Chapter 7 Problems

Hemoglibin: Portrait of a Protein in Action

1. Screening the biosphere. The first protein structure to have its structure determined was myoglobin from sperm whale. Propose an explanation for the observation that sperm whale muscle is a rich source of this protein.

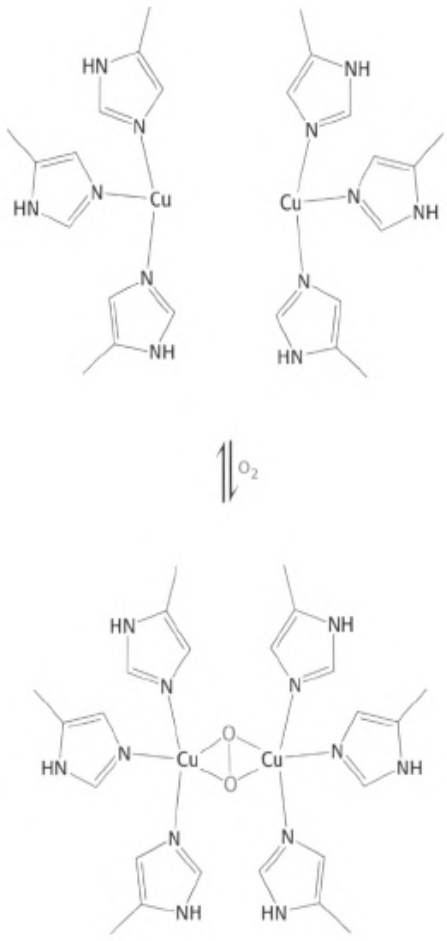
2. Hemoglobin content. The average volume of a red blood cell is 87 μm^3 . The mean concentration of hemoglobin in red cells is 0.34 g ml^{-1} .
(a) What is the weight of the hemoglobin contained in average red cell?
(b) How many hemoglobin molecules are there in an average red cell? Assume that the molecular weight of human hemoglobin tetramer is 65 kd.
(c) Could the hemoglobin concentration in red cells much higher than the observed value? (Hint: Suppose that a red cell contained a crystalline array of hemoglobin molecules in a cubic lattice with 65 Å sides.)

3. Iron content. How much iron is there in the hemoglobin of a 70-kg adult? Assume that the blood volume is *70* ml kg^{-1} of body weight and that the hemoglobin content of blood is 0.16 g ml^{-1} .

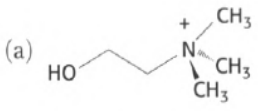
7. Carrying a load. Suppose that you are climbing a high mountain and the oxygen partial pressure in the air is reduced to 75 torr. Estimate the percentage of the oxygencarrying capacity that will be utilized, assuming that the pH of both tissues and lungs is 7.4 and that the oxygen concentration in the tissues is 20 torr.

8. High-altitude adaptation. After spending a day or more at high altitude (with an oxygen partial pressure of *75* torr), the concentration of 2,3-bisphosphoglycerate (2,3-BPG) in red blood cells increases. What effect would an increased concentration of 2,3-BPG have on the oxygen-binding curve for hemoglobin? Why would this adaptation be beneficial for functioning well at high altitude?

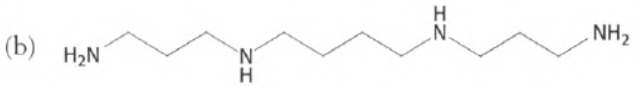
9. I'll take the lobster. Arthropods such as lobsters have oxygen carriers quite different from hemoglobin. The oxygen-binding sites do not contain heme but, instead, are based on two copper(I) ions. The structural changes that accompany oxygen binding are shown below. How might these changes be used to facilitate cooperative oxygen binding?



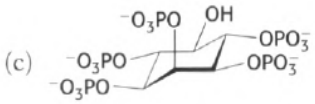
11. Successful substitution. Blood cells from some birds do not contain 2,3-bisphosphoglycerate but, instead, contain one of the compounds in parts *a* through *d,* which plays an analogus functional role. Which compund do you think is most likely to play this role? Explain briefly.



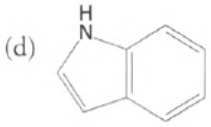
Choline



Spermine



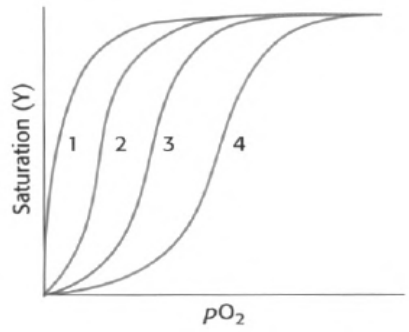
Inositol pentaphosphate



Indole

13. *Parasitic effect.* When *P. falciparum* lives inside red blood cells, the metabolism of the parasite tends to release acid. What effect is the presence of acid likely to have on the oxygen-carrying capacity of the red blood cells? On the likelihood that these cells sickle?

15. Leaning to the left or to the right. The illustration below shows several oxygen-dissociation curves. Assume that curve 3 corresponds to hemoglobin with physiological concentrations of CO_2 and 2,3-BPG at pH 7. Which curves represent each of the following perturbations?



(a) Decrease in CO_2
(b) Increase in 2,3-BPG
(c) Increase in pH
(d) Loss of quaternary

Chapter Integration Problem

16. Location is everything. 2,3-Bisphosphoglycerate lies in central cavity within the hemoglobin tetramer, stabilizing the T state. What would be the effect of mutations that placed the BPG-binding site on the surface of hemoglobin?