Adaptations for transport in animals...1

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Types of circulatory systems

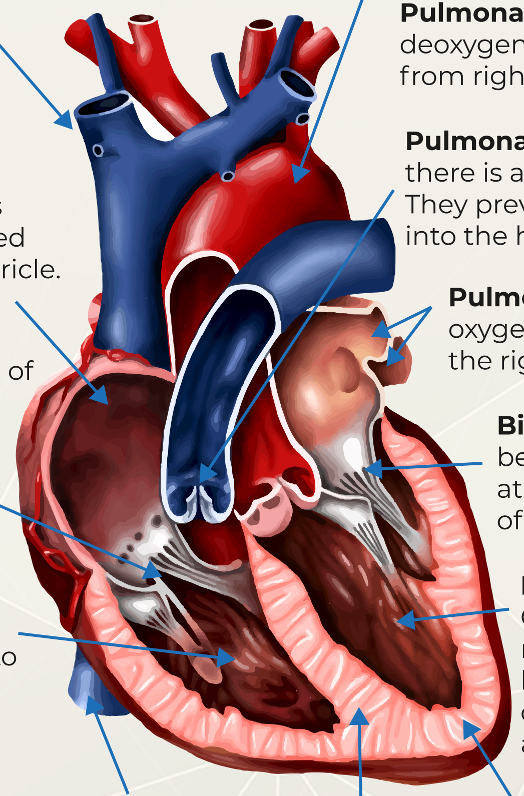
Open	Blood is pumped into a haemocoel, bathes organs and returns slowly to heart with little control over direction of flow.
Closed	Blood is pumped into a series of vessels; blood flow is rapid, and direction is controlled. Organs are not bathed by blood but by tissue fluid that leaks from capillaries.
Single	Blood passes through the heart once in each circulation.
Double	Blood passes through the heart twice in each circulation - once in the pulmonary (lung) circulation and then again pumping blood through the systemic (body) circulation.

Comparison of circulatory systems

Circulatory systems may have: • transport medium • a system of vessels • a pump • valves • a respiratory pigment to carry oxygen.

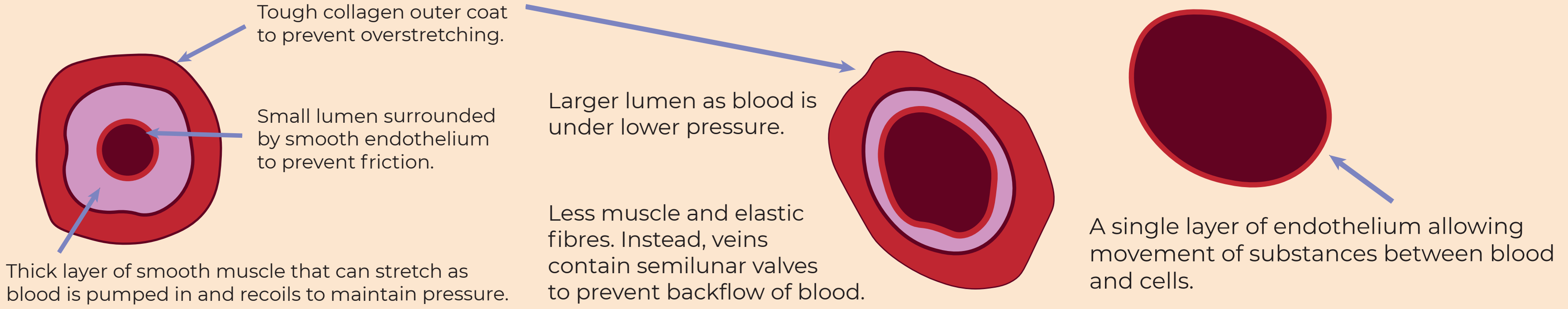
Insects	Earthworms	Fish	Mammals
Open circulatory system. Dorsal tube-shaped heart. No respiratory pigment in blood as lack of respiratory gases in blood due to tracheal gas exchange system.	Closed circulatory. 5 pseudohearts. Respiratory pigment haemoglobin carries respiratory gases in blood.	Closed, single circulatory system. Blood pumped to and oxygenated in the gills continues around body tissues. This means a lower pressure and slower flow around the body.	Closed, double circulatory system. High blood pressure to body delivers oxygen quickly. Lower pressure to lungs prevents hydrostatic pressure forcing tissue fluid into and reducing efficiency of alveoli.

The mammalian heart



Structure of arteries, veins and capillaries

Artery	Vein	Capillary



The cardiac cycle

Atrial systole	Atrial contract. Pressure opens atrio-ventricular valves. Blood flows into ventricles.
Ventricular systole	Ventricles contract. Atrio-ventricular valves close due to pressure in ventricles. Semilunar valves in aorta and pulmonary artery open. Blood flows into arteries.
Ventricular Diastole	Ventricle muscle relaxes. Semilunar valves close to prevent backflow of blood.
Diastole	Heart muscle relaxes and atria begin to fill from vena cava and pulmonary veins.

Initiating the heartbeat

- The heartbeat is myogenic; initiation comes from the heart itself.
- The Sino-atrial node acts as a pacemaker sending waves of excitation across the atria causing them to contract simultaneously.
- A layer of connective tissue prevents the wave of excitation passing down to the ventricles.
- The atrio-ventricular node transmits impulses down the bundle of His to the apex of the heart.
- The impulse then travels up the branched Purkinje fibres simulating ventricles to contract from the bottom up ensuring all the blood is pumped out.

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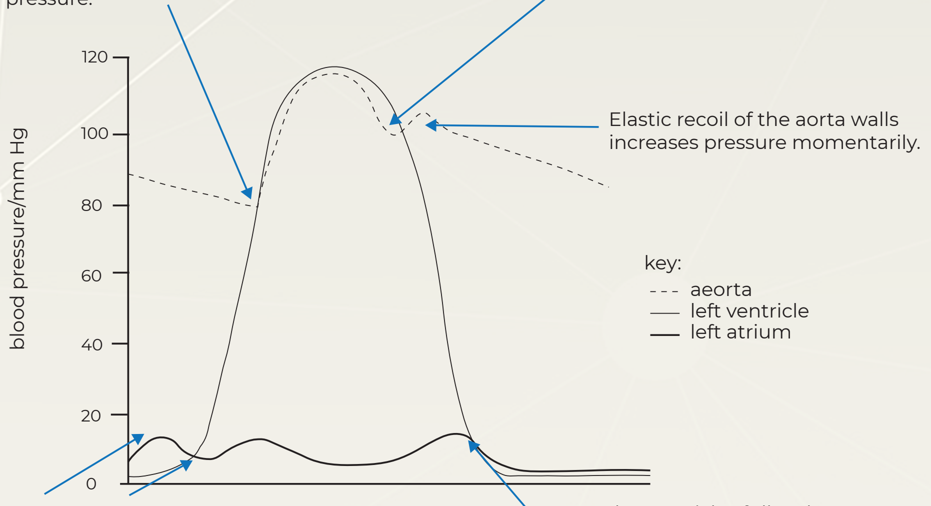
Pressure changes in the heart

Contraction of the thick muscular wall (systole) increases the pressure in the ventricle. At a certain level the semilunar valve leading to the aorta is forced open and blood enters the aorta, increasing the pressure.

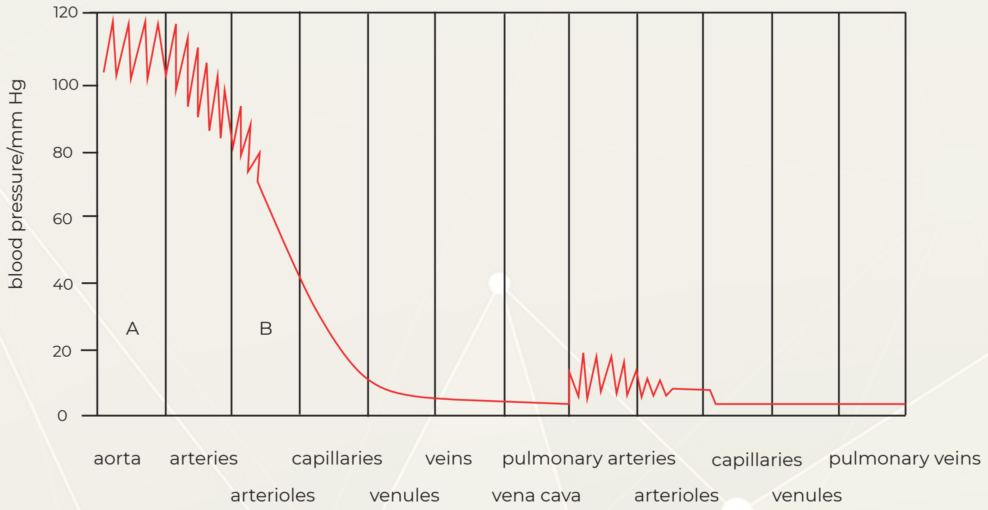
As the ventricle wall relaxes (diastole) the pressure drops in both the ventricle and aorta. The semilunar valve closes, preventing blood flowing back into the ventricle.



Pressure in atrium increases as it contracts, forcing blood through the atrio-ventricular valves into the ventricles. As the atria empty, the valves snap shut.

As the ventricles fully relax, contraction in the atria walls causes the atrio-ventricular valves to open and the ventricle to refill with blood.

Pressure changes in the vessels

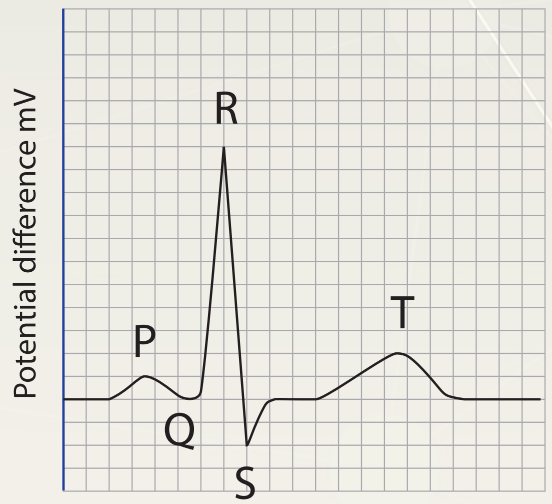


A - Pressure in the aorta is high due to contraction of the powerful left ventricle forcing blood into the vessel. It falls only slightly during ventricular diastole due to the elastic recoil of the arteries. Arterioles are further away from the heart, have a large surface area and are narrow, leading to a substantial drop in pressure. However, arterioles can adjust their diameter to control blood flow.

B - The huge cross-sectional surface area covered by the capillaries causes a dramatic decline in pressure. Slow moving blood is essential for effective exchange between blood and cells. Low pressure requires valves and massaging effect of muscles to aid the transport of blood through the veins back to the heart.

ECG

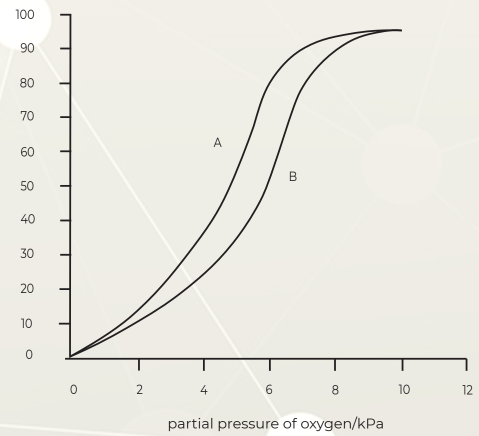
The electrical activity that spreads through the heart during the cardiac cycle can be detected using electrodes placed on the skin and shown on a cathode ray oscilloscope. This is called an electrocardiogram (ECG).



P wave	Depolarisation of the atria corresponding to atrial systole.
QRS wave	Spread of depolarisation through the ventricles resulting in ventricular systole.
T wave	Repolarisation of the ventricles resulting in ventricular diastole.

Oxygen dissociation curves

- Red blood cells transport oxygen.

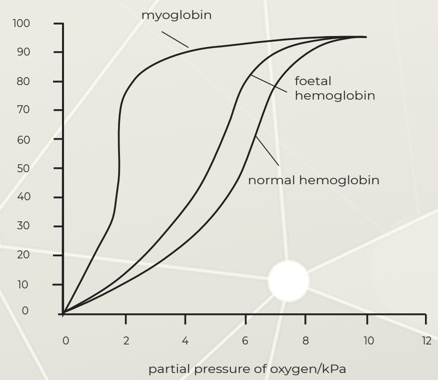


B – Where CO_2 is present the Bohr shift occurs and the curve moves to the right, meaning haemoglobin has a lower affinity for oxygen, releasing it more readily. This is helpful in respiring tissues.

A – a sigmoid curve that shows haemoglobin has a high affinity for oxygen at high partial pressures of oxygen (the lungs) but releases it readily at lower partial pressures (respiring tissues).

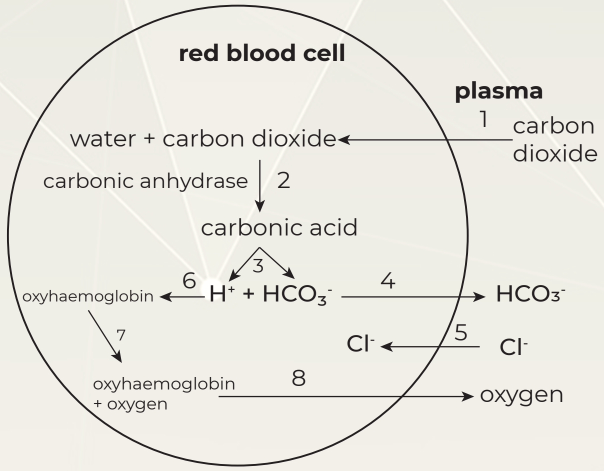
Myoglobin - curve shifts to the left. It has a high affinity for O_2 and holds on to it until partial pressures of O_2 are really low, it then releases it rapidly. It acts as a store of O_2 in muscle.

Foetal haemoglobin - curve just to the left, a higher affinity for O_2 than haemoglobin at all partial pressures so foetus can take O_2 from the mothers blood.



Chloride shift

Some CO_2 is carried in the blood dissolved in plasma, some as carbaminohaemoglobin but most is carried as hydrogen carbonate ions as shown below:



1	CO_2 diffuses into a red blood cell (RBC)
2	CO_2 combines with H_2O catalysed by the enzyme, carbonic anhydrase, forming carbonic acid.
3	Carbonic acid dissociates into hydrogen ions (H^+) and hydrogen carbonate ions (HCO_3^-) diffuse out of the RBC.
4	Hydrogen carbonate ions diffuse out of the RBC.
5	Chloride ions (Cl^-) diffuse (facilitated diffusion) into the RBC to maintain electrochemical neutrality - **the chloride shift**.
6	H^+ bind to oxyhaemoglobin, reducing its affinity for oxygen. **This is the Bohr effect.**
7	Oxygen is released from the haemoglobin.
8	Oxygen diffused from the RBC into the plasma and body cells.

Formation of tissue fluid – a link between blood and cells. Important as plasma transports nutrients, hormones, excretory products and distributes heat.

1. At the arterial end of the capillary bed, hydrostatic pressure is higher than osmotic pressure.
2. Water and small soluble molecules are forced through the capillary walls, forming tissue fluid between the cells.
3. Proteins and cells in the plasma are too large to be forced out.
4. Due to reduced volume of blood and friction, blood pressure falls and it moves through the capillary.
5. At the venous end of the capillary bed osmotic pressure of the blood is higher than the hydrostatic pressure.
6. Most of the water from tissue fluid moves back into blood capillaries (down its water potential gradient). The remainder of the tissue fluid is returned to the blood, via lymph vessels.