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SENIOR FIVE TERM 2

TOPIC 3: Transport in Humans

Competency: The learner appreciates the mechanisms of transport of substances in the blood, and the immune system's role in protecting the human body by analysing the processes and their role in the maintenance of human health, to prevent diseases in everyday life.

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Transport in humans

Transport is the movement of materials from one part of the body to another. Transport involves diffusion, and active transport at cellular level.

The circulatory system in humans perform the following functions

(i) Supplies metabolites and removes waste products from the cells at a faster rate than diffusion would do.

(ii) It enables separation of materials transported; e.g. oxygenated blood is transported different vessels from those that transport deoxygenated blood.

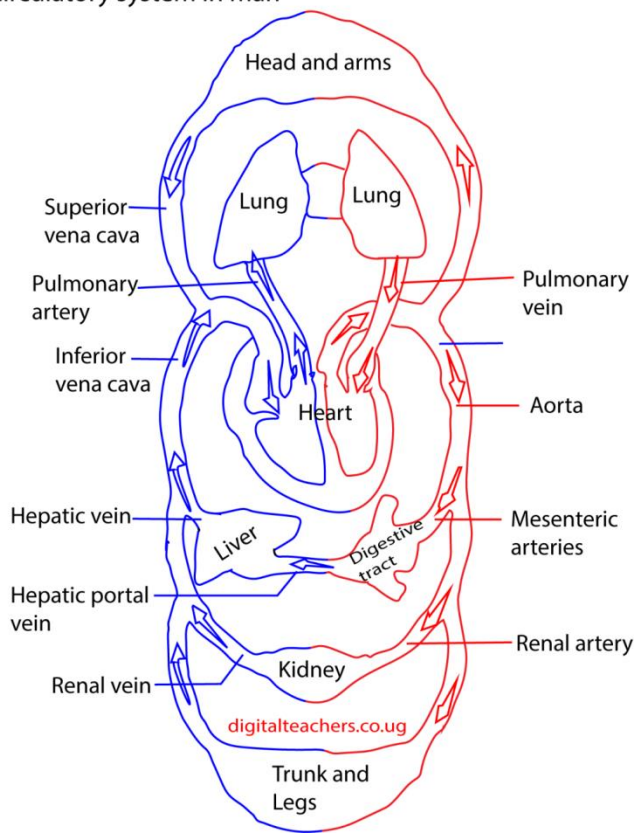
(iii) Avoids utilization of materials along the way.

The Human circulatory

The circulatory system consists of three independent systems that work together: the heart (cardiovascular), lungs (pulmonary), and arteries, veins, coronary and portal vessels (systemic). The system is responsible for the flow of blood, nutrients, oxygen and other gases, and as well as hormones to and from cells.

The figure below shows the main blood vessel in the human Circulatory system

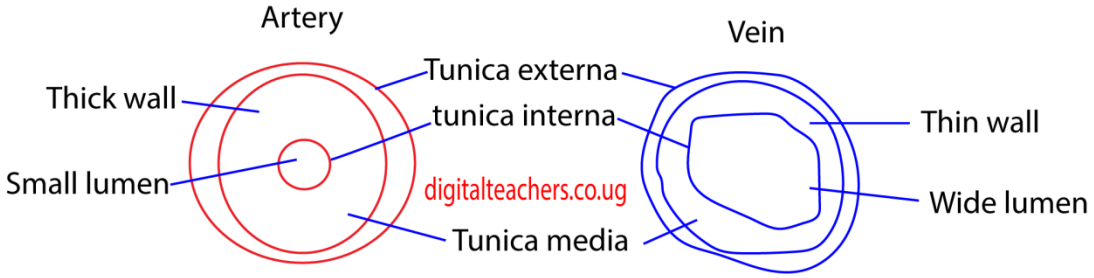
Circulatory system in man



Arties and vein

Arteries transport blood at high pressure to the body while veins transport blood at low pressure from the body to the heart.

Artery and vein



Adaptation of the arteries

- thick wall to accommodate high pressure
- have a narrow lumens to maintain high pressures
- some arteries like aorta valves to prevent back flow of blood.
- Deep seated in the body for protection
- Smooth endothelium to reduce resistance to blood

Adaptation of veins

- wide lumen to lower resistance to blood flow
- valves allow blood tom flow in one direction

Differences between arteries and veins

	Arteries	veins
1	Thick wall	Thin walls
2.	Narrow lumen	Broad lumen
3.	Have no valves except pulmonary artery and aorta	Have valves
4.	Carry oxygenated blood except pulmonary artery	Carry deoxygenated blood except
5.	Pulse detectable	Pulse not detectable
6.	Empty at time of death	Get filled up at death.

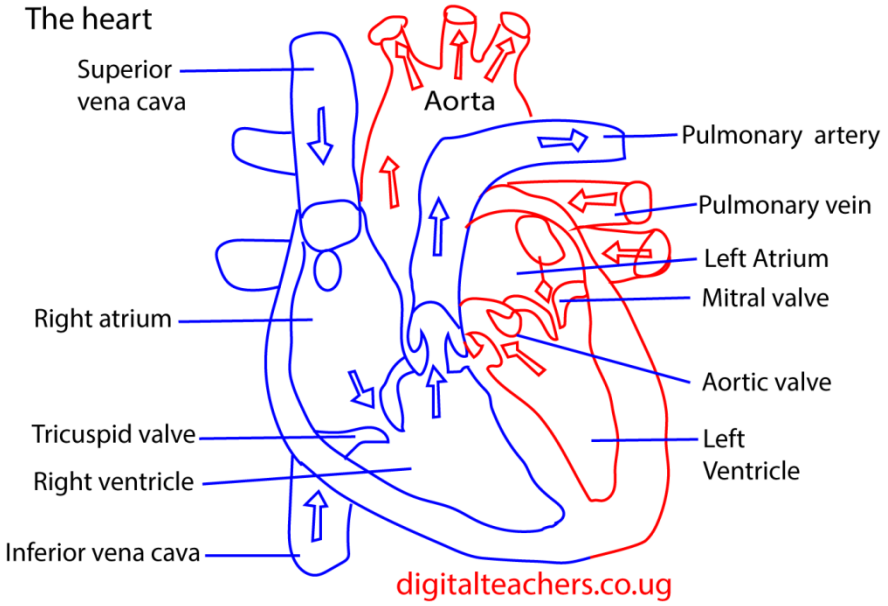
Capillaries

Is where exchange believe blood and cell takes place

Adaptation of capillaries

- thin walls for fast diffusion
- form a dense network that reaches every cell of the body.

The heart



The heart pumps blood to and from the body

Blood flow through the heart

Blood returning via the venae cava enters the right atrium. The resulting pressure in this chamber forces open the flaps of the **tricuspid valve.** The result is that blood flows through the atrioventricular opening into the right ventricle.

When the atrium and ventricle are full of blood the atrium suddenly contracts, propelling the remaining blood into the ventricle. The contraction spreads from the right atrium over the rest of the heart. A trial systole is relatively weak but the ventricles, whose thick walls are particularly well endowed with muscles, contract more powerfully. As a result, blood is forced from the right the ventricle into the pulmonary artery.

The blood is prevented from flowing back into the atrium by the flaps of the atrio-ventricular opening. The atrio-ventricular valve is prevented from turning inside out by tough strands of connective tissue, the tendinous cord or "heart strings" which run from the underside of each flag to the wall of the ventricle

Once in the pulmonary artery, blood is prevented from flowing back into the ventricle by pocket like **semilunar** valves guarding the opening of pulmonary artery.

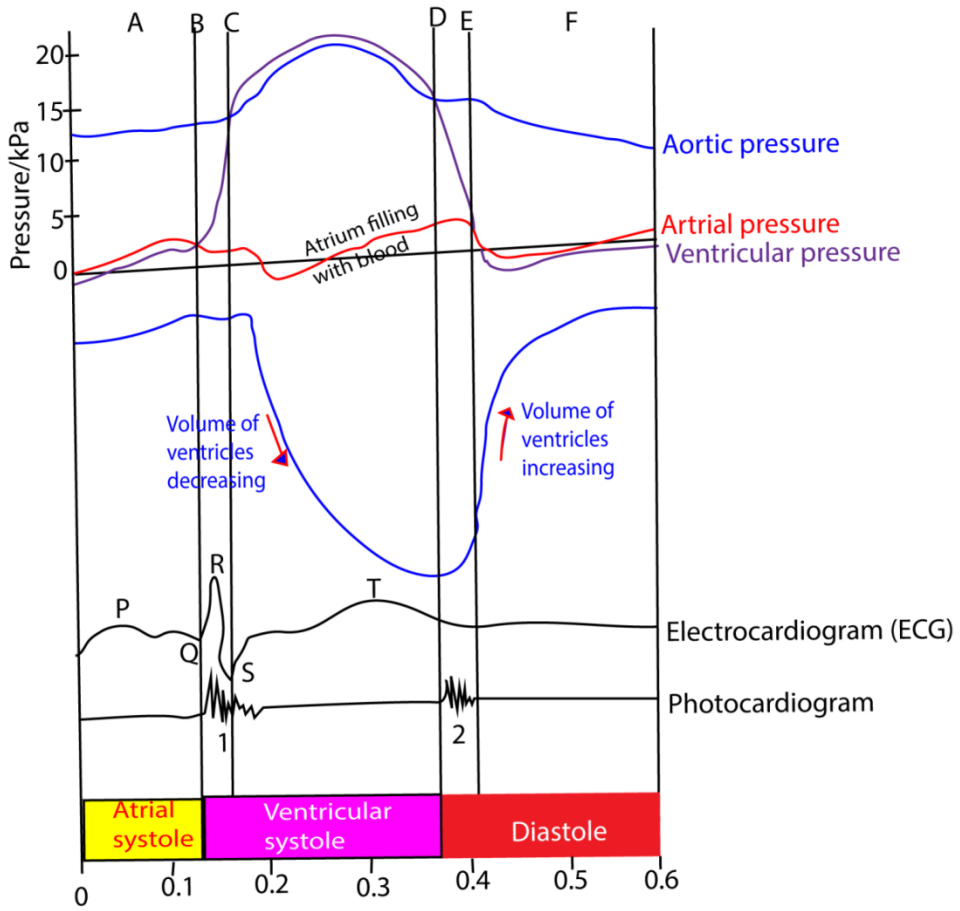
From the lungs oxygenated blood returns to the left atrium via the pulmonary veins. It is then conveyed to the left ventricle and so into the **systemic arch** which leads to the **aorta.** The flow of blood takes place in the atrioventricular valve consists of two flaps rather than three, for which reason. It is called the **bicuspid valve.** It is also known as the **mitral valve** because its two flaps are rather like a bishop's miter.

Although systole starts at the right atrium, it quickly spreads to the left so that the whole heart appears to contract synchronously. The de-oxygenated blood is pumped from the right ventricle into the pulmonary artery at the same time as oxygenated blood is pumped from the left ventricle in the aortic arch.

Systole is followed by diastole during which the heart refills with blood again. The entire sequence of events is known as the **cardiac cycle**.

The graph below illustrates the pressure and volume changes that occur during mammalian cardiac cycle (dog). Pressure changes were measured in the left atrium, ventricle and the aorta. Volume changes were measured for both ventricles. The electrical activity in the heart wall (Electrocardiogram) and heart sound (Phonocardiogram) as recorded in human subject are also shown.

The graph below illustrates the pressure and volume changes that occur during mammalian cardiac cycle (dog).



The actions at different points on the graph are described below

A - Atrium starts to contract: blood flows into ventricle

B - ventricle starts to contract: ventricular pressure exceeds atrial pressure; atrioventricular valve close

C - Ventricular pressure exceeds aortic pressure, forcing aortic valve to open; blood flows from the ventricle and ventricular volume falls

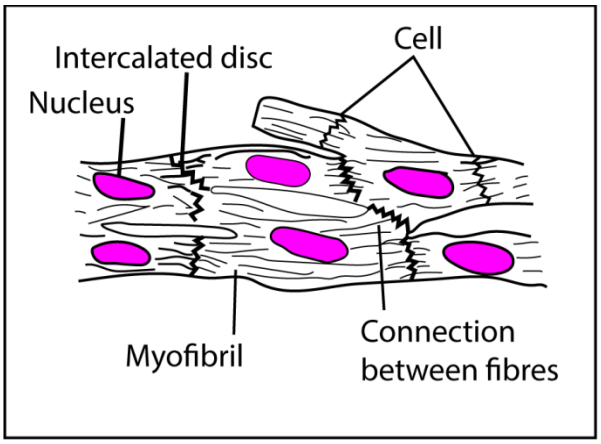
D - Ventricular pressure falls below aortic pressure; aortic valves close

E - Ventricular pressure falls below arterial pressure; blood flows from atrium to ventricle; ventricular volume raises rapidly.

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

Cardiac muscle

The most remarkable feature of the heart is the ability to contract rhythmically without fatigue. It owes this property to its muscle know as cardiac muscle. The muscle consists of a network of interconnected muscle fibres.



The fibres are divided up into uni-nucleated cells containing myofibrils. The interconnections (intercalated discs) between **the fibers ensure a rapid and uniform spread of excitation** throughout the walls of the heart which in turn ensure a uniform contraction.

Beating of the heart

Cardiac muscle is myogenic, that is, generate rhythmical contraction from within its muscle. The heart rhythm is initiated by specialized plexus (network) of fine cardiac muscle fibres embedded in the walls of the right atrium close to where the vena cava enters the heart, called sino atrial node (SAN) or the pacemaker. The contraction of the heart is preceded by a wave of electrical excitation from SAN and then spread over the heart atria. When the wave reaches the junction between the atria and ventricle, it excites another specialized group of modified cardiac muscle

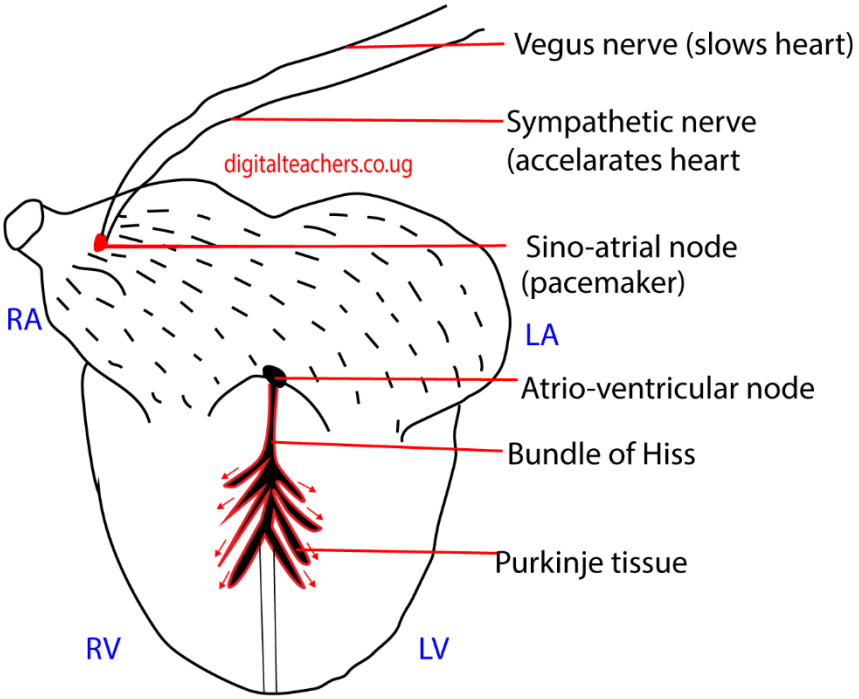
fibres called the atrio-ventricular node (AVN), Continuous with the AVN is a strand of modified cardiac muscles fibres called **Bundle of Hiss**. This runs down the inter-ventricular septum and fans out over the walls of the ventricle where it breaks up into a network of fibres called **Purkinje tissue** just beneath the endothelial lining.

When the AVN receives excitation from the atria, it sends impulses down the bundle of Hiss to purkinje tissue. The impulse then spread out to the cardiac muscle tissue in the walls of the ventricle making it to contract.

The role of AVN is to delay electrical impulse from the atria to the ventricle to allow atria contract before the ventricle.

The purkinje tissues ensure slow uniform spreading of excitation to the ventricle after the contraction of the atria.

The ventral view of heart showing the spread of electrical beating of the heart initiated by the pacemaker, the nerves simply serve to speed up or slow down the heart



Control of heartbeat by the brain

The cardio vascular center in the medulla of the brain controls the rate of heartbeat. Depending on circumstance, the cardiovascular center sends impulse down the sympathetic nerve to the

heart, increasing its rate of heart beat or down the Vegas nerves decreasing the rate of heartbeat.

Control of blood pressure

Blood pressure is controlled by

- the autonomic nervous system (ANS), which provides a short-term regulation by detecting changes in blood pressure and adjusting cardiac output and/ or blood vessel diameter
- the kidneys provide a long term regulation by managing blood volume with hormones. i.e. antidiuretic hormone (ADH) increases reabsorption of water in case of low blood volume.

The effect of carbon dioxide concentration on the heartbeat rate

Increased carbon dioxide (CO_2) concentration in the blood directly causes an increase in heart rate because the body's cardiovascular and respiratory systems work together to maintain stable levels of CO_2 and oxygen. When CO_2 levels rise, the heart must work faster to circulate blood to the lungs, where the gas can be expelled.

How the body detects and responds to high CO_2

The body has a built-in regulatory system to respond to rising CO_2 levels.

- **Chemoreceptors:** Specialized cells called chemoreceptors, located in the aorta and carotid arteries, detect the increase in blood CO_2.
- **Brain signals:** These chemoreceptors send signals to the cardiovascular control center in the brain's medulla oblongata, which is responsible for regulating the heart and lungs.
- **Increased heart rate:** The medulla oblongata then sends impulses to the sinoatrial (SA) node of the heart via the sympathetic nervous system. The SA node is the heart's natural pacemaker.
- **Release of noradrenaline:** Neurons release the neurotransmitter noradrenaline, which binds to receptors on the SA node. This binding causes the SA node to fire impulses at a faster rate, thus increasing the heart rate.
- **Increased ventilation:** In addition to increasing heart rate, the medulla also increases the rate and depth of breathing to expel the excess CO_2 from the lungs.

Examples of this response

- **During exercise:** When you exercise, your muscles produce more CO_2. This triggers the chemoreceptors and causes your heart and breathing rates to increase to transport oxygen to the muscles and remove CO_2.

- **Poorly ventilated spaces:** When people are in a room with poor ventilation, CO_2 levels can rise. Studies have shown that a rise in indoor CO_2 concentration can lead to an increase in heart rate.

- **7.5% CO_2 inhalation:** Research involving volunteers inhaling a high concentration of CO_2 showed an increase in heart rate and blood pressure, along with feelings of anxiety

The blood

Blood is a specialized tissue consisting of several types of cells suspended in fluid medium called plasma.

Functions of mammalian blood

(i) Transport of soluble organic compounds from the small intestine to various parts of the body.
(ii) Transport of soluble excretory matters to organs of excretion.
(iii) Transport of hormones from glands where they are formed to target organs.
(iv) Distribution of heat in order to maintain the body temperature
(v) Defense against diseases, which may be obtained through blood clotting, phagocytosis and immunity.
(vi) Maintenance of a right blood solute potential as a result of plasma proteins activity.
(vii) Transportation of respiratory gases i.e., CO_2 &O_2

Components of blood

1. **Water:**
   This maintains blood pressure and volume. It's where dissolved materials are transported around the body. Pressure is particularly important since the glomerulus require high pressure to form urine.
2. **Plasma proteins:**
   These include
   (i) *Serum albumen;* abundant to increase the viscosity of blood and binds with calcium. Calcium is important for the functioning of enzymes.
   (ii) Serum globulin which include
   - α-globulin, which binds with and transports hormone thyroxine, lipids and fat-soluble vitamins; A, D, E, K.

- β-globulin, binds and transport iron, cholesterol and fat soluble vitamins; A, D, E, K.
- γ-globulin are antibodies produced by lymphocytes for immune response.

(iii) *Prothrombin*- a catalytic agent involved in blood clotting.

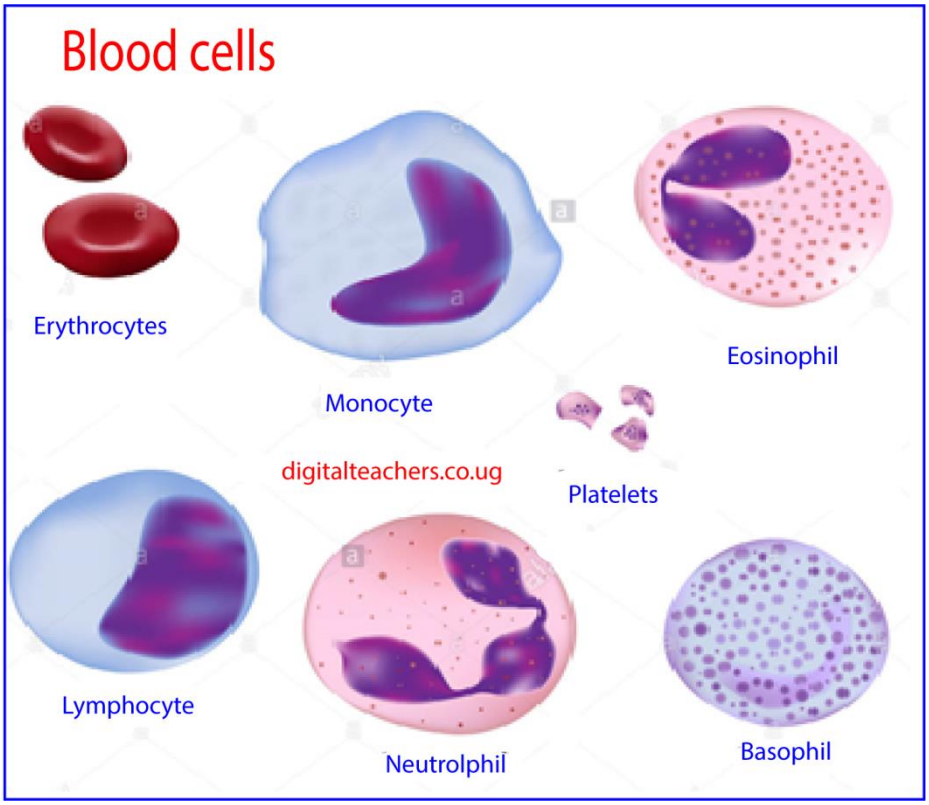
(iv) Fibrinogen- a protein involved in blood clotting.

(v) *Enzymes*- that control rate of metabolic activities in blood.

(vi) *Mineral salts:* include Na^+, K^+, Ca^{2+}, Mg^{2+}, HPO_4^{2-},HCO_3^-, Cl^-, etc. they regulate osmotic pressure and pH level of blood. Ca2+ helps nervous transmission and blood clotting.

(vii) *Dissolved products od digestion, excretory products, vitamins and hormones* that are transported in the body

3.



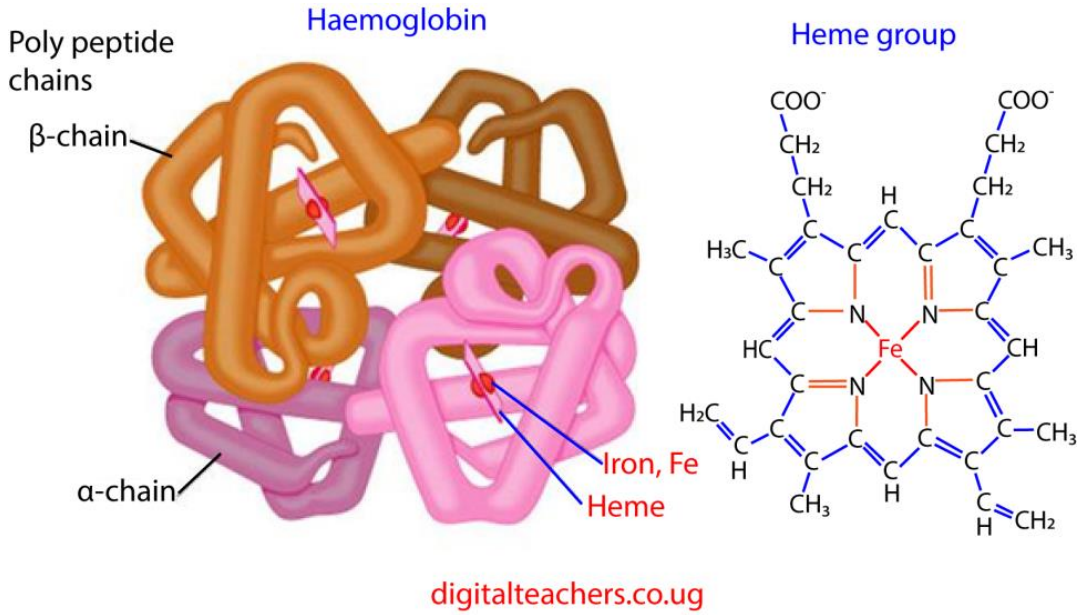
Transport of oxygen

Oxygen is transported by Erythrocytes or red blood cells. In embryo and infants, red blood cells are produced in the liver while in adults red blood cells are produced inn bone marrow.

Adaptations of red blood cells to its function

(i) They have a biconcave disc shape to increase the surface area for absorption of oxygen.
(ii) They lack a nucleus to increase the amount of haemoglobin to be packed into the cell.
(iii) They are small therefore able to squeeze between capillaries to deliver oxygen to the body cells.
(iv) They have a thin membrane permitting efficient diffusion of gases (short distance for diffusion)
(v) They contain haemoglobin, which has a high affinity but reversibly combine with oxygen such that it combines with oxygen in the lungs and delivers it to the cells in the body.
(vi) They do not carry out any metabolism so they do not utilize the oxygen being transported.

Structure of hemoglobin



(i) Hemoglobin comprises four subunits, each having one polypeptide chain and one heme group.
(ii) The polypeptide chains of adult hemoglobin are of two kinds, similar in length but differing in amino acid sequence.
(iii) The two alpha chains each has 141 amino acid residues while the two beta chains each has 146 amino acid residues
(iv) Heme, which accounts for only 4 percent of the weight of the molecule, is composed of a ring-like organic compound known as a porphyrin to which an iron in oxidation state II is attached.
(v) Oxygen binds reversibly to the ferrous iron atom in each heme group.
(vi) The binding of oxygen to the heme group of one subunit has an effect of increasing

the affinity of a neighboring subunit (on the same molecule) for oxygen.

Functions of hemoglobin

a. The main function of hemoglobin is to carry oxygen from the lungs to all the tissues of the body.
b. Some of carbon dioxide is transported from tissues to lungs through hemoglobin. Although the majority of it is transported via plasma but still it carries some of CO_2 to lungs.
c. Hemoglobin also acts as a buffer in blood. A buffer is a substance that resists change in pH. Blood has pH of 7.4 and it remains in the narrow range, because, if it changes, the life of the person may be endangered.
d. Hemoglobin also transports of various drugs to their site of action.

Carriage of oxygen

Oxygen diffuses into the red blood cells across its plasma membrane and combines with the haemoglobin to form oxyhemoglobin. The attachment of oxygen does not involve chemical oxidation of iron which remains in Iron (II) state throughout the process. The union is a loose one, the oxygen molecule being attached to haemoglobin in the lungs and equally readily detached in the tissues.

Factors that affect the amount of oxygen carried in the blood

Efficiency of haemoglobin as oxygen carrier

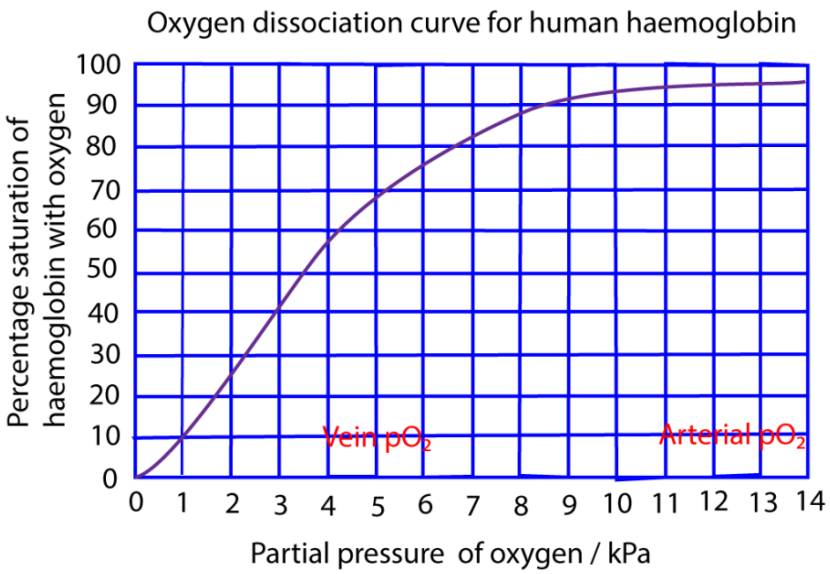
When one of the four polypeptide chains in haemoglobin molecule receives oxygen molecule in the lungs its structure is altered in such a way that the remaining three polypeptide chains accept oxygen readily. In the tissue the reverse occur: when one of the polypeptide chains loses its oxygen molecule and this causes the others to give up their oxygen more readily. In other words, haemoglobin takes up oxygen more rapidly if it already possesses one or more oxygen molecules, and releases it more rapidly if it has already released one or more oxygen molecules.

Oxygen dissociation curve

The ability of blood to transport enough oxygen to meet the needs of the body is largely attributed to the affinity of haemoglobin for oxygen.

This can determined by exposing a sample of blood to different partial pressures of oxygen (concentration of oxygen in air), and then determining the percentage saturation of blood with oxygen in each case.

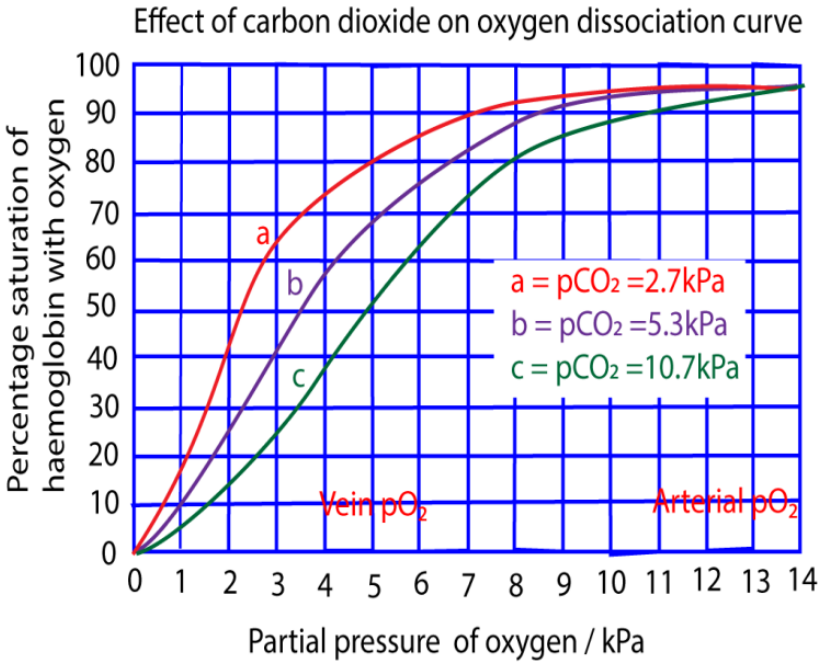
A plot of percentage saturation of haemoglobin with oxygen against partial pressure of oxygen gives an oxygen dissociation curve below



Oxygen dissociation curve is S-shaped (sigmoid) showing that it is very appropriate for a blood pigment. Over the steeply rising part of the curve, a small increase in the partial pressure of oxygen achieves a relatively high percentage saturation of blood.

The flat part of the curve at the top corresponds to the situation in the lungs: over this range a high saturation is maintained even if the partial pressure of oxygen in the alveoli falls.

The oxygen dissociation curve favors the loading oxygen in the lungs and offloads of oxygen the tissue.

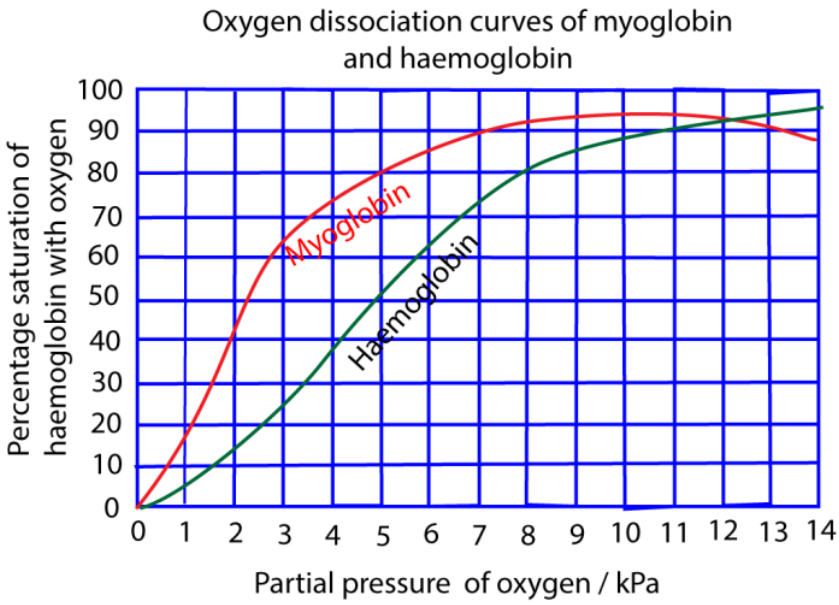


The graph above shows that a high concentration of carbon dioxide shifts the curve to the right. i.e. it lowers the affinity of haemoglobin for oxygen. The release of oxygen is therefore favored in the tissue where the partial pressure of carbon dioxide tends naturally to be high as result of its continual release from respiring cells. The oxygen uptake occurs in the lungs where the partial pressure of carbon dioxide is low.

In summary the affinity of haemoglobin for oxygen is reduced by

- Low oxygen concentration.
- High carbon dioxide concentration
- High body temperature
- Low PH

High carbon dioxide concentration (or low PH) has the effect of establishing deoxyhaemoglobin. This favors the unloading of hemoglobin hence reducing its affinity for oxygen.

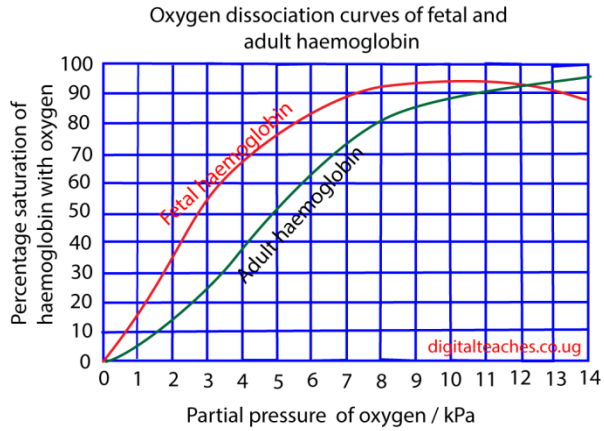


The oxygen dissociation curve of myoglobin lies at the left of that of hemoglobin because myoglobin has a high affinity for oxygen. Myoglobin is found in muscles; it picks oxygen from hemoglobin and stores it in order to be used when the partial of oxygen falls to a very low level as in severe muscle exertion.

Similarly, the hemoglobin of animals like lungworm, which burrow in oxygen-deficient mud, has higher affinity for oxygen than hemoglobin.

Location of the oxygen dissociation curve of an organism to the left of another usually indicates higher affinity for oxygen by its haemoglobin. Thus, the mountain gorilla has a high affinity for

oxygen than many other animals. This allows its haemoglobin to get saturated at low oxygen tension. This enables it to survive in condition of low oxygen partial pressure at high altitudes



The oxygen dissociation curve of fetal hemoglobin lies at the left of that of hemoglobin; this this because fetal hemoglobin has a high affinity for oxygen than adult hemoglobin this enable fetal hemoglobin to pick oxygen from the mother's blood.

Transport of carbon dioxide

CO_2 react with water to produce carbonic acid, H_2CO_3. In the red blood cells the reaction is catalyzed by carbonic anhydrase.

$$CO_2 + H_2O \longleftrightarrow H^+ + HCO_3^- \longleftrightarrow 2H^+ + CO_3^{2-}$$

Carbonic acid dissociates into hydrogen ions. Hydrogen ions combine with haemoglobin to form haemoglobinic acid while HCO_3^- diffuses and transported in blood to the lungs.

The electroneutrality in the red blood cells is maintained by an inward movement of chloride ions from the plasma so- called **chloride shift**.

In the lungs, hydrogen ions combine with hydrogen carbonate ions to give CO_2 which is lost to atmosphere.

The responses of athletes versus non-athletes, and low land dwellers versus high land dwellers, to exercise

The responses to exercise in athletes versus non-athletes, and low-land versus high-land dwellers, are primarily driven by physiological adaptations from training and environmental conditions. Athletes and high-altitude natives develop more efficient systems for oxygen delivery and use, though their specific adaptations and baseline metrics differ.

Athletes vs. non-athletes

Physiological factor	Athletes (trained)	Non-athletes (untrained)
Cardiovascular efficiency	**Higher.** Athletes experience greater stroke volume, the amount of blood pumped per heartbeat. Their heart rate is therefore lower at rest and during submaximal exercise to achieve the same cardiac output. The heart muscle itself becomes stronger and the ventricle walls thicken, a condition known as "athlete's heart".	**Lower.** Untrained individuals have a lower stroke volume and a higher resting heart rate. Their hearts are smaller and less efficient at pumping blood.
Physiological factor	Athletes (trained)	Non-athletes (untrained)
Oxygen uptake	**Higher.** Athletes have a higher maximal oxygen consumption rate due to enhanced oxygen delivery and extraction. This is a key indicator of cardiorespiratory fitness.	**Lower.** Maximal oxygen uptake is lower, indicating a less efficient oxygen transport system.
Musculoskeletal adaptations	**More developed.** Athletes have stronger, more efficient muscles with a higher density of capillaries, allowing for better nutrient and oxygen delivery. They also have more mitochondria, which increases the muscle's oxidative capacity.	**Less developed.** Muscle tissue is less efficient, with fewer capillaries and mitochondria. There is a higher percentage of body fat relative to lean muscle mass.
Recovery	**Faster.** After exercise, heart and breathing rates return to baseline values more quickly. Athletes also have higher stores of muscle glycogen, which replenish more efficiently after depletion.	**Slower.** Physiological parameters take longer to return to resting levels.
Metabolic efficiency	**Higher.** Trained individuals burn a higher proportion of fat during submaximal exercise, conserving glycogen for more intense efforts.	**Lower.** Untrained individuals primarily use carbohydrates for fuel during submaximal exercise.

Low-land vs. high-land dwellers

The primary difference between these populations is their long-term adaptation to hypoxia (lower oxygen availability) at high altitudes.

Physiological factor	High-altitude natives	Low-land dwellers (acclimatizing)
Maximal oxygen uptake	**Higher** than low-landers who have just arrived at altitude. Their bodies are genetically and developmentally adapted to maximize oxygen use in a low-oxygen environment.	**Decreased** upon acute exposure due to lower partial pressure of oxygen. While acclimatization improves performance.
Physiological factor	**High-altitude natives**	**Low-land dwellers (acclimatizing)**
Red blood cell count	**Higher.** Native high-land dwellers have higher concentrations of hemoglobin and total hemoglobin mass to increase oxygen-carrying capacity.	**Initially lower.** Upon arriving at altitude, the body gradually increases red blood cell production, stimulated by the hormone erythropoietin (EPO), but this process takes weeks to show significant effects.
Cardiovascular response	**More efficient.** High-land natives have a higher cardiovascular efficiency when exercising in their native environment.	**Stressful.** Acclimating individuals experience an increased heart rate and breathing rate at rest and during submaximal exercise to compensate for low oxygen levels.
Lactic acid buffering	**Enhanced.** Due to metabolic adaptations from generations of altitude exposure, high-land natives are more efficient at managing and buffering the build-up of lactic acid during intense exercise.	**Less efficient.** At high altitude, a low-lander's body relies more on carbohydrate metabolism, leading to faster lactic acid accumulation and fatigue.
Exercise capacity	**Higher.** They have a greater overall physical work capacity and endurance in hypoxic conditions compared to acclimatized low-landers.	**Reduced.** Initially, exercise feels more taxing and performance is significantly reduced. Exercise capacity improves with acclimatization but remains lower than at sea level.

Carbon monoxide poisoning

Carbon monoxide combines more readily with hemoglobin than oxygen. This prevent hemoglobin to combine with oxygen, thus carbon monoxide is powerful respiratory poison.

Sources of carbon monoxide poisoning

- Incomplete combustion of charcoal on sigiri/charcoal stove
- Burning rubbish
- Fireplaces
- Generators
- Tobacco smoke
- Wild/bush fires

Ways of reducing carbon monoxide poisoning

- Keeping burning charcoal stove outside the house
- Proper ventilation

How to manage carbon monoxide poisoning

- Remove the person from source of poisoning to a well-ventilated area.
- Keep the person still. Limit their activity to decrease their body's demand for oxygen
- Take the patient to the hospital facility

Defense against Diseases

Every animal is equipped with a complex system of defense mechanism which are designed it to withstand attacks by pathogens (bacteria, fungi and viruses) and to remove foreign materials form its system.

Antisepsis and asepsis

These artificial devises and technics aimed at elimination or prevention of entry of pathogens into the body.

(i) Sterilization by heat.
(ii) Use of solutions called antiseptics that kill microorganism.
(iii) Aseptic techniques which are aimed at eliminating germs from the environment altogether such as wearing sterilized clothes in the hospital theatre, keeping the theatre clean and leaning with disinfectants and detergents.

The immune system

This deals with microorganism that gain entry into the body. Immunity has been defined as by Sir MacFarlane Burnet as “the capacity of the body to recognize the intrusion of material foreign to the body and to mobilize cells and cell products to help remove that particular sort of foreign material with greater speed and efficiency.

The simplest component of the immune systems are the cell which engulf and digest foreign materials in blood and tissues in the same way as amoeba engulfs and digests its food by phagocytosis.

Role of the immune system

- Keeps invaders (like germs) from entering the body.
- Identifies and tags pathogens in the body
- Destroys pathogens by engulfing them or by use of antibodies.
- Store memory cells that produce an enhanced response to repeated infection by the same type of microorganism.
- Removes dead, faulty and cancer cells

Types of immunity

Natural/Nonspecific immunity

Nonspecific immunity, also known as innate immunity, is the body's first line of defense against pathogens and other foreign invaders. It provides a rapid, general response to a wide range of threats, distinguishing between "self" and "non-self" without needing prior exposure to the specific pathogen. Unlike specific (adaptive) immunity, innate immunity has no memory and reacts the same way to every encounter.

Components of nonspecific immunity

The innate immune system includes several layers of defense, which can be categorized into three main types.

Physical and mechanical barriers

These are the body's initial line of defense, preventing pathogens from entering in the first place.

(i) **Skin:** The skin is a tough, waterproof barrier with a layer of dead cells that most microorganisms cannot penetrate. It is also covered in harmless microorganisms that compete with pathogens.

(ii) **Mucous membranes:** These membranes line the respiratory, gastrointestinal, and urogenital tracts. They trap pathogens in a sticky substance known as mucus.

(iii) **Cilia:** These are tiny, hair-like structures found in the respiratory tract that sweep mucus containing trapped pathogens towards the throat to be expelled.

(iv) **Reflexes:** Actions such as coughing, sneezing, vomiting, and urination help to expel pathogens from the body.

Chemical barriers

These are fluids and substances that can kill or inhibit the growth of pathogens.

(v) **Gastric acid:** The stomach's low pH (high acidity) destroys most pathogens that are ingested.

(i) **Tears and saliva:** These fluids contain enzymes, such as lysozyme, which break down bacterial cell walls.

(ii) **Antimicrobial proteins:** Secretions like sweat, sebum, and defensins can kill bacteria and other microbes on the skin's surface.

(iii) **Complement system:** This is a group of proteins in the blood that can be activated to destroy foreign cells by punching holes in their membranes, a process called cell lysis.

Cellular defenses

If pathogens overcome the first two lines of defense, a variety of immune cells are deployed to attack and eliminate them.

(i) **Phagocytes:** These "eating cells" patrol the body and engulf foreign particles, dead cells, and invading microbes. Key phagocytes include:

(ii) **Macrophages:** Large phagocytes that can leave the bloodstream to hunt pathogens in tissues.

(iii) **Neutrophils:** Abundant phagocytes that are often the first responders to an infection site.

(iv) **Dendritic cells:** Found in tissues exposed to the environment, they can engulf pathogens and also help activate the specific immune system.

(v) **Natural killer (NK) cells:** These cells can identify and destroy compromised host cells, such as those infected by a virus or that have turned cancerous, by recognizing abnormalities on their surface.

(vi) **Basophils and eosinophils:** These cells release inflammatory mediators and are involved in fighting parasites and allergic responses.

General immune responses

- **Inflammation:** A localized response to tissue injury or infection. It involves swelling, heat, redness, and pain caused by the dilation of blood vessels. This process brings more immune cells to the affected area to fight the infection and initiate healing.

- **Fever:** A **systemic** response where the body's temperature is raised, which can inhibit the growth of some microbes and increase the metabolic rate of the body's cells to speed up repair.

Adaptive immunity/acquired immunity

This is different from natural immunity in the following ways.

a. It is **specific**, that is, different types of cells responsible for it can distinguish between different types of microorganism.
b. It has a **memory**, which enables its cells to produce an enhanced response to repeated infection by the same type of microorganism.
c. It is brought about by lymphocytes because they are abundant in the **lymphatic response**, particularly **lymph nodes**.

There are two types of lymphocytes in blood and lymph: B lymphocytes and T-lymphocytes also called B-cell and T cells respectively for short)

Antigen

It is any substance that initiates an adaptive immune response. It may be a pathogen, its toxic product, or various non-harmful molecules and cells such as pollen and ampicillin.

B lymphocytes

The B-lymphocytes originate in the bone marrow. When a B lymphocyte encounters an antigen it produces **antibody** a specific protein molecule called **immunoglobulin**. The antibody combines with antigen and helps to eliminate it from the body. What makes B lymphocytes so remarkable is that they can produce highly specific antibodies against a vast number of different types of antigen.

T lymphocytes

These look exactly like B lymphocytes but they do not produce antibodies. The T lymphocytes also originate in the bone marrow but they have to pass through the thymus gland during their maturation. They are responsible for what is called **cell-mediated immunity**. T lymphocytes are more varied in their action than B lymphocytes, they have to make contact with their matching antigen to work. They have special receptors on their surface which enable them to recognize the correct antigen.

a. T helper cells help other cells in the immune system. For example, they stimulate B lymphocyte to divide into antibody producing cells. If these helper cells are not present, the B lymphocytes cannot go into action. They also enhance the action of phagocytes. It is the T helper cells which are invaded by HIV.

b. T suppressor cells suppress other cells in immune system. They have opposite effect of T-helper cells on B lymphocytes and phagocytes. They act as brakes in immune system, dampening it down and preventing from over reacting.

c. T killer cells destroy cells infected with viruses before the viruses have time to proliferate. They also attack cells from other individuals if they get into the body and in doing so they cause the rejection problems associated with skin grafts and transplant surgery. T killer cells are regulated in the same way as B cells by the T helper and T suppressor.

   Together, the T helper and T suppressor cells regulate and control the production of antibodies by the B cells and enhance or suppress the action of phagocytes. T cells also secrete short-lived messenger proteins called **lymphokines** which activate or suppress every aspect of the immune response. One of their functions is to stimulate macrophages to engulf other cells much more readily. This enables the macrophages to attack bacteria which invade the immune system and fight fungal infection and tumors.

   One group of lymphokines are called interferons. These are effective against a wide range of viruses and they work by inhibiting the protein-making machinery of the infected cells so that viruses cannot proliferate. They also stimulate changes in infected cells which makes them resistant to the viruses.

The role of lymph nodes in prevention of diseases in animals

The lymph nodes monitor and cleanse the lymph flowing into them of pathogens, and store lymphocytes and other immune system cells that attack and destroy harmful substances like bacteria

Passive and active immunity

Passive immunity is the temporary protection from a disease by receiving pre-formed antibodies from an external source. In contrast, **active immunity** is long-lasting protection that results when your own immune system creates antibodies after exposure to a pathogen.

Both types of immunity can be acquired either naturally or artificially.

Active immunity

This type of immunity develops when your immune system encounters a pathogen or vaccine and is triggered to produce its own antibodies and memory cells. It is a slow process that takes time to build up, but it provides long-term protection, and sometimes even lifelong immunity.

How active immunity is acquired:

- **Natural exposure:** When you get an infection, like the chickenpox, your body produces specific antibodies and creates memory cells that recognize and fight the virus in the future.

- **Vaccination:** A vaccine introduces a killed or weakened form of a pathogen (or a specific component, such as an antigen) to trigger an immune response without causing the disease. The body then produces memory cells to remember how to fight the real pathogen later.

Passive immunity

This type of immunity is the direct transfer of antibodies from one individual to another, offering immediate but short-lived protection. Because the body doesn't produce its own memory cells, the immunity fades once the transferred antibodies are degraded.

How passive immunity acquired:

- **Natural transfer:** A mother passes antibodies to her baby across the placenta during pregnancy and through breast milk, providing the infant with temporary protection. This is especially crucial in the first few months of life, before the baby's immune system is fully developed.

- **Artificial transfer:** Antibodies are transferred via blood products, such as an injection of immune globulin or antivenom. This is typically done when immediate protection is needed, for example, after potential exposure to rabies or tetanus.

Comparison of active and passive immunity

Characteristic	Active Immunity	Passive Immunity
Source of Antibodies	Produced by your own immune system.	Transferred from an external source, such as a mother or another person.
Response Time	Slower; takes days or weeks to develop after initial exposure.	Immediate; protection is available as soon as antibodies are transferred.
Duration of Protection	Long-lasting, often for years or a lifetime.	Short-lived, typically lasting only a few weeks to months.
Immune Memory	Creates immunological memory, so the body can respond quickly to future infections.	No memory cells are generated, so there is no lasting immune memory.
Method of Acquisition	Natural infection or vaccination.	Maternal antibodies (placenta, breast milk) or injections (immune globulin).
Clinical Use	Routine vaccination for long-term protection.	Emergency treatment for immediate, rapid defense, or for immunocompromised individuals.

Ways/mechanism by which antibodies combat antigens

(i) **Neutralization**: Antibodies bind directly to a pathogen or toxin, blocking it from interacting with host cells or neutralizing its harmful effects. For example, they can block viral proteins needed to enter a cell, rendering the virus unable to infect.

(ii) **Opsonization**: Antibodies act as "tags" or "handles" on the surface of pathogens. This coating, or opsonization, makes it easier for phagocytic cells like macrophages and neutrophils to recognize, bind to, and engulf the pathogen for destruction.

(iii) **Complement Activation**: When antibodies bind to a pathogen, they can trigger the complement system. This is a cascade of proteins that can lead to the lysis (bursting) of the microbial cell or further attract immune cells to the site of infection.

(iv) **Agglutination**: Antibodies link multiple pathogens together, forming large clumps that are easier for phagocytes to clear from the body.

(v) **Precipitation**: Antibodies cause soluble antigens to clump together and fall out of solution, making them easier targets for phagocytosis.

Vaccination

Vaccination is the process of administering a vaccine to produce active acquired immunity against an infectious or malignant disease. Vaccines use a safe, modified version of a disease-causing germ or its components to train the immune system to recognize and fight off that specific threat, protecting an individual from future infection without having to get the illness.

How vaccines work

A vaccine works by harnessing the body's adaptive immune system, which has a memory for pathogens it has encountered before.

(i) **Antigen introduction:** The vaccine introduces an antigen—a key feature of the disease-causing germ (e.g., a weakened or killed microbe, a fragment of its protein, or genetic material that codes for it).

(ii) **Immune response:** The immune system recognizes the antigen as foreign and launches a response. It produces specialized cells (T-lymphocytes) and antibodies to fight it.

(iii) **Immune memory:** The immune system remembers the germ. If the body is exposed to the real pathogen later, the memory cells and antibodies can quickly mount a defense, preventing illness.

Types of vaccines

Vaccines come in several types, each using a different method to stimulate an immune response. These include live-attenuated (weakened live germ, like MMR), inactivated (killed germ, like polio), subunit (parts of the germ, like HPV), toxoid (weakened toxin, like tetanus), mRNA (genetic material instructing cells to make a germ protein), and viral vector (harmless virus delivering genetic material for a germ protein) vaccines.

Benefits of vaccination

Vaccination provides several benefits, including protecting the vaccinated individual by preparing their immune system, contributing to community immunity by making disease spread more difficult, saving millions of lives annually from preventable diseases, and even eradicating diseases like smallpox.

Vaccine safety and risks

Vaccines are subject to rigorous safety testing before and after approval. While most side effects are minor and temporary, serious side effects are rare, and the protective benefits of vaccination generally outweigh the risks.

Problems arising from immune system

1. Allergy: this is a group of unpleasant symptoms which result from an excessive immune responsible or hypersensitivity. These symptoms include bouts of sneezing, running nose, itchy eyes, fever and so on due to release of histamine. Allergies can be induced by a variety of agents/allergens such as grass pollen, cut fur, fungal spore, certain drugs and food, or as a result of an insect bite

2. Rejection of transplanted tissue.

Chemotherapy and antibiotics

Chemotherapy is the use of chemical substances, natural or synthetic, that kill or prevent the production of microorganisms in the body. The term is now extended to include the inhibition of dividing malignant cell in cancer. The chemical substances are called chemotherapeutic agents. Some of these substances such as penicillin are secreted by microorganism and are selectively toxic to other microorganism in which case they are called antibiotics.

The mechanism used in rapid test kits to detect infections

Rapid test kits typically use a technology called a **lateral flow immunoassay (LFIA)** to detect infections. This technology is a paper-based diagnostic platform that can confirm the presence of a specific target molecule, known as an analyte, within a liquid sample. For infectious disease

testing, the analyte is most often an antigen (a unique protein from a virus or bacterium) or, in some cases, the antibodies the body has produced in response to an infection.

The entire process relies on the principle of antigen-antibody binding, where highly specific antibodies are used to capture the target analyte.

Blood groups, the ABO system

The entire human population can be divided into four groups on the on the basis of the reaction between the blood group of different individuals when mixed together. These groups are called A, B, AB and O and are known as collectively as the ABO system. The capital letter stands for different types of glycoprotein present on the surface of person's red blood cells. These glycoproteins are antigen, similar to those found on the surface of bacteria. We all make antibodies against foreign antigens, but not of course against those on our own red blood cell.

The antibodies are called anti-A and anti-B. if an individual has a particular antigen on the red cells, the corresponding antibody is not present in plasma. Thus a person belonging to blood group A has red cells with antigens A on them; the plasma does not contain anti-A antibody; but it does contain Anti B antibodies. A person belonging to blood group B, has B antigens on the red cells and plasma contains anti-A antibody only. In blood of blood group AB, the red cells

carry both antigen A and B and neither antibodies are present in plasma. Group O blood has neither antigen but both antibodies. When blood of different kind, say, A and B mixed. They agglutinate or form chimps which may block the recipients blood vessel. For instance, if blood of group A is given to a patient of blood group B, the anti-A antibodies in the patient's blood will cause agglutination of the donors' red cells because they carry the A-antigen. It does not matter that the donor's antibodies (anti B) are incompatible with the recipient's antigen B because the recipient receives relatively little blood and the dilution effect minimizes agglutination. The table below summarizes what happens when blood of different groups are mixed.

	Oab	Ab	Ba	AB
Oab	-	-	-	-
Ab	+	-	+	-
Ba	+	+	-	-
AB	+	+	+	-

+ agglutination

- No agglutination

Capital letter- antigen

Small letter - antibody

A universal donor (group O) can give blood to a recipient of any blood group without causing agglutination.

A universal recipient (group AB) receives blood from any donor of any group without agglutination. In practice blood transfusion are normally carried out using blood from the same group as the of the recipient. The group to which sample of blood belong is determined by a compatibility test.

The Rhesus system

In addition to the ABO system, there are many other antigens on human red blood cells. One of these is the Rhesus antigen, so called because it was first identified by injecting rabbits with red blood cells obtained from the rhesus monkey. The majority of people possess red blood cells with the Rhesus positive antigen present, and they are known as Rhesus positive (Rh^+). The remainder lack the rhesus antigen and are called rhesus negative (Rh^-).

New-born haemolytic disease

Hemolytic disease of the newborn (HDN), also known as erythroblastosis fetalis, is a blood disorder that occurs when there is an incompatibility between the blood types of a mother and her unborn baby. This incompatibility triggers the mother's immune system to produce antibodies that cross the placenta and attack the baby's red blood cells, causing them to break down.

Though there are other causes, the most common forms of HDN involve incompatibility in the Rh and ABO blood group systems.

Causes

(i) Rh incompatibility

This is the most well-known and severe type of HDN, and it typically affects a second or later pregnancy. It occurs when:

- An Rh-negative mother carries an Rh-positive baby. The Rh-positive factor is inherited from the father.
- During pregnancy or delivery, a small amount of the baby's Rh-positive blood enters the mother's bloodstream.
- The mother's immune system recognizes the Rh-positive cells as foreign and creates antibodies to destroy them. This is called sensitization.
- This first pregnancy is usually unaffected, as the sensitization process takes time. However, in subsequent pregnancies with an Rh-positive fetus, the mother's memory antibodies can cross the placenta and attack the baby's red blood cells.

(ii) ABO incompatibility

This type of HDN is generally much milder than Rh incompatibility and can occur in a first pregnancy.

- It typically happens when a mother with blood type O carries a baby with blood type A or B.
- Unlike Rh antibodies, which must be created through exposure, women with blood type O already have natural anti-A and anti-B antibodies. These antibodies can cross the placenta and target the baby's red blood cells.

Effects on the newborn

The consequences of HDN can range from mild to severe.

- **Anemia:** The destruction of red blood cells (hemolysis) leads to a low red blood cell count, making it difficult for the baby's blood to carry enough oxygen.
- **Hyperbilirubinemia and jaundice:** As the baby's red blood cells break down, they release bilirubin, a yellow pigment. While the placenta clears some of this during pregnancy, after birth the baby's immature liver may be overwhelmed. This leads to a buildup of bilirubin (hyperbilirubinemia), causing the skin and eyes to appear yellow (jaundice).
- **Enlarged liver and spleen:** The baby's body attempts to compensate for the anemia by producing more red blood cells, which causes the liver and spleen to enlarge.
- **Kernicterus:** In severe, untreated cases of hyperbilirubinemia, excessive bilirubin can spill over into the brain, causing permanent brain damage, hearing loss, and cerebral palsy.
- **Hydrops fetalis:** In the most severe cases of anemia, the baby's organs begin to fail, causing large amounts of fluid to build up in tissues and organs. This can lead to heart failure and is life-threatening.

Prevention and treatment

Fortunately, significant advances in medical science have made HDN a largely preventable and treatable condition.

Prevention

- **Rh immunoglobulin (RhoGAM):** Rh-negative mothers who are not yet sensitized are given an injection of Rho(D) immune globulin, often around the 28th week of pregnancy and again after delivery. This substance contains Rh antibodies that destroy any Rh-positive fetal red blood cells that have entered the mother's circulation before her immune system has a chance to develop its own antibodies.

- Other situations that could cause fetal and maternal blood to mix—such as a miscarriage, abortion, or invasive prenatal testing—also warrant a RhoGAM injection.

Treatment

- **Phototherapy:** For mild to moderate jaundice after birth, the baby is placed under special blue lights. The light changes the bilirubin into a water-soluble form that the baby's body can more easily excrete.

- **Intravenous immunoglobulin (IVIG):** This blood product can be given to the baby to block the mother's antibodies from attacking the red blood cells, which reduces the need for an exchange transfusion.

- **Intrauterine blood transfusion:** In severe cases of fetal anemia, blood can be directly transfused into the baby while still in the womb.

- **Exchange transfusion:** For severely anemic newborns, this procedure involves removing a large portion of the baby's blood and replacing it with donor blood. This reduces the level of antibodies and bilirubin while increasing the red blood cell count

Revision question transport in human

1. The oxygen dissociation curves for aquatic animals are usually to the left of those of terrestrial ones because

A. there is less oxygen in water.

B. air is less dense than water.

C. aquatic animals are less active.

D. aquatic animals use less oxygen. A

20. Which one of the following is the correct order of events in the heart after the contraction of the atria?

A. Atrio -ventricular valves open, ventricles contract, semi lunar valves close.

B. ventricles contract, atrio-ventricular valves close, semi lunar valves open.

C. ventricles contract, atrio-ventricular valves semi lunar valves open.

D. Atrio- ventricular valves open, semilunar valves open, ventricles contract B

22. High concentration of carbon dioxide in the tissues leads to

A. Increase in the affinity for oxygen by haemoglobin.

B. Increase in the loading tension of haemoglobin.

C. Shifting the dissociation curve to the left.

D. Lowering of the affinity for oxygen by haemoglobin. D

13. The increase in supply of blood by heart to respiring tissues, is caused high

A. ventilation rate.

B. concentration of oxygen in the inhaled air.

C. carbon dioxide concentration in the blood.

D. carbon dioxide concentration in the tissues. C

* While high carbon dioxide concentration in the tissues (Option D) is the initial source, it is the *concentration in the blood* that acts as the main chemical stimulus for the systemic response by the heart and respiratory system

24. The lack of a nucleus in the red blood cells enables it to

A. have a high affinity for oxygen.

B. be more permeable to oxygen.

C. give up oxygen more readily.

D. contain more haemoglobin. D

19. High carbon dioxide concentration in respiring tissues is important because it causes

A. local vasodilation, allowing more blood into the tissues.

B. low pH in the tissues leading to unloading of oxygen.

C. local vasoconstriction creating high blood pressure.

D. increased heartbeat. B

* High carbon dioxide concentration in actively respiring tissues is crucial for two main reasons, both of which enhance oxygen availability where it is most needed:

(i) **Local Vasodilation (Option A):** An increase in local CO_2 concentration (along with other metabolic byproducts like lactic acid and a decrease in pH) causes the smooth muscles in the walls of local arterioles to relax, leading to vasodilation (widening of blood vessels). This increases blood flow to the active tissues, physically supplying more blood rich in oxygen.

(ii) **Lowering of Oxygen Affinity (Option B - Bohr Effect):** The high concentration of CO_2 increases the concentration of hydrogen ions (H+) and lowers the pH of the blood (making it more acidic). This change in pH alters the structure of hemoglobin, reducing its affinity for oxygen. As a result, hemoglobin releases more of its bound oxygen molecules precisely in the tissues where CO_2 levels are high and oxygen demand is high.

Both mechanisms work in concert to ensure that active tissues receive adequate oxygen. In many biological contexts, Option B (the Bohr effect) is highlighted as a key chemical regulatory mechanism directly affecting oxygen binding and unloading from hemoglobin.

20. Mixing of oxygenated and deoxygenated blood in amphibians is minimized by

A. rapid contraction of the ventricle.
B. spongy nature of heart muscles.
C. spiral valve in the truncus arteriosus.
D. columnae carnae in the ventricular C

21. An organism living in an oxygen deficient environment has

A. haemoglobin that easily picks up oxygen.

B. its oxygen dissociation curve to the right.

C. haemoglobin that readily releases its oxygen.

D. haemoglobin that less readily picks up oxygen A

22. Blood flows in the heart of an insect as a result of

A. raising the perivisceral membrane.

B. contraction of the alary muscles.

C. relaxation of the heart ligaments.

D. increase in the pericardia! pressure. B

23. The lung fish living in mud has its oxygen dissociation curve to the left of that for humans because

A. there is a high level of carbon dioxide concentration in the mud.

B. the lung fish's haemoglobin has a higher affinity for oxygen than that of humans.

C. of the lower temperature of the h

D. of low level of oxygen concentration in the mud. B

24. Which one of the following when at high levels in the blood, increases the rate of heart beat?

A. Carbon dioxide.

B. Thyroxine.

C. Oxygen.

D. Adrenaline. D

25. Which one of the following describes the chloride shift during transportation of carbon dioxide in mammals?

A. Hydrogen carbonate ions leave the erythrocytes as chloride ions from tissues, enter.

B. Chloride ions leave the erythrocytes as hydrogen carbonate ions from tissues, enter.

C. Chloride ions enter the lungs as hydrogen carbonate ions leave the erythrocytes.

D. Hydrogen carbonate ions enter the lungs as chloride ions leave the erythrocytes. A

26. Oxygen from myoglobin is released after oxy-haemoglobin supplies are exhausted because myoglobin

A. acts as a store of oxygen in resting muscles.

B. works better when the partial pressure of oxygen is high.

C. is produced in skeletal muscles when the oxygen demand is low.

D. has a lower affinity for oxygen than haemoglobin. A

27. The correct order of transmission of electrical impulses to initiate the heart beat is

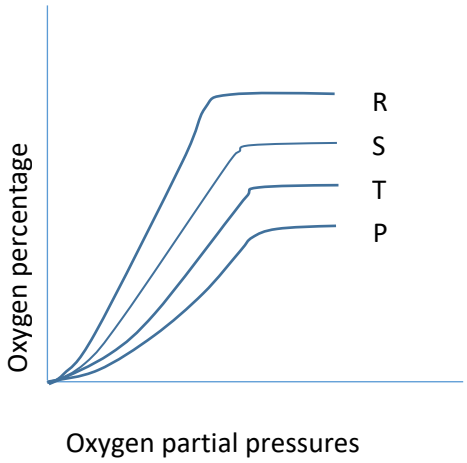
A. sino-atrio node — artria — atrio-ventcular node — purkinje tissue —ventricles.

B. sino-atrio node — ventricles — atrio-ventricular node — purkinje tissue— atria

C. atrio-ventricular node — atria — sino-atrio node — purkinje tissue — ventricles

D. atrio-ventricular node — purkinje tissue — ventricles — artria — sino-artrio node. A

28. Figure 4 shows the oxygen dissociation curves for mudfish, human foetus, adult human and an active flying bird.



Which curve is most likely to be that of an active flying bird?

A. R.

B. S.

C. T.

D. P. D

* Releases oxygen easily

29. Which one of the following conditions reduces the affinity of hemoglobin for oxygen?

A. High oxygen concentration.

B. High carbon dioxide concentration.

C. Low body temperature.

D. High pH of the blood. B

30. Which one of the following is responsible for increasing the pressure of blood flowing in veins, back to the heart?

A. The pumping action of the heart.

B. Contraction of skeletal muscles.

C. Closing of valves.

D. Inspiratory movements of muscles. B

Structured questions

31. Figure 6 illustrates two different mechanisms of gaseous exchange in fish A and B

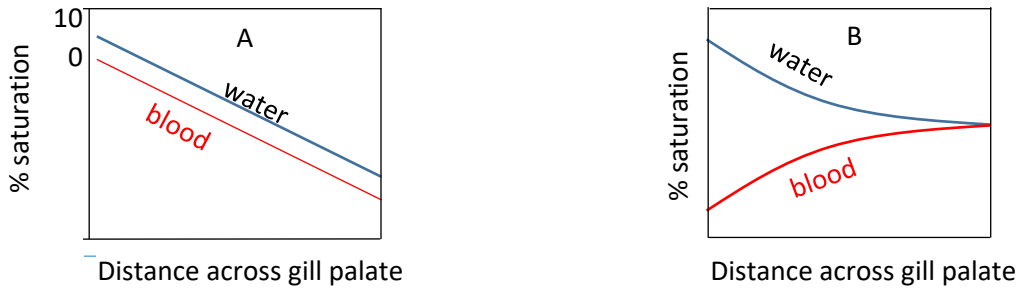


Fig. 6

32. Which one of the following is correct about the circulation of blood to and from the mammalian heart?

A. Oxygenated blood from lungs enters through pulmonary artery.
B. Deoxygenated blood from heart enters lungs through the pulmonary artery.
C. Oxygenated blood from heart goes to rest of the body through the vena cava.
D. Deoxygenated blood from body enters heart through pulmonary vessel. B

33. Which of the following organs is supplied and drained by a vein?

A. Stomach
B. Liver
C. Kidney

D. Pancreas B

- Hepatic portal vein from intestine supplies the liver

34. Which one of the following is the route a red blood cell takes from the liver to the lung?
    A. Hepatic portal vein, vena cava, pulmonary artery
    B. Hepatic vein, pulmonary vein, pulmonary artery
    C. Hepatic artery, pulmonary artery
    D. Hepatic vein, vena caca, pulmonary artery D
35. Which one of the following organ is supplied and drained by a vein?
    A. Stomach
    B. Liver,
    C. kidney
    D. Pancreas B
36. In mammalian heart, the thick walls of left ventricle are vital for
    A. Resisting pressure of blood coming into the ventricle
    B. Maintaining the shape of the heart
    C. Producing enough pressure to pump blood to all parts of the body
    D. Resisting back flow of blood from the body C
37. Which of the following blood vessel contains blood with the highest amount of oxygen?
    A. Vena cava
    B. Hepatic vein
    C. Pulmonary vein
    D. Hepatic portal vein C
38. Which one of the following is not a function of blood?
    A. Regulation of sugar level in blood
    B. Healing of damaged part of the body
    C. Regulation of body temperature
    D. Transportation of wastes A
39. Which one of the following contains the lowest concentration of urea?
    A. Hepatic portal vein
    B. Renal artery
    C. Hepatic vein
    D. Renal vein D
40. Which one of the following is the correct reason for the thickness of the walls of atria and ventricle?
    A. Atria are thicker because they have to generate higher pressure
    B. Atria are thicker because they have to resist higher pressure
    C. Ventricles are thicker because they have to generate higher pressure
    D. Ventricles are thicker because they have to resist higher pressure. C
41. Blood in pulmonary artery is at lower pressure than aorta because in pulmonary circulation
    A. Blood travels a shorter distance
    B. The right ventricle has thinner walls
    C. The vessel carrying blood is smaller
    D. Fewer organs are supplied. A

42. Which of the following blood vessel transports blood rich in nutrients?
    A. Pulmonary artery
    B. Hepatic portal vein
    C. Mesenteric artery
    D. Renal vein B

43. In human heart, the mixing of oxygenated and deoxygenated blood is prevented by the
    A. Septum
    B. Bicuspid valve
    C. Tricuspid valve
    D. Semilunar valve A

44. (a) State two differences between the two systems of oxygen concentration (2marks)

Differences

Fish A	Fish B
Oxygen concentration of blood is above 50% at the end of the gill plate.	Oxygen concentration of the blood is about 50% at the end of the gill plate.
water always has a higher oxygen concentration than blood	Initially water has a higher oxygen concentration, but at the end of the gill plate, the oxygen concentration blood and water are the same.
Oxygen concentration of the blood increase linearly along the gill plate.	Oxygen concentration of the blood increase first rapidly then decreases gradually and reaches a constant valve at 50%

(b) Explain the physiological advantage of fish A over B(2marks)

Fish A maintains a steep concentration gradient between the water and blood that the fish picks up enough oxygen from the water and deposits sufficient quantities of excess carbon dioxide in it.

(c) Describe how a gill is structurally adapted as a respiratory surface (4marks)

- It is covered with a thin highly permeable membrane to reduce the diffusion distance.
- It has a rich blood to increases the efficiency to gaseous exchange.

- It's wet in order to increase chance of picking up gases readily dissolve in the moisture.
- Numerous filaments increase the surface area

45. Figure 7 shows the oxygen dissociation curve for a tadpole blood and that of adult frog

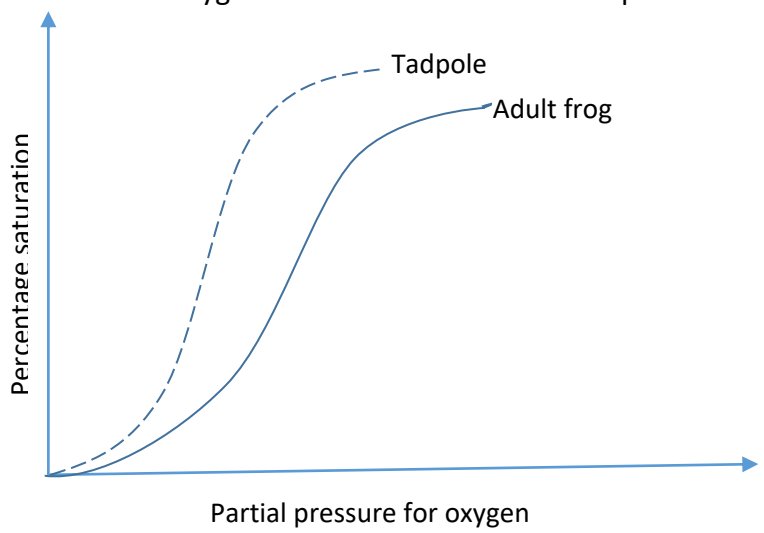


Fig. 7

(a) Explain the relative position of the curve for the tadpole blood and that of an adult frog.

The tadpole curve is to the left adult frog curve. This means that Tadpole blood has higher affinity for oxygen than that of adult frog because the tadpole lives entirely in water with less oxygen concentration compared to adult frog that breathes air with more stable oxygen supply

(b) What advantage is the position of the dissociation curve for the tadpole in its environment

It allows the tadpole to survive in water with low oxygen tension

(c) How is the skin of an adult frog adapted for gaseous exchange?

- The skin of the frog is moist. Respiratory gases can easily dissolve in the moisture, so enhancing their diffusion across the skin.
- The skin of the frog is thin. This reduces the distance across which the gases have to diffuse during gaseous exchange.
- It is supplied by a dense network of blood capillaries. This maintains a steep diffusion gradient across the skin and encourages exchange of the gases.

46. (a) Give the meaning of each of the following:

(i) Chloride shift

Chloride shift is the movement of chloride ions into red blood cells as bicarbonate ions leave during carbon dioxide transport from the tissue by the blood. It helps to restore electro-neutrality within the red blood cells in tissue capillaries when bicarbonates ions diffuse into plasma.

(ii) Bohr effect.

Bohr effects is a rightward and downward shift of the haemoglobin oxygen dissociation curve that as a result of increased carbon dioxide partial pressure or decrease in blood pH. It has the effect of reducing the affinity of haemoglobin for oxygen

(b) Explain the effect of each of the following on the oxygen dissociation curve of haemoglobin in mammals

(i) Increase in environmental temperature

Increase in environment temperature causes a right and down shift of the oxygen dissociation curve. This is because the bond between oxygen and haemoglobin is thermo-labile and therefore weakens with increase in temperature. Therefore, the haemoglobin becomes less efficient at picking up oxygen but more efficient at releasing it.

(ii) High the carbon dioxide levels in body tissues.

High carbon dioxide levels in the tissues cause a shift of the oxygen dissociating curve to the right.

This is because carbon dioxide reacts with water to form carbonic acid which dissociate of liberate hydrogen ions into plasma. The hydrogen ions stabilize deoxybaemoglobin and therefore encourage the conversion of oxyhaemoglobin to deoxyhaemoglobin, so reducing haemoglobin affinity for oxygen.

(c) Explain the physiological advantage of a high concentration of myoglobin in skeletal muscles

Myoglobin has a higher affinity for oxygen compared to haemoglobin. It holds onto its oxygen and only release it when the oxygen partial pressures have become very low. As a result, it acts as an oxygen store, releasing its oxygen to the issue when oxyhaemoglobin becomes depleted (as during exercise)

47. (a) Explain the following

(i) Breathing in pure oxygen at higher pressures than atmospheric pressure is dangerous

The tissue metabolizes rapidly at first to keep with the oxygen supply. As oxygen builds up, it becomes toxic respiratory enzymes and central nervous system causing death.

(ii) Breathing in air rich in carbon dioxide is dangerous.

It increases the acidity of the blood and tissue fluids, inhibiting enzymes and stopping essential metabolic processes.

It also reduces the affinity of haemoglobin for oxygen so that little oxygen is delivered to the tissue from the lungs

Accumulation of carbon dioxide also interferes with respiration at the cellular level by inhibiting respiratory enzymes.

This may eventually cause tissue death as a result of lack of enough oxygen

(b). Outline three adaptations of animals that live in environments of low oxygen tension

- Increased affinity of their haemoglobin for oxygen.
- Increased haemoglobin concentration in their blood.
- Increased number of red blood cells in their blood.

  Other
- Increased force and rate of heart contraction.
- Increased rate of breathing.

48. Figure 3 shows diagrams of two types of blood circulatory system A and B in animals. The arrows show the direction of blood flow.

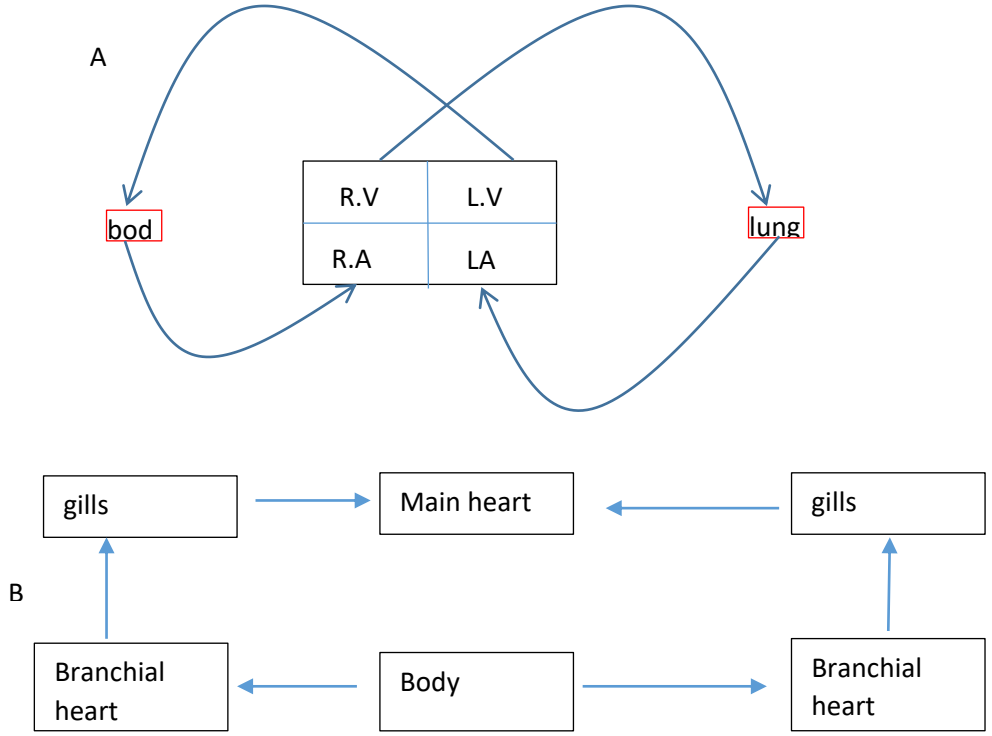


Fig.3

(a) Describe each circulatory system

(i) A

Blood flows from the right atrium into right ventricle, from where it is pumped to the lung. From the lungs, blood flows to the left atrium and then into the left ventricle, from where it is pumped to the rest of the body. From the body, blood returns to the heart through the right atrium. The cycle repeats

(ii) B

From the heart, blood is pumped into the body, from where it flows to the branchial hearts on either side. The branchial hearts pump blood to the gills from where it returns to the main heart and the cycle repeats.

(b) How does each system maintain a high blood pressure?

(i) A

In this double circulation system, the contraction of the heart muscles pumps the blood first to the lungs and then to the rest of the body in each circuit of the circulation. This ensures that pressure is restored in the blood after leaving the capillaries. Blood to the lungs is pumped at a lower pressure because of the shorter distance compared to that of the body

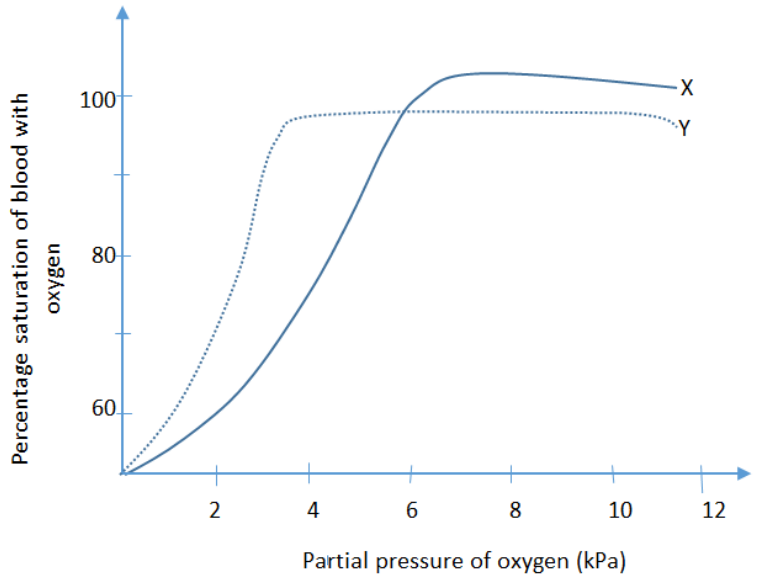
(ii) B

The main heart's contraction generates sufficient pressure to push the blood through the vessels in the body. The branchial hearts then maintain the pressure of the blood by continuing to pump the blood into the gills and back to the main heart.

(c) What is the advantage of maintaining a high blood pressure over a fluctuating pressure in a circulatory system of an animal?

High blood pressure helps to propel blood at a high speed along the arteries to the body tissue. This facilitates faster delivery of oxygen and nutrients to the body tissues and removal of waste products from the body.

49. Figure 2 show oxygen dissociation curves for haemoglobin of two animals, X and Y, living in different habitats.



(a) From the figure, state three differences in the behavior of haemoglobin of the two animals.

(2marks)

X	**y**
Has a lower affinity for oxygen. Has a lower rate of oxygen saturation Releases oxygen slowly at lower oxygen partial pressures	Has a higher affinity for oxygen Has a higher rate of oxygen saturation Releases oxygen rapidly at lower oxygen partial pressures.

Other:

X	**y**
Becomes fully saturated only at oxygen partial pressures greater than 8kpa Has a higher full saturation capacity (above 80%)	Becomes fully saturated only at oxygen partial pressures greater than 5kpa Has a lower full saturation capacity (about 80%)

(b) (i) Outline the characteristics of the haemoglobin of animals **y**. (3marks)

- Has a higher oxygen affinity
- Has a high rate of oxygen uptake at lower oxygen partial pressures

Others:

- Becomes fully saturated at lower oxygen partial pressures (≤ 4kpa)
- Has a high saturation capacity (over 80%)

(ii).From characteristics in (b) (i) suggest the nature of the habitat in which animal **y** lives

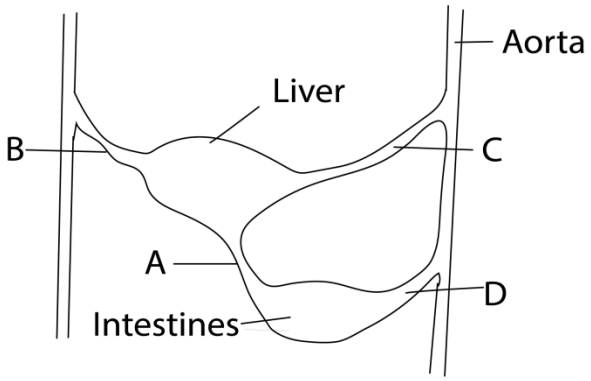
(01mark)

Animal **y** lives in a habitat with low oxygen partial pressures such as at high altitude or mud

(c). Human haemoglobin has a higher affinity for carbon monoxide than oxygen. What is the effect of the fact? (03marks

In the haemoglobin molecule,, carbon monoxide readily replaces oxygen. It binds irreversibly with haemoglobin molecules and thus reduces oxygen carriage of the blood. As a result, the body tissues are deprived of oxygen leading to tissue death.

50. The figure below is a diagram showing part of mammalian circulation system



(a) Name the blood vessels labeled A, B, C and D.(02 marks)
A: Hepatic portal vein

B. Hepatic vein

C: Heopatic vein

D: mesenteric artery

(b) Using arrows, show on the diagram the direction of blood flow in blood vessels labeled A and B.

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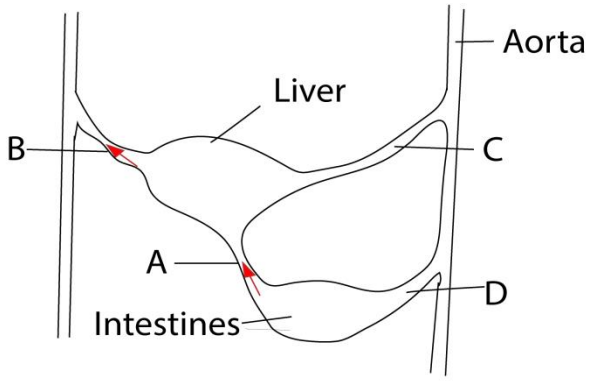


(c) State three differences in composition of blood flowing in A and B. (03marks)
A contains high concentration of food nutrients than B

A contains less waste products than in B
A contains more oxygen than in B

(d) Explain the changes in composition of glucose in A and B (02mark)
Liver removes excess glucose from A and converts it to glycogen or fats

(e) How is blood vessel A structurally adapted to perform its function?(02marks)
Wide to reduce resistance to blood flow

51. The table below shows the composition of blood of three adult individuals. One lives at high altitude, another is anaemic and the other has an infection. It also shows the average number of each blood component in an adult human. Study the information in the table and answer the questions that fallow.

Components of blood	Person A	Person B	Person C	Average number in adult human
Red blood cells per mm^3	7,500,000	5,000,000	2,000,000	5,000,000
White blood cells per mm^3	6,000	8,000	12,000	5,000 – 10,000
Blood platelets cells per mm^3	250,000	255,000	100,000	250,000

(a) Giving a reason, suggest the person
(i) Who lives at high altitude (03marks)
A has high number of red blood cells
(ii) Who is anemic (03marks)
C has low read blood cells than normal
(iii) Who has infection (03marks)
C has big number of white blood cells

(b) Suggest a likely effect of observed number of blood platelets in person C (02marks)
Formation of clot,

52. (a) List the substances transported by the blood circulatory system (04marks)

(b) give the importance of transporting each of the substances named in (a) above. (11marks)

Substance Transported	Importance / Function
Oxygen (O_2)	Essential for **cellular respiration** (metabolism), the process that produces energy (ATP) for all bodily activities.
Carbon Dioxide (CO_2)	A waste product of cellular respiration; it must be removed from tissues and transported to the lungs for **exhalation** to prevent toxic buildup and maintain blood pH .
Nutrients	Absorbed from the digestive system (e.g., glucose, amino acids, fatty acids, vitamins, minerals); they provide the **building blocks** and **energy** required for cell growth, repair, and metabolism.
Hormones	Chemical messengers produced by endocrine glands; they coordinate and **regulate diverse body functions**, such as growth, metabolism, reproduction, and stress responses, by acting on target organs.
Waste Products	Metabolic wastes (e.g., urea, creatinine, excess water, salts) produced by cells are transported to the **kidneys** for excretion as urine, preventing toxic accumulation in the body.
Heat	Blood helps in **thermoregulation** (maintaining a stable body temperature) by transferring heat from actively respiring tissues to the skin's surface, where it can be dissipated.
Immune Cells and Antibodies	White blood cells (leukocytes) and antibodies (immunoglobulins) are transported to sites of infection or injury to provide **defense against pathogens** and facilitate healing.
Water	The main component of blood plasma; it acts as a **solvent** for all transported substances and is crucial for maintaining blood volume, pressure, and hydration of tissues.

53. (a) What is an artery? (1mark)

An artery is a type of blood vessel that carries oxygenated blood **away** from the heart to the rest of the body's tissues and organs.

(b) State three differences between artery and vein. (3marks)

Feature	Artery	Vein
Direction of Blood Flow	Carries blood **away** from the heart.	Carries blood **toward** the heart.
Oxygen Content	Generally carries **oxygenated** blood (except pulmonary artery).	Generally carries **deoxygenated** blood (except pulmonary vein).
Blood Pressure	High pressure; blood flows in pulses.	Low pressure; blood flows smoothly and continuously.
Wall Thickness	Walls are **thicker**, more muscular, and more elastic.	Walls are **thinner**, less muscular, and less elastic.
Valves	**No valves** (except semilunar valves at the heart's exit).	**Have valves** (especially in limbs) to prevent backflow.

Lumen Size	Has a smaller internal diameter (lumen).	Has a larger internal diameter (lumen).

(c) State how arteries and veins are suited for their function

(i) artery (03marks)

- Thick muscles to withstand pressure
- Elastic wall to withstand pressure surge
- Narrow lumen to maintain high pressure
- Smooth endothelium to reduce friction on blood
- Located deep in the body for protection

(ii) veins (03marks)

- Valves prevent blood from flowing backwards
- Thin wall to reduce resistance blood flow
- Large lumen to reduce resistance to blood flow

Revision question about defense against disease

1. Which one of the following couple is likely to produce a fetus suffering from fatal erythroblastosis?
   A. Rh^+ mother and Rh^- father
   B. Rh^- mother and Rh^- father
   C. Rh^+ mother and Rh^+ father
   D. Rh^- mother and Rh^+ father D
   * This happens when an Rh-negative mother carries an Rh-positive fetus, which can occur if the father is Rh-positive. The mother's immune system may create antibodies against the Rh-positive red blood cells of the fetus, which can cross the placenta and destroy the fetal red blood cells, leading to severe anemia. This is particularly a risk in a second or subsequent pregnancy
2. When a fetus receives antibodies from the mother through the placenta, it acquires
   A. Active immunity
   B. Long-term immunity
   C. Passive immunity
   D. Artificial immunity C
3. Which one of the following is not the method by which antibodies attack antigen?
   A. Engulfing
   B. Agglutination
   C. Lysis
   D. Absorption on surface A
4. Which one of the following are target cells for the HIV (AIDS virus)?
   A. Erythrocytes
   B. Thrombocytes
   C. Lymphocytes
   D. Phagocytes C

*** Explanation**

- **HIV targets immune cells.** Human Immunodeficiency Virus (HIV) attacks the body's immune system, specifically white blood cells.

- **Lymphocytes are a type of white blood cell.** The primary targets of HIV are a specific type of lymphocyte called **CD4+ T helper cells**.

- **The virus uses CD4+ T cells to replicate.** HIV binds to the CD4 molecule on the surface of these cells and uses them to multiply, ultimately destroying them and weakening the immune system.

5. Which of the following statement about immunity is incorrect?
   A. Heat killed bacteria become antibodies when injected into an animal.
   B. Antibodies are special proteins
   C. Antibodies are produced against specific antigen
   D. Antigens can be molecules on foreign microbe A
6. The biochemical property of blood essential for its protective function of the body is the

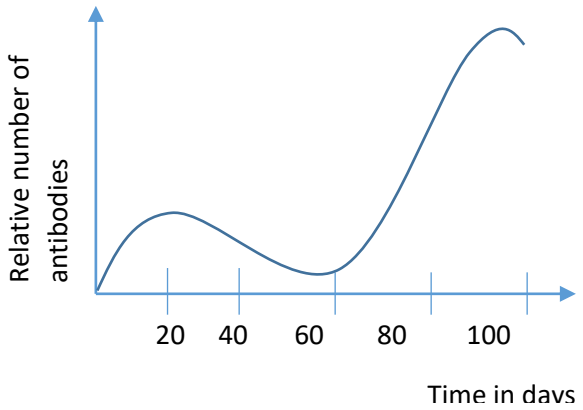
   A. ability to clot.

   B. possession of antibodies.

   C. presence of hemoglobin.

   D. possession of white blood cells. B

7. The figure below shows the immune response of a person's blood after vaccinations are given on day one and 60days later.



   (a) What is the effect of giving immunization to an individual? (1Mark)

   Immunization provides an individual with immunity (resistance) to a specific infectious disease

   (b) From the graph, state the type of immunity acquired by the individual, giving a reason. (2marks)

   Active immunity because it was able to recognize and respond rapidly to reintroduced pathogen after 60 days .

   (c) Explain the shape of the graph (04marks)

Vaccination triggered an immune response without causing illness and the body produced memory cells to remember how to fight the real pathogen later

When the body was exposed to the real pathogen 60 days later, the memory cells and antibodies quickly mounted a defense, to prevent the illness.

(d) Describe three ways in which antibodies combat antigens (3marks)

(vi) **Neutralization**: Antibodies bind directly to a pathogen or toxin, blocking it from interacting with host cells or neutralizing its harmful effects. For example, they can block viral proteins needed to enter a cell, rendering the virus unable to infect.

(vii) **Opsonization**: Antibodies act as "tags" or "handles" on the surface of pathogens. This coating, or opsonization, makes it easier for phagocytic cells like macrophages and neutrophils to recognize, bind to, and engulf the pathogen for destruction.

(viii) **Complement Activation**: When antibodies bind to a pathogen, they can trigger the complement system. This is a cascade of proteins that can lead to the lysis (bursting) of the microbial cell or further attract immune cells to the site of infection.

(ix) **Agglutination**: Antibodies link multiple pathogens together, forming large clumps that are easier for phagocytes to clear from the body.

(x) **Precipitation**: Antibodies cause soluble antigens to clump together and fall out of solution, making them easier targets for phagocytosis.

Thank you

Dr. Bbosa Science