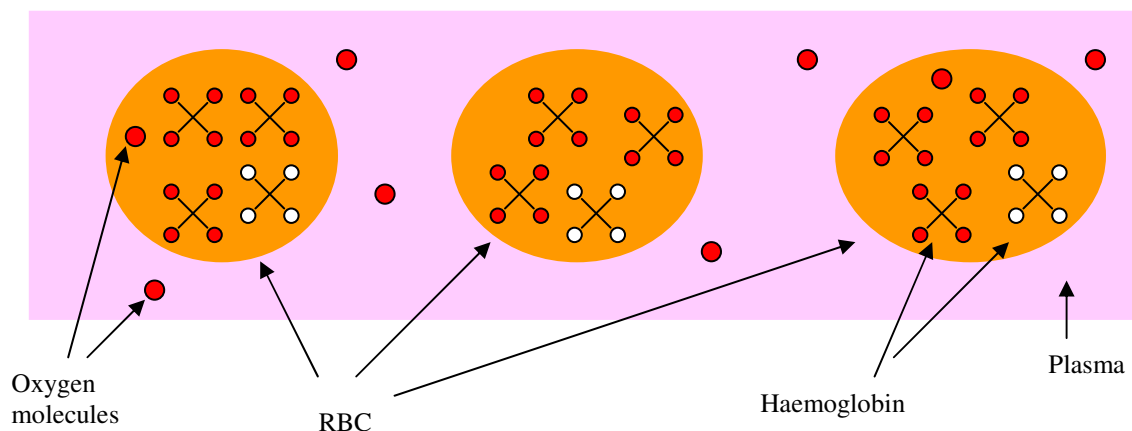


My notes on Oxygen concentration in plasma and tissue

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The hemoglobin concentration in blood:

Adult male: 135-175 g/L

Adult female: 122-150 g/L

Children: 100-140 g/L

Rats: ?

(Ref: www.ohse.edu/pathology/POC/procedures/hemecue.html)

The molecular weight of hemoglobin = 64450 g/mol. Hence we can transform the above hemoglobin concentrations into mmol/L (or mM = milli Molar, 1 Molar = 1 mole/L) as

Adult male: 2.1-2.7 mM

Adult female: 1.9-2.3 mM

Children: 1.55-2.2 mM

Rats: ?

The hemoglobin concentration decreases as blood flows from large arteries to the cerebral regions of the brain. The cerebral-to-large vessel hematocrit ratio is 0.69 (Ref: Wyatt et al, 1990, Wyatt, J. S., Cope, M., Delpy, D. T., Richardson, C. E., Edwards, A. D., Wray, S. & Reynolds, E. O. (1990). Quantitation of cerebral blood volume in human infants by near-infrared spectroscopy. *Journal of Applied Physiology* **68**, 1086-1091.)

Hence if the hemoglobin concentration in blood is assumed 2.5mM in large vessels, then the hemoglobin concentration in blood in the cerebral regions of the brain is $2.5 \times 0.69 = 1.725 \text{ mM}$.

When hemoglobin is totally saturated, each hemoglobin molecule carries four oxygen molecules. In the cerebral regions however, the blood in arterioles are not 100%

saturated. It is more likely that the blood saturation (due to hemoglobin) is between 0.7-0.8. Hence if we assume the blood saturation of 0.75, then the *oxygen* concentration in blood in the cerebral regions of the brain would be $C_B=1.725*4*0.75=5.175\text{mM}$.

The Hill equation relates C_B to C_P (oxygen concentration in plasma) as

$$C_B = C_P + \frac{[Hb]PO}{1 + \left(\frac{\alpha P_{50}}{C_P}\right)^h} \quad (1)$$

where

$[Hb]$ = tetra haemoglobin concentration in blood = **1.725** mmol. L⁻¹;

(In Valabregue, this is set to= 150 g/L = 150(g/L)/64.45 (g/mmol) = 2.3 mmol. L⁻¹);

PO = oxyphoric power = 4;

h = Hill coefficient = 2.73;

P_{50} = value of P_{O_2} at which haemoglobin is 50% saturated = 26 mmHg

α = solubility coefficient = $1.39 \times 10^{-3} \text{mmol.L}^{-1} \cdot (\text{mmHg})^{-1}$.

Solving the Hill equation with the above parameters indicates that at $C_B=5.175\text{mM}$, the oxygen concentration (not due to hemoglobin, but due to individual oxygen molecules) in plasma is $C_p=0.053\text{mM}$.

It is known that the oxygen concentration in plasma (almost water) is related to the partial pressure of oxygen P_{O_2} (also known as the oxygen tension) by the coefficient of oxygen solubility in water (α) as

$$C_P = \alpha P_{O_2} \quad (\text{Henry's law})$$

from which we can calculate the partial pressure of oxygen in plasma when $C_p=0.053\text{mM}$. This leads to:

$$P_{O_2} = \frac{C_P}{\alpha} = \frac{0.053}{1.39 \times 10^{-3}} = 38 \text{mmHg}$$

This matches reasonably well to the oxygen dissociation curve which shows that at oxygen saturation (due to hemoglobin) of 0.75, the P_{O_2} is about 40mmHg.

The tissue (which is also largely water) partial pressure is between 5-15mmHg according to Valabregue, or about 16mmHg (median value) according to Hudetz (1999, Brain Research Vol 817 p75-83). Hence the ratio of the oxygen concentration (i.e., g in the OTT model) between the tissue and the plasma at the arterial end of the capillary bed may lie between 0.1 to 0.4. We normally select $g=0.2$.

Calculation of Hbt concentration (at rest) in brain

Again let us assume that the hemoglobin concentration in blood is 2.5mM in large vessels, then the hemoglobin concentration in blood in the cerebral regions of the brain is $2.5 \times 0.69 = 1.725\text{mM}$.

The cerebral tissue density is $1.05 \times 10^3 \text{ g/L}$. (Ref: Sabatini U, Celsis P, Viillard G, Rascol A, Marc-Vergens J-P. (1991) 'Quantitative assessment of cerebral blood volume by single photon emission computed tomography.' Stroke, Vol.22, 324-330.)

The cerebral blood volume:

Average normal CBV:	$3.3 \pm 0.4 \text{ mL/100g (n=7)}$	$= 3.3 \pm 0.4 \times 10^{-5} \text{ L/g}$
Cortical gray matter:	$4.5 \pm 0.6 \text{ mL/100g}$	$= 4.5 \pm 0.6 \times 10^{-5} \text{ L/g}$
White matter:	$2.5 \pm 0.6 \text{ mL/100g}$	$= 2.5 \pm 0.6 \times 10^{-5} \text{ L/g}$
Basal ganglia:	$3.7 \pm 0.4 \text{ mL/100g}$	$= 3.7 \pm 0.4 \times 10^{-5} \text{ L/g}$

(Ref Hamberg L M, Hunter G J, Kierstead D, Lo E H, Gilberto Gonza lez R, Wolf G L. (1996) 'Measurement of cerebral blood volume with subtraction three-dimensional functional CT'. AJNR (American Journal of Neuroradiology?) Vol.17, 1861-1869.)

The blood volume to tissue volume ratio in percentages is given by:
(cerebral blood volume) x (cerebral tissue density) x 100%. Hence

Average normal CBV:	3.47%
Cortical gray matter:	4.73%
White matter:	2.63%
Basal ganglia:	3.89%

Thus the hemoglobin concentration in brain tissue (average) can be calculated from
 $1.725(\text{mM}) \times 3.47\% = 0.06 \text{ mM} = 60 \mu\text{M}$

The hemoglobin concentration in gray matter is given by
 $1.725(\text{mM}) \times 4.73\% = 0.082 \text{ mM} = 82 \mu\text{M}$

We usually use $75 \mu\text{M}$ for baseline Hbt concentration. This seems reasonable.