TRANSPORT IN ANIMALS

Animals have vascular systems for the transport of substances. Each vascular system is made up of three characteristic components;

a. **A contractile pumping organ.** It pumps a fluid around the body of the animal. This function is performed by the **heart**.
b. **Circulating fluid.** It delivers materials to the body parts, this fluid can be blood.
c. **Tubes.** These are where the circulating fluid flows and they are the blood vessels.

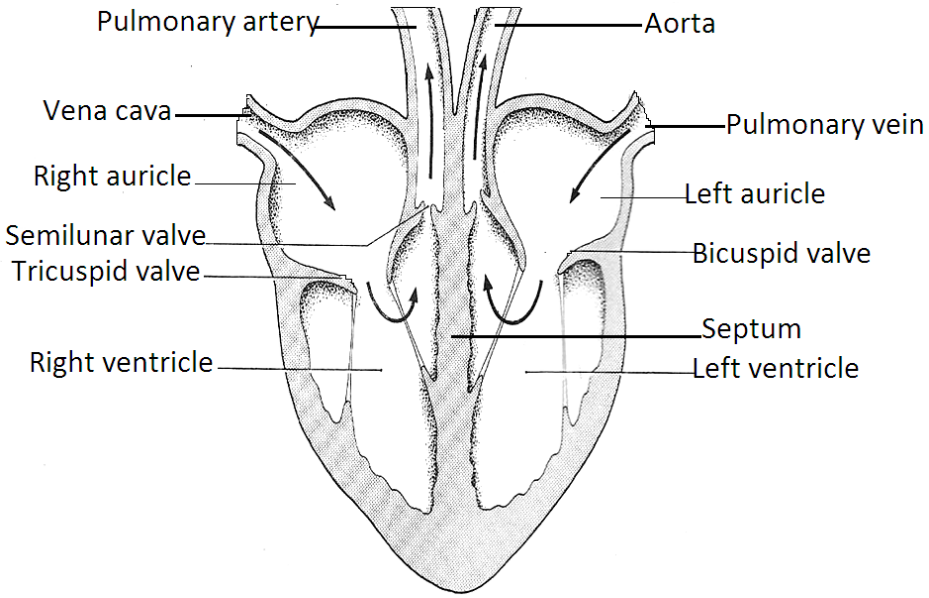
THE MAMALIAN HEART

The heart is a muscular organ located in the chest region. The heart is made up of a special type of muscle called the **cardiac muscle**, which contracts and relaxes throughout life without fatigue. It is covered by a **pericardium** membrane which maintains it shape. This membrane secretes the pericardial fluid which prevents friction during pumping.

STRUCTURE OF THE MAMMALIAN HEART

- The mammalian heart consists of **four chambers** with two chambers on each side of the heart i.e left and right hand side.
- The two sides of the heart are separated by a central wall called **septum.**
- On each side of the heart, there's an atrium (plural **atria**) or **auricle** which receives blood from the circulation and below each atrium is a thick walled **ventricle**.
- **Atrio-ventricular valves** exist between the atrium and ventricle on either side i.e tricuspid valve between right atrium and ventricle while bicuspid valve exists between left atrium and ventricle.
- Each heart chamber opens into a major blood vessel which connects with the general circulation. The atria are connected to the major veins i.e the vena cava and pulmonary artery which return blood to the right and left atrium respectively while the right and left ventricle open into the pulmonary artery and aorta respectively. These are the major arteries carrying blood away from the heart.
- **Semilunar valves** exist at the base of arteries leaving the heart.

DIAGRAM SHOWING LONGITUDINAL SECTION THROUGH THE MAMMALIAN HEART



Note;

a. The function of the ventricle is to pump blood out of the heart and due to do this; the ventricles have got thicker and more muscular walls than the atria.

b. There is a difference in the thickness of the muscles walls of the right and left ventricles because the right ventricle pumps blood to the lungs which are nearer to the heart whereas the left ventricle pumps blood to other parts which are far away from the heart.

c. Although the heart is filled with blood, it doesn't use the blood in its chambers to obtain oxygen and glucose for its cells in order to carry out respiration but instead the nutrients are supplied by the coronary artery, which is a branch from the aorta.

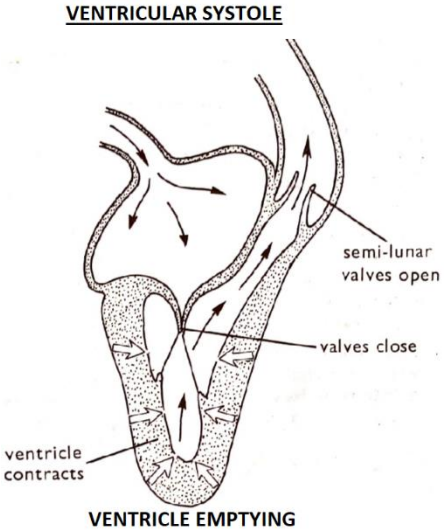
MECHANISM OF THE HEART BEAT

The pumping action of the heart consists of alternate contractions (called **systole**) and relaxations (called **diastole**). The cyclic series of events which occur during the pumping of the heart involving alternate contractions and relaxations is what is referred to as the **cardiac cycle**.

DESCRIPTION OF THE CARDIAC CYCLE.

Ventricular Systole

- The right and left ventricles contract pushing/squeezing blood into the pulmonary artery and aorta respectively.
- The tricuspid valve and bicuspid valve close due to pressure in the ventricles being higher than that in the atria.
- The semi-lunar valve and aortic valves open by the high pressure in the ventricles. Thus blood flows into the pulmonary artery and aorta from the right ventricle and left ventricle respectively.
- Meanwhile, the right atrium fills with blood due to low pressure in them as they are relaxed.

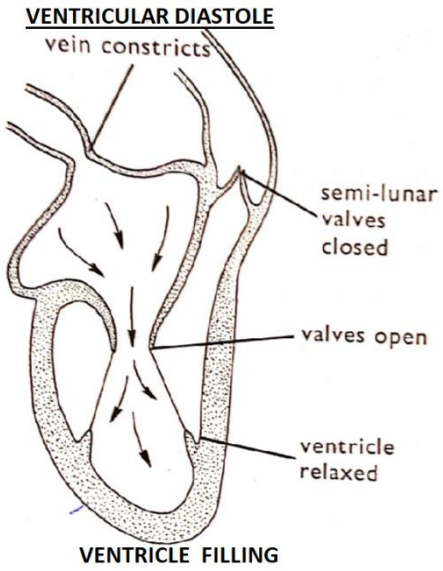


Atrial diastole

- After ventricular systole there is a short period of simultaneous atrial and ventricular relaxation (joint diastole).
- During atrio diastole; the right and left atria relax. Their volume increases and so, pressure falls.
- Blood flows into the right and left atria through the vena cava and pulmonary artery respectively

Ventricular diastole

- The right and left ventricles relax. Their volume increases and so, pressure falls.
- The ventricles relax as the atria contract.
- Pressure in the ventricles fall below atrial pressure.
- The tricuspid valve and bicuspid valve open due to the higher pressure in the atria.
- Blood then flows into the ventricles and thus ventricles fill with blood.
- Meanwhile, the semi-lunar valve and aortic valves close due to ventricular pressure being lower than the pressure in the pulmonary artery and/or in the aorta. This prevents the back flow of blood into the ventricles.



Note; Systole takes about 0.3 seconds and diastole takes 0.5 seconds. Therefore one complete heart beat takes about 0.8 seconds and one minute consists of 75 heart beats.

Factors that affect the heart beat

1. Exercise
2. Hormones
3. Body size
4. Temperature
5. Drugs and poisons
6. Age
7. Health.

EXERCISE:

- The heart beat is faster in a person involved in vigorous exercise compared to a person at rest because an exercising person has a high rate of respiration to produce the required energy. During aerobic respiration a lot of carbon dioxide is produced which increases the heart rate to increase blood flow carrying the carbon dioxide away from tissues and to supply the respiring cells with the require oxygen.

HORMONES:

- Hormones like Adrenalin are produced in situations of fright or fear and emotional distress which increase the rate of heart beat in preparation to the prevailing situation.

BODY SIZE

- The heart beat is faster in small organisms because they have a large surface area to volume ratio thus easily lose heat implying that they must develop a high metabolic rate to maintain their body temperatures and this in turn requires high levels of oxygen so a fast rate of blood flow is require to supply the required oxygen.

TEMPERATURE:

- The rate of heart beat of mammals increases in cold conditions in order to increase blood flow rate to supply enough oxygen required for an increased metabolic rate to produce heat to warm the body.

DRUGS AND POISON:

- Some drugs slow down the rate of heart beat e.g. depressants, anaesthetics, chloroform while other drugs accelerate the rate of heart beat e.g. cocaine.

AGE:

- The heart beat decreases with increase in age i.e it is faster in younger mammals because they are growing, very active hence have a high metabolic rate which requires a lot of oxygen which is supplied by blood pumped by the heart.

HEALTH:

- The heart beat is faster in a sick person compared to a normal person.

BLOOD VESSELS

These are hollow tubes which transport blood to and from the tissues.
There are three main types of blood vessels, arteries, veins and capillaries.

ARTERIES

These are blood vessels that transport blood away from the heart.

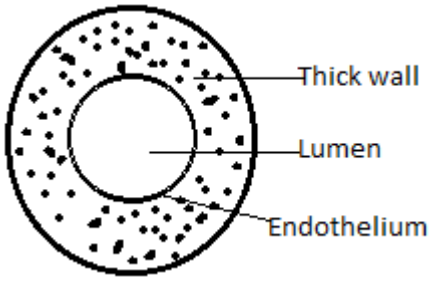
Characteristics

- They are thick walled
- The wall is elastic.
- They have a small lumen
- They carry blood which is under high pressure and this explains why their walls are thick and elastic.
- All arteries, with the exception of the pulmonary artery, carry oxygenated blood.

Adaptations of arteries to their function

i. They are thick walled to withstand the high pressure of blood in them
ii. They have elastic walls to allow stretching due to the high blood pressure
iii. They have a narrow lumen which maintains blood flow at high pressure

Diagram showing Cross-section of an artery



VEINS

These are blood vessels that transport blood towards the heart.

Characteristics

- The veins have a thin wall relative to their diameter. Their wall is less muscular and have less elastic tissue than arteries.
- They have a wide lumen
- The blood which flows in the vein is under low pressure
- The veins have valves which stop blood flowing backwards
- All veins carry deoxygenated blood except the pulmonary vein

Note: Valves are not needed in arteries because the force of the heart beat keeps blood flowing in the artery.

Adaptations of veins to their function

i. They have valves to prevent the flow back of blood
ii. They have relatively thin walls which can withstand the low blood pressure in them
iii. They have a wide lumen to encourage the flow of blood which is at a low pressure

Transverse section of a vein

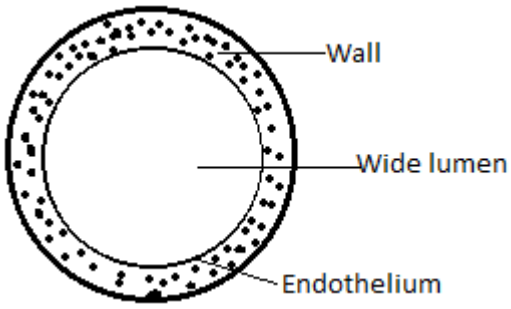
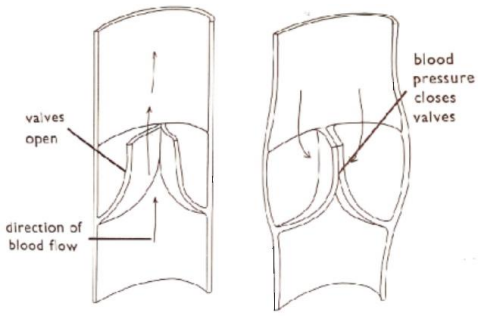


Diagram to show action of valves in a vein



CAPILLARIES

These are very tiny vessels;

- They have thin walls which are one-cell thick
- They are not elastic and do not have valves
- There are gaps between the cells where blood plasma that contains dissolved substances needed by the cells leaks out.
- They link arteries to veins.

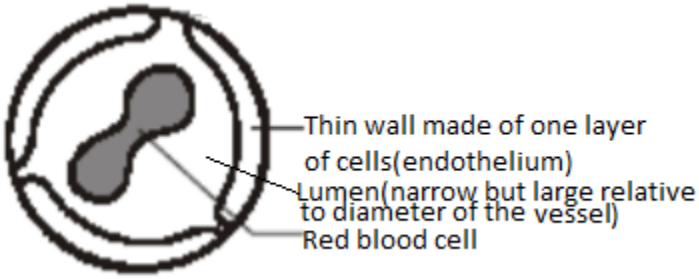
Adaptations of capillaries to their function

i. They have very thin walls made of a single layer of cells to allow permeability.
ii. They have a narrow lumen so that cells e.g red blood cells squeeze to pass through which increases contact between the cell membrane the wall of vessel, reducing the

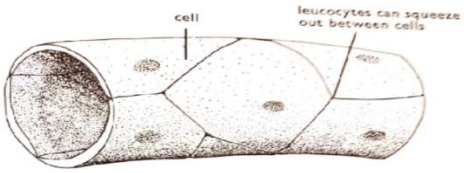
distance for diffusion to enhance exchange of materials e.g respiratory gases carried by the red blood cells.

iii. Being tinny vessels enables them to occupy a small space between cells as they penetrate through tissues to distribute blood.

Transverse section of a capillary

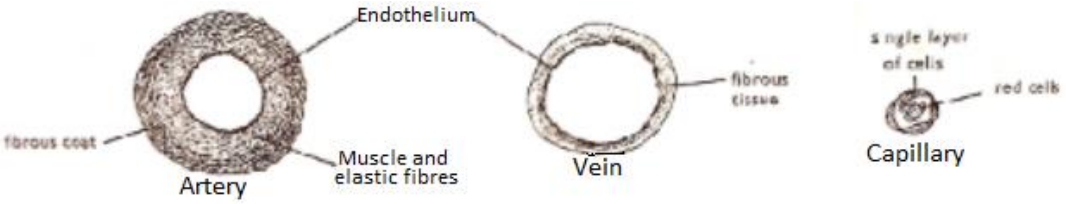


Stereogram of a blood capillary



A comparison between arteries, veins and capillaries

Arteries	**Veins**	**Capillaries**
All carry blood away from the heart	All carry blood to the heart	carry blood to and from the heart
All carry oxygenated blood except the pulmonary artery	All carry deoxygenated blood except the pulmonary vein	carry oxygenated or deoxygenated blood
Valves are not present except at the base of the aorta and the pulmonary vein	Valves are present	Valves are not present
Have thick muscular walls	Have thin muscular walls	Have the thin walls without muscles
Walls Not permeable	Permeable	Permeable
Have a small lumen, relative to diameter	Have a wide lumen, relative to diameter	Have a small lumen, but large relative to diameter
Blood flows rapidly at high pressure	Blood flows slowly at low pressure	Blood flows slowly at low pressure
Blood flows in pulses	Blood flows continuously	Blood flows continuously
They lie deeper in the body	They lie nearer to the skin	Dispersed within tissues



BLOOD CIRCULATION

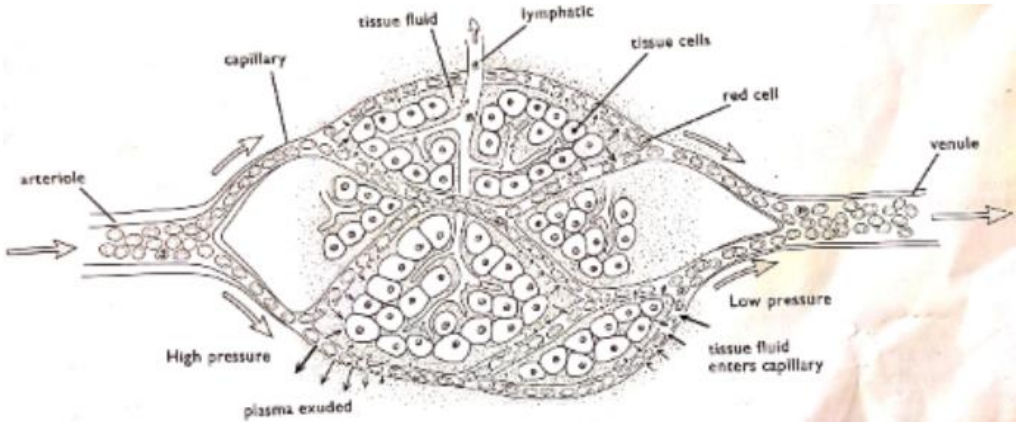
When the ventricles contract they force blood into the arteries leaving the heart. The force of contraction increases the volume of the lumen of arteries. After contraction, the elastic tissue in the arteries tries to return the lumen to the original size, a phenomenon known as **elastic recoil**. The semi-lunar valves in the great arteries prevents the back flow of blood into the

heart, the elastic recoil force therefore results in pushing of blood forward in the arteries. This combines with the effect of the heart not pumping blood continuously, resulting into blood always flowing in pulses within the arteries.

As blood continues to flow away from the heart, the arteries divide repeatedly into smaller and tiny arteries called **arterioles**, which penetrate the tissues. In the tissues, the arterioles divide into capillaries which are very tinny blood vessels. The region where blood flows through capillary is called **a capillary bed.** It is here that substances can be exchanged between blood and the cells. The capillaries allow some blood components to leak out while retaining other components. The leaked (filtered) components form the **tissue fluid**/intercellular fluid which is in contact with the cells directly (a fluid that bathes the cells).

The capillaries which arise from a single arteriole eventually unite to form a single **venule**. The various venules unite to form a vein which then returns blood to the heart.

Diagram to show the structure of a capillary bed



CIRCULATORY SYSTEMS

There are two types of circulatory systems, an **open circulatory system** and a **closed circulatory** system.

Open circulatory system

This is the system in which blood does not stay in the vessels, it passes from the heart into the aorta and then into blood spaces called haemocoel.

The blood under low pressure moves slowly between the tissues and then returns to the heart through open-ended veins.

It occurs in most arthropods and some molluscs.

Closed circulatory system

This is the system where blood stays in blood vessels during circulation. It does not come into direct contact with the body tissues.

It occurs in echinoderms, molluscs (snails), annelids (earthworm) and vertebrates including man.

Differences between open and closed circulatory systems

Open	Closed
1. Blood flows in a body cavity called haemocoel	Blood flows in blood vessels
2. Blood is in direct contact with tissues	Blood not in direct contact with tissues
3. Blood pressure is low.	Blood pressure is high
4. Blood flows slowly	Blood flows faster

There are two types of closed circulatory systems, namely;

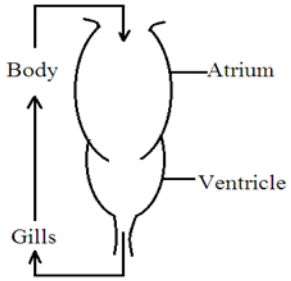
a) Single closed circulatory system
b) Double circulatory system

Single circulatory system

This is a system in which blood passes through the heart once for a complete circulation through the body.

Single circulation occurs in fish.

Diagram showing single circulation in fish



Disadvantage of single circulation

- It has a disadvantage of slow movement of blood in veins of the animals.

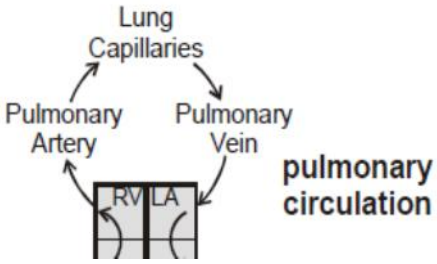
Double circulatory system

This is a system in which blood passes through the heart twice for a complete circulation of blood through the body.

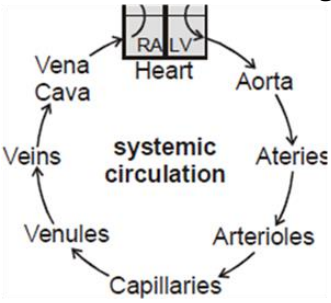
In double circulation, the heart has more than two chambers unlike in single circulation where the heart has two chambers.

In double circulation blood flows in two phases, namely, the **pulmonary circulation** and the **systemic circulation**.

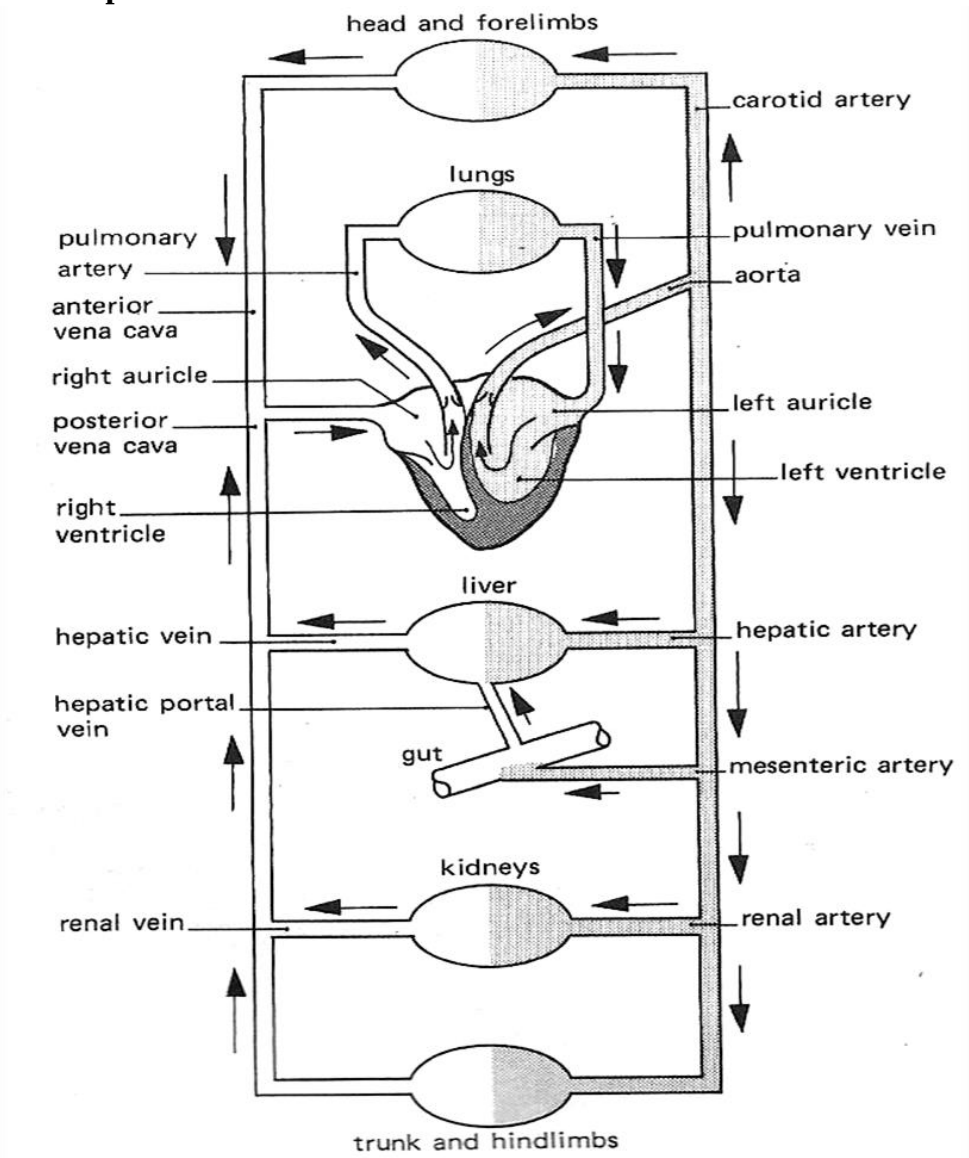
1. **pulmonary circulation**
   This is where blood flows from the heart to the heart through the pulmonary artery, to the lungs, and back to the heart through the pulmonary vein. The blood is oxygenated in this circulation and it only flows in the pulmonary vessels.



2. **systemic circulation**
   This is where blood that is oxygenated flows from the heart to all body organs, except the lungs, and back to the heart through the venacava.



Generalized plan of double circulation in man



Note; there's only one portal vein in man. A portal vein is one which begins and ends in capillaries. The hepatic portal vein carries blood from the ileum to the liver.

Disadvantage of Double Circulation

The disadvantage of double circulation is that blood has to pass through two capillary networks before returning to the heart, and this has the effect of reducing the blood pressure as well as altering the concentration of the respiratory gasses.

CIRCULATORY SYSTEMS IN SOME ORGANISMS

Insects

An insect such as grasshopper has an open circulatory system. The body cavity (coelom) is reduced and replaced by a blood filled space (haemocoel) in which the internal organs are found/ bathed.

Insect blood is colourless and contains no haemoglobin. The blood therefore serves to distribute digested food, collect excretory products and it has the important hydraulic functions in expanding certain regions of the body to split the old cuticles and in pumping up wings of the newly emerged insect.

There is a single dorsal vessel which propels blood forward and releases it into the body cavity, thus maintaining a sluggish circulation. Apart from this vessel, blood is not confined to blood vessels, but occupies the haemocoel. In the haemocoel, materials move in and out of the cells.

The earthworm

An earthworm has a closed circulatory system. It has a dorsal vessel and a ventral vessel. These vessels are connected by five tubes called hearts. Blood is pumped downward through the hearts to the main vessel near the lower surface of the earthworm. Blood carries oxygen and nourishments to the main blood vessel near the upper (dorsal) side of the earthworm.

Fish

This is the simplest circulating system among vertebrates. It includes the heart and blood vessels.

Fish have a closed circulatory system with a two-chambered heart. One chamber is larger than the other, and it pumps blood throughout the body.

Oxygen and carbon dioxide are exchanged at the gills after blood has left the large chamber. It then flows to other body parts through thin walled capillaries. Rich in carbon dioxide and low in oxygen, blood from all over the body returns to the small chamber. The blood then moves to the large chamber, completing a cycle of blood circulation. Fish therefore have a single closed circulatory system.

REVISION QUESTIONS

2. (a) Distinguish between the following terms.

(i) Open circulation and closed circulation.

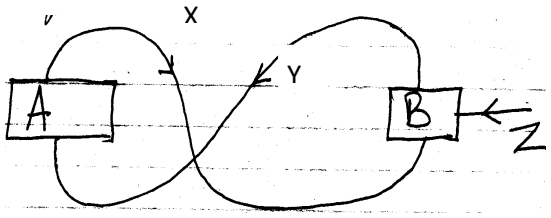
(ii) Single circulation and double circulation.

(a) Complete the table below

Part of the body	**Main artery**	**Main vein**
Lungs		
Liver		
Kidney		

(b) Of what advantage is blood passing twice through the heart in a single complete circulation?

3. Study the flow diagram above on mammalian blood circulation and answer the questions that follow.



(a) (i) If organ A is the lung and B is the heart: name blood Vessels labeled.
X Y, and Z

(iii)State the difference in composition between X and Y.

(b) Suggest 3 structural differences between vessel X and Y.

X	Y

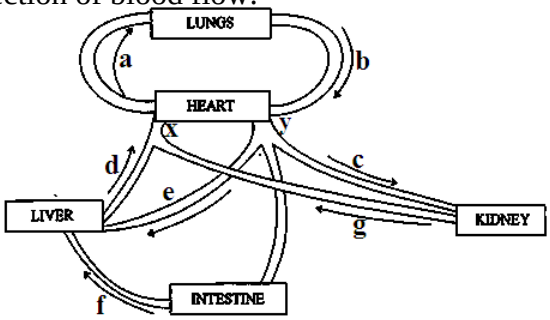
(c) Give the reason to why blood

(i) **Flows to lungs.**……

(ii) **Flows back to heart** before being circulated to the whole body.

(b) Name four constituents of blood.

4. Figure below represents blood vessels supplying selected organs. The arrows show the direction of blood flow.



(a) Name the vessels labeled a to f.

a:……

b:……...

c:……

d: ……

e:……

f:……

(b) State the differences in composition of blood in vessels;

i) **c** and **g**: … ii) **a** and **b**: iii) **d** and **f**:

(c) Explain the difference in blood pressure in blood vessels **x** and **y**.

-END-