Hemoglobin and Oxygen Binding

Hemoglobin (Hb) is a transport protein that carries oxygen in the blood. It is necessary because oxygen is not very soluble in water - most part of the blood is water. Each Hb is capable of binding a total of 4 oxygen molecules (one molecule per subunit). The average hemoglobin concentration in the human blood is 0.16 g/ml, which means that in 100 ml of human blood there are about 1.5x10^20 hemoglobin molecules (molecular weight of Hb: 64,000 Da). This yields a total of 6x10^20 oxygen molecules in 100 ml of our blood. But is this number the same everywhere in our body? Where can we find more oxygen molecules? Where are they less concentrated? What is the difference between the number of oxygen molecules in these places?

The functional Magnetic Resonance Imaging (fMRI) provides noninvasive reports of neural activity detected by a blood oxygen level dependent (BOLD) signal. It detects the local reduction in deoxyhemoglobin (dHb), based on the Hb and dHb different magnetic properties. So how good is the detection? How many dHb molecules can the equipment detect?

One property of the oxygen molecule is that it has a positive cooperativity, because the binding of oxygen in the Hb increases its affinity for more oxygen. This happens because of an allosteric activation (the binding of one ligand enhances the attraction between substrate molecules and other binding sites). The binding of oxygen to one subunit induces a conformational change in that subunit that interacts with the remaining active sites to enhance their oxygen affinity. Therefore, the oxygen is both substrate and effector. So we can analyze Hill equation for oxygen binding in Hb and the Hill coefficient.

But there are other factors that alter oxygen binding, such as the pH and the concentration 2,3-diphosphoglycerate (2,3-DPG). The latter is responsible for making it possible that people acclimated to high altitudes can deliver a larger amount of oxygen to tissues under conditions of

lower oxygen tension. How does the concentration of 2,3-DPG in the blood vary with the altitude where someone lives? How exactly does it help on the oxygen delivery?

Regarding the pH, there is the Bohr effect, which can be summarized as the control of Hb's affinity for oxygen by the binding and release of carbon dioxide.

There are other interesting problems. The fetal Hb binds oxygen with greater affinity than adult Hb. So how does this help the fetus get oxygen from the mother? How many oxygen molecules per second does the fetus get from the mother? Is this significant for her?