Transport of oxygen in the blood

Blood

Blood is an 'aqueous body fluid'. In other words it is water containing a whole range of substances. It is contained in a complex network called the vascular system and is pumped around the body by the heart.

Blood has two main functions. It:

- provides defence against disease
- transports compounds, ions, and some elements to and from other tissues and cells

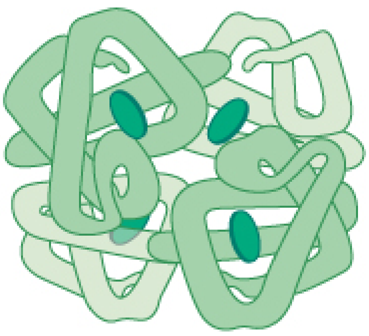
See also:

> Some basic chemistry
> Inorganic ions
> Water and living organisms

Red blood cells and haemoglobin

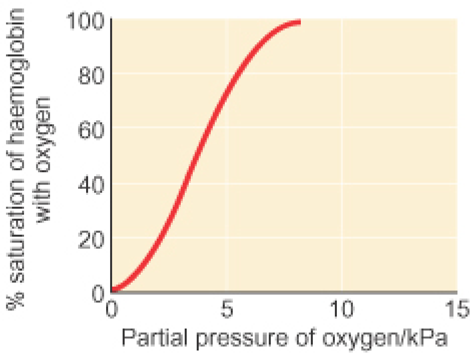
Oxygen is one of the substances transported with the assistance of red blood cells. The red blood cells contain a pigment called **haemoglobin**, each molecule of which binds four oxygen molecules. Oxyhaemoglobin forms. The oxygen molecules are carried to individual cells in the body tissue where they are released. The binding of oxygen is a **reversible reaction**.

$Hb + 4O_2 \rightleftharpoons Hb.4O_2$



The four 'disks' in the diagram of haemoglobin are the parts of the molecule where the oxygen molecules bind, while the four folded 'sausage shapes' represent polypeptide chains.

At high oxygen concentrations oxyhaemoglobin forms, but at low oxygen concentrations oxyhaemoglobin dissociates to haemoglobin and oxygen. The balance can be shown by an oxygen dissociation curve for oxyhaemoglobin.



The curve shows that:

- at relatively low oxygen concentrations there is uncombined haemoglobin in the blood and little or no oxyhaemoglobin, e.g. in body tissue
- at relatively high oxygen concentrations there is little or no uncombined haemoglobin in the blood; it is in the form of oxyhaemoglobin, e.g. in the lungs.

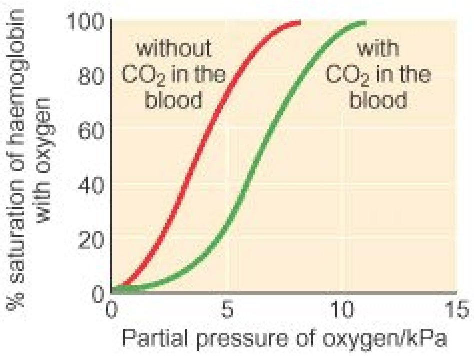
Note Historically oxygen and carbon dioxide concentrations are expressed as partial pressures (measured in kPa), also called oxygen or carbon tension. The amount of oxygen held by the haemoglobin, i.e. its saturation level, is normally expressed as a percentage.

Oxygen dissociation curves can be used to illustrate Le Chatelier's Principle which states that a system in dynamic equilibrium responds to any stress by restoring the equilibrium. For example shifts in the position of the curve occur as a result of the concentration of CO_2 or changes in pH.

The effect of carbon dioxide in the blood

Haemoglobin can also bind carbon dioxide, but to a lesser extent. Carbaminohaemoglobin forms. Some carbon dioxide is carried in this form to the lungs from respiring tissues.

The presence of carbon dioxide helps the release of oxygen from haemoglobin, this is known as the **Bohr effect**. This can be seen by comparing the oxygen dissociation curves when there is less carbon dioxide present and when there is more carbon dioxide in the blood.



When carbon dioxide diffuses into the blood plasma and then into the red blood cells (erythrocytes) in the presence of the catalyst carbonic anhydrase most CO_2 reacts with water in the erythrocytes and the following dynamic equilibrium is established

$$H_2O + CO_2 \rightleftharpoons H_2CO_3$$

Carbonic acid, H_2CO_3, dissociates to form hydrogen ions and hydrogencarbonate ions. This is also a reversible reaction and undissociated carbonic acid, hydrogen ions and hydrogencarbonate ions exist in dynamic equilibrium with one another

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

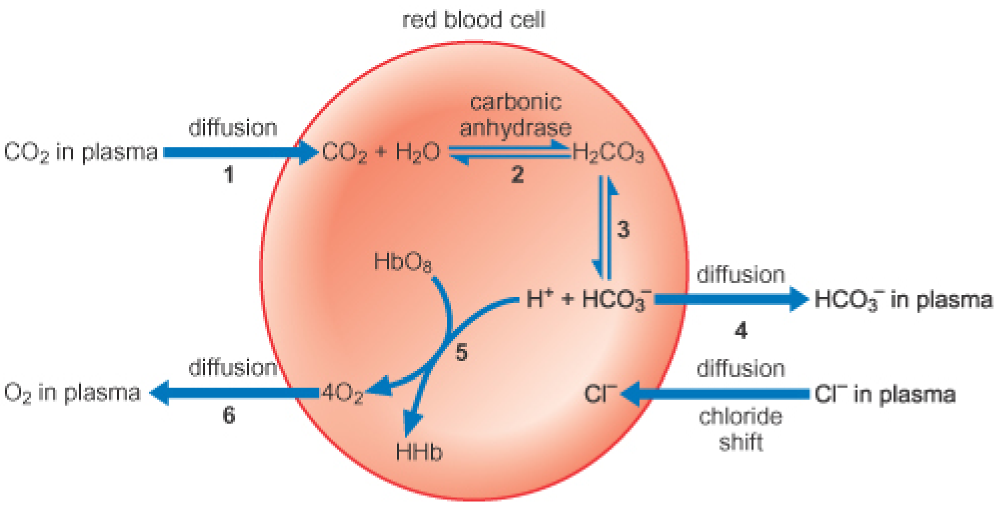
Inside the erythrocytes negatively charged HCO_3^- ions diffuse from the cytoplasm to the plasma. This is balanced by diffusion of chloride ions, Cl^-, in the opposite direction, maintaining the balance of negative and positive ions either side. This is called the '**chloride shift**'.

The dissociation of carbonic acid increases the acidity of the blood (decreases its pH). Hydrogen ions, H^+, then react with oxyhaemoglobin to release bound oxygen and reduce the acidity of the blood. This buffering action allows large quantities of carbonic acid to be carried in the blood without major changes in blood pH.

$$Hb.4O_2 + H^+ \rightleftharpoons HHb^+ + 4O_2$$

($Hb.4O_2$ is sometimes written HbO_8.)

It is this reversible reaction that accounts for the Bohr effect. Carbon dioxide is a waste product of respiration and its concentration is high in the respiring cell and so it is here that haemoglobin releases oxygen.



Now the haemoglobin is strongly attracted to carbon dioxide molecules. Carbon dioxide is removed to reduce its concentration in the cell and is transported to the lungs were its concentration is lower. This process is continuous since the oxygen concentration is always higher than the carbon dioxide concentration in the lungs. The opposite is true in respiring cells.

Test your knowledge

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