UNIT 8 - TRANSPORT IN MAMMALS

The mammalian cardiovascular system consists of 3 main components:

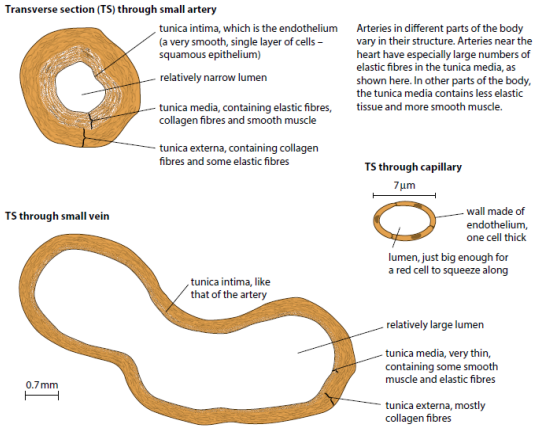
1) The heart
2) The blood
3) Blood vessels

The mammalian transport system is a double-circulatory system. It is also a closed system.
Why? - because blood goes through the heart twice (hence "double") and because the blood always remains within the blood vessels (thus "closed")

- In a double-circulatory system. There is the pulmonary circuit and the systemic circuit
- Organs arranged in parallel, not in series
- Pulmonary circulation is the smaller circuit in which deoxygenated blood is pumped to the lungs to get oxygenated before returning to the heat
- Systemic circulation is the larger circuit in which oxygenation blood is pumped around the body, providing oxygen to respiring tissue. The blood is deoxygenated when it returns to the heart.

Blood vessels

Artery - thick-walled, carries blood at high pressures. Arteries transport blood AWAY from the heart (Artery - Away)
Vein - thin-walled, carries blood at low pressures. Veins transport blood INTO the heart (Vein - Into)



Arteries:
Must withstand very high pressures of blood pumped out from the left ventricle.

Elastic fibers allow blood vessels to stretch without rupturing. They also help smoothen out blood for more consistent pressure.
The further from the heart the vessels are, the fewer elastic fibers are present in their walls.

Veins:

- Thinner walls when compared to arteries. They are also less elastic.
- Blood moves in the veins at much lower pressures. Veins have valves to prevent blood from flowing backward

Arterioles - small arteries

- They have little to no elastic fibers
- They contain smooth muscle at intervals

Venules - small veins

Capillaries

- Arterioles branch to form capillaries
- These form capillary beds - a network of blood vessels with an increased surface area to maximize substance exchange

Blood vs. Lymph vs. Tissue fluid

Blood contains red blood cells, white blood cells, water, large molecules (e.g. proteins), hormones, oxygen, carbon dioxide, and glucose. Tissue fluid on the other hand is only composed of molecules such as oxygen and carbon dioxide, as well as some white blood cells and simple sugars as large molecules such as proteins are not able to squeeze through the capillary walls and so remain in the blood plasma. Lymph contains carbon dioxide, proteins, and white blood cells.

The Formation of Tissue Fluid

- Tissue fluid is formed when plasma leaks through fenestrations in the capillaries due to high pressures.
- Tissue fluid is almost identical to plasma with regards to composition, but it has much fewer proteins as they are too large to fit through the gaps in the capillary walls.
- Some phagocytes are also able to squeeze through these gaps and into the intercellular spaces.
- The volume of fluid that leaves the capillary to form tissue fluid is a result of two opposing pressures: solute potential and hydrostatic pressure.
- Since there are fewer proteins in the tissue fluid, the solute concentration gradient is steep, so fluid should theoretically always be moving into the intercellular spaces, but it doesn't.
- At the arteriole end, the hydrostatic pressure is high enough to overcome the solute difference. The effect is that the water potential inside the capillaries is higher, so fluid moves out.
- Hydrostatic pressure decreases significantly as blood passes through the capillaries.
- At the venule end, due to lower hydrostatic pressure, the net effect is that the water potential inside the capillaries is lower, so fluid moves back into the capillaries.

Importance of Tissue Fluid

- It forms the immediate environment around the cells as it fills the intercellular spaces surrounding them.
- The exchange of substances takes place in the tissue fluid.

Functions of the Lymphatic System

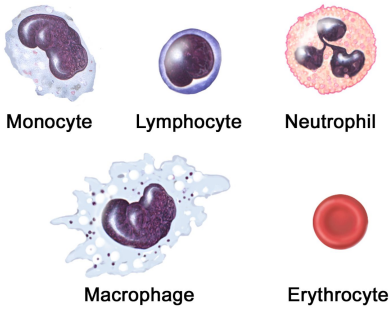
- Collection of excess fluid from tissue and the return of this fluid to the blood
- Absorption of lipids from the gut
- Reabsorption of protein from tissue fluid since the valves are large enough to allow for their entry
- Lymphocytes accumulate in the lymph nodes and produce antibodies, whilst phagocytes engulf bacteria and foreign particles in the lymph

Blood

Red blood cells -

- Contain hemoglobin and have no organelles to allow for more space to carry oxygen
- Each red blood cell can carry 4 molecules (8 atoms) of oxygen at a time
- Red blood cells have a biconcave shape which allows for flexibility to squeeze into small capillaries

White blood cells -



- They are key components of the immune system. The four types of white blood cells in the AS level syllabus are neutrophils, monocytes & macrophages, and lymphocytes
- **Neutrophils**: are types of phagocytes that contain a multi-lobed nucleus. Their role is to engulf pathogens
- **Monocytes & Macrophages**: monocytes are immature macrophages and reside in the bloodstream for 1-3 days before migrating to lymph, where they mature. Their task as phagocytes is also to engulf pathogens. They may also present antigens on their surface.
- **Lymphocytes**: they have a very large nucleus that takes up most of the cell. Their role is to produce plasma cells (for antibodies) and to specialize into memory cells

Plasma -

- Blood plasma is a straw-colored liquid composed of 91% water, 7% protein, and 2% other materials (e.g. carbon dioxide, vitamins, hormones, etc.)
- It suspends all the other components of the blood

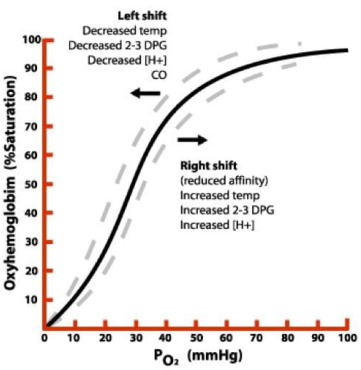
Platelets -

- Cell fragments suspended in the plasma
- They are involved in the formation of blood clots and bind to each other using fibrin when activated

Hemoglobin

- Hemoglobin is a quaternary protein comprising 4 polypeptide chains and 4 prosthetic groups containing iron.

$$Hb + 4O2 \rightarrow HbO_8 \text{ (oxyhemoglobin)}$$

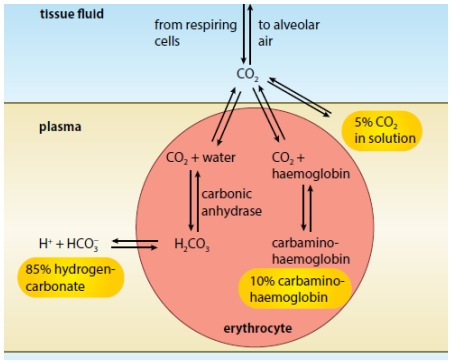


Hemoglobin binds with oxygen via cooperative binding. When one molecule of oxygen binds to hemoglobin, it makes it easier for the molecules to bind. It is responsible for the sigmoid shape of the curve.

The curve's START indicates oxygen saturation at <u>respiring tissues</u> because the oxygen has been transferred from the hemoglobin to the tissue.

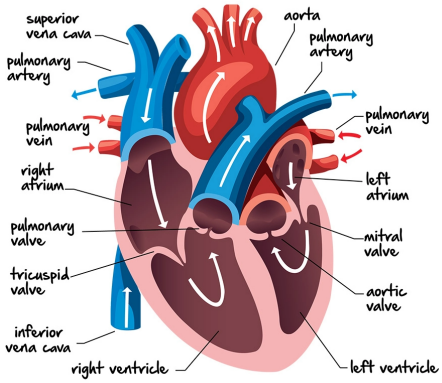
The MIDDLE of the curve indicates oxygen saturation at <u>resting tissues</u>, which require less oxygen so less is transferred from hemoglobin to the tissues.

The END of the curve indicates oxygen saturation in the <u>lungs</u>, where the oxygen carried by the red blood cells is replenished.



Chloride shift - H^+ ions would lower the pH of the blood and so Cl^- ions from the plasma replace them to neutralize the pH.

Haemoglobin has a higher affinity for carbon dioxide than oxygen, so oxygen is released in respiring tissues and carbon dioxide is taken up. At the lungs, there is a steep concentration gradient so carbon dioxide is released and oxygen is taken up.



The Pathway of Blood

1) Blood enters the right atrium through the vena cava and the left atrium through the pulmonary vein.
2) The atria contract during atrial systole and blood is forced through the atrioventricular valves and into the ventricles.
3) The ventricles contract and the blood is forced through the semi-lunar valves. Blood in the right ventricle travels through the pulmonary artery and to the lungs while blood in the left ventricle travels through the aorta to the rest of the body.

Atrial Systole:

- Both the atria contract
- The atrioventricular valves OPEN
- The rest of the valves (semilunar valves, pulmonary and aortic valves) are CLOSED

Ventricular Systole:

- The atria relax and the atrioventricular valves CLOSE
- Both the ventricles contract and blood is forced through the pulmonary and aortic valves which are OPENED

Ventricular Diastole:

- The atria and ventricles relax
- Only the pulmonary and aortic valves are CLOSED

The heart is a myogenic organ, meaning that it can contract and relax on its own, without any signaling from the brain. The tissues responsible for this behavior are the sinoatrial node (SAN) and the atrioventricular node (AVN).

- The SAN is a patch of cardiac muscle in the right atrium. It sends out an electrical impulse that causes the atrial walls to contract. The excitation wave reaches the AVN, located in the septum
- When the AVN receives this impulse, it delays the wave for a fraction of a second, then lets it travel down the Purkyne tissue in the septum, causing the ventricles to contract.