

Hemoglobin (continued)

1. The Bohr effect describes physiological and molecular responses to changes in pH with respect to oxygen and carbon dioxide in the body. The oxygen effects arise from changes in the tertiary structure of hemoglobin arising from binding of protons to histidines in the molecule when under low pH.
2. Rapidly metabolizing tissues (such as muscle) generate low pHs, due to release of carbon dioxide and the conversion of this to carbonic acid by carbonic anhydrase. Carbonic acid readily loses a proton, becoming bicarbonate.
3. Thus, rapidly metabolizing tissues generate protons, which get absorbed by hemoglobin, which releases oxygen to feed the tissues.
4. CO_2 can also be taken up by hemoglobin at amine residues, causing protons to be released. Note that CO_2 binds hemoglobin at a site other than what oxygen binds. CO, however, can compete with oxygen for binding to the heme.
5. In the lungs, a reversal of this process occurs. Remember that the oxygen concentration in the lungs is high, so oxygen forces off the carbon dioxide and the carried protons from the hemoglobin. Addition of a proton to bicarbonate re-creates carbonic acid, which undergoes the reversal of the earlier carbonic anhydrase reaction, causing CO_2 to be released to the lungs as a gas.
11. Sickle cell anemia is a genetic malady that results in a hemoglobin that polymerizes under low oxygen conditions, causing blood cells to form sickle shapes. These can get stuck in capillaries (painful) and the cells can be removed by the body as possibly damaged, resulting in anemia.
12. Sickle cell anemia appears to provide protection against malaria.

Enzymes

1. Enzymes are proteins that catalyze reactions.
2. Enzymes are capable of speeding reactions quadrillions of times faster than the same reactions would occur in the absence of enzymes.
3. Non-proteinaceous molecules that bind to enzymes and help the enzymes to catalyze reactions are called coenzymes.
4. The Gibbs free energy is the energy available to do useful work in reactions. The change in the Gibbs free energy for a reaction is important because it determines whether a reaction is favored ($\Delta G < 0$), unfavored ($\Delta G > 0$), or at equilibrium ($\Delta G = 0$).
5. Thus, when the Gibbs free energy change is negative, the reaction in question goes forward as written, but when the Gibbs free energy change is positive, the reaction goes in reverse.
6. A related term to ΔG is ΔG° , which is the Standard Gibbs Free Energy change. This refers to the Gibbs Free Energy change for a reaction under standard conditions. Since most reactions

occur at non-standard conditions, ΔG is much more useful than ΔG° . In fact, the sign of ΔG° does NOT tell the direction of a reaction, except under standard conditions.

7. Chemical reactions require activation energy (I'll call it ΔG^+ here) in order to get started.

Catalysts (both enzymes and non-biological catalysts) act by lowering ΔG^+ . Catalysts DO NOT CHANGE ΔG . All they do is lower the energy required to activate the reaction. While enzymes speed reactions immensely, they therefore DO NOT CHANGE THE OVERALL REACTION CONCENTRATION AT EQUILIBRIUM. They simply allow the reaction to get to equilibrium faster.

8. ΔG is affected by the concentration of reactants and products of a reaction by the following equation

$$\Delta G = \Delta G^\circ + RT \ln[\text{Products/Reactants}]$$

Thus, as product concentrations increase, the ΔG will become more positive.

9. If one performs an experiment in which a fixed amount of enzyme is added to 20 different tubes, each containing a different amount of substrate (molecule that the enzyme catalyzes the reaction on) and then lets the reaction in each tube go for a fixed amount of time, one will create varying amounts of product when the tubes are analyzed. The greatest amount of product will be found in the tube which had the greatest amount of substrate. If one measures the concentrations of each product and divides by the time the reaction occurred, one obtains a velocity for each reaction. A plot of the velocity versus the substrate concentration (V versus S) from the experiment looks like the binding curve of myoglobin for oxygen - hyperbolic.

10. Velocity of an enzymatic reaction is measured as the concentration of product formed per time. Maximum velocity (V_{\max}) occurs in a reaction when the enzyme is saturated with substrate. V_{\max} depends on the amount of enzyme used to measure it.

11. In contrast to V_{\max} , K_{cat} is a constant for an enzyme. It is also known as the turnover number and corresponds to the number of molecules of product made per molecule of enzyme per second. 1000/second means 1000 molecules of product per molecule of enzyme per second.