Transport of O2 and CO2 in the blood

Transport of O_2

Only ~1% of oxygen in the blood travels as free O_2. However, it is still important as an indicator for peripheral pO_2 chemoreceptors.

However, most O_2 is transported in the blood by binding to the heme moiety of hemoglobin.

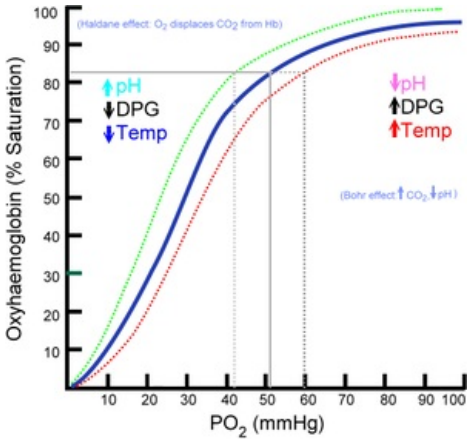
Hemoglobin is a tetramer (adult: 2α, 2β; fetal: 2α, 2γ), which can be described differently, depending on the state of the heme:

- Methemoglobin (Fe3+)
- Carboxyhemoglobin (bound to CO)
- Carbaminohemoglobin (bound to CO2)
- Oxyhemoglobin (bound to O2)
- Deoxyhemoglobin (not bound)

The four chains participate in cooperative binding to O_2 depending on its partial pressure (https://en.wiktionary.org/wiki/partial_pressure). Their affinity for O_2 increases for greater pO_2 values. Hemoglobin is fully saturated if pO_2 = 100%; at pO_2 = 50%, about half of the chains are bound to O_2. This is visualized by the dissociation curve.

Increased P_{CO2} decreases the pH, decreases the affinity of heme to O_2, and shifts the curve right – **Bohr effect**. This helps release oxygen in regions where it is deficient.

The greater differences in the curves at intermediate oxygen amounts are necessary for normal physiological function.



Oxyhaemoglobin dissociation curve

Transport of CO_2

CO_2 is produced in the tissues, diffuses in the blood. Inside erythrocytes, it reacts with water to form HCO_3^- and is released back into the plasma – this is how 85% of CO_2 is transported.

Since HCO_3^- left, the charge needs to be balanced, and Cl^- ions are pumped in – this is known as the **chloride shift** or Hamburger effect. This also brings in water; venous RBCs are therefore bigger.

CO_2 is also transported in a chemical bond with Hb (10%), and dissolved as a gas (5%).

Defects

Hypoxia: decreased delivery or use of O_2 by tissue, when pO_2 < 21 kPa

Multiple types:

- **Hypoxic**: decreased decreased pO_2 → decreased heme saturation. Due to higher altitude (lower pO2 in atmospheric), hypoventilation (can be mechanical - broken ribs), pathophysiological causes in regulatory centers, neuromuscular diseases, defects of diffusion, V/Q ratio (https://en.wikipedia.org/wiki/Ventilation/perfusion_ratio), right-to-left shunts
- **Anaemic**: reduced transport capacity (ex: hemoglobin problems or RBC problems).
- **Ischemic**: due to circulatory problems (ex: artery obstruction, heart failure)
- **Histotoxic**: due to cellular inability to take up or use O_2 (ex: cyanide poisoning).

Hypercapnia: abnormal retention of CO_2 leads to increased partial pressure (5.3-6.65 kPa). Can be due to decreased respiration or extension of dead space.

- mild (5.3-6.65 kPa): causes stimulation of the respiratory center (therapeutic use: pneumoxid = mixture of oxygen + 2-5% CO_2)
- around 10 kPa: CO_2 narcosis. Respiratory depression; preceded by dyspnea, headache, and confusion
- acute (over 12 kPa): significant respiratory depression, leads to coma and death

References

Costanzo, L., 2019. *Physiology - Board Review Series*. 7th ed. Philadelphia: Wolters Kluwer, p.127-133