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TRANSPORT OF CARBON DIOXIDE IN BLOOD

Carbon dioxide (CO_2) is the major waste product of aerobic respiration. Too much or too little CO_2 in the blood can lead to serious consequences. This article will consider CO_2 **transport** in the blood, its role in maintaining blood pH and also what can happen when CO_2 is impaired.

Carbon Dioxide in the Blood

It is important to highlight the role of CO_2 in the blood. The main role of CO_2 is to regulate the **pH** of the blood – this is much more important that transporting CO_2 to the lungs for exhalation.

$$CO_2 + H_2O \xleftrightarrow{\text{Carbonic anhydrase}} H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

Fig 1 – The reaction that produces bicarbonate within the body.

Figure 1 shows how CO_2 dissolves in the blood. The conversion of **carbonic acid** (H_2CO_3) to a hydrogen and bicarbonate ion ($H^+ + HCO_3^-$) is almost instantaneous. A small amount of dissolved CO_2 produces a small rise in hydrogen ions which is capable of altering the blood pH. The proportion of CO_2 to HCO_3^- is critical and explains why this occurs.

This ratio is roughly 1:20. Therefore a rise of 1 CO_2 requires a corresponding rise of 20 HCO_3^- to prevent alterations to blood pH by buffering the increase in acidity. As detailed in the reaction above only 1 **HCO_3^-**, is generated from every CO_2 therefore the blood pH will become more acidic due to the excess hydrogen ions. There must therefore be an alternate method of transportation to prevent severe acidosis every time we respire and create CO_2.

Methods of Transport

CO_2 is transported in the blood in 3 ways; as a hydrogen carbonate (HCO_3^-), as **carbamino** compounds and as dissolved CO_2.

Carbamino Compounds

About 30% of all CO_2 is transported as carbamino compounds. At high concentrations carbon dioxide directly binds to **amino acids** and the amine groups of haemoglobin to create carbaminohaemoglobin. Carbamino formation is most effective at the periphery where CO_2 production is high due to cellular respiration.

The **Haldane** effect also contributes to the formation of carbamino compounds. That is, where O_2 concentration is lower (as in the active peripheries where O_2 is being consumed) the CO_2 carrying capacity of the blood is increased. This is because release of O_2 from Hb promotes binding of CO_2.

Formation of carbamino compounds achieves 2 goals:

- Stabilising **pH** – CO_2 is unable to leave the blood cell to contribute to changes in pH
- **Bohr** effect – it stabilises the T state of haemoglobin, promoting the release of O_2 from the other subunits of haemoglobin into the tissues that are most active, undergoing the most respiration and producing the most CO_2

When the blood cell reaches areas of high O_2 concentrations again (such as the lungs), it preferentially binds O_2 again. This stabilises the R state, promoting the release of CO_2 (Haldane effect) allowing more O_2 to be picked up and transported in the blood.

HCO_3^- ions

60% of all CO_2 is transported through production of HCO_3^- ions in the red blood cell. This is explained in the diagram below (Figure 2). CO_2 diffuses into the red blood cells and is converted to H^+ and HCO_3^- by an enzyme called **carbonic anhydrase**. This HCO_3^- is transported back into the blood via a chloride-bicarbonate exchanger (aka anion exchanger/AE). The HCO_3^- can now act as a buffer against any hydrogen in the blood plasma.

The H^+ created by the carbonic anhydrase reaction in the red blood cell binds to haemoglobin to produce **deoxyhaemoglobin**. This contributes to the Bohr effect as O_2 release from haemoglobin is promoted in active tissues where H^+ concentration is higher. It also prevents hydrogen entering the blood to lower pH, stabilising the pH.

When the red blood cells reach the lungs, oxygen binds to the haemoglobin and promotes the **R state**, allowing the release of H^+ ions. These hydrogen ions become free to react with bicarbonate ions to produce CO_2 and H_2O, where the CO_2 is exhaled. Thus the high O_2 concentrations reduce the CO_2 carrying capacity of blood, in accordance with the Haldane effect.

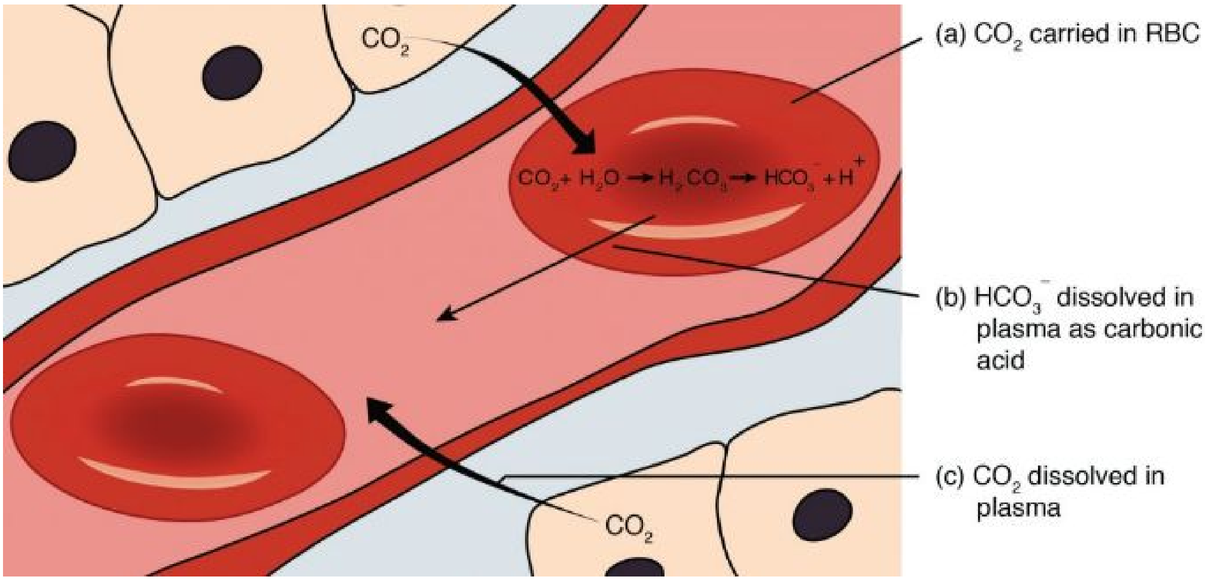

Fig 2 – Diagram showing methods of transporting carbon dioxide in the blood. The reaction producing bicarbonate is shown within the red blood cell.

Dissolved in Plasma

About 10% of all CO_2 is transported dissolved in plasma. The amount of gas dissolved in a liquid depends on its solubility and the partial pressure of the gas. CO_2 is very soluble in water (23x more soluble than O_2) and the partial pressure of inspired CO_2 is ~40mmHg. Despite its solubility, only a **minority** of the total CO_2 in blood is actually transported dissolved in plasma.

The partial pressure, however, is higher in the periphery where tissues are producing CO_2 and lower at the alveoli where CO_2 is being released. This allows more CO_2 to be dissolved in the periphery while it is released into the gas phase at the alveoli where the partial pressures are lower.