TRANSPORT IN ANIMALS

Many materials including oxygen, carbon dioxide, soluble food substances, urea, etc, need to be transported from one point or part to another using a transport network and medium. The transport system of animals is mainly made up of blood vessels consisting of blood (medium), circulating through them to various body tissues.

A transport system is also composed of the pump i.e. heart which circulates blood throughout the body by pumping it. The transport system is also composed of lymph vessels containing lymph fluid.

The larger, compact and more active an organism is, the more the need for a transport system. There are some organisms however which lack a transport system eg protists, platyhelminthes, cnidarians. This is because of being small in size and even being flattened in shape. They have a large surface area to volume ratio which enables free and rapid diffusion of materials from one part to another part of the body.

In some organisms with a large circulatory system, blood flow is not confined to blood vessels but with body cavities or spaces called haemocoel in arthropods and molluscs.

IMPORTANCES OF BLOOD CIRCULATORY SYSTEM IN ANIMALS

a) Tissue respiration

It enhances formation of energy in the tissues by transporting oxygen and soluble food substances to the tissues to be used as raw materials for respiration. Carbon dioxide is also transported away from the tissues mainly in the form of bicarbonate ions as a by-product of respiration and taken by lungs for its removal from the body. Oxygen is transported in the form of oxyhaemoglobin from the respiratory surfaces to the tissues.

b) Hydration by transporting water from the gut to all tissues.
c) Nutrition by transporting soluble well digested food materials from the gut to the body tissues.
d) Excretion

By transporting metabolic waste products from the tissues to the excretory organs for their removal from the body e.g. urea from the liver is transported to the kidney in order to be removed from the body.

e) Temperature regulation by the distribution of heat from the body organs where it mainly generated e.g. the muscles and liver evenly throughout the body.
f) Maintenance of constant pH- via the maintenance and circulation of plasma proteins manufactured by the liver which act as buffers to maintain the pH of the body fluid constant.
g) Growth, development and coordination: by transporting different metabolites including the hormones needed for growth and development of the body to take place.

Downloaded from www.exoduspublishers.org

h) Defence- by using leukocytes (white blood cells) which phagocytically invaginate and ingest microbes. By also helping the formation of blood clot around the would be entry point of microbes into the body. By also using the immune response mechanisms towards infections.

BLOOD

It is a highly specialised fluid tissue which consists of different cell types, suspended in a pale yellow fluid known as blood plasma.

BLOOD PLASMA

This is a pale yellow fluid component of blood composed of plasma proteins and blood serum where the blood cells are suspended. Blood plasma constitutes the biggest passage of blood and consists of a watery colourless fluid known as blood serum and plasma proteins. It is in the blood serum that all different soluble materials are dissolved e.g. soluble food substances, hormones, bicarbonate ions, urea, etc.

The plasma proteins are manufactured by the liver and they include;

- Fibrinogen which is important for normal blood clotting by changing into fibrin in presence of thrombin.
- Prothrombin.
- Globulin
- Albumin

Plasma proteins also help to maintain the pH of the body fluids constant by acting as buffers.

BLOOD CELLS

There are three main types of blood cells which include; erythrocytes, leukocytes and blood platelets

ERYTHROCYTES (RED BLOOD CELLS)

These are small numerous biconcave disc-shaped cells mainly important for transportation of oxygen in the form of oxyhaemoglobin from the respiratory surfaces e.g. alveoli of the lungs to the tissues. Erythrocytes are manufactured by bone marrows in adults while in the fetus, they are manufactured by the liver.

Adaptations of the red blood cells

- ✔ They are biconcave disc shaped which provides a large surface area which enhances maximum diffusion of enough oxygen into them.
- ✔ They lack a nucleus to provide a large and enough space for haemoglobin hence carriage of enough oxygen in form of oxyhaemoglobin.
- ✔ They have a dull red pigment called haemoglobin in their cytoplasm which has a

Downloaded from www.exoduspublishers.org

high affinity for oxygen in that it readily combines with oxygen and a bright red compound oxyhaemoglobin is formed which is the form in which oxygen is transported in the body.

- ✔ They are numerous in number i.e. 5 million per mm^3 of blood to provide a large surface area to increase the oxygen carrying capacity from the respiratory surfaces to the tissues.
- ✔ They have a thin and permeable membrane which enables free diffusion of oxygen and carbon dioxide into them.
- ✔ Red blood cells have an enzyme known as carbonic anhydrase within their cytoplasm which enables most of carbon dioxide to be transported in the form of bicarbonate ions by catalysing the reaction between carbon dioxide and water.
- ✔ They have a pliable membrane which can enable them to change their original shape as they squeeze into the blood capillaries.

The red blood cells have a lifespan of 120 days.

Diagram to show the red blood cells

LEUCOCYTES (WHITE BLOOD VESSELS)

These are amoeboid cells nucleated with a colourless cytoplasm, important for defence of their body against infections. They are fewer than the red blood cells i.e. about 7000 cells/mm^3 of blood. They are mainly manufactured by the bone marrow. They are classified into two main types which include; **agranulocytes** and **granulocytes.**

GRANULOCYTES

These are leukocytes with granules in their cytoplasm. They are three main types of granular leukocytes which include **basophils, eosinophils and neutrophils.**

a) Basophils (0.5%)

They produce heparin and histamine, heparin is an anticoagulant which prevents blood clotting in blood vessels. Histamine is a substance that is released during allergic reactions e.g. hay fever histamine brings about allergic reactions by causing dilation and increased permeability of small blood vessels which results in symptoms such as localised swelling, itching, running nose, etc.

Downloaded from www.exoduspublishers.org

b) **Eosinophils (1.5%)**

These possess antihistamine properties and their number increases in people with allergic conditions like hay fever, asthma to counteract the effect of histamine.

Neutrophils (70%) (phagocytes)

They engulf phagocytically and digest pathogens actively fast. Neutrophils can squeeze themselves between the cells of the capillary walls and enter the intercellular spaces, a process known as **diapedesis.**

Agranulocytes

These are leukocytes whose cytoplasm lacks granules. Agranulocytes are of two types: **monocytes and lymphocytes.**

Monocytes (4%)

These are formed in the bone marrow and have a bean shaped nucleus. They are actively phagocytic and ingest bacteria and any large foreign particles.

Some monocytes develop into macrophages whereby they leave the bloodstream and they enter into the tissue where they ingest pathogens and cell debris and are also responsible for the breakdown of worn out red blood cells.

Lymphocytes (24%)

They are leukocytes with large nucleus and small cytoplasm formed by the bone marrow, lymphoid tissues and spleen. Their main role is to mediate or cause immune reactions like antibody production, graft rejection and tumour cell killing.

BLOOD PLATELETS

These are irregularly shaped membrane bound cell fragments frequently enucleated and formed from bone marrow cells called **megakaryocytes.** They initiate the mechanism of blood clotting. They are about $2500/mm^3$ of blood.

CARRIAGE OF OXYGEN

Oxygen is carried from the lungs to the tissues in the form of oxyhaemoglobin. Oxygen combines with haemoglobin because haemoglobin has a high affinity for it that it can readily combine with oxygen.

The combination of oxygen with haemoglobin to form oxyhaemoglobin occurs under conditions when the partial pressure of oxygen is high such as the alveoli of the lung capillaries. When the partial pressure of oxygen is low as in the capillaries which supply the respiring tissues, the bonds binding oxygen to haemoglobin become unstable and oxygen is released to the tissues. This diffuses in solution to the surrounding cells.

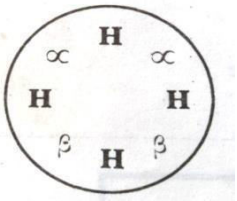
Haemoglobin therefore has a high affinity for oxygen where oxygen is of a high partial

Downloaded from www.exoduspublishers.org

pressure and combines with it to form oxyhaemoglobin which is taken to the tissues and dissociates into oxygen and haemoglobin because the affinity of haemoglobin for oxygen is reduced in an environment where oxygen is of low partial pressures. The affinity of haemoglobin for oxygen is also high in the lungs because of low carbon dioxide partial pressures and the affinity is reduced in the capillary of the tissues because of high carbon dioxide concentration there.

Each haemoglobin molecule consists of four haem prosthetic groups, each of which is made up of Fe^{2+} (iron ii) atoms which loosely combine with one molecule of oxygen without being oxidised. Each haemoglobin is associated with either alpha or beta polypeptide chains.

A cross section through a haemoglobin molecule



The structure of haem, the prosthetic group of haemoglobin

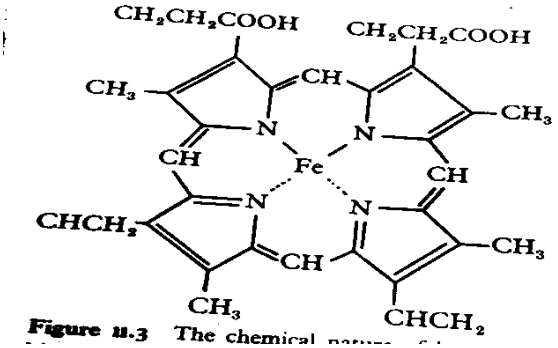


Figure 11.3 The chemical nature ...

OXYGEN TENSION AND OXYHAEMOGLOBIN FORMATION

The ability of the red blood cells to carry oxygen to the tissues is due to haemoglobin having a high affinity for oxygen i.e. it can readily combine with it and become fully saturated with it and release it at low partial pressures.

Partial pressure of a gas is a measure of its concentration in kpa (kilopascals) or millimetres of mercury mmHg). The high affinity of haemoglobin for oxygen is measured exponentially by determining the percentage saturation of haemoglobin with oxygen. When the percentage of oxygen saturated by blood is plotted against the partial pressure of oxygen, an S- shaped or sigmoid curve called the **oxygen dissociation curve** is obtained as shown below. (**understanding bio page 414 (fig 21.3)**

Downloaded from www.exoduspublishers.org

The curve indicates that a slight or a small increase in partial pressure of oxygen results in a relatively sharp or steep increase in the percentage saturation of haemoglobin with oxygen. This reflects that haemoglobin has a very high affinity for oxygen in that it combines readily with it and becomes saturated with it at its high partial pressure.

The S-shape of the oxygen dissociation curve is a clear indication of the efficiency of haemoglobin at taking up oxygen. This can be explained using the figure below:

Using the figure above, consider the situation where the partial pressure of oxygen is, say 8.0 kPa. At this partial pressure, the percentage saturation of blood with oxygen is over 90%. However, if the relationship between oxygen partial pressure and percentage saturation was a linear one, as shown by the hypothetical broken line, the percentage saturation at the same partial pressure of oxygen (8.0 kPa) would be only 60%. In other words, the S-shaped curve indicates that blood can become fully saturated at relatively low partial pressure of oxygen.

The S-shape of the oxygen dissociation curve is due to the way in which oxygen binds with haemoglobin molecules. The first molecule of oxygen combines with the haem group with difficulties and distorts the shape of haemoglobin during the process. The subsequent and the remaining oxygen molecules bind with the haemoglobin molecule more quickly than the preceding ones. The last oxygen is therefore taken up by the last haem group more readily than the rest.

Downloaded from www.exoduspublishers.org

Conversely, when oxyhaemoglobin is exposed to regions where the partial pressure of oxygen is low ie in the respiring tissues, the first oxygen molecule is released easily and fastest but the last one released with difficulty and least readily.

The steep part of the curve corresponds to the range of oxygen partial pressures found in the tissues. Over this part of the curve, any small drop in oxygen partial pressure results in a relatively large decrease in the percentage saturation of blood due to dissociation of oxyhaemoglobin to release oxygen to the respiring tissues.

Conclusively, this indicates that haemoglobin has a high affinity for oxygen where the oxygen tension is high ie in the lungs, alveolar capillaries but the affinity is lowered where the blood capillaries serve blood to the respiring tissues.

EFFECTS OF CHANGING CARBON DIOXIDE CONCENTRATION ON THE AFFINITY OF HAEMOGLOBIN FOR OXYGEN

When the carbon dioxide concentration is low, the affinity of haemoglobin for oxygen is high, hence the oxygen dissociation curve lies on the left. This is because the pH of the medium is slightly alkaline because there is less carbon dioxide to react with water to form carbonic acid.

But when the carbon dioxide concentration increases, the oxygen dissociation curve of haemoglobin shifts to the right indicating that its affinity for oxygen reduces with increase in carbon dioxide concentration, whereby haemoglobin can hardly combine with oxygen to form oxyhaemoglobin, but oxyhaemoglobin readily dissociates to form haemoglobin and oxygen.

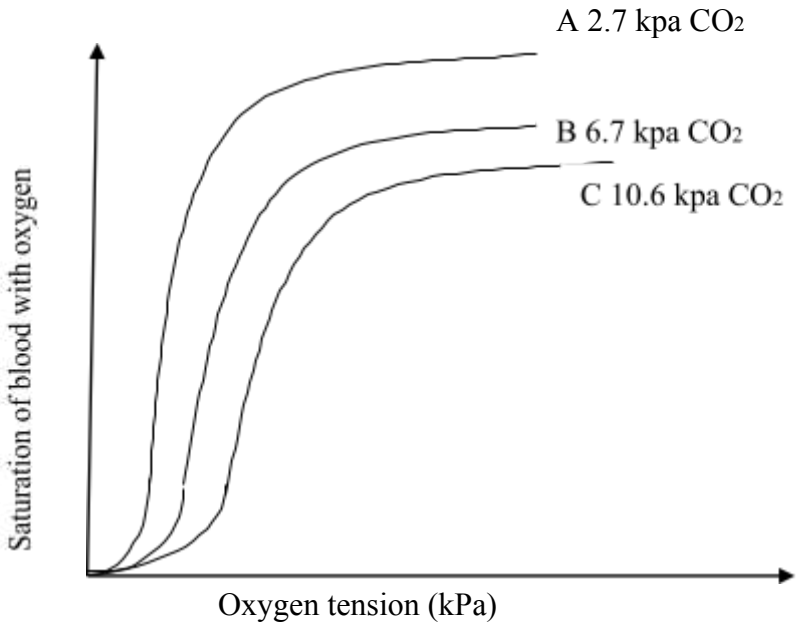
This is due to the decrease in the pH of the medium into acidity as a result of reaction of carbon dioxide with water under catalysis of carbonic anhydrase enzyme to form carbonic acid which dissociates to form free H^+ and HCO_3 ions.

The shifting of the oxygen dissociation curve downwards to the right due to increase in carbon dioxide concentration is known as **Bohr effect.** The significance of the Bohr effect is to induce rapid dissociation of oxyhaemoglobin for fast release of enough oxygen to the respiring tissues.

The Bohr effect is not shown by the haemoglobin of animals like *Arenicola* which live in environments with low oxygen tensions. As the environment of these animals frequently has a high level of carbon dioxide, the Bohr effect would cause the oxygen dissociation curve to shift to the right, reducing haemoglobin's affinity for oxygen. As the environment contains little oxygen, this reduced affinity for it would prevent them from taking up sufficient quantities for their survival.

Downloaded from www.exoduspublishers.org

Figure: Curves A, B and C showing the influence of different carbon dioxide concentrations on the oxygen dissociation curve for haemoglobin



EFFECT OF CARBON MONOXIDE ON THE AFFINITY OF HAEMOGLOBIN FOR OXYGEN

There is a loose and reversible combination between the oxygen molecule and the iron ii atoms of haem groups of the haemoglobin to form oxyhaemoglobin. This means that iron ii is not oxidised to iron iii as it combines with oxygen.

In the presence of carbon monoxide and oxygen, haemoglobin combines with carbon monoxide to form a permanent compound called **carboxyhemoglobin** which does not dissociate because carbon monoxide chemically oxidises Fe^{2+} of the haem group to Fe^{3+}. This reduces the number of free haemoglobin molecules available to carry oxygen leading to severe anoxia and death of the victim who inhales carbon monoxide. Carbon monoxide is therefore a respiratory poison because haemoglobin has a higher affinity for it than for oxygen.

Physiological Impact: Symptoms include headache, dizziness, confusion, nausea, and, in severe cases, unconsciousness or death due to oxygen starvation in vital organs like the brain and heart.

Treatment: Immediate removal from the CO source is critical. Administration of 100% oxygen via a mask accelerates CO displacement from haemoglobin. In severe cases, hyperbaric oxygen therapy in a pressurized chamber enhances oxygen delivery and CO elimination.

EFFECT OF TEMPERATURE ON THE OXYGEN DISSOCIATION CURVE

Increased temperature as a result of increased metabolic activity in a given part of the body produces a reduction in the affinity of haemoglobin for oxygen and an increased dissociation

Downloaded from www.exoduspublishers.org

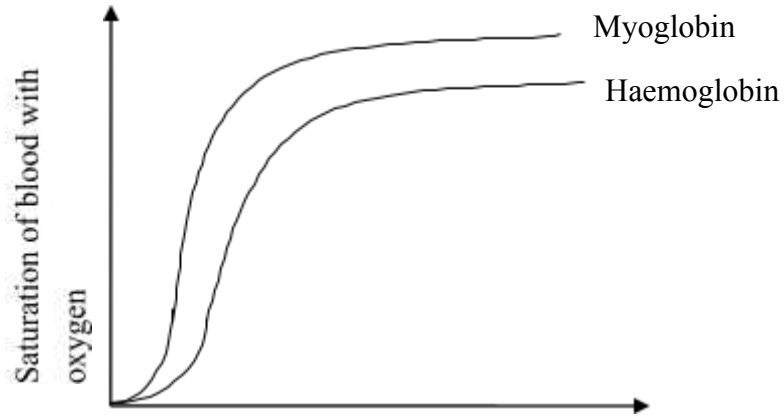
of oxyhaemoglobin. Thus the dissociation curve is shifted to the right. This is physiologically advantageous as more oxygen is delivered to the actively respiring tissues.

MYOGLOBIN AND OTHER PIGMENTS

Myoglobin is a respiratory pigment which is conjugated with iron containing haem groups, it is mostly found in muscles. Myoglobin has a higher affinity for oxygen than haemoglobin in.the way that it combines more readily with oxygen than haemoglobin whereby it becomes fully saturated with it at its lowest partial pressure.

Myoglobin also acts as a store of oxygen in resting muscles and only releases it when supplies of oxyhaemoglobin have been exhausted i.e. mainly during a vigorous muscular activity.

Because myoglobin has a higher affinity than haemoglobin for oxygen, the oxygen dissociation curve for myoglobin lies to the left of that of haemoglobin as shown below.



There are other respiratory pigments mostly found in lower animals which include **haemocyanin** which contains copper, and it is commonly found in some snails and crustaceans. Others include **chlorocruorin** and **hemoerythrin** both of which contain iron as do haemoglobin and myoglobin.

NB:

- The more the dissociation curve of a particular pigment is displaced to the right, the less readily it picks up oxygen, but the more easily it releases it.
- The more the dissociation curve of a particular pigment is displaced to the left, the more readily it picks up oxygen, but the less readily it releases it.

Comparison between the oxygen dissociation curves of maternal haemoglobin and foetal haemoglobin

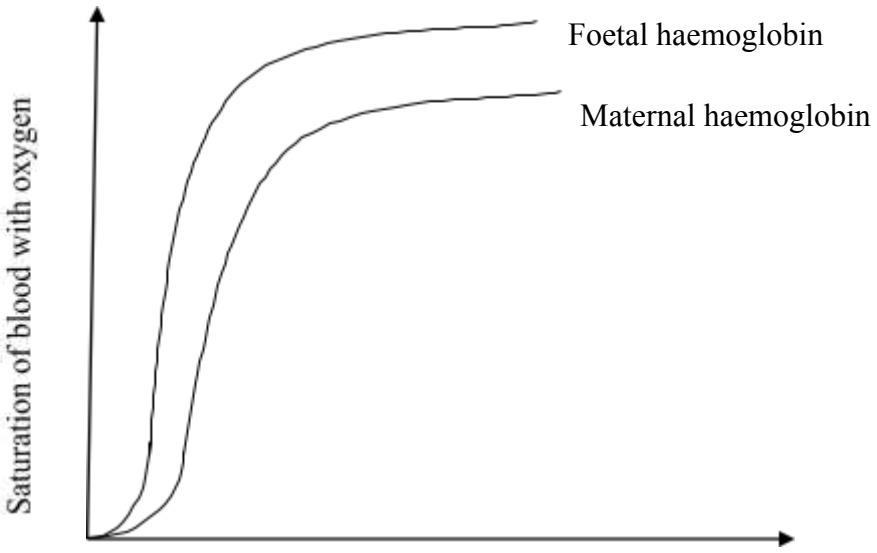
The oxygen dissociation curve of foetal haemoglobin lies on the left of that of maternal haemoglobin. This indicates that the fetal haemoglobin has a higher affinity for oxygen than that of the mother.

This enables the fetal haemoglobin to pick enough oxygen from the mother via the placenta

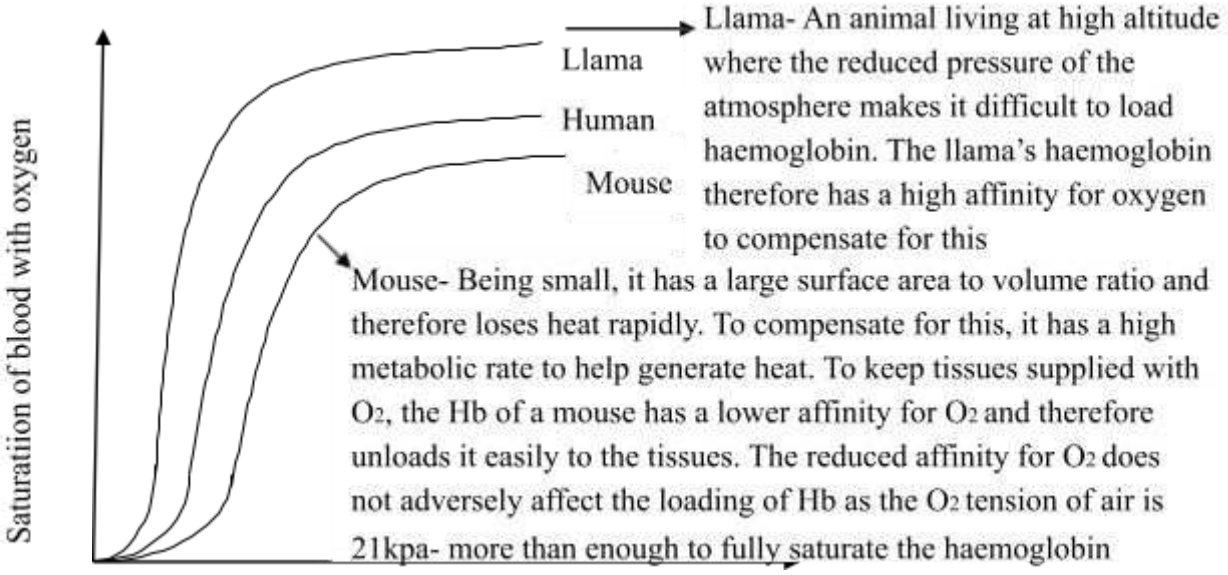
Downloaded from www.exoduspublishers.org

by diffusion and also to increase the oxygen carrying capacity to the tissues in a situation where both deoxygenated and oxygenated blood are mixed.

Oxygen dissociation curve of foetal and maternal haemoglobin



Oxygen dissociation curves for haemoglobin of three mammals



Adaptations in Low-Land vs. High-Land Dwellers:

High-Land Dwellers e.g., Andean or Ethiopian populations: Live at altitudes above 2,500 meters where lower atmospheric pressure reduces oxygen availability (partial pressure of oxygen drops from 21 kPa at sea level to ~12 kPa).

Adaptations include:

Downloaded from www.exoduspublishers.org

- Elevated haemoglobin levels to increase oxygen-carrying capacity.
- Larger lung volumes and higher ventilation rates to maximize oxygen intake.
- Increased capillary density in muscles for efficient oxygen diffusion.
- Genetic mutations enhance hypoxia response, optimizing oxygen use.

Low-Land Dwellers: At high altitudes, they experience acute mountain sickness (AMS) with symptoms like headache, nausea, and shortness of breath due to hypoxia.

Acclimatization (over days to weeks) involves increased erythropoietin production, boosting red blood cell count, and hyperventilation to compensate for low oxygen.

CARRIAGE OF CARBON DIOXIDE IN THE BODY OF MAN

Carbon dioxide is carried/transported in the body from respiratory tissues to lungs in three different forms which include;

i. As a physical solution in blood plasma (5%).
ii. As a carbaminohemoglobin (10-20)% in erythrocytes formed from the reaction of carbon dioxide with the amino group of haemoglobin.
iii. As bicarbonate ions (HCO_3^-) in blood plasma (85%).

When carbon dioxide diffuses from the respiring tissues into the blood capillaries and eventually into the erythrocytes, it reacts with water under catalysis of carbonic anhydrase enzyme to form carbonic acid. The acid dissociates into free H^+ and bicarbonate ions. The bicarbonate ions diffuse out of the cells into the blood plasma.

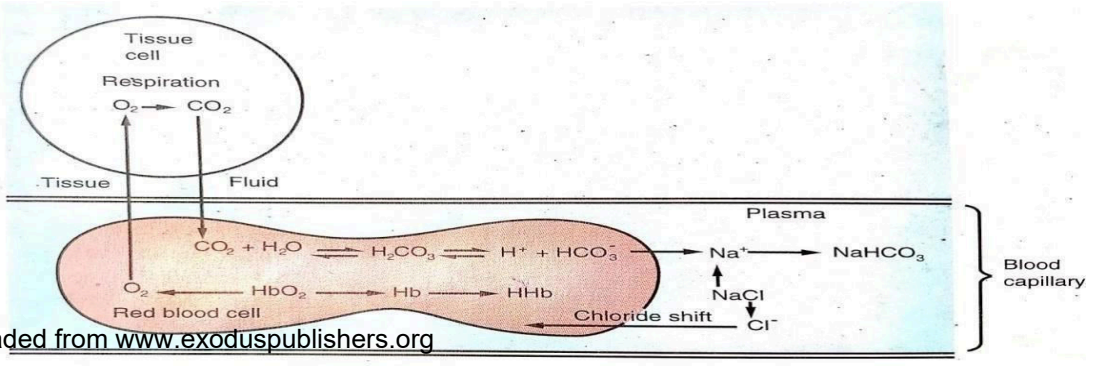
The free H^+ ions reduce the pH and acidity which lowers the affinity of haemoglobin for oxygen. Oxygen diffuses due to a concentration gradient into the tissues for aerobic respiration. Haemoglobin is used to buffer the free protons into a weaker acid called **haemoglobinic acid.** Any excess free hydrogen ions are buffered by the plasma proteins to form a weaker acid called **proteinic acid** which reduces the acidity.

$Hb + H^+ \longrightarrow$ HHb (haemoglobinic acid)

H^+ + plasma proteins $\longrightarrow$ proteinic acid.

The bicarbonate ions which diffuse out of the red blood cells into the plasma combine with sodium ions from the dissociation of sodium chloride to form sodium hydrogen carbonate.

The loss of the negatively charged HCO_3^- ions from the red blood cells is balanced by the inward diffusion of negative chloride ions from the dissociation of sodium chloride thereby restoring the electroneutrality of the red blood cells. This is known as the **chloride shift.** Chloride shift can also be defined as the exit of electrons from the red blood cell to restore



Downloaded from www.exoduspublishers.org

its electroneutrality.

When the bicarbonate ions reach the lungs, they react with the H^+ from dissociation of haemoglobinic acid to form carbonic acid which dissociates into carbon dioxide and water. Due to a concentration gradient, carbon dioxide diffuses from the blood capillaries into the alveoli of the lungs and becomes expelled from the body during expiration.

$$H^+_{(aq)} + HCO^-_{3(aq)} \longrightarrow H_2CO_{3(aq)} \longrightarrow CO_{2(g)} + H_2O_{(l)}$$

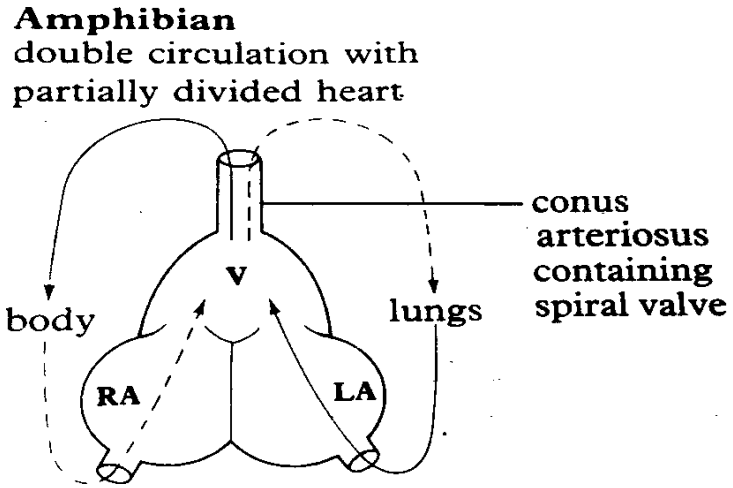
CLOSED DOUBLE BLOOD CIRCULATION

This is the flow of blood through the heart twice for each complete circuit of the body. With double circulation, there is fast flow of blood to the tissues which ensures fast supply of enough oxygen and soluble food materials to the respiring tissues. There are two types of double blood circulation which include; **incomplete double circulation** and **complete double circulation.**

INCOMPLETE DOUBLE CIRCULATION

This is the flow of blood through a three chambered heart twice for each complete circuit of the body e.g. in frogs and toads. The deoxygenated blood is pumped at a high pressure to the lungs for its oxygenation. The oxygenated blood flows back to the left atrium of the heart then to the ventricle which pumps it to the body tissues. From the body tissues, deoxygenated blood flows back to the right atrium into the ventricle.

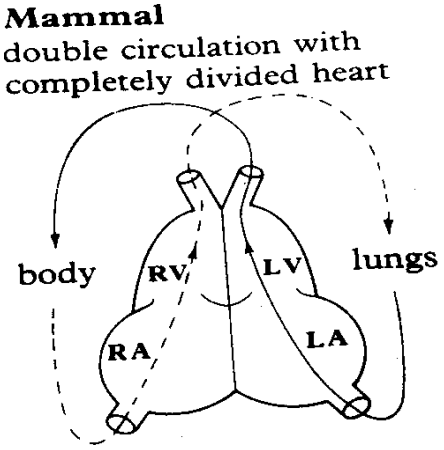
Both oxygenated and deoxygenated blood flow through the same ventricle at the same time without mixing because the walls of ventricles have infoldings or ridges which separate oxygenated blood from deoxygenated blood. This separation also increased the spiral valves within the **conus arteriosus**.



In complete double circulation, deoxygenated blood from the body tissues flow into the right atrium of the heart and then enter into the right ventricle. The right ventricle pumps it at a high pressure into the pulmonary artery to the lungs where it becomes oxygenated.

Downloaded from www.exoduspublishers.org

Oxygenated blood flows through the pulmonary vein into the left atrium of the heart to the left ventricle. The ventricle pumps it more powerfully at a high pressure into the aorta back to the body tissues.



THE STRUCTURE OF THE MAMMALIAN HEART

This is a large thick walled and muscular organ. It has four chambers i.e. right and left atria and right and left ventricles. The left chambers are separated from the right chambers by the vertical septum which enables the flow of oxygenated and deoxygenated blood through the heart at the same time without mixing.

The walls of the ventricles are thick and more muscular than the atrial walls because the ventricular walls must contract more powerfully to pump blood upwards at a higher pressure into the arteries.

The walls of the left ventricle are however thicker and more muscular than those of the right ventricle to enable the former to contract more powerfully and pump oxygenated blood upwards at a higher pressure into the aorta to enable it to move long distances to all the body tissues.

The heart has valves which prevent the backflow of blood and these include; the **atrioventricular valves** and **aortic and semilunar valves.**

The atrioventricular valves include the 2 flapped valves called **bicuspid valves** located between the left atrium and left ventricle, a 3-flapper valve called **tricuspid valve** between the right atrium and right ventricle.

The heart is connected with four blood vessels which include;

a) **Vena cava (main vein)-** used to transport deoxygenated blood from the body tissues into the right atrium of the heart.
b) **The pulmonary artery-** This transports the deoxygenated blood from the right ventricle to the lungs.
c) **The pulmonary vein-** This transports oxygenated blood from the lungs into the left atrium of the heart.

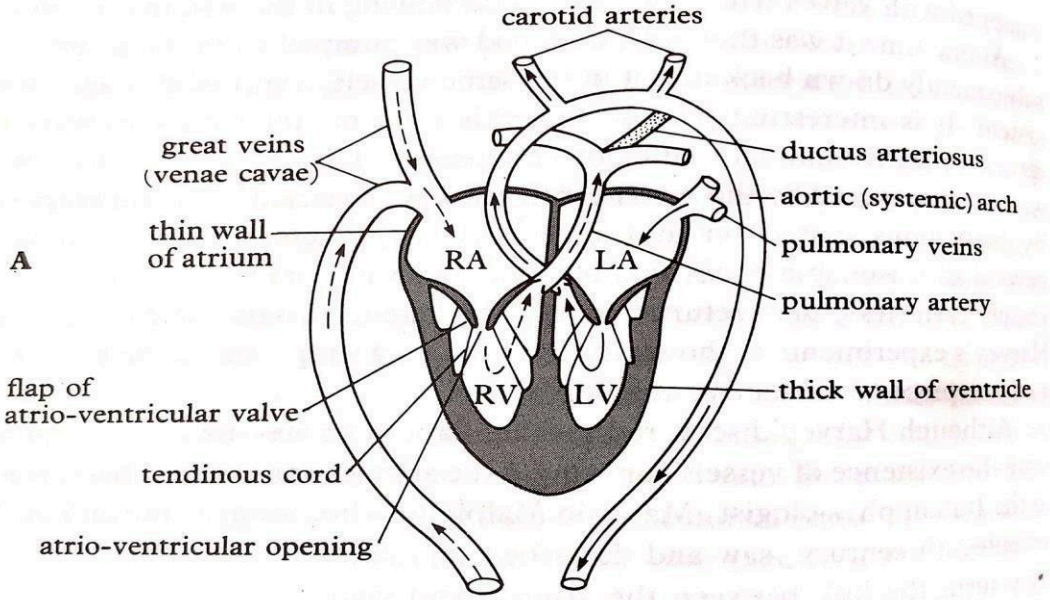
Downloaded from www.exoduspublishers.org

d) **The aorta (main artery)-** This transports oxygenated blood from the left ventricle to all the body tissues.

Below the attachment of the vena cava to the right atrium of the heart, there is a bundle or group of modified and specialised cardiac muscle fibres called **Sino atrial node (SAN)** which acts as a pacemaker by emitting waves of electrical excitation which stimulate and initiate contraction of other cardiac muscle fibres within the heart beat.

The valves are separated into the capillary muscles of the walls of the ventricle by the tendinous chords which prevent them from being inverted due to increased pressure in the ventricles.

THE LONGITUDINAL SECTION OF THE HEART



THE MAMMALIAN BLOOD CIRCULATION

It is a closed double blood circulation composed of two types which include; **pulmonary blood circulation and systemic blood circulation**

Pulmonary blood circulation

This involves the flow of deoxygenated blood from the right ventricle at a higher pressure into the pulmonary artery to the lungs. It is oxygenated and from the lungs, oxygenated blood flows to the left atrium and into the left ventricle of the heart.

NB: A much lower pressure should be developed in the pulmonary artery to prevent rupture of the delicate pulmonary capillaries.

Systemic blood circulation

This involves pumping oxygenated blood by the left ventricle of the heart into the aorta at a high pressure to all the body tissues. Via the vena cava through the veins, the vena cava

Downloaded from www.exoduspublishers.org

transports the deoxygenated blood into the right atrium of the heart and then into the right ventricle.

The oxygenated blood of the systemic circulation reaches the body capillaries at a much higher pressure. This is essential for the efficient function of the organs and tissue fluid formation and permits a high metabolic rate and a high body temperature to be maintained.

THE CARDIAC CYCLE

It refers to the sequence of events which occur during completion of a single heart beat. Cardiac cycle involves alternate diastole and systole. Diastole is the relaxation of the heart walls and systole is the contraction of the heart walls/cardiac muscles of the heart.

During atrial diastole, the atrial walls relax thereby increasing the atrial volume and reducing the atrial pressure. This enables them to be filled with blood.

When the atria are filled with blood, they undergo atrial systole. This involves contraction of the walls of the atria which reduces the atrial volume and increases the atrial pressure which exceeds the ventricular pressure. This forces the atrioventricular valves to open allowing blood to flow from the atria into the relaxed ventricles i.e. deoxygenated blood from the right atrium into the right ventricle and oxygenated blood from the left atrium to the left ventricle.

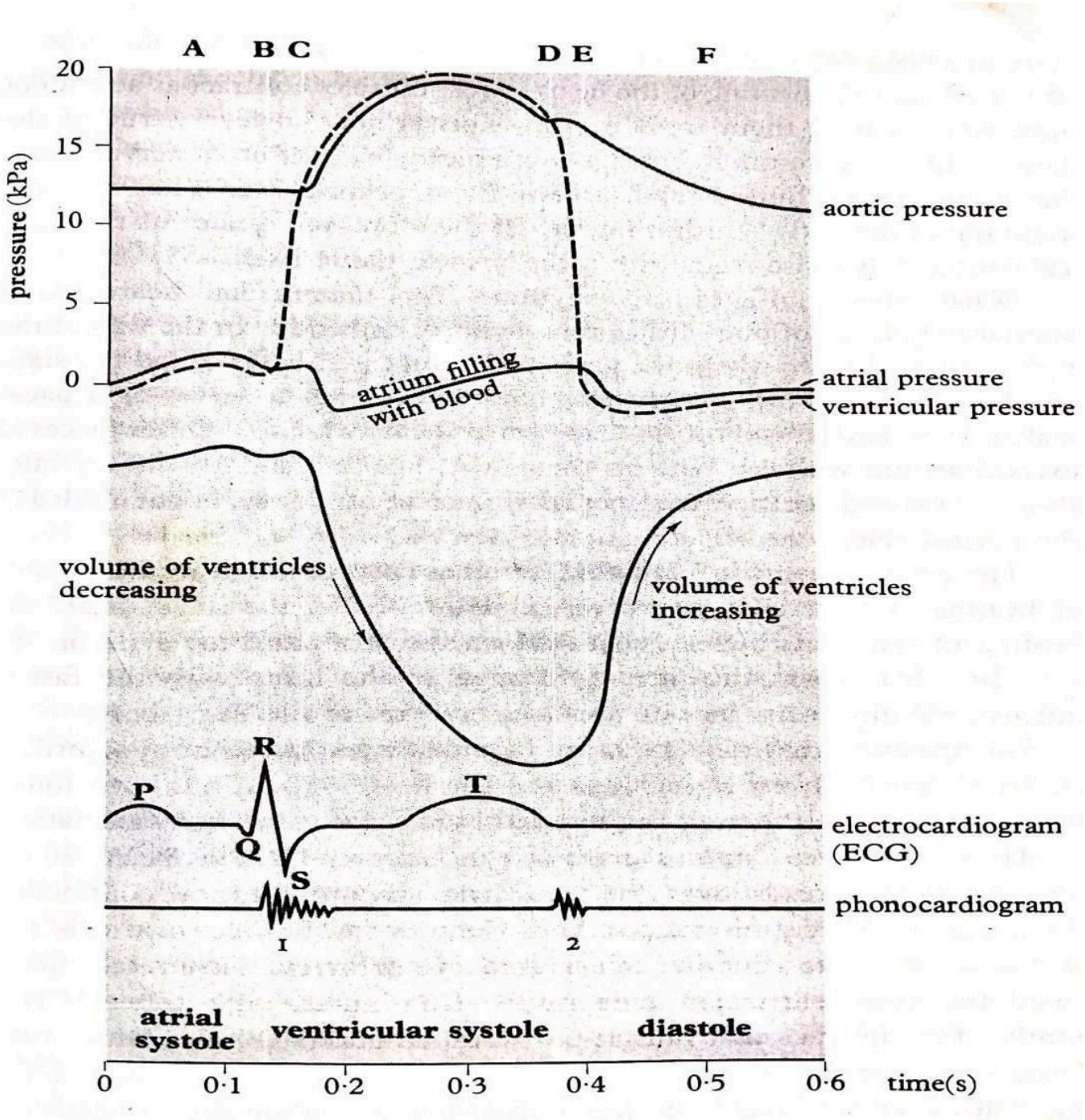
When the ventricles are filled with blood, they undergo ventricular systole where their walls contract which reduces their volume and increases their pressure which exceeds the atrial and aortic pressures. This closes the atrioventricular valves to prevent backflow of blood thereby making a '**lub sound'** which can be detected by the phonocardiogram.

The increased pressure in the ventricles forces the semilunar and aortic valves to open thereby pumping blood upwards at a high pressure into the arteries is deoxygenated blood from the right ventricle into the pulmonary artery and oxygenated blood from the left ventricle into the aorta.

Increased pressure within the pulmonary artery and the aorta together with the decrease in pressure of relaxed ventricles cause a slight back flow of blood into the arteries which closes the semilunar and aortic valves. The sound made due to closure of the semilunar and aortic valves is known as the '**dub sound'.**

GRAPHS ILLUSTRATING THE PRESSURE AND VOLUME CHANGES THAT OCCUR DURING THE MAMMALIAN CARDIAC CYCLE

Downloaded from www.exoduspublishers.org



A- Atrium contracting: blood flows into the ventricle.

B.- Ventricles start to contract: ventricular pressure exceeds atrial pressure so the atrio-ventricular valve closes.

C- Ventricular pressure exceeds aortic pressure forcing open aortic valve; blood therefore flows from ventricle into aorta, and ventricular volume falls.

D- Ventricular pressure falls below aortic pressure resulting in closure of aortic valve; ventricular volume starts to rise.

Downloaded from www.exoduspublishers.org

E- Ventricular pressure falls below atrial pressure so blood flows from atrium to ventricle; ventricular volume rises rapidly.

F- Atrium filling with blood from pulmonary vein; atrial pressure exceeds ventricular pressure so blood flows from atrium to ventricle.

INITIATION OF THE HEART BEAT

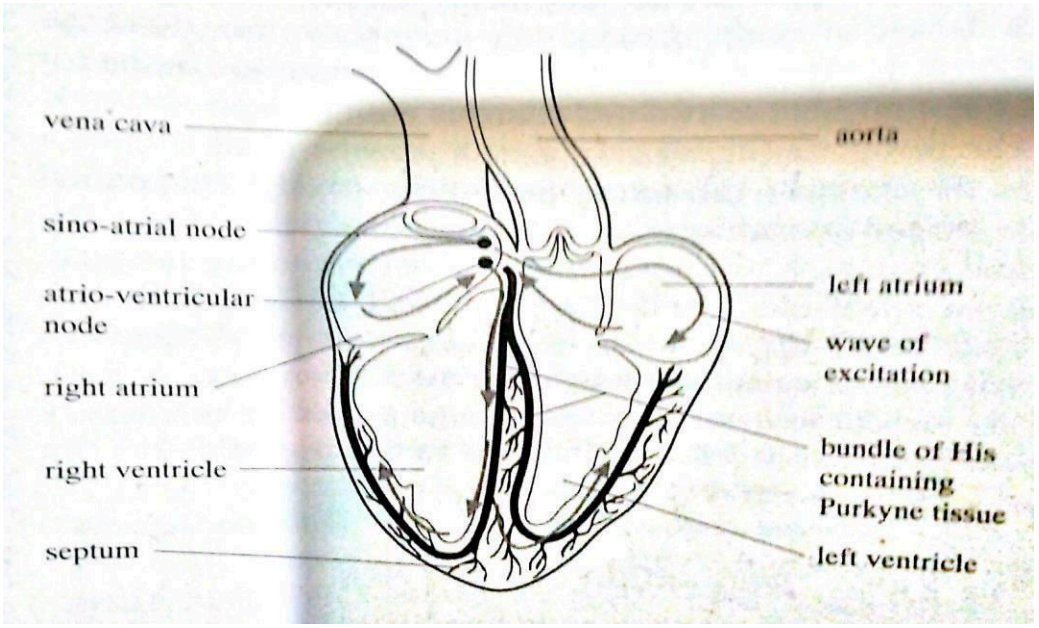
The cardiac muscles of the heart are myogenic in nature in that they initiate the contraction instead of the central nervous system. The myogenicity of the cardiac muscles enables them to contract continuously and rhythmically without stopping.

Beneath the connection of the vena cava onto the right atrium of the heart, there is a bundle or group of specialised and modified cardiac muscle fibres called the **Sino atrial node** which acts as a pacemaker by initiating and stimulating the contraction of cardiac muscle fibres in the atrial and ventricular walls by emitting waves of electrical excitation which are similar to impulses.

These are spread to the walls of the atria, thereby stimulating their cardiac muscle fibres to contract during atrial systole and force blood to the ventricles. From the atria, the wave of electrical excitation is connected to the strand of modified cardiac muscle fibres called the **atrioventricular node (AVN).** The AVN is connected to the **bundle of His** via the AV bundle.

From the bundle of His, the waves spread to the walls of the ventricles via fine branched fibres called the **purkinje fibres.**

Position of the SAN & AVN and the bundle of His



CONTROL OF THE RATE OF HEART BEAT

Downloaded from www.exoduspublishers.org

The heart rate is the number of heart beats per minute. The heart rate determines the cardiac output. Cardiac output is the volume of blood pumped out of the heart in a particular period of time.

Another factor which determines the cardiac output is the stroke volume. The stroke volume is the amount of blood which flows out of the heart per beat.

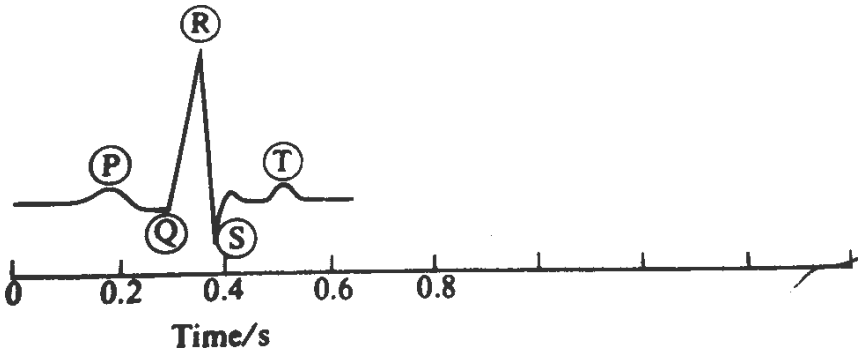
Therefore cardiac output = stroke volume × heart rate

The rate of heart beat is controlled by the sympathetic nervous system and the parasympathetic nervous system.

Because the SAN is controlled by the vagus nerve of the parasympathetic nervous system and the sympathetic nerve of the nervous system, when the stretch receptors within the walls of the vena cava stimulated due to increased volume of the blood which flows back due to increased muscular activities, they fire impulses along the afferent or sensory neuron to the cardiac accelerator centre of the medulla oblongata. This sends impulses along the sympathetic nerve of the sympathetic nervous system to the SAN. The SAN sends more waves of electrical excitation to the cardiac muscles of the heart thereby increasing the rate of heart beat, to increase the supply of oxygen and soluble food substances to the respiring tissues for their fast respiration.

As the volume of blood flowing through the carotid artery and aorta increases, the stretch receptors become stimulated and send impulses to the cardiac inhibitory centre of the medulla oblongata. This sends impulses along the vagus nerve of the parasympathetic nervous system to the SAN. The SAN reduces the rate of emitting waves of electrical excitation thereby reducing the rate of heart beat.

Electrocardiogram



Electrocardiogram to establish the electrical activity of the heart. It shows the electrical potential across the heart during one cardiac cycle.

P- Represents waves of electrical excitation to the atrial walls during atrial systole

QRS- represent waves of electrical excitation during ventricular systole.

T- Represents the beginning of ventricular diastole.

Downloaded from www.exoduspublishers.org

HORMONAL CONTROL OF THE RATE OF HEART BEAT

Adrenaline and thyroxine directly increase the rate of heart beat by stimulating the SAN to increase the rate at which it emits the waves of electrical excitation. Thyroxine can however increase the rate of heart beat by increasing the basal metabolic rate, heat generation and oxygen demand by the respiring tissues which increases the rate of heart beat to meet the high oxygen demand by the tissues.

Other factors which influence the rate of heart beat include:

- ✔ High temperature increases the rate of heart beat while low temperature reduces it.
- ✔ High pH of the body fluids reduces the rate of heart beat while low pH increases it.
- ✔ Different mineral ions affect the rate of heart beat directly or indirectly.

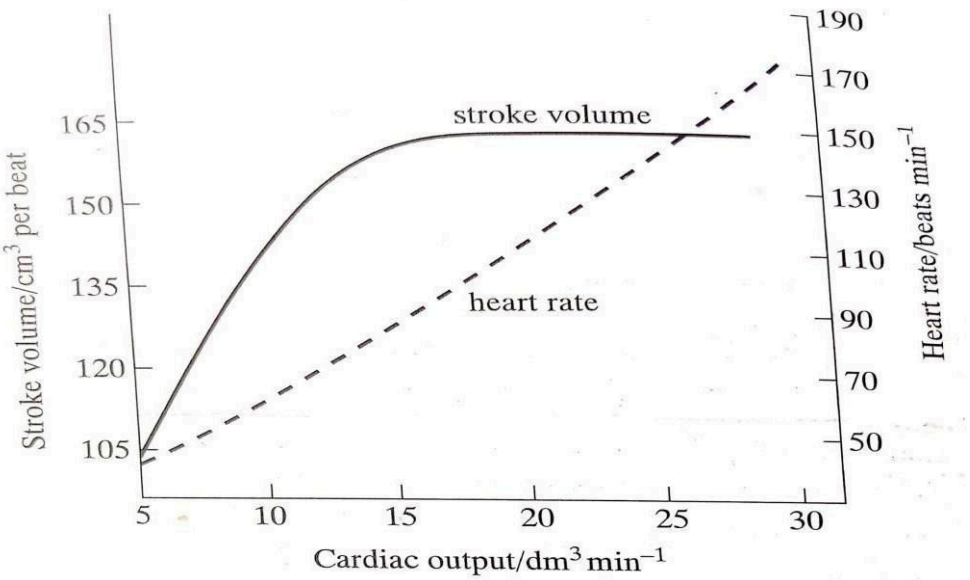
EFFECTS OF EXERCISE ON THE CARDIOVASCULAR SYSTEM

Short term effects

During exercise, the muscles need an increased blood supply so that oxygen and glucose can be provided for aerobic respiration and waste carbon dioxide and heat can be removed. Blood flow is increased drastically and this is achieved in a number of ways:

- Increase in cardiac output of blood from the left ventricle of the heart from the resting condition of 4-6dm^3min^{-1} to 15 (untrained female) and 22 (untrained male) or even 30 for an athlete.
- Increase in heart rate.
- Increase in stroke volume.

Effects of exercise on a marathon runner



Long term effects

Downloaded from www.exoduspublishers.org

Long term training results in a stronger heart and a higher cardiac output. The chambers of the heart get larger and the mass of the muscle increases by 40% or more. All aspects of function improve from an increase in blood vessels to greater numbers and size of mitochondria in the muscle fibres.

Responses in Athletes and Non-Athletes During Intense Exercise

Athletes: Training enhances cardiovascular efficiency, increasing maximum oxygen uptake by 2-3 times compared to non-athletes. Adaptations include a higher stroke volume, lower resting heart rate, and increased mitochondrial density in muscles for efficient oxygen use.

During intense exercise, athletes maintain aerobic respiration longer, producing less lactic acid and delaying fatigue.

Non-Athletes: Lower cardiovascular efficiency leads to quicker reliance on anaerobic respiration, causing rapid lactic acid buildup and muscle fatigue. Higher heart rates and less efficient oxygen delivery limit endurance.

BLOOD PRESSURE

Blood pressure is the force exerted by blood against the walls of the blood vessels. It is divided into systolic blood pressure and diastolic blood pressure.

Systolic pressure- This is the pressure exerted by blood against the walls of the blood vessels due to contraction of the ventricular walls. It is such a high pressure measuring to 120 mmHg of an average adult and healthy person.

Diastolic pressure- This is the force exerted by blood against the walls of the arteries due to relaxation of the ventricular walls. It is as low as 80mmHg.

FACTORS WHICH DETERMINE BLOOD PRESSURE

- The strength of the heart beat
- The stroke volume
- The rate of heart beat
- The peripheral resistance of blood vessels especially arterioles towards blood flow

CONTROL OF BLOOD PRESSURE

When blood pressure falls below normal, baroreceptors of the carotid sinuses and the aortic arch become stimulated and fire impulses along the sensory neuron to the vasomotor centre of the medulla oblongata of the hindbrain.

The vasomotor centre of the medulla oblongata sends impulses along the sympathetic nerve of the sympathetic nervous system to the smooth muscles of the arterioles stimulating them to contract and cause vasoconstriction of the arterioles. This in turn increases the peripheral resistance of arterioles towards blood flow and thus increases the blood pressure back to the normal one.

But when the blood pressure increases above the normal, the vasomotor centre sends

Downloaded from www.exoduspublishers.org

impulses along the vagus nerve of the parasympathetic nervous system to the smooth muscles of the arterioles. The smooth muscles are stimulated to relax and cause vasodilation of the arterioles and so reduce blood pressure back to the normal one. This follows a reduction in the peripheral resistance of arterioles towards blood flow.

NB: 1. The rate of heart beat as controlled by the cardiac accelerator centre and cardiac inhibitory centre of the medulla oblongata can also indirectly control the blood pressure by determining the strength of heartbeat, stroke volume and heart rate each of which determines blood pressure. A rise in blood carbon dioxide concentration also causes a rise in blood pressure. This increases the speed at which blood is delivered to the lungs and so helps to remove carbon dioxide quickly. Hormones like adrenaline similarly increase the blood pressure.

BLOOD VESSELS

There are three main types of blood vessels which include; **arteries, veins, and blood capillaries.**

ARTERIES

These transport oxygenated blood except the pulmonary artery from the heart to the respiring tissues. The pulmonary artery transports deoxygenated blood from the right atrium of the heart to the lungs.

Blood flows through the arteries in a smaller volume at a high pressure and speed due to powerful contraction of the thick and more muscular walls of the left ventricle of the heart during ventricular systole. The oxygenated blood flow is pulsatile ie it flows in pulses.

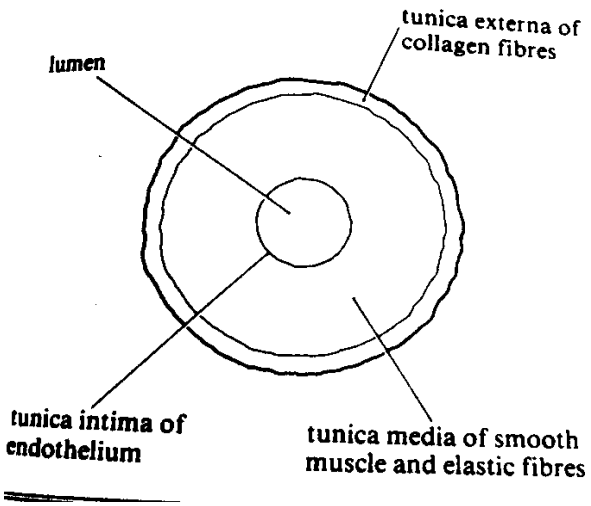
Pulse: These are waves of dilation of the artery walls due to pumping of blood into them at a high pressure.

NB:

- ✔ All arteries transport blood away from the heart.
- ✔ They lack valves, except at the base of the pulmonary artery and aorta.
- ✔ They have thicker and more muscular tunica media which can withstand the high pressure of blood into them.
- ✔ They have a smaller lumen relative to their diameter.
- ✔ Blood flow in arteries is intermittent, the blood flowing rapidly during systole and slowly during diastole

A diagram showing a transverse section

Downloaded from www.exoduspublishers.org



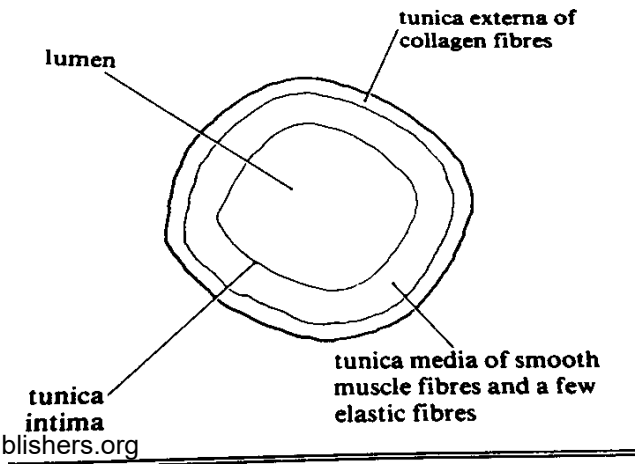
Because of having more elastic fibres and smooth muscle, the artery walls have a high level of elasticity.

VEINS

These transport deoxygenated blood from the tissues to the heart except the pulmonary vein which transports oxygenated blood from the lungs to the left atrium of the heart.

- ✔ They handle a large volume of blood which flows through them at a low pressure and speed.
- ✔ They all transport blood generally to the heart.
- ✔ They have valves along their entire length to prevent the backflow of blood.
- ✔ Blood flows through them smoothly without pulses ie non pulsatile flow of blood.
- ✔ They have a wide lumen relative to the diameter.
- ✔ They have a less muscular and less thick Tunica media.
- ✔ They are less elastic/have less elastic walls.

Structure



Downloaded from www.exoduspublishers.org

BLOOD CAPILLARIES

These occur in a dense network due to the tissues. They are used as a medium of exchange of materials between the tissues and the blood circulatory system.

Being in a dense network i.e. capillary bed, they offer a large surface area for fast diffusion and exchange of materials between the tissues and the circulatory system e.g. carbon dioxide diffuses from the respiring tissues into blood.

They have thin walls with only *Tunica intima* to reduce the diffusion distance for fast diffusion and exchange of materials. They have a relatively high volume of blood which registers a non pulsatile flow of a falling pressure and speed due to high resistance.

- ✔ They lack valves.
- ✔ They have a very narrow lumen.
- ✔ Being in close contact with the tissues, they increase the diffusion rate and exchange of materials.
- ✔ They have permeable walls to allow free and fast diffusion and exchange of materials between blood and tissues which minimise resistance.
- ✔ Blood flow is even. The gradual change from intermittent to even flow is made possible by the elasticity of the arterial walls which contain much elastic tissue and smooth muscle.

NB: Each artery branches into smaller vessels known as arterioles which transport oxygenated blood from an artery to the capillary bed.

They are capable of vasoconstriction and dilation. Towards their end, they have precapillary sphincter which regulates the amount of blood which enters into the capillary bed. In some parts of the body, large muscular vessels form a direct connection between arteries and veins, thereby bypassing the capillaries.

NB: That each vein also has smaller branches (venules) which connect it to the capillary bed and transport deoxygenated blood from the bed.

The Lymphatic System

It comprises lymphatic vessels, lymph nodes, spleen, thymus, and bone marrow. Lymphatic vessels are thin-walled with valves to prevent backflow, forming a one-way system that drains into the bloodstream via the thoracic duct and right lymphatic duct. Lymph nodes are small, bean-shaped structures containing lymphocytes and macrophages.

Functions:

- Fluid Balance: Collects excess interstitial fluid (leaked from capillaries) as lymph and

Downloaded from www.exoduspublishers.org

returns it to the blood, preventing edema.

- Immune Defense: Lymph nodes filter lymph, trapping pathogens. Macrophages and dendritic cells process antigens, activating T and B lymphocytes for immune responses.
- Lipid Absorption: Lacteals in the small intestine absorb dietary fats (chylomicrons) into lymph, which is transported to the bloodstream.

Note: Lymph Formation and Flow: Interstitial fluid enters lymphatic capillaries due to pressure gradients. Lymph flows through vessels, passing through lymph nodes, and empties into the subclavian veins.

DEFENSIVE MECHANISM OF THE BODY TOWARDS INFECTION

The body can defend itself against infections via;

- Normal blood clotting
- Phagocytosis
- Immune response towards infections

NORMAL BLOOD CLOTTING

When the body becomes wounded, the platelets and damaged tissue on exposure to air becomes stimulated and secrete thrombokinase or thromboplastin enzyme which in presence of calcium ions and vitamin K stimulate the conversion of prothrombin (formed from vitamin K by the liver) to thrombin. Thrombin together with blood clotting factors vii and x catalyse the conversion of fibrinogen into a meshwork of fibrin fibres in which the blood cells become entangled.

The fibres with the cells form a fibrin clot which hardens, covers and protects the body from entry of microbes into it. Blood clotting also prevents excessive loss of blood due to over bleeding.

When an animal is wounded, its overall pressure rises, but the area in the vicinity of the wound swells as a result of local vasodilation. Suggest what the advantages of these changes might be.

Local vasodilation in the wounded area enables more blood carrying oxygen and nutrients to arrive there and speed up the process of repair and replacement. Increased body blood pressure prepares the body of the animal to respond to any further stress more readily and efficiently.

PHAGOCYTOSIS

This involves phagocytes, mainly the neutrophils and monocytes. These cells engulf the microbes and destroy them. They usually use opsonins or complements to identify and become attracted towards the microbes.

When the phagocytes get in contact with the microbes, its part in contact infolds or

Downloaded from www.exoduspublishers.org

invaginates into a flask-like depression which encloses the microbes fully to form a phagocytic vacuole which breaks off from the cell membrane.

The lysosome fuses with the vacuole to form a **phagolysosome**. The lysosomes release acids, hydrolytic enzymes and lysozymes into the vacuole to break down and digest microbes to soluble products.

Some useful materials diffuse into the cytoplasm and utilised by the phagocyte while the unwanted materials are lost from the cell by exocytosis which involves fusing of the phagocytic vacuole with the cell surface membrane and thereafter, the membrane ruptures to release the materials out of the cell.

IMMUNE RESPONSE TOWARDS INFECTIONS

Immune response is the production of antibodies against certain antigens.

Immunity- This is the ability to detect or recognise intrusion of materials foreign to the body and mobilise cells and their products to eliminate them with greater speed and efficiency.

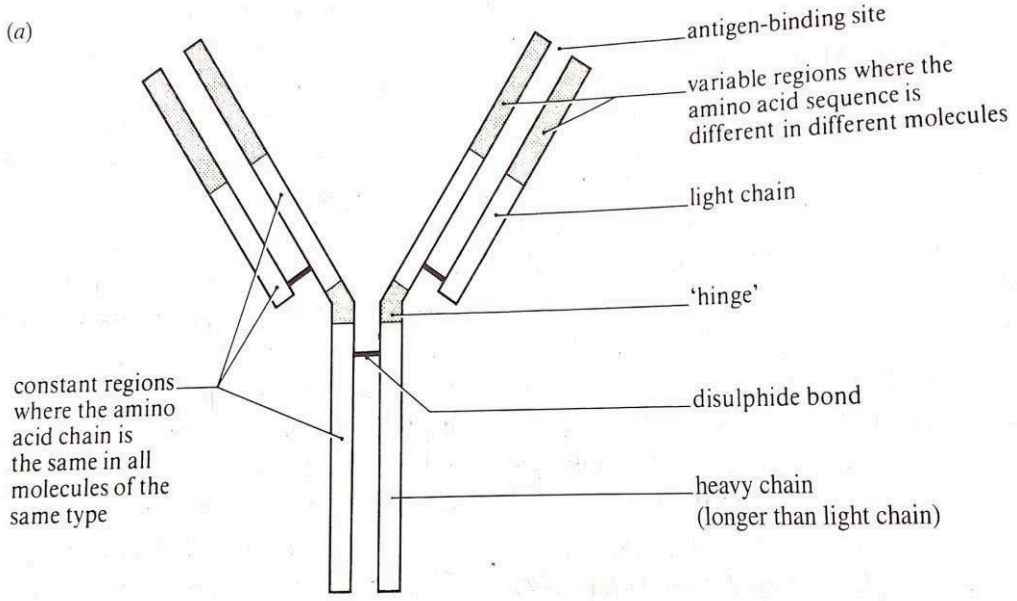
Antibody- This is an immunoglobulin protein molecule which is manufactured by the animal body in response to presence of certain antigens (for which they have a higher affinity).

Antigen- This is a molecule which stimulates production of antibodies. Antigens can be in the form of microbes or any foreign material to the body.

THE STRUCTURE OF AN ANTIBODY

An antibody is a Y shaped immunoglobulin molecule with four polypeptide chains whereby two are long and heavy chains H-chains while the remaining two are short and light L-chains.

At the end of the chains are antigen binding sites. Each chain has variable and constant regions. The variable region is where the sequence of amino acids varies with different antibody molecules while the constant region is where the sequence of amino acids is the same in all the antibody molecules of the same type.



Downloaded from www.exoduspublishers.org

The heavy chains are hinged.

There are a number of different antibodies each performing a different function;

a) Agglutination- Some antibodies have many binding sites and can join to antigens on many different pathogens. In this way, the antigens can be joined together in clumps making them more vulnerable to attack from other types of antibody.
b) Precipitation- Some antibodies bind together soluble antigens into larger units which are thus precipitated out of solution. As such, they are more easily ingested by phagocytes.
c) Neutralisation- Certain antibodies bind to toxic molecules produced by a pathogen and in doing so neutralise their harmful effects.
d) Lysis- Antibodies which are attached to a pathogen act as binding sites for a number of blood proteins which are collectively known as the complement system. Some of these proteins are enzymes which cause the breakdown of the pathogen.
e) Opsonisation- some antibodies combine with microbes to enable the phagocytes to identify them, get attracted to them and engulf them.

MECHANISM OF IMMUNE RESPONSE TOWARDS INFECTION

Immune response is due to B and T lymphocytes which are formed from the stem cells of the bone marrow. T lymphocytes undergo maturation in the thymus gland under the influence of **thymosine hormone.** While in the thymus gland, they develop into **thymocytes.** At this stage, any cells that recognise self (the body's own antigens) are destroyed so that the body does not attack itself later.

B lymphocytes are named so because they mature from the bursa, the part of the gut in birds in which their B cells develop. The bursa is absent in mammals although an equivalent tissue exists.

In the presence of a microbe, the macrophages chop off a piece from it and present it to the surface of the T or B lymphocytes. The T lymphocytes use a receptor on its surface membrane to detect the microbe and undergo rapid proliferation by mitosis to form T clone cells. These cells differentiate into **T_4 or helper cells** and **T_8** cells which occur in two types ie **killer cells/cytotoxic cells & suppressor cells.**

The helper cells (T_4)

They produce lymphokines (small peptide molecules) with various functions which include:

- Stimulate rapid proliferation of killer cells.
- Promotes inflammation.
- Stimulate the B lymphocytes to secrete antibodies.
- Stimulate the suppressor cells to stop the activities of the phagocytes, B and T lymphocytes when the microbes have been cleared out of the body to prevent self destruction of the body.

Downloaded from www.exoduspublishers.org

The killer cells (cytotoxic cells)

- Destroy the infected body cells by punching holes into them.
- Destroy the cells of the transplanted organs of the body.
- Destroy cancerous body cells.

NB: The action of the T lymphocytes constitutes the **cell mediated immune response.**

B CELLS AND THE HUMORAL RESPONSE

The B lymphocytes undergo rapid proliferation/multiplication in presence of microbes (antigen) to form numerous B clone cells. Activation requires the presence of lymphokines secreted by the helper T cells as well as antigen. The B clone cells differentiate into the **effector cells or plasma cells** which secrete antibodies to eliminate the microbes and the **memory cells** which retain the capacity to recognise the microbes on reinfection and stimulate rapid production of many antibodies to curb down the microbes before they register a significant damage to the body in different ways ie lysis, agglutination, precipitation, opsonization, neutralisation. This is known as a secondary **immune response** as compared to the **primary response** which involves production of antibodies towards microbes of the first infections. Memory cells can last for a long period of time and that is why the immunity of an individual against a particular infection increases as a person suffers from it.

TYPES OF IMMUNITY

There are four types of immunity which include;

- ✔ Natural passive immunity
- ✔ Natural active immunity
- ✔ Artificial passive immunity
- ✔ Artificial active immunity

Natural passive immunity- This involves acquisition of antibodies by the foetus from mother via the placenta or colostrum in order for the foetus to obtain temporary resistance against infections.

Natural active immunity- This involves production of antibodies by the infected body to fight against the microbes. This is a permanent form of immunity because due to presence of the microbes in the body, the body is stimulated to manufacture long lasting memory B cells which stimulate rapid production of numerous antibodies which curb down the microbes on reinfection before they cause a significant damage to the body.

Artificial passive immunity- Here, antibodies which have been formed in one individual are extracted and then injected into the blood of another individual which may or may not be of the same species. For example the antibodies for diphtheria and tetanus are cultured in the body of the horse, extracted and injected into the body of the human beings to offer them

Downloaded from www.exoduspublishers.org

temporary immunity.

Artificial active immunity- This involves injecting or oral taking of a small dose of antigens called vaccines into the body of a living person to provoke it to manufacture specific antibodies towards the antigens or microbes.

The vaccine also provokes or stimulates the body to manufacture the memory cells which retain the capacity to stimulate rapid production of many antibodies against the actual microbes when the body is infected by the active and living microbes.

NB: The differences between passive immunity and active immunity are summarised below

Passive immunity	Active immunity
Gives immediate protection	Takes a few days or weeks to build up
Provides protection against infections for a few weeks.	Provides protection against infection for a long period of time.

Rhesus Incompatibility

Occurs when an Rh-negative mother carries an Rh-positive fetus (Rh factor is an antigen on red blood cells). During delivery or miscarriage, fetal Rh-positive red blood cells may enter the mother's circulation, triggering her immune system to produce anti-Rh IgG antibodies.
In subsequent pregnancies with Rh-positive fetuses, these antibodies cross the placenta, attacking fetal red blood cells, causing hemolytic disease of the newborn (HDN).

Symptoms of HDN:

- Fetal anemia
- Jaundice
- In severe cases, kernicterus (brain damage from bilirubin accumulation).

Prevention:

- Administration of Rho(D) immune globulin (RhoGAM) to Rh-negative mothers within 72 hours of delivery, miscarriage, or invasive procedures.
- RhoGAM contains anti-Rh antibodies that destroy fetal Rh-positive cells in the mother's circulation before her immune system is sensitized.

TYPES OF VACCINES

There are three major types of vaccines which include; **toxoids, attenuated microbes and killed microorganisms.**

Toxoids

These are toxic substances produced by microbes which are rendered non toxic by treating them with chemicals e.g. formaldehyde and injected into the body of a living individual to stimulate it to produce antibodies and memory cells without developing any symptoms.

Attenuated microbes

Downloaded from www.exoduspublishers.org

These are modified living pathogens which are capable of reproduction but are rendered non infectious due to high temperature or chemical treatment.

They stimulate production of antibodies and memory cells without causing any symptoms e.g. the rubella or measles viruses, the bacteria for TB, etc.

Killed viruses and bacteria

These can be injected in a body of a living organism to provoke it to manufacture antibodies, memory cells whereby when the actual living viruses or bacteria enter the body, the memory cells stimulate rapid production of many antibodies to destroy the microbes rapidly before causing a significant damage.

INFLAMMATION

When an area of the body is wounded or infected, the tissue surrounding the wound becomes swollen and painful. This is called **inflammation** and is due to the escape of chemicals including histamine from the damaged tissues. Collectively they cause local vasodilation of capillaries. This increases the amount of blood in the area and raises the temperature locally.

Leakiness of the capillaries is also increased, permitting escape of plasma and white blood cells into the surrounding tissues and a consequent swelling of the area, a condition known as **oedema.**

WOUND HEALING

Towards the end of the inflammatory phase, cells called **fibroblasts** appear and secrete collagen. This is a fibrous protein and becomes linked to polysaccharide to form a meshwork of randomly arranged fibrous scar tissue.

After about 14 days, the disorganised mass of fibres is reorganised into bundles arranged along the lines of stress of the wound. Numerous small blood vessels begin to spread through the wound. They function to provide oxygen and nutrients for the cells involved in repairing and healing the wound. Some epidermal cells migrate into the wound and ingest much of the debris and fibrin of the blood clot which has formed over the wound.

When the epidermal cells meet, they unite to form a continuous layer under the scar. When this is complete, the scab sloughs off thus exposing the epidermis to the surrounding atmosphere.

Summary of the events

- Wound occurs, blood flows.
- Clotting process occurs.
- Inflammation occurs.
- White blood cells migrate into the wound. They absorb foreign matter and bacteria, and remove cell debris.
- Fibroblasts enter the wound and synthesise collagen which is built up into the

Downloaded from www.exoduspublishers.org

scar tissue.

- Epidermal cells remove any final debris in the wound, and also begin to dismantle the scar.
- Epidermis creates a new skin surface in the area of the wound.
- Scab sloughs off.

BLOOD GROUPS AND BLOOD TRANSFUSION

There are four types of blood groups which include; A, B, AB & O. In individuals of blood group A, their erythrocytes possess an antigen or agglutinogen A on their surface membrane and have an antibody or agglutinin b in their blood plasma.

Individuals with blood group B have on the surface of their erythrocytes an antigen B and an antibody a in their plasma.

Individuals with blood group AB have antigens A and B on the surface of their erythrocyte and lack antibodies in their plasma.

Individuals of blood group O lack antigens on their red blood cells and have antibodies a and b in their plasma.

Blood group	Antigen	Antibodies
A	A	B
B	B	A
AB	A & B	None
O	None	a & b

Before blood transfusion, blood must be checked to establish that it is microbe free and also that a donor and recipient are compatible whereby on mixing together, agglutination does not occur.

Agglutination

This is the clumping together of the erythrocytes of the recipient due to the reaction of the corresponding antigen of the donor with the antibodies of the recipient.

In other words, when the antigens of the donor correspond with the antibodies of the recipient, the antibody antigen reaction occurs which leads to agglutination.

But when the antigens of the donor and the antibodies of the recipient do not correspond, antibody antigen reaction does not occur hence no agglutination.

Donor		recipient
A	=	a (agglutination)
A	≠	b (no agglutination)

When an individual of blood group A donates blood to a recipient of blood group A, no

Downloaded from www.exoduspublishers.org

agglutination occurs because the antibody b of blood group A of the recipient does not correspond with the antigen A of blood group A of the donor.

When a donor of blood group A donates blood to a recipient of blood group B, agglutination occurs because antigen A of blood group A of the donor stimulate blood group B of the recipient to produce a corresponding antibody a which attack the antigen and via antibody antigen reaction, the donors erythrocytes become clumped together.

A to AB- no agglutination because blood group AB of the recipient lacks antibodies. For this reason, blood group AB is referred to as a universal recipient in that it can obtain blood from all the four blood groups and mix thoroughly without agglutination.

A to O, agglutination occurs because antigen A of blood group A of the donor stimulates blood group O of the recipient to produce a corresponding antibody a and via antibody antigen reaction, agglutination occurs.

Downloaded from www.exoduspublishers.org



EXODUS PUBLISHERS
CRAFTING FOR GENERATIONS

WHAT WE DO?

1. Website development
2. Logo design
3. Social media gra[phics
4. Printing & branding
5. Banner, Flyers & posters
6. Profile / portifolio design
7. Software dev't
8. Book layouts
9. Business registrations
10. Proposals
11. Professional CV's & Resumes

AFFORDABLE PRICES

Get Discount On Bulky Orders

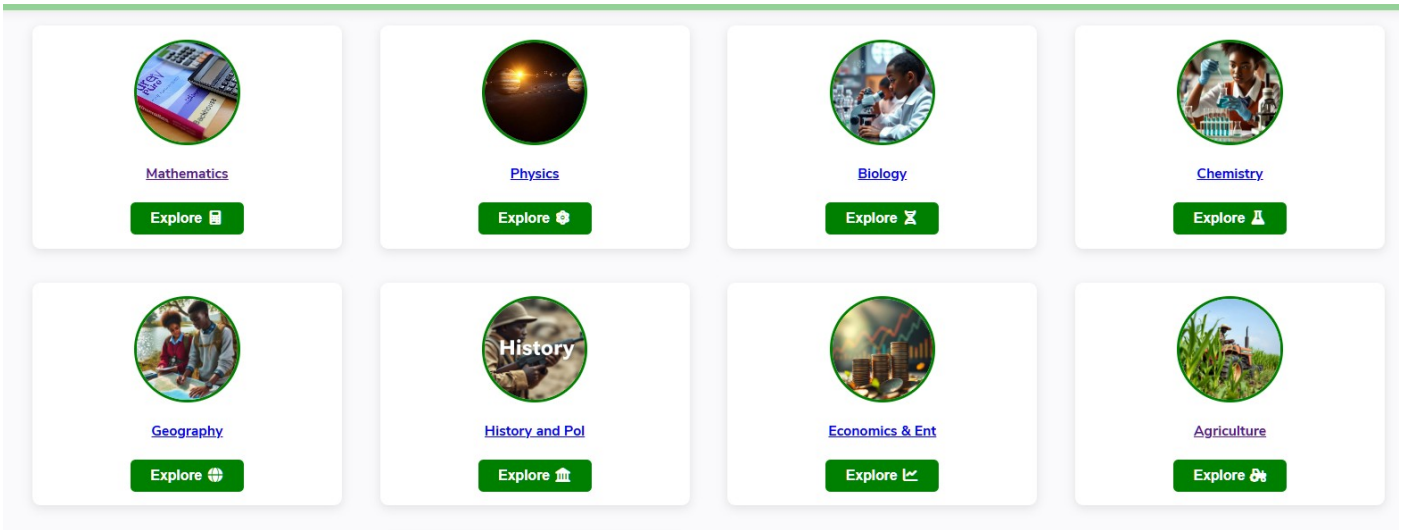
FOR MORE INFORMATION MESSAGE US:

0788060585

EXODUS PUBLISHERS

Downloaded from www.exoduspublishers.org

This document was downloaded from https://exoticnotes.com



NOTES for Secondary (S1 – S4)
https://exoticnotes.com/notes/secondary/o-level/

NOTES for Secondary (S5 – S6)
https://exoticnotes.com/notes/secondary/a-level/

PAPERS and Assessment items for Secondary (S1 – S6)
https://exoticnotes.com/papers/secondary/

Scenario Questions (with some Answers) (S1 – S6)
https://exoticnotes.com/scenario-questions

For New A level Curriculum (Notes, Assessment and Constructs, etc)
https://exoticnotes.com/new-a-level-curriculum

For New O level Curriculum (Notes, Scenarios, Papers, AOI, Syllabi, etc)
https://exoticnotes.com/new-o-level-curriculum