Dr. Bbosa Science

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Transport in animals

Transport is the movement of materials from one part of the organism to another. Transport involves diffusion, and active transport in simple and small animal and at cellular level.

Big animals require a mass flow circulatory system to deliver food materials and other essentials and remove waste products from the cell. This is because big animals have small surface area to volume ratio that they cannot meet their transport requirement by diffusion.

Advantages for circulatory systems in big animals

1. Supplies metabolites and removes waste products from the cells at a faster rate than diffusion would do.
2. It enables separation of materials transported; e.g. oxygenated blood is transported different vessels from those that transport deoxygenated blood.
3. Impermeability of external surface to remove water. Example of thick cuticle of insects.
4. Avoids utilization of materials along the way.

Development of transport system in Animals

In the course of evolution, advanced organism attained a more advanced transport system than primitive one. This can be shown in the following examples:

1. Protozoans: transport their materials by cytoplasmic streaming. Simple diffusion across membrane surface, facilitated diffusion and active transport as well as pinocytosis and phagocytosis.
2. Cnidarians: transport by movement of body wall to create water current in their body cavity, which circulate food, water and dissolved gases.
3. Platyhelminthes: have very thin flattened shape enabling materials to be exchanged between the organism and the environment by diffusion.
4. Annelids have a coelom separating body wall from internal organs (gut) so needs a system between the two regions to enable food, gases and waste products to be transported between the regions. Earthworm has a closed blood circulatory system with pigmented blood.
5. Arthropods: have a hard exoskeleton so cannot depend on simple diffusion for the transport of materials between its tissues and the environment. They use a tracheal

system to transport oxygen and carbon dioxide and have a haemocoel containing a colorless blood in which organs are suspended. Thus, the body organs are in direct contact with blood. The blood does not transport oxygen and therefore does not contain haemoglobin.

6. Vertebrates: circulatory system has muscular heat to pump blood through blood vessels throughout the body.

Features of circulatory systems

1. Transport medium or blood to carry dissolved materials such as food oxygen and carbon dioxide.

2. Vessels to carry the medium to all parts of the body

3. A pump to propel the medium in the vessel

4. One- way values to keep the medium flowing in one direction

5. A close association between the tissue and medium so that the cell can obtain the required substances from the medium and deliver their waste products to it.

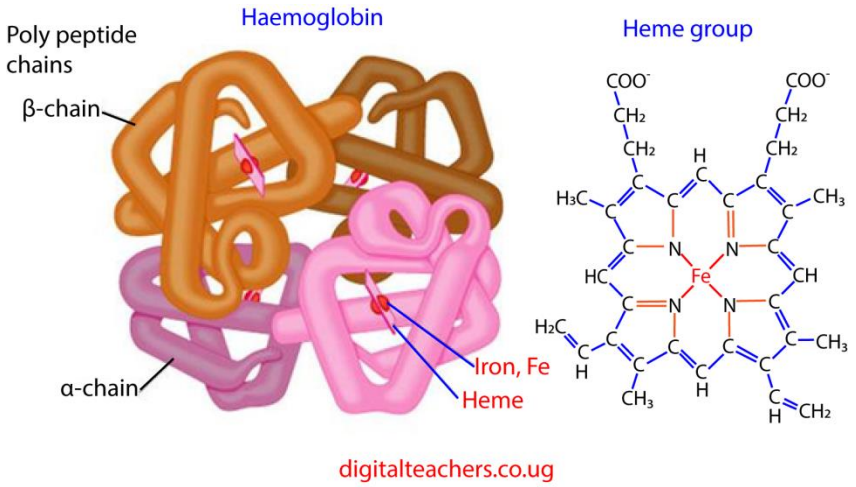
A. Transport medium

A few animals have a type of blood, which is more or less like seawater. One of the substances to be transported is oxygen. To increase oxygen carrying capacity of water most active animals have pigments in their blood. In most species, the pigment is contained in special cell but in some species is free in the fluid part of blood the plasma.
Each pigment consists of a prosthetic group and a protein.

Comparison of oxygen carrying pigments

Pigment	Metal in prosthetic group	Color of pigment	Example of animals	
Hemoglobin	Iron	red	vertebrate	Plasma or cells
Hemocyanin	Copper	blue	arthropods	plasma
Chlorocruorin	iron	green	annelid	plasma
Hemerythrin	iron	violet-pink	sipunculids, priapulids, brachiopods	Cells or plasma

Structure of hemoglobin



Structure of haemoglobin

(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 residue 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. Buffering action:
Hemoglobin also acts as a buffer. 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. Interaction with drugs: For not only oxygen, but also hemoglobin act a very important role the transport of various drugs to their site of action.

The blood

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

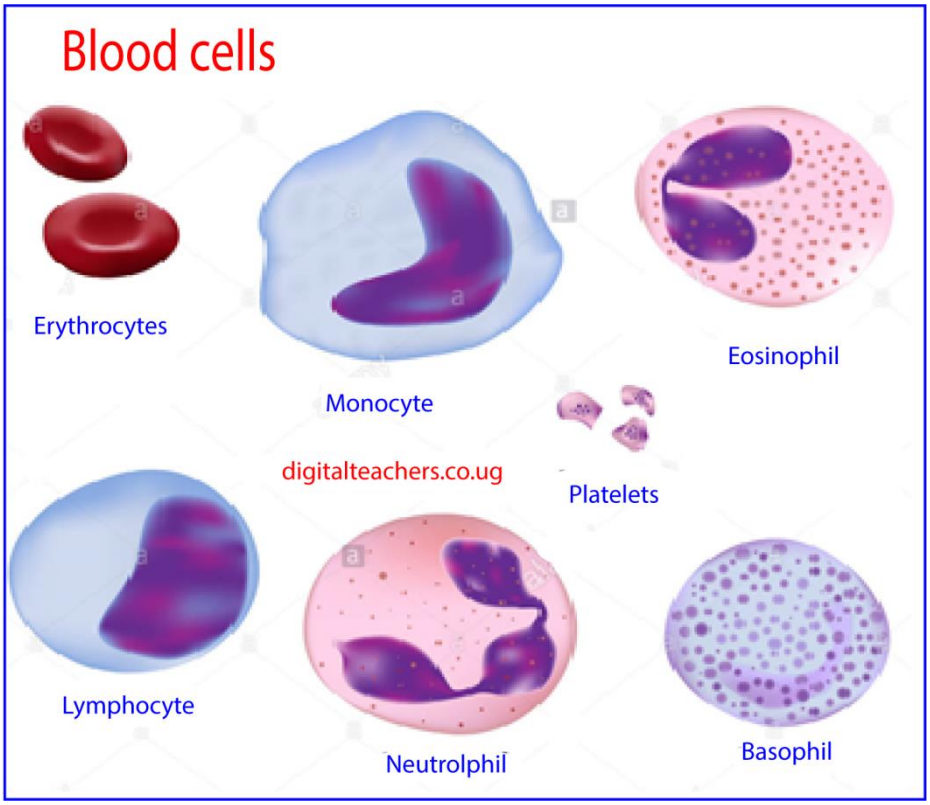
Functions of mammalian blood

1. Transport of soluble organic compounds from the small intestine to various parts of the body.
2. Transport of soluble excretory matters to organs of excretion.
3. Transport of hormones from glands where they are formed to target organs.
4. Distribution of heat in order to maintain the body temperature
5. Defense against diseases, which may be obtained through blood clotting, phagocytosis and immunity.
6. Maintenance of a right blood solute potential as a result of plasma proteins activity.
7. 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



(a) **Erythrocytes:** Produced in the liver in infants, embryo and cartilaginous organisms or in bone marrow in those organisms that have bones. Their function is to carry oxygen.

Adaptations of red blood cells to its function

1. They have a biconcave disc shape to increase the surface area for absorption of oxygen.
2. They lack a nucleus, which permits haemoglobin to be packed into the cell.
3. They are small therefore able to squeeze between capillaries
4. They have a thin membrane permitting efficient diffusion of gases (short distance for diffusion)
5. They contain haemoglobin, which has a high affinity for oxygen.
6. They do not carry out any metabolism so they do not utilize the oxygen being transported.

Carriage of oxygen

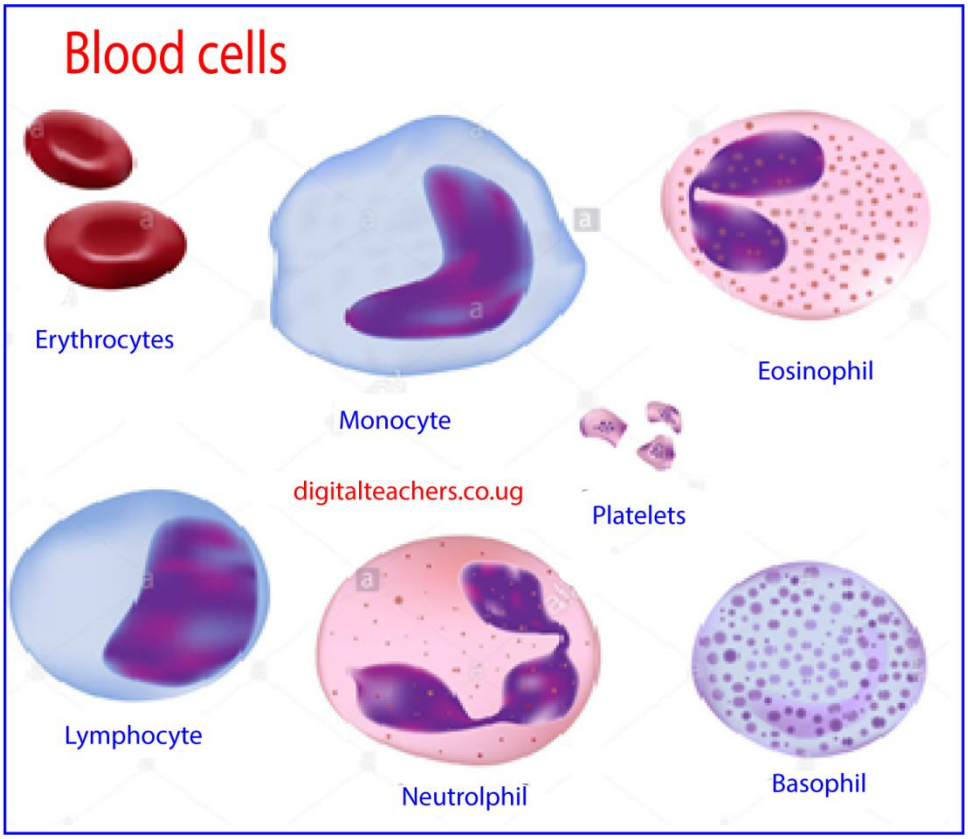
Oxygen diffuses into the red blood cells across its plasma membrane and combines with the haemoglobin to for oxyhemoglobin. The attachment of oxygen does not involve chemical oxidation of iron which remains in Iron (II) state throughout the process. The union is a loose one, the oxygen molecule being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

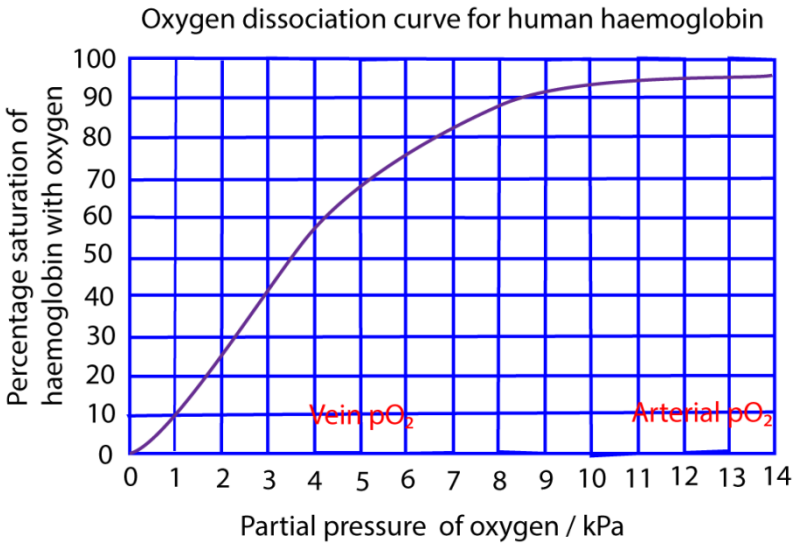
Efficiency of haemoglobin as oxygen carrier
When one of the four polypeptide chains in haemoglobin molecule receives oxygen molecule in the lungs its structure is altered in such a way that the remaining three polypeptide chains accept oxygen readily. In the tissue the reverse occur: one of the polypeptide 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.

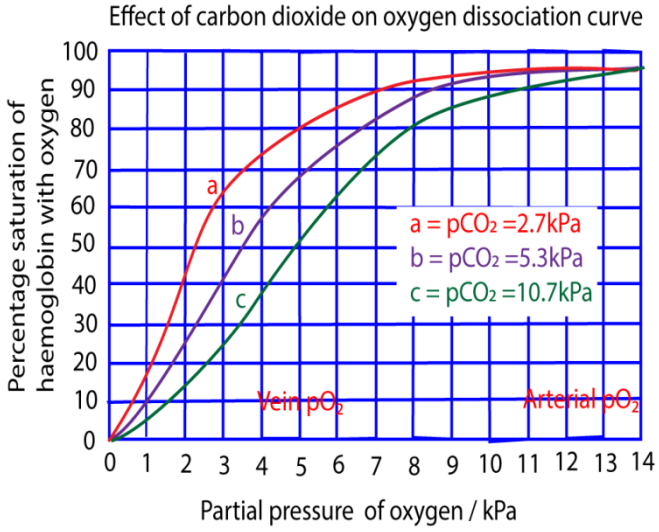
A plot of percentage saturation of haemoglobin with oxygen against partial pressure of oxygen gives an oxygen dissociation curve below





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 offload of oxygen the tissue.



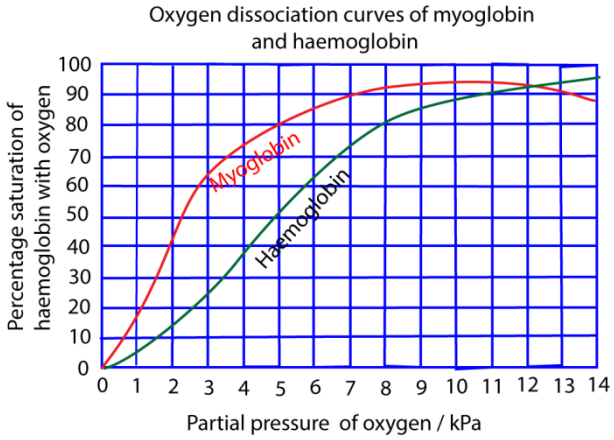
The graph above shows that a high concentration of carbon dioxide shifts the curve to the right. i.e. it lowers the affinity of haemoglobin for oxygen. The release of oxygen is therefore favored in the tissue where the partial pressure of carbon dioxide tends naturally to be high as result of its continual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

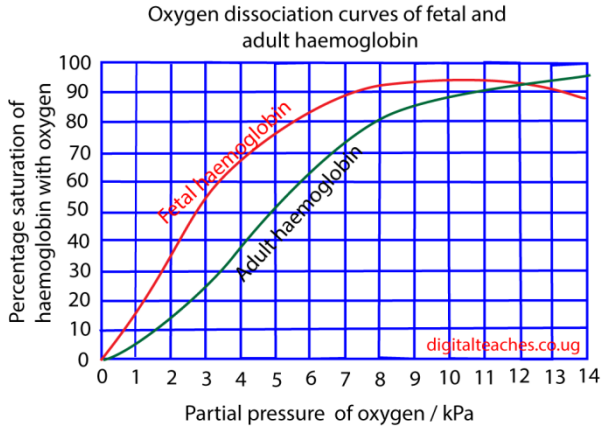
This favors the unloading of hemoglobin hence reducing its affinity for oxygen.



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 from hemoglobin and stores oxygen 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 then 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.

Effect of carbon monoxide on oxygen carriage of hemoglobin

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

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 dissociate into hydrogen ions. Hydrogen ions combine with haemoglobin to form haemoglobinic acid while HCO_3^- diffuses into blood.
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.

(b) White blood cells

These are produced in the bone marrow and are of various types:

a. Granulocyte; these constitutes 72% of the total leucocytes. They have an irregular lobed nucleus and a cytoplasm containing granules. The granulocytes are divide in 3 types.

(i) The granules of *neutrophils* remain unstained when a dye, eosin is applied to them.
(ii) *Eosinophils*: stain red with the eosin dye. They are one of the immune system components responsible for combating multicellular parasites and certain infections in vertebrates. They possess anti- histamine properties, which help to reverse allergic conditions. E.g. asthma or hay fever
Bosophils. These stain blue with eosin dye. The cells produce heparin an anticlotting hormone and histamine in inflammation.

b. Agranulocytes;
These have a rounded or bean shaped nucleus. Their cytoplasm has no granules They include lymphocytes and monocytes.

(i) Lymphocytes
These have a rounded nucleus with no cytoplasmic granules. They originate from the lymph nodes and cause antibody production and immediate immune reactions such as willing of tumors, grafts etc.

(ii) Monocytes
These are formed in the bone marrow and have a bean shaped nucleus. They are phagocytes and ingest bacteria

c. **Platelets;** are produced in bone marrow and initiate blood clotting.
These are irregularly shaped membrane bound cell fragments frequently nucleated and made from the bone marrow. They are used in blood clotting.

B. Vascular systems in Animals

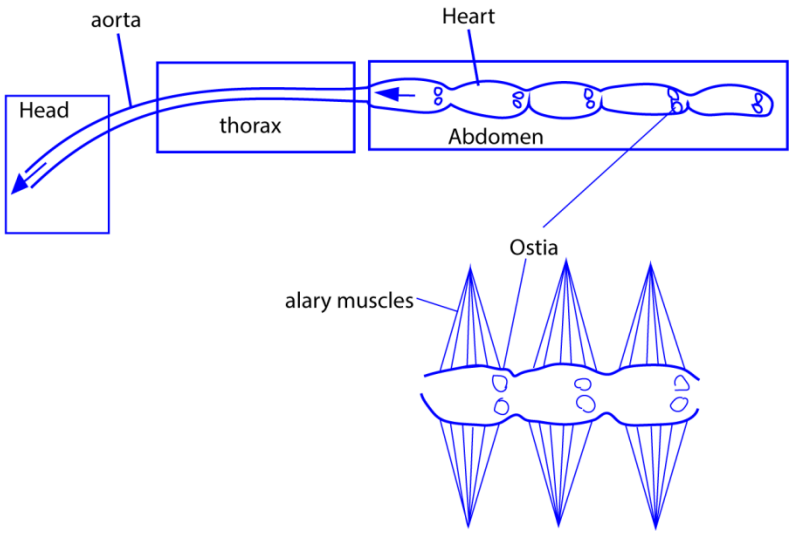
There two types of vascular systems: **open** and **closed vascular systems.**

(a) The **open vascular system:** (most arthropods, some cephalad molluscs, tunicates). Blood is pumped by heart into an aorta which branches into a number of arteries. These open into a series of blood spaces collectively called **haemocoel.** Here cells are in contact with the blood and materials are exchanged by direct diffusion through the plasma membrane.

Blood under low pressure blood moves slowly between tissues gradually percolating back into the heart via open-ended veins. Distribution of blood in tissue is poorly controlled. This limits the efficiency of the open system.

Fortunately, gaseous exchange in insects takes place through the tracheal system. The insect circulatory system is not therefore concerned with transporting oxygen and carbon dioxide. Accordingly, it lack an oxygen carrying pigment. However, it plays an important role in distributing food substance and eliminating nitrogenous waste.

Circulatory system of an insect



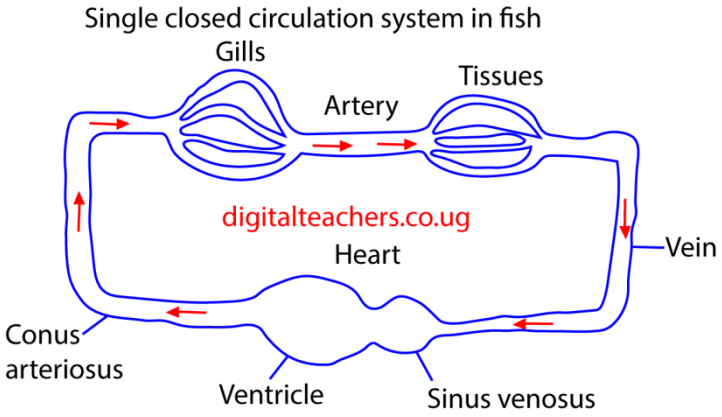
(b) **The closed vascular system:** (echinoderm, cephalo, molluscs, annelids, vertebrate). Here blood is confined in a series of specific vessels and not permitted to touch the body tissues. In animals with a closed system the heart more muscular heart and blood is pumped by the heart rapidly around the body under sustained high pressure and back to the heart. Material exchange occurs across the wall of **blood capillaries**, which ramify through the organs and come into close association will all cells. Animals with closed systems are generally larger and often more active.

The disadvantage of closed circulatory system is that the blood is contained in vessels whose walls form a barrier between the blood and the surrounding tissues. Oxygen and other materials have to cross this barrier. However, capillaries having very thin walls reduce this barrier.

(i) Single closed circulatory system

Here blood possesses through the heart once in every circuit of blood.

In fish, for example, blood is pumped from the heart to the gills. After acquiring oxygen from the gills, blood flows to the body tissues and then back to the heart.



The problem with this arrangement is that blood has to pass through two capillary systems, the capillaries of the gills and then those of the body, before returning to the heart. Capillaries offer considerable resistance to the flow of blood, and this means that in fishes there is marked drop in blood pressure before the blood completes a circuit. For this reason the blood flow from tissues to the heart is sluggish. This is overcome to some extent by the fact that fishes have large **sinuses,** which offer minimum resistance to blood flow, in places of veins. Nevertheless, the problem of getting blood back to the heart is an acute one and probably imposes severe limitation on the activities of many species of fish.

(ii) Double Circulation

In double circulation blood passes through the heart twice in every complete circuit.

Advantage

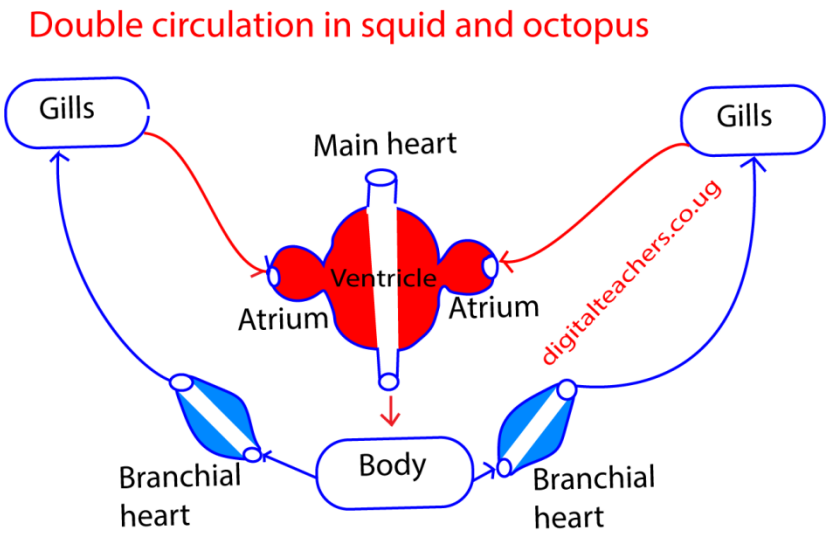
- Blood is pumped to the lungs at a much lower pressure than that at which it is pumped to the rest of the body. In human the pressure in the pulmonary artery is about one - sixth of that in aorta.
- Deoxygenated blood is separated from oxygenated blood and then pumped at different pressure to the lung and the body respectively.

(iii) Incomplete double circulation

A frogs heart has two atria and one ventricles, however, blood mixing in the ventricle is prevented by the **spiral valve** in the **conus arteriosus** a heart chamber immediately before blood is pumped into big arteries.

(iv) Separate hearts

The squids and octopuses solved the pressure problem by having two having two hearts: blood is pumped from the main heart to various parts of the body. It the flows through a system of sinuses to a pair of branchial hearts which pump it to the gills.

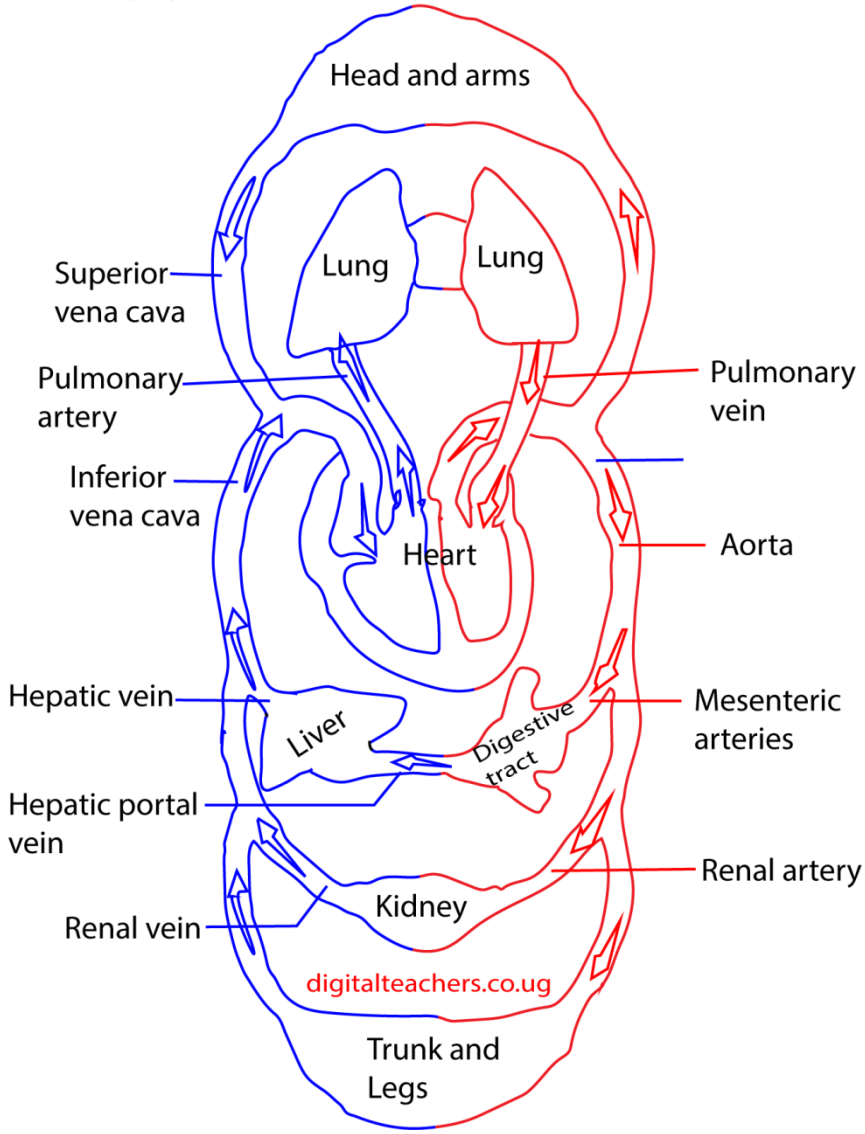


The Human circulatory

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 cell

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

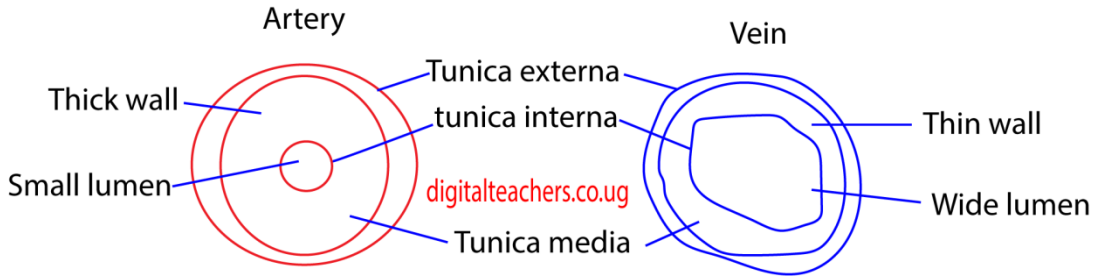
Circulatory system in man



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

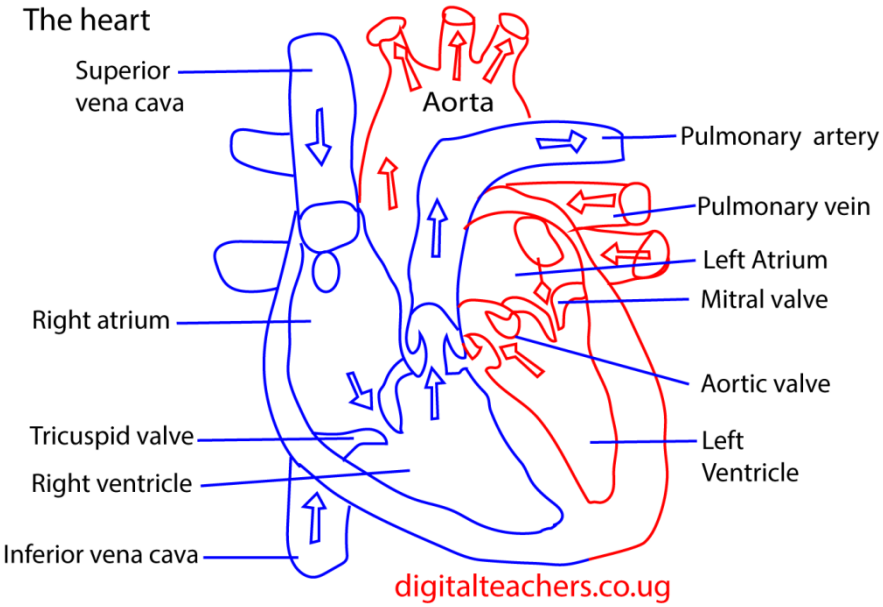


Adaptation of the artery
-thick wall to accommodate high pressure

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

Capillaries
Is where exchange believe blood and cell takes place

Adaptation of capillaries
-thin walls for fast diffusion



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

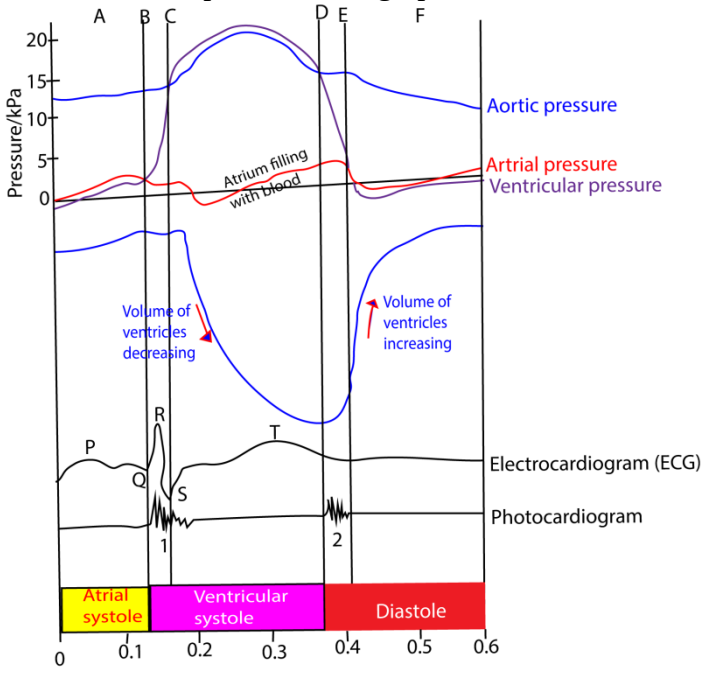
Once in the pulmonary artery, blood is prevented from flowing back into the ventricle by pocket like **semilunar** valves guarding the opening of pulmonary artery.

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**.

A graph illustrating the pressure and volume changes that occur during mammalian cardiac cycle (dog). Pressure changes were measured in the left atrium and ventricle. Pressure changes were measured in the left atrium and 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 actions at different points on the graph as follows:



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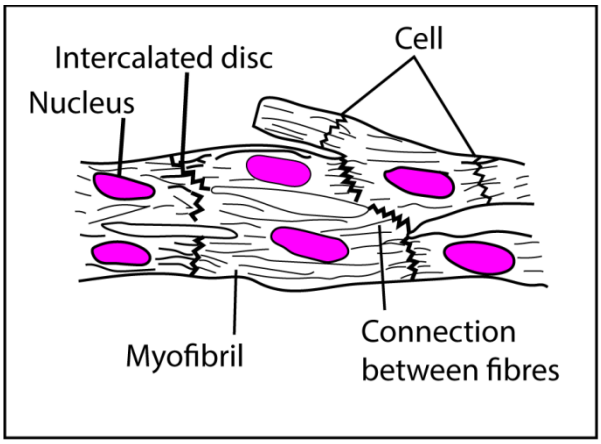
A Atrium start to contract: blood flows into ventricle
B Ventricle starts to contract: ventricular pressure exceeds atrial pressure so atrioventricular volume close
C: Ventricular pressure exceeds aortic pressure, forcing aortic valve opens: blood therefore flows from ventricular volume falls.
D: Ventricular pressure below aortic pressure resulting in closure in closure of aortic valve.
E: Ventricular pressure falls below arterial pressure so blood flows from atrium to ventricle: ventricular volume rises 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 ability to contract rhythmically without fatigue. It owes this property to it's muscle known a cardiac muscle. The muscle consists of a network of interconnect muscle fibres.



The fibres are divided up into uninucleated cells containing fine contracting myofibrils. The **interconnections between the fibres ensure a rapid and uniform spread of excitation** throughout the wall of the heart which in turn ensure a uniform combination.

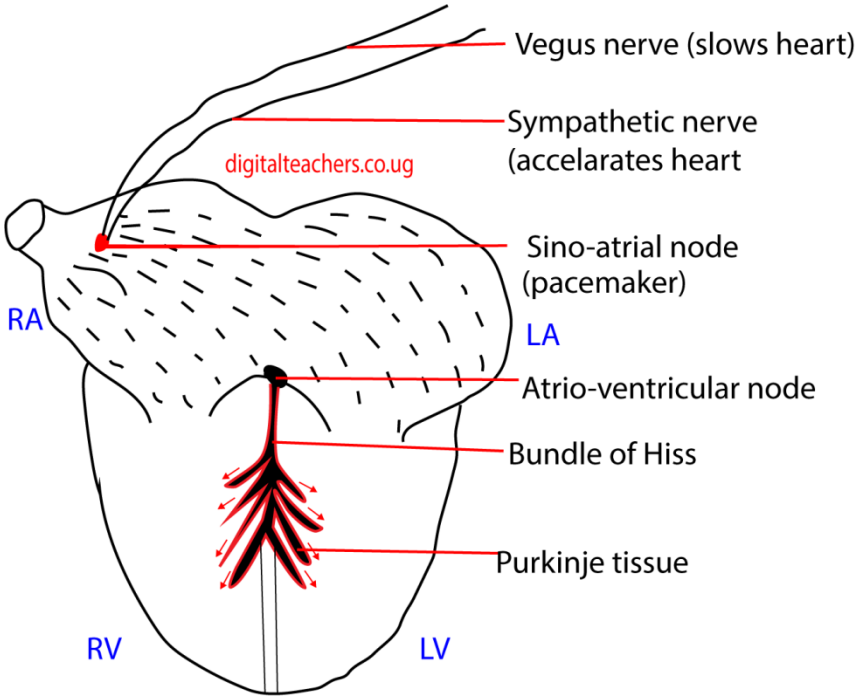
Beating of the heart.

Cardiac muscle in myogenic, then it's rhythmical attraction arise from within the muscle tissue itself. The heart rhythm is initiated by specialized plexus (network) of the fine cardiac muscle fibre embedded in the wall of the right atrium close to where the venae cava enter it called sino atrial (SAN) or the pacemaker. The contraction of the heart is preceded by a wave of electrical excitation from SAN and then spreads over the heart atria. When the wave reaches the function between the atria and ventricle it excites another specialized group of cardiac muscle fibres called the atrioventricular node (AVN) continuous with the AVN is a strand of modified cardiac muscle fibre called the bundle of Hiss. This runs down the interventricular septum and fans out over the walls of the ventricles 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 His to purkinje tissue. The impulses then spread out to the cardiac muscle tissue in the walls of the ventricle, making it to contract.

AVN series to delay electrical impulses from the atria to the ventricle to all the atria to contract before the ventricle. The purkinje tissue allow slow uniform spreading of the excitation to the ventricle after the attraction of the atria. Ventricle view of the heart showing the spread of electrical excitation that causes contraction

Ventral view of heart showing the spread of electrical beating of the heart initiated by the pacemaker, the nerve s merely serving the speed up or slow down the rate.



NB. The Purkinje tissue transmits impulses relatively slowly so as to ensure that the ventricles contract after the atria.

Control of the circulation

The cardio vascular centre in the medulla of the brain controls the rate of the heartbeat. Depending on circumstance, the cardiovascular centre sends impulses down the sympathetic nerve to the heart, increasing its rate of beating, as down the Vagus nerve decreasing the rate of heartbeat.

Exercise

1. The mountain gorilla lives at high altitudes and has its oxygen dissociation curve located at the left of many animals. This suggests that
   A. there is low carbon dioxide tension at high altitudes.
   B. its hemoglobin has a higher affinity for oxygen than many animals.
   C. temperatures are lower at high altitudes.
   D. it has a high concentration of myoglobin in its muscles.

2. Which of the following is the role of capillary network around alveoli in mammals>
   A. make alveoli more permeable
   B. Increases surface area for alveoli
   C. maintains steep diffusion gradient
   D. Makes alveoli thiner

3. Which of the following substances is not transported by blood circulatory system in arthropod.
   A. nutrients
   B. respiratory gases
   C. hormones
   D. nitrogenous wastes
4. Which of the following features does not contribute to the efficiency of a red blood cell?
   A. biconcave shape
   B. Being filled with hemoglobin
   C. being numerous
   D. absence of nucleus

5. 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 blood

6. Which one of the following is responsible for increasing the pressure of blood following in veins, back to the heart?
   A. The pumping of the heart
   B. Contraction of skeletal muscles
   C. Closing of valves
   D. Inspiratory movement of muscles

7. 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.

8. Loss of water from the body in human body can result into
   A. Lowering temperature
   B. Slowing down the rate of breathing
   C. Lowering of blood pressure
   D. Slowing down of heart beat

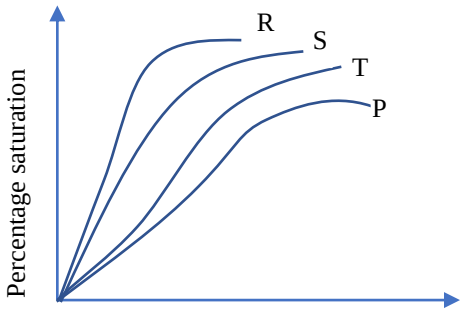
9. The oxygen dissociation curves for aquatic animals are usually to the left of those of terrestrial animals because

   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

10. Which of the following is the correct order of events in the heart after the contraction of the atria?
   A. Atrio-ventricular valves open, ventricle contract, semilunar valve close
   B. Ventricles contract, atrio-ventricular valves close, semilunar valve open
   C. Ventricles contract, atrio-ventricular valves open, semilunar values open
   D. Atrio-ventricular valve open, semilunar valves open, ventricles contract

11. High concentration of carbon dioxide in the tissues lead to
   A. Increase in affinity for oxygen by hemoglobin
   B. Increased in the loading tension of hemoglobin
   C. Shifting of the dissociation curve to the left
   D. Lowering of the affinity for oxygen by hemoglobin

12. The figure shows the oxygen dissociation curve for mudfish, human fetus, and adult human and active flying bird.



Which curve lying bird?
   A. R
   B. S
   C. T
   D. P

13. 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 the tissue, enter
   B. Chloride ions leave the erythrocytes as hydrogen carbonate ions from the tissue, enter
   C. Chloride ions enter the lungs as hydrogen carbonate ions enter the erythrocytes
   D. Hydrogen carbonate ions enter the lungs as the chloride ions leave the erythrocytes.

14. Oxygen from myoglobin is released after oxyhemoglobin 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 hemoglobin

15. The correct order of transmission of electrical impulses to initiate the heart beat is
   A. Sino-atrio node → atria → atrio-ventricular node → purkinje tissue → ventricles →
   B. Sino-atrio node → Ventricle → atrio-ventricular node → purkinje tissue → ventricles → atria →
   C. Atrio-ventricular node → atria → Sino-atrio-node → purkinje tissue → ventricles →

D. Atrio-ventricular node → purkinje tissue → ventricles → Atria → Sino-atrio node

16. 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 pericardial pressure

17. The lung fish living in mud has its oxygen dissociation curve to the left of that of human because
    A. There is high level of carbon dioxide concentration in the mud
    B. The lung fish's hemoglobin has a higher affinity for oxygen than that of humans
    C. Of the lower temperature of the lung fish
    D. Of lower level of oxygen concentration in the mud

18. Which one of the following when at high levels in the blood, increase the rate of heart beat?
    A. Carbon dioxide
    B. Thyroxine
    C. Oxygen
    D. Adrenaline

19. Which of the following ions move from plasma into red blood cells to maintain electroneutrality during the uptake of carbon dioxide by the blood in the tissue?
    A. Cl^- B. CO_3^{2-} C. K^+ D. HCO_3^-

20. High carbon dioxide concentration in the respiring tissues is important because it causes
    A. Local vasodilation, allowing more blood into the tissues
    B. Low pH in the tissue leading to unloading of oxygen.
    C. Local vasodilatation creating high blood pressure
    D. Increase heart bean

21. Mixing of oxygenated and deoxygenated blood in amphibians is minimized by
    A. Rapid contraction of the ventricles
    B. Spongy nature of the heart muscles
    C. Spiral valve in truncus arteriosus
    D. Columnae carnae in the ventricular walls

22. An athletic competition organized on high lands required participant from lowlands to report three months before the competition in order to enable them
    A. Get familiar with the place
    B. Develop strong muscle
    C. Acquire high red blood cell count
    D. Have extensive deposition of fat their skins

23. The lack of a nucleus in the red blood cell enables it to
    A. Have high affinity for oxygen
    B. Have more permeable to oxygen
    C. Give up oxygen more readily
    D. Contain more hemoglobin

24. Myoglobin is more abundant in active muscles because it
    A. easily gives up its oxygen to the muscles
    B. gives the color of the muscle
    C. slowly releases oxygen to the muscles
    D. has low affinity for oxygen

25. Which of the following is true about the blood circulatory system in amphibian?
    A. Double with partially divided heart
    B. Single with undivided heart

C. Double with completely divided heart
D. Partially double with completely divided heart

26. Which of the following substances are **not** transported in the mammalian blood?
    A. Urea and glucose
    B. Insulin and pepsin
    C. ATP and pepsin
    D. Carbon dioxide and sodium chloride

27. The main problem of a single circulation is the
    A. Slow speed of blood to the tissues
    B. Mixing of oxygenated and deoxygenated blood
    C. Low rate of oxygenation of blood
    D. Slow speed of blood to the heart

28. Which of the following does not involve mass flow?
    A. Blood flow in the arteries
    B. Uptake of food by the tapeworm
    C. Movement of food and water in the gut
    D. Transport of water and mineral salts by the xylem

29. Which one of the following in **not** true about both the blood circulatory and lymphatic system in mammals? The fluid contains
    A. Excretory product
    B. Leucocytes
    C. Plasma proteins
    D. Dissolved food

30. Which one of the following features of red blood cells does not contribute to their high absorptive nature of oxygen? They
    A. Possess thin flexible membrane
    B. Possess a biconcave disc shape
    C. Are filled with hemoglobin
    D. Are manufactured at a high rate
31. Which one of the following structures is responsible for initiating the contraction of the heart?
    A. Purkinje tissue
    B. Atrio-ventricular node
    C. Sino atrial node
    D. Heart muscles
32. Which one of the following is the correct route taken by blood on leaving the heart, in a single circulatory system?
    A. Gills → body → heart
    B. Body → gills → heart
    C. Gills → heart → body
    D. Body → heart → gills

33. The spiral valve in the conus arteriosus of an amphibian is to
    A. Allow one directional flow of blood
    B. Increase the pressure of blood
    C. Reduce resistance to blood flow
    D. Separate oxygenated and deoxygenated blood
34. Which one of the following animals has a double circulatory system?
    A. Fish
    B. Octopus
    C. Frog
    D. Squid

35. Which of the following pigments contain copper?
    A. Hemocyanin
    B. Myoglobin
    C. Hemerythrin
    D. hemoglobin

36. In a single circulatory system, the route taken by blood on leaving the heart is
    A. gills → body → heart
    B. body → gills → heart
    C. gills → heart → body
    D. body → heart → gills

37. Which one of the following substances is not transported in the blood?
    A. Urea and glucose
    B. Insulin and adrenaline
    C. ATP and pepsin
    D. Carbon dioxide and sodium chloride

38. The ability of the heart to contract without fatigue is owed to the
    A. Sino ventricular node
    B. Cardiac muscle
    C. Sinoatrial node
    D. Purkinje tissue

39. Which blood vessel are able to change their resistance to blood flow, regulating distribution of blood flow to organs?
    A. Veins
    B. Arteries
    C. Arterioles
    D. capillaries

40. Which organ in the body contains cardiac muscle?
    A. Gizzard
    B. Diaphragm
    C. Esophagus
    D. heart

41. The artery is adapted to withstand high pressure resulting from the pumping of the heart by having a
    A. Superficial location on the body to allow distension
    B. Thin elastic wall that extends with increased pressure
    C. Thick tough wall to withstand the pressure
    D. System of valves that prevent back flow of blood.

42. Which one of the pairs of animals listed below possess an incomplete double circulation system?
    A. Rat and frog
    B. Cow and baboon
    C. Frog and lizard
    D. Snake and dolphin

43. 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.

44. Loss of water from the blood in human body can result into is the

A. Lowering of body temperature.
B. Slowing down the rate of breathing.
C. Lowering of the blood pressure.
D. Slowing down of the heartbeat.

45. 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.

46. Which one of the following is the correct order of vents 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

47. Which of the following animal groups body segments and closed circulatory tern?

A. Crustacea.

B. Platyhelminthes.

C. Annelida.

D. Insect.

48. (a) Give the meaning of each of the following
(i) Chloride shift (2marks)

(ii) Bohr effect (2marks)
(a) Explain the effect of each of the following on the oxygen dissociation curve of hemoglobin in animals.
(i) Increasing environmental temperatures (02marks)
(ii) High carbon dioxide levels in body tissues (02 marks)
(b) Explain the physiological advantage of a high concentration of myoglobin in skeletal muscles. (2marks)

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

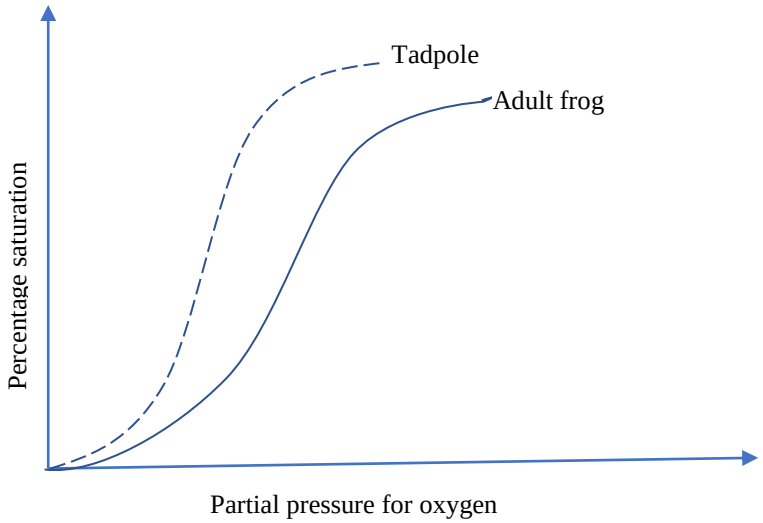


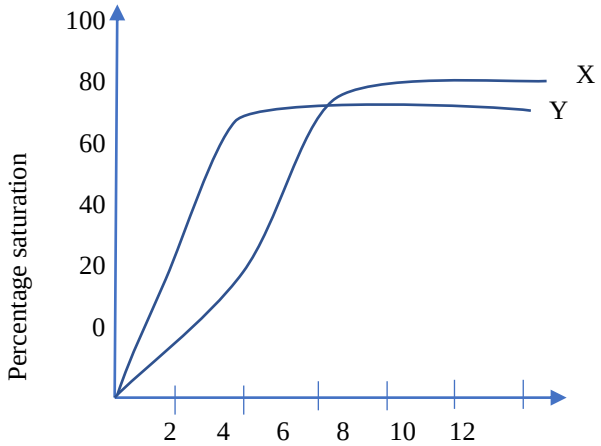
Fig. 7

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

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

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

50. The figure shows oxygen dissociation curves of hemoglobin of two animals A and Y in different habitats.



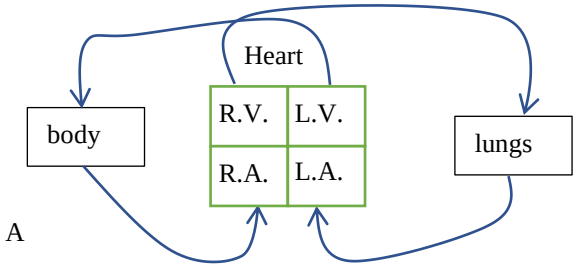
(a) From th avior of haemoglobin os hemoglobin of the two animals

(b) (i) outline the characteristic of hemoglobin of animal Y (3marks)

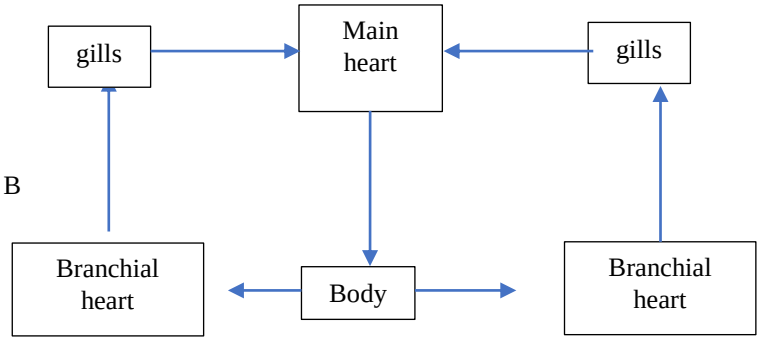
(ii) From the characteristics in (b) (i) suggest the nature of the habitat in which animal y lives (1mark)

(c) Human hemoglobin has higher affinity for carbon monoxide then oxygen. What is the effect of this fact? (03marks)

51. Thef figure shows diagrams of two types of circulatory sysems A and B, in animals. The arrows show the direction of the blod flow



A



B

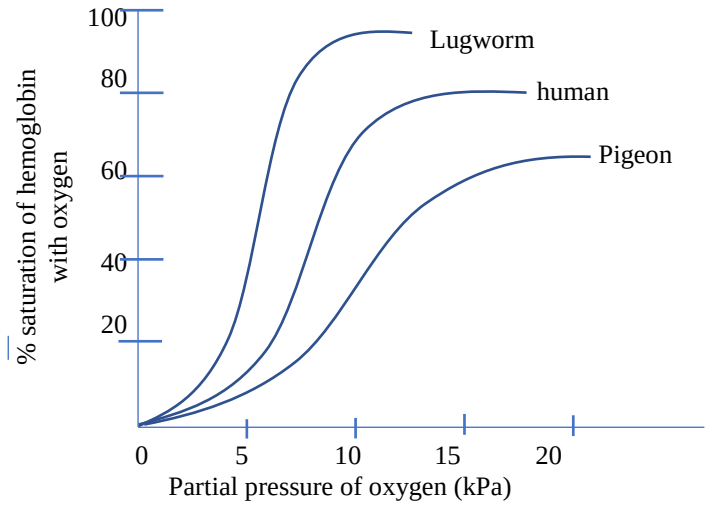
(a) Describe each circulatory system
(i) A (02 marks)
(ii) B (02maks)

(b) How does each maintain high blood pressur?

(i) A (02 marks)
(ii) B (02maks)

(c) What is the advantage of maontaining a high blood pressure in a circulatory sysytem of an animal (2marks)

52. The figure showsthe oxygen dissociation curves at 2.7kPa of carbon dioxide, in three organisms: pegeon, human and lugworm that lives in muddy, water logged burrows.



(a) Explain the position of the curve for the lugworm and pegeon in reference to that for human
(i) Lugmorm (3marks)
(ii) Pigeon
(b) (i) on the same graph sketch oxygen dissociation curves for the lugworm and human if both organism were subjected to the same higher carbon dioxide tension. (2marks)
(ii) Explain the position of each of the curves you have sketched in (b)(i) (2marks)

53. How is each of the following suited for itsnfunctions
(a) A red blood cell (4marks)
(b) A xylem vessel (6marks)

54. (a) What is a closed circulatory system?
(b) How is blood flow maintained in such a sysytem?
(c) How is blood pressure controlled in the closed system?

55. (a) What are eassential featires of the mammalian blood vascualr sysytem?
(b) Describe the role of blood vascular sysytem of mammal in each of the following process.
(i) Immunity
(ii) Excretion
(iii) Hurmonal control
(c) Comment on the absence of blood vescular system in animals such as protozoa and coelenterates.

Assay questions

56. (a) (i) Describe the structure of the hemoglobin molecule.

(ii) Explain why the affinity of hemoglobin for oxygen increases when it already possesses oxygen.

(b) Describe how the pH of blood and tissue fluids in mammals is maintained.

57. (a) Describe the adaptations of blood in terrestrial animals living in the following environmental conditions
(i) Extreme oxygen tensions (08 marks)
(ii) High altitudes (04 marks)

(b) Explain how each of the following affects the dissociation of hemoglobin in the mammalian blood, suggesting in each case, the physiological advantage of the effect.

(i) Increased body temperature (04 marks)

(ii) Small body size (04 marks)

Suggested answers

1	B	6	B	11	D	16	B	21	C	26	C	31	C	36	A	41	C	46	B
2	C	7	B	12	D	17	B	22	C	27	A	32	A	37	C	42	C	47	C
3	B	8	B	13	A	18	A	23	D	28	B	33	D	38	C	43	B		
4	C	9	A	14	A	19	A	24	C	29	C	34	B	39	C	44	C		
5	B	10	B	15	A	20	B	25	A	30	D	35	A	40	D	45	A		

48. Give the meaning of each of the following:
(i) Chloride shift

(ii) Bohr effect.

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

(i) Increase in environmental temperature

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

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

Solution

(a) (i) 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 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) (i) Increase in environment temperature causes a right 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 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 o xyhaemoglobin to deoxyhaemoglobin, so reducing haemoglobin affinity for oxygen.

(c) 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)

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

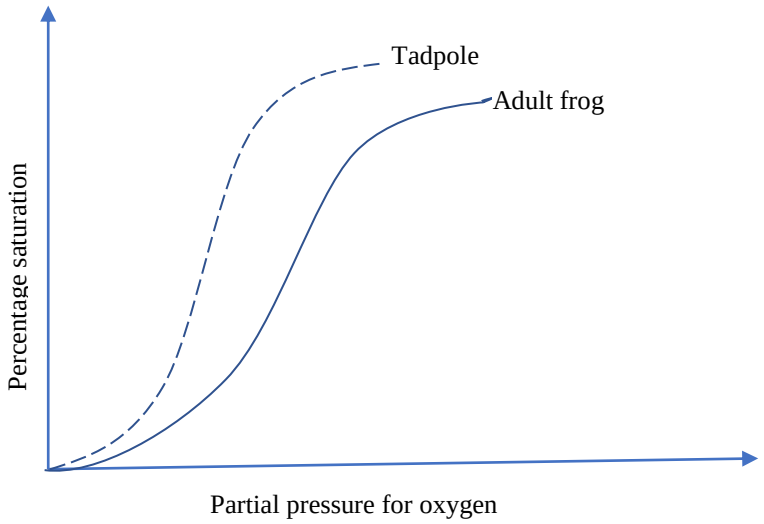


Fig. 7

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

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

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

Solution

(a) 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

This is because affinity allows its haemoglobin to get saturated at low oxygen tension.

(b) Tadpole haemoglobin becomes fully saturated at low environmental partial pressure of oxygen. This allows it to thrive in the low oxygen tension environment.

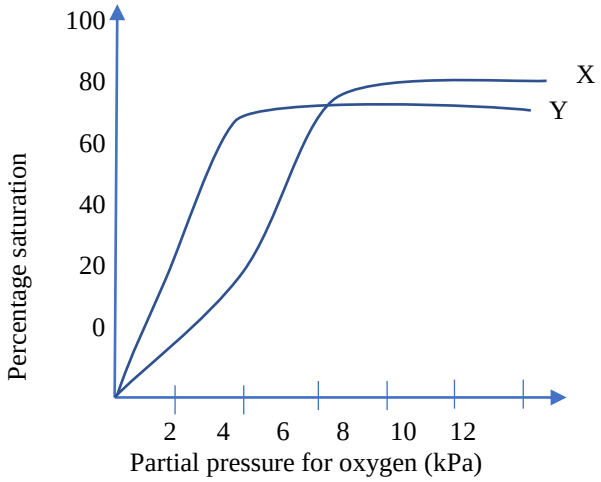
Tadpole blood releases oxygen quickly to the tissue that are at very low oxygen.

(c) 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.

50. The figure shows oxygen dissociation curves of hemoglobin of two animals A and Y in different habitats.



(a) From the figure, state three differences in the behavior of haemoglobin os

hemoglobin of the two animals (03marks)

(b) (i) outline the characteristic of hemoglobin of animal Y (3marks)

(ii) From the characteristics in (b) (i) suggest the nature of the habitat in which animal y lives (1mark)

(c) Human hemoglobin has higher affinity for carbon monoxide then oxygen. What is the effect of this fact? (03marks)

(a)

X	**y**
Has a lower affinity for oxygen. Has a lower rate of oxygen saturation Releases oxygen slowly at lower oxygen partial pressures Becomes fully saturated only at oxygen partial pressures greater than 8kpa Has a higher full saturation capacity (above 80%)	Has a higher affinity for oxygen Has a higher rate of oxygen saturation Releases oxygen rapidly at lower oxygen partial pressures. Becomes fully saturated only at oxygen partial pressures greater than 5kpa Has a lower full saturation capacity (about 80%)

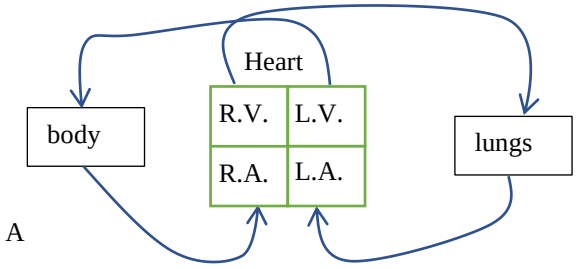
(b) (i) Has a higher oxygen affinity

- Has a high rate of oxygen at lower oxygen partial pressures
- Becomes fully saturated at lower oxygen partial pressures ($\geq$ 5kpa)
- Has a high saturation capacity (over 80%)

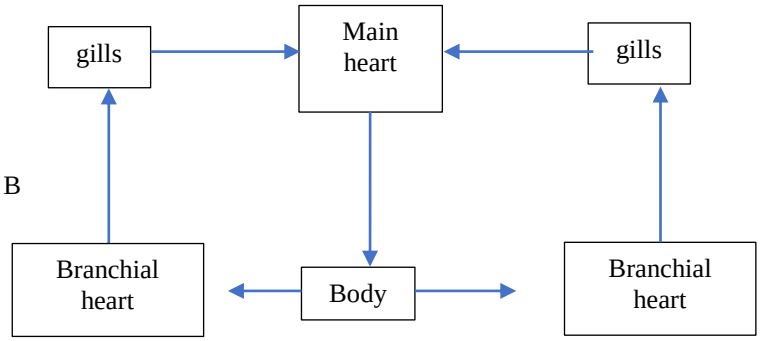
(ii). Animal **y** live in a habitat with low oxygen partial pressures such as at high altitude.

(c) 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.

51. Thef figure shows diagrams of two types of circulatory sysems A and B, in animals. The arrows show the direction of the blod flow



A



B

(a) Describe each circulatory system
(iii) A (02 marks)
(iv) B (02maks)

(b) How does each maintain high blood pressur?

(iii) A (02 marks)
(iv) B (02maks)

(c) What is the advantage of maontaining a high blood pressure in a circulatory sysytem of an animal (2marks)

Solution

(a) (i) A

- Blood flows from the right atrium into right ventricle, from where it is pumped to the lungs
- It then 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) (i) A

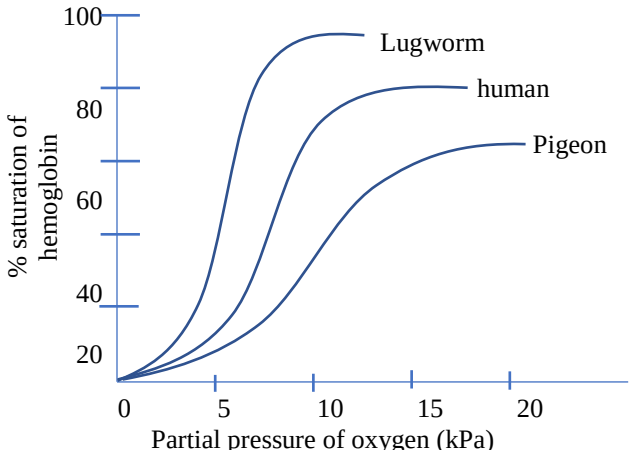
- In this double circulation system, the contraction of the heart muscles pumps the blood first to the lungs and then to the rest of the body in each circuit of the circulation. This ensures that pressure is restored in the blood after leaving the capillaries. Left ventricle has thick muscles that pumps blood to the body with higher pressure than it is pumped to the lungs.

(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) – 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.

52. The figure showsthe oxygen dissociation curves at 2.7kPa of carbon dioxide, in three organisms: pegeon, human and lugworm that lives in muddy, water logged burrows.



(a) Explain the position of the curve for the lugworm and pegeon in reference to that for human

(i) Lugworm (3marks)

(ii) Pigeon

(b) (i) on the same graph sketch oxygen dissociation curves for the lugworm and human if both organism were subjected to the same higher carbon dioxide tension. (2marks)

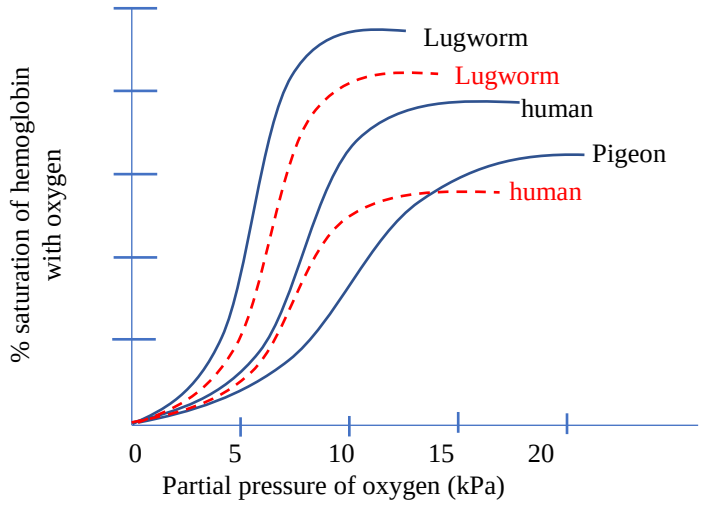
(ii) Explain the position of each of the curves you have sketched in (b)(i) (2marks)

Solution

(a)(i) the oxygen dissociation curve of lungworm is at the left of that of man because the haemoglobin of a lungworm has higher affinity for oxygen than human haemoglobin. This is because lungworms live in area of low oxygen tension. Thus, lungworm haemoglobin is adapted to pick oxygen at low oxygen tension.

(ii) the oxygen dissociation curve of pigeon is at the right of that of man because the haemoglobin of a pigeon has lower affinity for oxygen than human haemoglobin. The pigeon requires high amount of oxygen due to its high metabolic rate resulting from flight; this is availed by haemoglobin of low oxygen affinity.

(b)(i)



(b)(ii) Both curve shift to the right because the affinity of hemoglobin for oxygen lowers with increase in carbon dioxide concentration. The oxygen dissociation curve for human haemoglobin shift more because it is more sensitive to carbon dioxide.

53. How is each of the following suited for itsnfunctions

(a) A red blood cell (4marks)

(b) A xylem vessel (6marks)

Solution

(a) Adaptation of red blood cells to their functions

(i) The biconcave shape increases surface area for absorption of oxygen

(ii) Lack of nucleus increase space for carriage of haemoglobin

(iii) Having haemoglobin helps it to carry oxygen

(iv) Thin membrane reduces diffusion distance

(v) Presence of carbonic anhydrase helps to carry carbon dioxide

(b) Adaptation of xylem
(i) Lack of end walls reduces resistance to flow
(ii) Lignin makes cell walls impermeable to water that reduces water lower.
(iii) Spiral and annular thickening increases tensile strength that the vessel do not collapse under low pressure.
(iv) Presence of pits allows passage of water in and out of the lumen.
(v) Lignin strengthens vessels for support.

54. (a) What is a closed circulatory system?
(b) How is blood flow maintained in such a sysytem?
(c) How is blood pressure controlled in the closed system?

Solution
(a) A closed circulatory system is where blood is confined in blood vessels
(b) Blood flow is maintained by pumping of the heart at high blood pressure and one way valves in the blood vessels.
(c) High blood pressure is generated by the pumping of the heart

56. (a) What are eassential features of the mammalian blood vascualr sysytem?
(b) Describe the role of blood vascular sysytem of mammal in each of the following process.
(i) Immunity
(ii) Excretion
(iii) Hurmonal control
(c) Comment on the absence of blood vescular system in animals such as protozoa and coelenterates.

Solution
(a) Mammalian vascular system is a closed with the following feature
(i) Has blood to carry dissolved materials such as food oxygen and carbon dioxide.
(ii) Has heart to pump blood to the lungs and the body.
(iii) Arteries carry blood to the body while veins carry blood to the heart form the body.
(iv) Veins and some arteries contain one- way values to keep the blood flowing in one direction
(v) Contain blood capillaries that make a close association between the tissue and blood to allow exchange between blood and tissues
(b) (i) role of blood in immunity
- Contain antibodies that protect the body against invading microorganism
- Contain white blood cells that engulf and kill invading micro oeganism
- Contain protein responsible for blood clotting preventing entry of pathogenic organism

(ii) role of blood in excretion
- carry carbon dioxide to the lungs for elimination
- carry nitrogen wastes to the kidney for elimination.

(iii) Role of blood in hormonal control
Blood transports hormones from their source to target organisms.

(c) Protozoa and coelenterates are too small to carry blood vascular system. Secondary they have a big surface area to volume ratio that that sufficient for their exchange needs.

57. (a) (i) Describe the structure of the hemoglobin molecule.

(ii) Explain why the affinity of hemoglobin for oxygen increases when it already possesses oxygen.

(b) Describe how the pH of blood and tissue fluids in mammals is maintained.

Solution

(a) (i) a hemoglobin molecule has a quaternary structure of four polypeptide chains (2 alpha and 2 beta chains) each polypeptide chain is linked to a haem group. An iron atom in the ferrous form (Fe^{2+}) is located within each haem group.

(ii) Each haem group in the haemoglobin molecule can combine with one molecule of oxygen. When this happens a conformational change occurs that exposes the rest of the haem groups to bind with oxygen molecules.

(b) pH of blood and tissue fluids is maintained by mechanisms operating in the kidneys, lungs and the blood plasma, to regulate the H^+ ion concentration.

Role of the kidneys

- When the blood pH starts to lower, hydrogen ions are actively secreted into the lumen of the tubule and collecting ducts by an ATP-dependent Na^+/H^+ exchanger. The hydrogen ions an arise from dissolution of carbon dioxide in plasma or from metabolic wastes such as lactic acid.
- In the tubules, the H^+ ions are buffered by sodium hydrogen phosphate which takes up H^+ ions to form sodium dihydrogen phosphate. This reverse occurs when pH rises.
- When the acidity of renal fluid is exceptionally high, the cells of the distal convoluted tubules produce ammonia from glutamic amino acids.
- The ammonia then combines with the excess hydrogen ions to form ammonium ions which are excreted.

Role of the lungs/respiratory system

- An increase in blood carbon dioxide concentration (or low pH); stimulates the chemoreceptor cells in the carotid sinus and aortic bodies which send an impulses to the respiratory centre. An instruction is sent to the respiratory muscles to contract more rhythmically leading to an increase in rate and depth of breathing.

This rids the blood and body fluids of carbon dioxide and so restores the pH to normal. The reverse occurs when there is an increase in pH or reduction in carbon dioxide concentration.

Role of plasma proteins

- Plasma proteins usually act as buffers of blood pH. In acidic conditions, they bind the H^+ ions from the plasma while alkaline conditions, they release H^+ ions into the plasma to neutralize the excess hydroxyl ions. This maintains blood plasma pH.

58. (a) Describe the adaptations of blood in terrestrial animals living in the following environmental conditions
    (iii) Extreme oxygen tensions (08 marks)
    (iv) High altitudes (04 marks)

(b) Explain how each of the following affects the dissociation of hemoglobin in the mammalian blood, suggesting in each case, the physiological advantage of the effect.

(i) Increased body temperature (04 marks)

(ii) Small body size (04 marks)

Solution:

(a) (i) Eextremes of oxygen tension can the very high or very low values of oxygen partial pressure. In all these conditions, the blood of terrestrial animals must be adapted to deliver adequate oxygen efficiently to the tissues.

At high oxygen partial pressure,

- The hemoglobin concentration in blood is lower but adequate, since enough oxygen is always available to the mammal.
- The number of red blood cells is also lower.

At low oxygen tensions;

- The volume of blood is higher in order to increase the amount of oxygen carried to the tissues in a unit time.
- The hemoglobin concentration of blood increases. This increases the oxygen carrying of the blood.
- The number of red blood cells increases in order to increase the oxygen carrying capacity of blood.
- The hemoglobin/respiratory pigment has a high affinity for oxygen so as to pick up a lot of oxygen.

(v) At high altitude the oxygen tension is very low. Thus, the adaptations of blood are the same as those for the mammal at a low oxygen tension.

- The hemoglobin concentration of blood increases. This increases the oxygen carrying capacity of the blood.
- The number of red blood cells increases in order to increase the oxygen carrying capacity of the blood.
- The hemoglobin/respiratory pigment has a high affinity for oxygen so as to pick up a lot of oxygen.

(b) (I) increased body temperature shifts the oxygen dissociation curve to the right. This is because the bond hemoglobin and oxygen is thermal liable and breaks easily at high temperatures.

Physiological advantage.

At a higher temperature the metabolic rate is high and thus producing a lot of carbon dioxide is produce. Shift of the dissociation curve to the right makes hemoglobin to release oxygen to the tissue and easily pick up the carbon dioxide produced.

(ii) Small body size shifts the oxygen dissociation curve to the right

Physiological advantage.

Smaller organisms have a large surface area to volume ratio and thus are bound to lose more heat from the body surface. To counter this, they have a high metabolic rate which requires continuous supply of oxygen. The required oxygen is then readily supplied by the hemoglobin of higher affinity.