shaped structure which contains the glomeruli.
* Glomerulus is a fine network of blood capillaries enclosed by the Bowman’s capsule.
* It is made the afferent and efferent arterioles.
* Blood entering the kidney via the renal artery is rich in nitrogenous wastes such as urea.
* Also it has dissolved food substances, plasma proteins, mineral ions, hormones and oxygen.
* Afferent arteriole entering the Glomerulus is wider than the efferent arteriole leaving it.
* This creates extremely high pressure in the Glomerulus coupled with the fact that renal artery branches directly from the aorta where blood is at high pressure.

***Diagram: structure of the nephron***

* Due to the high pressure in the glomeruli, the liquid part of the blood and dissolved substances of low molecular sizes including urea, glucose, salts and amino acids are forced out of the Glomerulus into the cavity of the Bowman’s capsule.
* The large sized molecules in the plasma such as proteins and blood cells are not filtered out.
* This is because the capillary walls of the Glomerulus and bow mans capsule have very small pores.
* This process is known as ***ultra-filtration*** and the filtrate formed is called ***glomerular*** filtrate.
* The filtrate then enters the proximal convoluted tubule.

***Diagram of ultra-filtration at the Glomerulus***

1. **Proximal convoluted tubule**
* As the filtrate flows along the renal tubules, most of the filtered substances in the glomerular filtrate useful to the body are selectively reabsorbed back into the blood.
* The following substances are actively reabsorbed using energy in the proximal convoluted tubule; ***All glucose, Amino acids and Mineral salts.***
* The proximal convoluted tubule is adapted in the following ways for efficient re-absorption of these substances.
1. Presence of mitochondria in the cells lining to provide with energy required
2. Cells of the tubule have micro-cilli (infoldings) which increase surface area for re-absorption.
3. Tubule is long and coiled to increase the surface area.
4. Coiling of the tubule reduces the speed of flow of filtrate giving more time for efficient re-absorption.
5. Tubule is well supplied with blood capillaries.
6. **Loop of Henle**
* This is where particularly sodium chloride is actively reabsorbed into the blood.
* Loop of Henle has counter current flow between the flow of filtrate and the flow of blood i.e. the filtrate and blood flow in opposite directions.
* The hormone ***Aldosterone*** secreted by the adrenal glands regulate the absorption of sodium salts.
* Low content of sodium salts in the blood stimulates adrenal glands to secret more *Aldosterone* hormone and therefore more salts are reabsorbed from the filtrate.
1. **Distal convoluted tubule**
* When the filtrate reaches here, some water is reabsorbed into the blood by osmosis.
* This is made possible by the following;

- Active intake of sodium salt into the blood at the loop of Henle increases the osmotic potential of the blood.

- The antidiuretic hormone (ADH) secreted by the pituitary gland. ADH increases the permeability of the tubule and blood capillaries to water

* When there is excess water in the body there is less production of ADH and less water is reabsorbed hence production of large amounts of dilute urine.
* If the body has lost a lot of water such as through sweating, this raises the osmotic pressure of blood. Pituitary gland releases more ADH which increases permeability of the kidney tubules to water. More water is reabsorbed hence production of little but concentrated urine.
* The distal convoluted tubule has large surface area, it is has a wall that is one cell thick and is surrounded by may blood capillaries.
1. **Collecting tubule**
* The filtrate in the collecting tubule becomes the urine and moves to the collecting duct.
* Urine flows into the pelvis via the pyramids and is finally emptied into the urinary bladder through the ureter. About 1-2 litres of urine are formed in a day.
* About 250ml of urine in the urinary bladder initiates the urge to urinate. The sphincter muscles relax and urine pass.

**Urine Composition**

|  |  |
| --- | --- |
| **Substance**  | **% Composition.** |
| **Water** |  **95%** |
| **Urea** | **2%** |
| **Uric acid** | **0.03%** |
| **Creatine**  | **0.1%** |
| **Salts** | **1.4%** |
| **Ammonia** | **0.04%** |
| **Proteins** | **0%** |
| **Glucose** | **0%** |

* The quantity and concentration of the urine in animals is affected by
1. Physiological adaptations.
2. Habitat of an organism e.g. terrestrial, desert or aquatic.
3. Structural adaptations of the animals e.g. a desert rat has long kidney tubules to increase water reabsorption.

**Study Questions. Page 93.**

**Comparison Between Aquatic and Desert Animals**

|  |  |
| --- | --- |
| **Fresh Water Animals** | **Desert Animals.**  |
| 1. Have many glomeruli to increase ultrafiltration.
 | Few glomeruli to reduce ultrafiltration. |
| 1. Short loop oh Henle to reduce water reabsorption.
 | Long kidney tubules to increase water reabsorption. |
| 1. Produce large quantity of dilute urine.
 | Produce small quantity of concentrated urine. |

**Comparison of Composition of urine with that of Glomerular Filtrate and Blood Plasma.**

|  |  |
| --- | --- |
| **Substance**  | **% Composition of;** |
| **Plasma**  | **Glomerular Filtrate.** | **urine** |
| **Urea** | **0.03** | **0.03** | **2.0** |
| **Uric acid** | **0.005** | **0.005** | **0.03** |
| **Ammonia** | **0.001** | **0.001** | **0.004** |
| **Glucose** | **0.1** | **0.1** | **0** |
| **Amino acids** | **0.05** | **0.05** | **0** |
| **Mineral salts** | **0.70** | **0.70** | **1.4** |
| **Blood proteins.** | **8.00** | **0** | **0** |

**Functions of the kidney include:**

1. Excretion.
2. Osmoregulation.
3. Ionic balance.
4. Regulation of PH

**Kidney Diseases**

1. *Nephritis*

This is the inflammation of the glomerulus of the kidney. It is caused by bacteria or infections such as small pox and measles.

**Symptoms**

* Headaches and vomiting
* Fever
* Passing coloured urine
* Presence of proteins in urine

**Treatment**

* Use of antibiotics
1. Use of just adequate amounts of salts and proteins in diets *Kidney stones*

**Causes**

* Lack of vitamins such as vitamin A and inadequate intake of water
* Chemical salts in urine that crystallize to form hard stones.

**Symptoms**

* Increased frequency in passing out urine
* Pain and soreness in the upper backside
* Difficulty in passing out urine
* Fever

**Control & Treatment**

* Seeking medical assistance
* Taking a balanced diet with adequate amount of water and vitamins
* Dialysis or artificial washing out of the wastes
* Use of laser beam to disintegrate the stones
* Kidney transplant
1. *Kidney failure*
* This is the failure of the kidney to perform as a result of a drop in blood pressure due to heart failure, haemorrhage or shock.
* If failure is due to other causes, the condition can be corrected by;
* Kidney dialysis
* Kidney transplant
1. *Albiminuria (Proteins in Urine).*
* This is also called *Proteinuria*
* Capillaries of the glomerulus lose their ability to be selective and start allowing blood proteins to pass through into the kidney tubules. These proteins are released in urine.

**D The Liver and its Structure**

* This is the second largest excretory organ after the skin. It receives blood from two blood vessels; ***the hepatic portal vein from the alimentary canal and hepatic artery from the aorta***.



**Homeostatic Functions of the Liver**

 ***Regulation of blood sugar level***

* Excess glucose is converted to glycogen ;and stored in the liver under the influence of the hormone insulin secreted by the pancreas. Another hormone called glucagon; stimulates the conversion of glycogen to glucose; when there is shortage of glucose in the body; Glucagon is also secreted by the pancreas
1. ***Deamination***
* The liver breaks down excess amino acids; The amino group is removed as ammonia which is toxic;
* Ammonia is changed into urea which is less toxic in the *ornithine cycle*.

Ornithine Cycle

Enzyme arginase

2NH3 + CO2 CO(NH2)2 + H20

Ammonia Carbon iv Urea Water

(Toxic) Oxide (less toxic)

* The remaining carbon skeleton oxidized to carbon IV oxide and water; this process leads to release of energy. The carbon skeleton may be converted to glucose to be used during respiration;
1. ***Detoxification***
* Toxic substances are made harmless in the liver e.g.
* Ammonia from the process of deamination is converted in the liver into urea; which is less toxic.
* Bacterial toxins are converted to less toxic substances by liver cells;
* Hydrogen peroxide produced by respiring cells is broken down into water and oxygen which are harmless by the enzyme catalase found in the liver.

Enzyme

Catalase

Hydrogen Peroxide Water + Oxygen

(H2O2) (H2O) (O2)

1. ***Regulation of plasma proteins***
* The liver produces most of the proteins found in blood; fibrinogen and prothrombin which play a role in blood clotting. Albumin and globulins are also produced by the liver. Globulins act as antibodies;. Albumin contributes to the maintenance of osmotic pressure in the body; Non essential amino acids are synthesized by the liver;
1. ***Storage of vitamins A, B,D,E and K and mineral salts***
* The liver store vitamins A, B, D, E and K. Iron released from the breakdownof erythrocytes is stored in the liver cells; in the form of a compound called ferritin. The liver therefore is a good source of these vitamins and iron;
1. ***Heat production (Thermoregulation)***
* The various metabolic activities of the liver lead to release of heat energy; This energy is distributed by the blood to other parts of the body hence contributing to maintenance of constant body temperature;
1. ***Inactivation of hormones and drugs***
* After performing their functions, hormones and drugs are chemically modified to inactive compounds; The by-products are eliminated through the kidneys and faeces and via bile;
1. ***Storage of blood***
* The large size and high capacity for contraction and expansion of its veins enables the liver to hold a large volume of blood; It therefore regulates the volume of blood in the general circulation depending on the body’s requirements ;
1. ***Regulation of cholesterol and fat metabolism***
* When carbohydrates are in short supply in the body, fats in different parts of the body are mobilized and taken to the liver; The fats are oxidized to carbon (IV) oxide and water with the production of energy or modified and sent to tissues for oxidation;
1. ***Manufacture of red blood cells in foetus.***

**Liver Diseases and Disorders**

1. **Liver Cirrhosis**
* This is the hardening of the liver tissues due to death of liver cells.
* This is caused by ingestion of toxic chemicals such as alcohol.
* Bacteria, viruses and parasites such as liver flukes can also cause the disease.

**Control**

* Avoid excess alcohol.
* Avoid fatty diets.
* Low salt intake
1. **Hepatitis**
* This is a viral disease causing inflammation of the liver.
* It is transmitted through contaminated food, milk and water.
* There are two types of hepatitis; Hepatitis A and B**.**
1. **Jaundice**
* This is characterized by the yellowing of the skin due to the failure of the liver to excrete bile.

**Homeostasis**

* This is the maintenance of internal environment of cells under constant Conditions E.g. temperature, osmotic pressure, blood sugar and chemical constituents.

**Principles of Homeostasis**

* Various body systems such as circulatory, excretory, endocrine (hormonal) and nervous work in a coordinated way to bring about homeostasis.
* These systems work on a feedback mechanisms. There are two types of feedback mechanisms**.**
1. ***Negative Feedback Mechanism***
* When a factor in the body such as temperature or blood sugar level falls below normal or rises above the normal, it is detected and corrected via the negative feedback mechanism.
* Such an action is through:
1. *An increase in the level if it is dropping*
2. *A decrease in the level if it is increasing*
* This restores the condition to the normal.

**Further Excess**

 **Positive feed back**

**Corrective**

**Mechanism**

**Excess**

**(Negative Feedback)**

**Normal**

**(Set Point)**

**Normal (Set Point)**

**(Negative feedback)**

**Corrective**

**Mechanism**

**Deficiency**

 **Positive feedback**

**Further deficiency**

1. ***Positive Feedback Mechanism***
* In positive feedback mechanism, a change below or above the normal is not corrected.

*The following are some of the factors regulated through homeostasis.*

* *Temperature*
* *Osmoregulation (water and salt balance)*
* *Ionic content regulation*
* *Blood sugar regulation*
1. **Temperature Regulation. (Thermoregulation)**
* Hypothalamus of the brain is the thermoregulatory center. It also controls other homeostatic processes such as Osmoregulation, and blood sugar level.

**Skin and Thermoregulation**

The skin is adapted in the following ways to effect thermoregulation;

1. ***It has Hair shaft;***
* Connected to erector pili muscles**;**
* In low Temperature Erector pili muscle contract raising hair shaft erect**;**
* Hair traps air which insulates the body/poor conductor of heat.;
* In high temperature, the Erector pili muscle relax and extends**;**
* Hair shaft lies on the skin**;**
* Little or no air is trapped**;**
* Skin loses heat through convection /conduction /radiation **;**
1. ***Blood vessels***
* In High temperature they vasodilate**;**
* More blood flows near skin surface**;**
* Heat is lost through conduction /convection/ radiation**;**
* In Low temperature they Vasoconstrict**;**
* Little blood flows near the skin**;**
* Less heat or ho heat lost through conduction/convection/ radiation**;**

**Diagrams**

 3***) Sweat gland***

* In High temperature**,** Sweating occurs and ( evaporates)andCarries latent heat of vaporization; cooling the body**;**

4) *Has subcutaneous layer*; contains fat which acts as a heat-insulating layer. Organisms in cold areas have thick subcutaneous layer for heat insulation.

**Homoiotherms and Poikilotherms**

**Homoiotherms (Endotherms)**

* They are the animals whose body temperature is maintained at a constant body temperature despite the wide fluctuations in the temperature of the external environment e.g. birds and mammals.

**Poikilotherms (Ectotherms)**

* These are organisms with variable body temperature according to the temperature of the local atmosphere e.g. in organisms such as reptiles, amphibians, insects, and fish.

**Methods of Regulating Body Temperature in Animals**.

1. Metabolic activities of the Body, such as shivering to raise body temperature.
2. Insulatory mechanisms such as dilation or constriction of blood vessels, hair movement etc.
3. Behavioral activities such as clustering together, burrowing, basking, hibernation, aestivation, putting on warm clothes etc.
4. Presence of adaptive features such as hair/fur, subcutaneous tissue etc.

***Hibernation*** is where animals go into deep sleep for long period of time due to cold.

***Aestivation*** is where animals go into deep sleep due to dry and harsh conditions.

***Differences Between* *Homoiotherms and Poikilotherms.***

|  |  |
| --- | --- |
| **Poikilotherms** | **Homoiotherms** |
| 1. They are sluggish under cold conditions.
 | 1. They remain active even under cold conditions.
 |
| 1. They hibernate to avoid death by freezing under very cold conditions.
 | 1. Only the small animals hibernate because they have large surface area to volume ratio hence lose a lot of heat.
 |
| 1. They aestivate under very hot conditions.
 | 1. They do not aestivate because they can maintain constant body temperature.
 |
| 1. They are easy prey to predators due to their hibernation and aestivation.
 | 1. Not easy to prey because they active always.
 |
| 1. Require less food because they get heat from the environment to warm their bodies.
 | 1. Require more food because they use it to generate heat for maintaining the temperature constant.
 |

1. **Osmoregulation (Water and Salt Balance).**
* The osmotic pressure of the body fluids must be kept at a constant so as to have a favourable environment for the normal functioning of cells. This is determined by the relative amounts of water and solutes (salts) in the body fluids.
* If the osmotic pressure of these fluids falls below that of the cells, the cells take in water by osmosis, swell and may burst.
* If the osmotic pressure of thee fluids was higher than that of the cells, the cells would lose water and shrink.
* The hypothalamus and the Pituitary gland are involved in Osmoregulation in the following ways;
1. When the osmotic pressure of the blood rises due to dehydration, the hypothalamus is stimulated and sends an impulse to the pituitary gland which secretes the ***Antidiuretic Hormone (ADH) or Vasopressin*** into the blood. ADH increases permeability of the kidney tubules to water. More water is reabsorbed, osmotic pressure of the blood falls hence production of little but concentrated urine.
2. When osmotic pressure of the blood falls due to excess water in the body there is less production of ADH and less water is reabsorbed hence production of large amounts of dilute urine.

**Diabetes Insipidus**

* This is a condition whereby large quantities of dilute urine are produced when the pituitary gland fails to produce ADH or produces it in inadequate amounts. This condition is also known as ***Diuresis.***
1. **Regulation of Ionic Content**
* Important ions must be regulated within narrow ranges for efficient functioning of the cells.
* Ions are involved in processes such as respiration, protein synthesis, muscle contraction etc.
* The level of sodium ions is regulated by a hormone called ***Aldosterone*** produced by the adrenal glands.
* When the level of sodium ions is low in the blood, more Aldosterone is released which stimulates reabsorption of sodium ions into the blood.
* If sodium ions concentration in the blood rises above the optimum level, adrenal glands produce less Aldosterone into the blood and less amounts of sodium ions are reabsorbed.
1. **Regulation of Blood Sugar Level**.
* All sugars such as galactose, lactose and fructose are converted to glucose.
* Glucose is broken down to release energy and excess is converted into glycogen and stored in the liver or converted into fats as stored as adipose tissue.
* Some glucose flows in general circulation of blood and is maintained within a narrow range of 90-100mg per 100cm3 of blood.
* The pancreas produces two hormones Insulin and Glucagon that are responsible for blood sugar regulation.
* When there is *excess sugar in the blood, insulin is produced* and regulates the blood sugar level by the following;
1. Converts excess glucose into glycogen for storage.
2. Inhibits conversion of glycogen to glucose.
3. Converts glucose into fats.
4. Increases breakdown of glucose to release energy.
* When the level of the *blood sugar falls, glucagon* is secreted and corrects the situation by the following;
1. Increases the breakdown of glycogen into glucose.
2. Increases the conversion of fats and proteins into glucose.
3. Inhibits the conversion of glucose into energy.

NB/. *The hormone adrenaline produced by the adrenal glands also has homeostatic effect on glucose.*

*It is released during emergencies to avail glucose for fight or flight.*

**Diabetes Mellitus (Sugar Disease)**

* This is due to a deficiency in insulin secretion from the pancreas.
* This leads to very high levels of sugar in the blood that cannot be utilised by cells hence eliminated by kidney in urine.

**Symptoms**

* Presence of glucose in urine
* Loss of body weight due to breakdown of fats and proteins
* Chronic starvation
* Thirst sensation.

**Control**

* Insulin injection into the blood stream
* Avoid foods rich in sugars.
* Avoid excessive intake of alcohol.

**Question**

* Explain why insulin is not administered orally (through the mouth)

Corrective mechanism, the liver;

1. Converts excess glucose into glycogen for storage.
2. Inhibits conversion of glycogen to glucose.
3. Converts glucose into fats.
4. Increases breakdown of glucose to release energy.

Normal glucose level

90mg/100ml blood

Corrective mechanism, the liver;

1. Increases the breakdown of glycogen into glucose.
2. Increases the conversion of fats and proteins into glucose.
3. Inhibits the conversion of glucose into energy.

Normal glucose Level.

90mg/100ml blood

**Fall**

**Rise**

**Fall**

**Rise**

***Revision questions***

**Gaseous Exchange**

* This is the process by which respiratory gases (oxygen and carbon IV oxide) are passed across the respiratory surface.
* Gases are exchanged depending on their concentration gradient.
* In simple organisms such as amoeba, diffusion is enough to bring about gaseous exchange.
* CO2 diffuses out into the surrounding water while oxygen diffuses from the water across the plasma membrane into the amoeba.

**Diagram**

**Importance of Gaseous Exchange**

1. Promote oxygen intake for respiration.
2. Facilitate carbon IV oxide removal from the body as a metabolic waste product.

**Gaseous Exchange in Plants**

* During the day, green plants take in carbon IV for photosynthesis.
* Oxygen is given out as a byproduct of photosynthesis and is released into the atmosphere.

**Examples of respiratory Surfaces in Plants**

* Stomata in leaves
* Roots e.g. pneumatophores
* Lenticels in woody stems

**Structure and Function of the Stomata**

* They are tiny openings on the leaf surfaces. They are made up of two guard cells.
* Guard cells are the only epidermal cells containing chloroplasts. They regulate the opening and closing of the stomata.

**Adaptations of Guard Cells**

1. They are bean shaped/sausage shaped.
2. Contain chloroplast hence can photosynthesize.
3. Inner walls are thicker while outer wall is thin to facilitate the opening and closing of stomata.

**Diagram**

**Mechanism of Opening and Closing of Stomata**

* There are three theories that try to explain how the stomata open and close.
1. Photosynthetic theory
2. Starch Sugar inter-conversion Theory. (effect of changes in pH of guard cells)
3. Potassium Ion Theory.
4. **Photosynthetic theory**
* During the day, guard cells photosynthesize forming glucose.
* This glucose increases the osmotic pressure in the guard cells.
* Guard cells draw in water from the neighbouring epidermal cells and become turgid.
* The stoma opens.
* During the night, there is no photosynthesis due to absence of light.
* Glucose is converted into starch lowering the osmotic pressure in the guard cells.
* Guard cells lose water and become flaccid closing the stomata.
1. **Starch Sugar inter-conversion Theory. (effect of changes in pH of guard cells)**
* This is under the influence of pH in the guard cells.
* During the day CO2 is used up during photosynthesis raising the pH in the guard cells.
* In this high pH, enzymes convert more starch into glucose.
* Osmotic pressure of the guard cells increases and water enters into them, making them turgid hence opening the stomata.
* During the night, there is no photosynthesis. The level of CO2 increases lowering the pH.
* Enzymes become inactivated and starch is not converted into glucose.
* Osmotic pressure of guard cells falls making them to lose water by osmosis.
* Guard cells become flaccid and stoma closes.

**Mechanism of Gaseous Exchange in Plants**

* Oxygen diffuses from the atmosphere where it is more concentrated into the plant.
* CO2 diffuses out as a metabolic waste product along a concentration gradient into the atmosphere.
1. **Gaseous Exchange through the Stomata**
* Stomata are modified in number of ways depending on the habitat of the plant.

***Xerophytes:*** These are plants adapted to life in dry areas.

* They have less number of stomata that are small in size.
* Stomata may be sunken, hairy and in some they open during the night and close during the day.

***Hydrophytes:*** These are the aquatic plants (water Plants)

* They have many stomata that are large in size and mainly found on the upper leaf surface.
* Hydrophytes have the aerenchyma tissue with large air spaces to store air for gaseous exchange.

**Diagrams**

***Mesophytes***: They are plants growing in areas with adequate amounts of water.

* They have a fairly large number of stomata found on both leaf surfaces.
1. **Gaseous Exchange through the Lenticels**
* They are openings found on woody stems and they are made of loosely packed cells.
* They allow gaseous exchange between the inside of the plant and the outside by diffusion.
* Actual gaseous exchange occurs on some moist cells under the lenticels.

**Diagram**

1. **Gaseous Exchange through the Roots**
* Plants like the mangroves growing in muddy salty waters have specialized aerial breathing roots called pneumatophores.
* Pneumatophores rise above the salty water to facilitate gaseous exchange.

**Gaseous Exchange in Animals**

**Types and Characteristics of Respiratory Surface**

* Different animals have different respiratory surfaces depending on the animal’s size, activity and the environment in which it operates as shown below.

|  |  |  |
| --- | --- | --- |
| **Type of Respiratory Surface** | **Environment/Medium of Operation** | **Example of Organism** |
| 1. Cell Membrane.
 | Water  | Amoeba |
| 1. Gill Filaments
 | Water | Fish |
| 1. Tracheoles
 | Air | Insects  |
| 1. Alveoli/Lungs
 | Air | Mammals |
| Birds |
| Frogs |
| Reptiles  |
| 1. Skin
 | Water | Frog  |
| Air  | Earthworm  |
| 1. Buccal Cavity
 | Air  | Frog  |

* The respiratory surface is the basic unit of any breathing system upon which actual gaseous exchange occurs by diffusion.
* Respiratory surfaces have the following main characteristics.
1. *Must have a large surface area.*
2. *Must be moist to allow gases to diffuse in solution form.*
3. *Have a dense network of blood capillaries for efficient gaseous exchange.*
4. *Have a thin membrane to reduce the diffusion distance*.

**Gaseous Exchange in Insects**

 Insects have their gaseous exchange system made of many air tubes forming the tracheal system.

* Tracheal system is made up of spiracles and Tracheoles.
* Spiracles are external openings found on both sides of the abdomen and thorax.
* Spiracles have valves to control their opening and closing. They also have hairs to prevent excessive water loss from the body tissue.
* Spiracles open into tubes called trachea. Trachea is reinforced with spiral bands of chitin to keep them open.
* Trachea subdivides into finer air tubes called Tracheoles. Tracheoles are in direct contact with body tissues and organs and they supply individual cells with oxygen.
* Tracheoles do not have bands of chitin and therefore they allow gaseous exchange across their thin moist walls.

**Diagram**

 **Mechanism of Gaseous Exchange in the Tracheal System of an Insect**

* Air is drawn into and out of the tracheal system by muscular movement of the abdominal wall.
* When spiracle valves are open, air is drawn into the tracheal system. The valves close and air is forced along the system by muscle movement.
* Oxygen diffuses into the tissue fluid and into the cells.
* CO2 diffuses out of the cells and into the tissue fluid then into the tracheal system.

**Gaseous Exchange in Fish**

* The breathing system of the fish consists of the following;
	+ **Mouth (buccal) cavity.**
	+ **Gills.**
	+ **Opercular cavity.**
	+ **Operculum.**
* Gills are made of a long curved bone called the gill bar.
* Gill filaments arise from one side of the gill bar. They are many and suspend freely in water providing a large surface area for gaseous exchange.
* Gill rakers arise from the other side of the gill bar. They are teeth like and they prevent solids present in water from damaging the delicate gill filaments.
* Blood vessels enter the gill bar and branch into the gill filaments as blood capillaries.
* Operculum is found on either side of the body near the head and it also protects the delicate gills.

**Diagram**

**Mechanism of Gaseous Exchange in the Gills of a Bony Fish**

* Floor of the mouth cavity is lowered increasing the volume of the mouth cavity but lowering the pressure.
* Water flows into the mouth cavity and the operculum closes.
* Operculum on either side bulge outwards without opening. This increases volume in the gill cavity but the pressure drops.
* Water containing dissolved oxygen flows from the mouth cavity to the gill chamber over the gills.
* The mouth closes and the floor of the mouth cavity is raised.
* The remaining water in the mouth is forced to flow towards the gill chamber.
* Oxygen diffuses from the water into the blood through the thin walls of the gill filaments. It combines with haemoglobin for transportation to all body parts.
* CO2 diffuses from the blood into the flowing water.
* To ensure maximum gaseous exchange, the water flowing over the gills and the blood in the gills flows in opposite directions.
* This is called counter current flow system and it ensures that at all the points, concentration of oxygen is always higher in the water than in the blood.

**Diagram**

* If the water and blood were flowing in the same direction, gaseous exchange will not be that effective.
* Where the oxygen is 50% in water, there is no concentration gradient because blood also has 50% oxygen concentration.

**Diagram**

**Mechanism of Gaseous Exchange in Amphibians**

* Amphibians live on both land and water and therefore exhibit the following methods of gaseous exchange.
1. Gaseous exchange through the lining of the buccal cavity
2. Gaseous exchange through the lungs
3. Gaseous exchange through the skin
4. **Gaseous exchange through the mouth (buccal) cavity**
* Air is taken in or expelled from the mouth cavity by raising and lowering of the floor mouth.
* Lining of the mouth cavity is moist to dissolves oxygen.
* There is a rich supply of blood capillaries under the lining of the mouth cavity. Oxygen diffuses into the blood and is carried by haemoglobin to all parts of the body.
* Carbon IV oxide from the tissues is brought by the blood to the mouth cavity where diffuses out.
* **Gaseous exchange through the lungs**
* The frog has two lungs which are connected to the buccal cavity.
* T he inner lining of the lungs is moist, thin and is richly supplied with blood capillaries.
* During inspiration, the floor of the mouth cavity is lowered and nostrils are open. Air rushes through the open nostrils into the mouth cavity.
* Nostrils close and the floor of the mouth cavity is raised. This reduces the volume and increase the pressure in the mouth cavity forcing air into the lungs.
* Carbon IV oxide from the tissues diffuse into the lung while the oxygen from the lungs diffuses into the tissues.
1. **Gaseous exchange through the skin**
* Frogs have a thinner and moist skin than the toads.
* There is large network of blood capillaries below the skin to carry the respiratory gases.
* Oxygen from the air and water diffuse through the skin into the blood stream.
* Carbon IV oxide diffuses out of the blood capillaries through the moist skin into the surrounding water and air.

**Mechanism of Gaseous Exchange in Mammals**

* The following structures are involved in gaseous exchange in mammals;
* **Nose (Nostrils)**
* **Larynx**
* **Trachea**
* **Chest cavity (ribs and intercostals muscles)**
* **Diaphragm**.
1. **Nose**
* It has two openings called nostrils which let in air into the air passages.
* As air moves in the passages, it is warmed and moistened
* The lining of the nasal cavity has also the sense organs for smell.
1. **Larynx**
* It is located on top of the trachea
* It is called the voice box. It controls the pitch of the voice.
1. **Trachea**
* It is a tube made of rings of cartilage which prevents it from collapsing during breathing.
* Inside it is lined with ciliated epithelium. Cilia beat in waves and move mucus and foreign particles away from the lungs towards the pharynx.
* As the trachea enters the lungs, it divides into two branches called Bronchi (Bronchus).
1. **Lungs**
* They are found in the chest cavity and they are enclosed by a double membrane called the pleural membrane.
* The space between the membranes is called the pleural cavity.
* Pleural cavity is filled with pleural fluid which reduces friction making the lungs to move freely in the chest cavity during breathing.

**Diagrams**

* In the lungs each bronchus divides into small tubes called bronchioles.
* Bronchioles branch further to form air sacs called alveoli (alveolus)
* Alveolus is covered by a fine network of blood capillaries.

**The mechanism of breathing**

* Breathing is achieved by changes in the volume and air pressure of the thoracic cavity.
* Thoracic cavity is enclosed by ribs.
* Ribs are covered by intercostals muscles.
* The diaphragm is a muscular sheet of tissue below the chest cavity. It curves upwards in the form of a dome shape.
* Breathing mechanism involves two processes.
1. Inspiration (Inhalation) i.e. breathing in.
2. Expiration (Exhalation) i.e. breathing out.

**Inspiration (Inhalation) i.e. breathing**

* This occurs when the volume of thoracic cavity increases and the pressure decreases.
* External intercostals muscles contract while the internal intercostals muscles relax.
* Ribs are pulled upwards and outwards.
* Diaphragm flattens increasing the volume of the thoracic cavity while decreasing the pressure inside it.
* Air rushes into the lungs through the nose and trachea inflating the lungs.

**Diagrams page 62**

**Expiration (Exhalation) i.e. breathing out**

* Volume of thoracic cavity decreases while pressure increases. This is brought about by the following;
* External intercostals muscles relax while internal ones contract.
* Ribs move downwards and inwards.
* Diaphragm relaxes and regains its original dome shape.
* Volume of the thoracic cavity decrease and pressure increases.
* Air is forced out of the lungs through the air passages to the atmosphere.

**Gaseous exchange in the alveolus**

* Alveoli and blood capillaries are made of very thin walls.
* The wall of the alveolus is covered b a film of moisture which dissolves oxygen in the inhaled air.
* Oxygen diffuses through the epithelium of the alveolus, the capillary wall and through the cell membrane of the red blood cells.
* In the red blood cells it combines with haemoglobin.
* Carbon (iv) oxide is more concentrated in the blood capillaries than in the alveoli.
* It therefore diffuses from the capillaries into the alveoli.
* Water vapour also passes out of the blood by the same process.

**Diagram page 64 KLB**

M

N

Z

**Percentage composition of gases in inhaled and exhaled air**

|  |  |  |
| --- | --- | --- |
| **Gas**  | **% in inhaled air.** | **% in exhaled air** |
| **Oxygen**  | **20** | **16.9** |
| **Carbon (iv) oxide** | **0.03** | **4.0** |
| **Nitrogen and other gases** | **79.97** | **79.97** |

**Regulation of Breathing**

This is controlled by a part of the brain called *Medulla oblongata*.

**Factors affecting the rate of breathing in humans**

1. **Exercise**

Breathing rate increases during vigorous activity.

1. **Age**

Younger people have a faster breathing because their bodies have more energy demand.

1. **Emotions**

Things like anxiety, fear and fright increases the breathing rate.

1. **Temperature**

Relatively high temperatures increase the rate of breathing. However, very high temperatures reduce the breathing rate.

1. **Health**

If there is fever (high body temperature), the breathing rate increases. Some respiratory diseases however, make breathing difficult.

**Lung Volumes**

1. *Lung capacity*

This is the total amount of air the lungs can hold when completely filled. The lungs of an adult have a capacity of about 5,500cm3

1. *Tidal volume*

This is the amount of air taken in and out of the lungs during normal breathing. Tidal volume is about 500cm3

1. *Inspiratory reserve volume*

This is an additional volume attained after having a forced inhalation in addition to the tidal volume. It is about 2000cm3

1. *Inspiratory capacity*

This is the tidal volume +Inspiratory reserve volume.

1. *Expiratory reserve volume*

This is air removed after a forced exhalation. It can be up to 1,300cm3

1. *Vital capacity*

This is the deepest possible exhalation. This air can only be forcibly pushed out of the lungs.

1. *Residual volume*

This is the air that normally remains in the lungs after the deepest exhalation. It is normally about 1,500cm3

 **Diagram**

**Diseases of the Respiratory System**

1. ***Asthma***

It is caused by:

* Allergens such as pollen grains, certain foods and drugs
* Infections of the lungs by bacteria and viruses

**Symptoms**

* Difficulty in breathing
* Wheezing sound when breathing

**Treatment and Control**

* Avoiding the causative agents
* Injection of drugs and oral application of pills
* Spraying directly into the bronchial tubes with a muscle relaxant
1. ***Bronchitis***

There are two types; Acute and Chronic

**Symptoms**

* Production of thick greenish or yellowish sputum
* Difficulty in breathing
* Difficulty in walking and sleeping

**Treatment**

* Seeking early medical assistance
1. ***Whooping cough***

It is caused by a bacterium called *Bordetella pertussis.*

***Symptoms***

* Prolonged coughing and vomiting
* Conjuctival haemorrhage (bleeding)
* Convulsions and coma
* Severe pneumonia in the bronchioles
* Ulcers and heart complications
* Emaciation due to repeated vomiting

**Treatment**

* Use of antibiotics
* Use of a balanced diet on patients

**Control**

* Children immunization at early age
1. ***Pneumonia***

It is caused by a bacterial called *Streptococcus pneumoniae*

**Symptoms**

* Coughing
* Fever
* Chest pains
* Deposits of fluids in the lungs

**Treatment**

* Use of antibiotics such as penicillin and sulphonamides

**Control**

* Avoid overcrowding.
* Good ventilation in living houses
1. ***Pulmonary Tuberculosis***

It is caused by a bacterium called ***Mycobacterium tuberculosis*.**

**Symptoms**

* Weight loss
* Coughing with blood stained sputum.
* Fever

**Treatment**

* Use of antibiotics such as streptomycin

**Control**

* Pasteurization of milk
* Immunization using BCG (Bacille Calmette Guerin)
* Use of radiography (X-Ray)
1. ***Lung cancer***

Cancer is uncontrolled cell growth in the body causing tumours.

**Some general causes**

* Smoking
* Inhalation of cancer causing substances such as asbestos
* Exposure to radiations such as X-rays, radioactive substances such as uranium and substances that alter the genetic composition of the cell such as mustard gas

**Treatment and control**

* Surgery to remove the tumour
* Radiotherapy
* Chemotherapy
* Use of some drugs
* Not smoking

**Revision Questions**

**RESPIRATION**

* Process by which food substances are chemically broken down in living cells to release energy, carbon (iv) oxide, water or alcohol.
* Respiration takes place mainly in the mitochondria. It has two membranes, inner and outer.
* Inner membrane is folded into projections called cristae. Cristae provide a large surface area for respiratory enzymes. Respiratory enzymes are bound to the cristae.

**Diagram**

**Practical Activity 1**

**To investigate the gas given off when food is burnt**.

**Types of Respiration**

* **Aerobic Respiration**
* **Anaerobic Respiration.**

**Aerobic Respiration**

* Process by which food substances such as glucose are broken down in the presence of oxygen to release energy, water and carbon (IV) oxide.
* The energy is stored in the form of a chemical substance called Adenosine Triphosphate (ATP).
* This energy is released in small quantities since a lot of heat energy would burn the body cells.

Respiratory

Enzymes

C6H12O6 + 6O2 6CO2 + 6H2O + Energy (ATP)

* Respiration takes place in two phases with each phase consisting of series of reactions.

**First Phase (Glycolysis)**

* This takes place in the *cell cytoplasm*. *Oxygen is not required* in this stage.
* Glucose is broken down into a 3 carbon compound called Pyruvic acid through a process called glycolysis.
* In glycolysis *one molecule of glucose gives 2 molecules of ATP*.
* In absence of oxygen Pyruvic acid is broken down into lactic acid in animals and into alcohol (ethanol) in plants.

**Second phase (Krebs Cycle)**

* This takes place in the *matrix of the mitochondria* and involves a series of enzyme controlled reactions *that require oxygen*.
* Pyruvic acid formed in the first phase is oxidized by oxygen in a series of enzymatic reactions (Krebs cycle) into energy, water and carbon (IV) oxide.
* In this phase *one molecule of glucose gives 38 molecules of ATP*.
* The following conditions are required in this phase;
1. Cells must be provided with glucose/food.
2. Oxygen must be present.
3. Respiratory enzymes must be present to catalyse the reaction.
4. Temperature must be favourable for efficient functioning of enzymes.
5. End products of the reaction (energy, water and carbon (iv) oxide) must be constantly removed from the mitochondrion.

***Practical Activity 2***

***To investigate heat production in germinating seeds*.**

**Anaerobic Respiration in Plants and Animals**

* This is the process by which food substances are broken down in the absence of oxygen to release energy.
* The glucose is not completely broken down hence less energy is given out.
* In plants glucose is broken down into energy, carbon (iv) oxide and ethanol (alcohol).

**Glucose Ethanol + Energy. + Carbon (iv) oxide**

**(C6H12O6) (2C2H5OH) (ATP) (CO2)**

* Anaerobic respiration in plants is also referred to as *fermentation*.
* In animals glucose is broken down into energy and lactic acid

**Glucose Lactic acid + Energy.**

**(C6H12O6) (2C3H6O3) (ATP)**

**Oxygen Debt**

* This is oxygen required to get rid of the lactic acid that accumulates in the body tissues when the oxygen supply is less than required.
* Accumulation of lactic acid causes fatigue and muscle crumps.
* Oxygen debt is paid back by breathing more quickly and more deeply in order to increase oxygen supply such as during recovery period after a race when a person pants.
* When paying back the oxygen debt, lactic acid is oxidized to energy, water and carbon (iv) oxide or it is taken to the liver and converted into glycogen.

**Application of Anaerobic Respiration**

1. Baking industry
2. Beer brewing and distillery industry.
3. Dairy industry in the production of yoghurt and cheese.
4. Production of vinegar citric acid, oxalic acid, butyric acid and some drugs.
5. Production of power alcohol which is used as a substitute for petrol.
6. Silage making.
7. Biogas production.
8. Making compost manure

**Practical Activity 3**

**To investigate gas produced during fermentation.**

**Comparison between Aerobic and Anaerobic Respiration**

|  |  |
| --- | --- |
| **Aerobic Respiration**  | **Anaerobic Respiration.** |
| 1. Oxygen is required
 | Oxygen not required  |
| 1. High amount of energy is released as one molecule of glucose yields 38 ATP molecules (2880 KJ)
 | Low amount of energy is released as one molecule of glucose yields 2 ATP molecules (210 KJ) |
| 1. There is complete breakdown of the substrate into carbon (iv) oxide and water.
 | There is incomplete breakdown of substrate hence lactic acid or alcohols are produced. |
| 1. End products are energy, water and carbon (iv) oxide
 | End products are energy, alcohol in plants and lactic acid in animals. |
| 1. Water molecules are produced.
 | Water molecules are not produced. |
| 1. Over a short period of time, energy is not released faster
 | Over short period of time, energy is released faster. |
| 1. Occurs in the cytoplasm and in the mitochondrion.
 | Occurs only in the cell cytoplasm. |

**Respiratory Substrates**

* These are energy rich foods which when oxidized release energy. They include;
1. *Carbohydrates* –
* They are the main source of energy mainly in the form of simple sugars such as glucose, fructose and galactose.
* They produce about 17KJ (2898/mole) per gram when completely oxidized.
1. *Fats* –
* They produce more energy than carbohydrates or proteins. One gram of fats yields about 38 KJ of energy when completely oxidized.
* They are however not the main substrate because they are not very soluble in water hence not easily transported to the sites of respiration. It also requires more oxygen to oxidize one gram of fats than one gram of glucose.
1. *Proteins* –
* They are not normally used in respiration unless in cases of extreme starvation.
* One gram of proteins yields 22KJ of energy when completely oxidized.

**Assignment**

* *Where do plants and animals get the following from;*
* *Carbohydrates.*
* *Fats*
* *Proteins*

**Respiratory Quotient (RQ) and its Significance**

* RQ is the ratio showing the relationship between the amounts of carbon (iv) oxide used against the amount of oxygen used in respiration.

RQ = $\frac{volume ofcarbon \left(iv\right)oxide produced}{volume of oxygen consumed}$

* RQ varies with the type of substrate being oxidized. For example carbohydrates have a RQ of 1.0 when fully oxidized, fats have 0.7 and proteins have 0.9.
* RQ can therefore be used to indicate the type of substrate being oxidized and also whether aerobic respiration or anaerobic respiration is taking place.
* RQ is also affected by factors such as age, health of the organism and the temperature.

**Factors Affecting the Rate of Respiration**

1. *Oxygen concentration.* When the amount of oxygen increases, the respiration rate also increases. Decrease in oxygen concentration will lead to decreased respiration rate.
2. *Substrate concentration.* Increase in sugar concentration increases respiration and vice versa.
3. *Hormones.* Presence of some hormones such as ***adrenaline and thyroxine*** in the body increases the rate of respiration.
4. *Surface area to volume ratio (Body size).* If the SA/volume ratio is high, the organism would lose more heat energy. As more heat is lost to the surrounding more is required to replace the lost energy hence more respiration.
5. *Age.* Young people require more energy because their cells are actively dividing hence respiration rate is higher in them than in older people.
6. *Occupation.* People engaged in heavier tasks have higher rate of respiration.
7. *Sex.* Generally male’s have faster respiration rate than females due to presence of more muscles in their bodies.
8. *Basal metabolic rate.* This is the energy required to maintain normal body functions such breathing, heartbeat, blood circulation etc while at rest.

**Revision Questions**