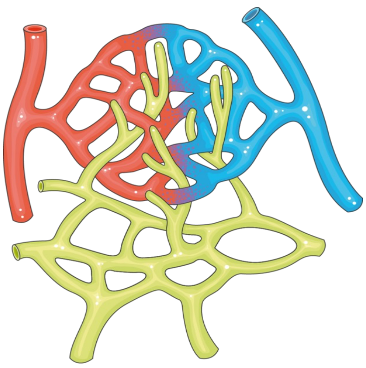
BLOOD SYSTEM

Content Statements:

B3.2.11	Release and reuptake of tissue fluid in capillaries
B3.2.12	Exchange of substances between tissue fluid and cells in tissues
B3.2.13	Drainage of excess tissue fluid into lymph ducts
B3.1.11	Adaptations of foetal and adult haemoglobin for the transport of oxygen
B3.1.12	Bohr shift
B3.1.13	Oxygen dissociation curves as a means of representing the affinity of haemoglobin for oxygen at different oxygen concentrations

FLUID SYSTEMS

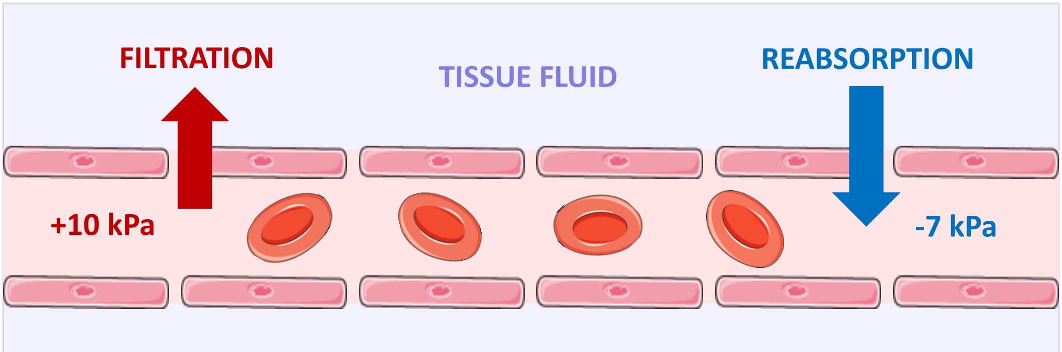
The human body consists of two interconnected fluid systems that function to circulate materials between the different tissues. The **circulatory system** contains arteries that transport blood from the heart at high pressure and veins which return blood to the heart at low pressure. The two vessels are connected by capillaries, which function as the site of material exchange. Fluid in the blood *(plasma)* is released into tissues as part of this exchange. Most of the tissue fluid will be returned to the capillaries, but excess fluid will drain into the **lymphatic system** (becoming *lymph*). The fluid is filtered at specific points called lymph nodes, with the presence of valves ensuring unidirectional movement before the fluid is returned to blood circulation.



Circulatory + Lymphatic

FLUID EXCHANGE

The exchange of fluid between the blood and tissues allows for the transfer of materials that are dissolved within the fluid. Oxygen and glucose are transferred to respiring tissues to fuel metabolic processes, while metabolic waste products (such as carbon dioxide and urea) are removed from the tissues. Hormones and antibodies can also be transferred to mediate homeostatic regulation and immune activity. The movement of fluid is facilitated by the higher **hydrostatic pressure** at the arteriole end of a capillary, which functions to force fluid into the tissues. Conversely the venous end of a capillary has a lower hydrostatic pressure, which allows tissue fluid to drain back into the bloodstream. Additionally, the presence of plasma proteins in the blood generates **oncotic pressure** when fluid is lost and this promotes the reuptake of fluid into the blood via osmosis (the fluid returns from the tissue as the plasma proteins function to lower the water potential).



Blood → Tissues

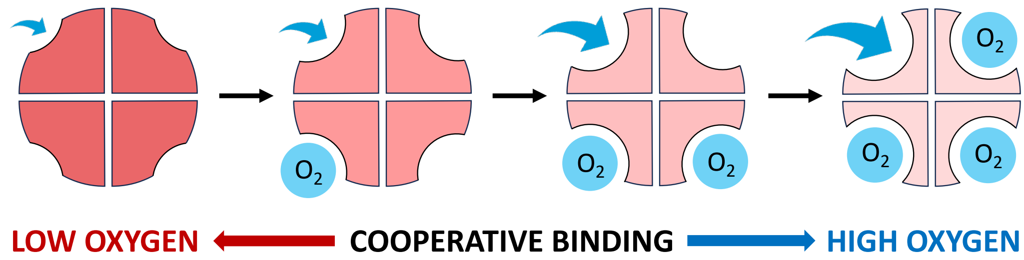
glucose, oxygen, amino acids, ions

Tissues → Blood

carbon dioxide, urea (waste)

HAEMOGLOBIN

Oxygen is transported within the blood by red blood cells (erythrocytes), which contain an oxygen-binding protein called haemoglobin. This protein is conjugated and has a quaternary structure – it is composed of four polypeptide chains each with an oxygen-binding heme group (meaning haemoglobin can transport up to eight oxygen atoms ($Hb + 4O_2 \rightarrow HbO_8$). As each oxygen molecule binds, it alters the conformation of the haemoglobin, making subsequent binding easier (**cooperative binding**). This means haemoglobin will have a higher affinity for O_2 in oxygen-rich areas like the lungs (promoting oxygen loading) and have low affinity in areas like respiring tissues that are oxygen-poor (promoting oxygen unloading). Additionally, CO_2 can also bind to haemoglobin via an **allosteric site** that further reduces the oxygen affinity in heavily respiring tissue.

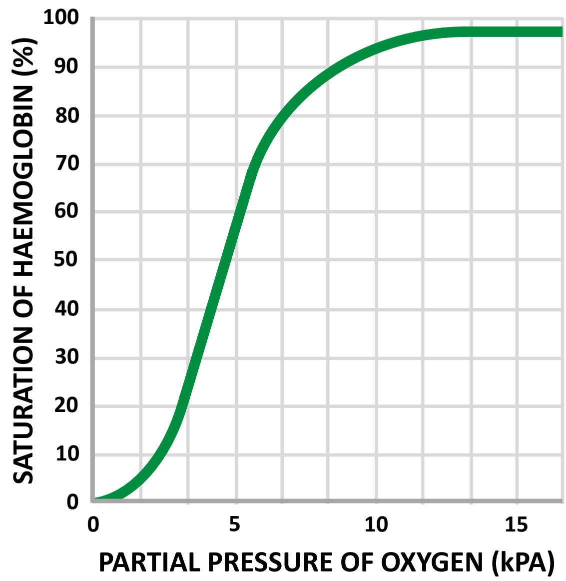


Cooperative Binding

The oxygen binding sites on the protein are more accessible as more O_2 is loaded

OXYGEN DISSOCIATION CURVES

Oxygen dissociation curves show the relationship between O_2 levels (as partial pressure) and haemoglobin saturation. An oxygen dissociation curve for haemoglobin is **sigmoidal** due to cooperative binding. At high pO_2 levels in the lungs, there is very little dissociation of oxygen from haemoglobin (the curve will plateau). At low pO_2 levels in hypoxic tissue, haemoglobin will not readily take up oxygen (curve is flat). However, when pO_2 levels are moderate (respiring tissues), small changes in pO_2 levels can cause large changes in the percentage saturation of haemoglobin (gradient is steep). Different forms of haemoglobin will demonstrate distinct curves. **Foetal haemoglobin** has greater affinity for oxygen (due to gamma chains instead of beta chains) and this will move a dissociation curve to the ***left*** of adult haemoglobin.



Oxygen Dissociation Curve (Adult)

CARBON DIOXIDE TRANSPORT

Carbon dioxide changes the affinity of haemoglobin for oxygen and shifts a dissociation curve to the ***right***. This is called the **Bohr effect**. Some carbon dioxide can bind directly to haemoglobin via an allosteric site and cause a conformational change to reduce oxygen affinity. However most of the carbon dioxide within the red blood cell will combine with water to form **carbonic acid**, which the dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). The bicarbonate ions are pumped out of the cell and transported in the plasma as sodium bicarbonate (the bicarbonate is exchanged with **chloride ions** to maintain the charge and osmolarity of the cell). The hydrogen ions bind to the haemoglobin and reduce its affinity for oxygen. This is a helpful change in respiring tissue where carbon dioxide levels are higher, as it means more oxygen will be released by haemoglobin and made available for aerobic respiration. When a deoxygenated red blood cell returns to the lungs, the chloride ions are pumped out of the cell to enable the entry of bicarbonate ions and the hydrogen ions are released from haemoglobin to reconstitute carbon dioxide and water. This acts to increase haemoglobin affinity for oxygen within the alveoli of lungs, while the carbon dioxide is exhaled.