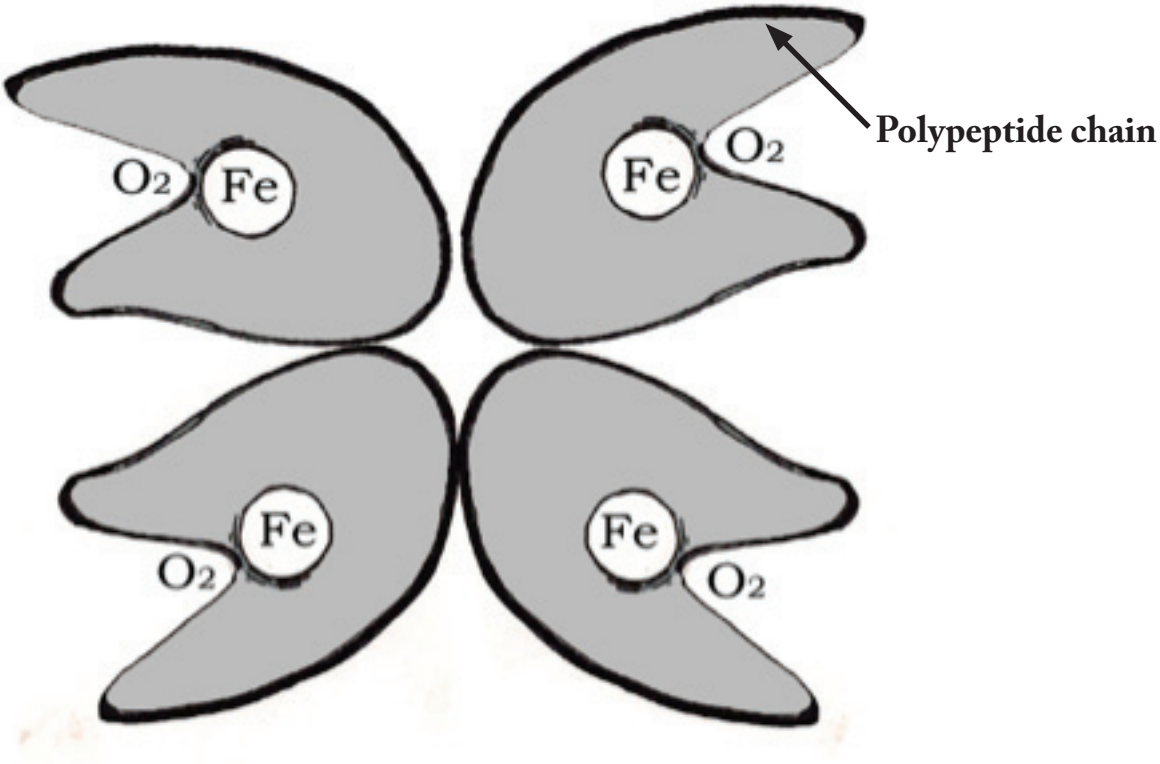
Determinants of Blood Oxygen Content

Model 1: Oxygen Binding to a Single Hemoglobin Molecule

Hemoglobin (Hb) is a large molecule consisting of four peptide chains. Each peptide contains a heme group with an iron in the center. An oxygen molecule has the ability to bind to each heme group under the appropriate conditions. The number of oxygen molecules bound determines its saturation.

Saturated Hemoglobin Molecule



QUESTIONS:

1. When a hemoglobin molecule is completely saturated, how many oxygen molecules are attached?

2. When a hemoglobin molecule is 75% saturated, how many oxygen molecules are attached?

3. Assuming you started with the molecule in Model 1, how many molecules of oxygen would need to be released in order for the hemoglobin to be 75% saturated?

4. The number of oxygen molecules bound to hemoglobin tends to fluctuate up and down. *(Discuss the following questions with your group, and then write your answer)*

   a) Where in the body does oxygen bind to hemoglobin?

   b) Where in the body are oxygen molecules released from hemoglobin?

5. Is it possible for one hemoglobin molecule to be 82% saturated? Why or why not?

6. How many molecules of oxygen are carried on 100 molecules of hemoglobin when all the hemoglobin molecules are completely saturated?

7. If after passing through a capillary bed, those 100 molecules of hemoglobin become 75% saturated with oxygen, how many molecules of oxygen were unloaded (released)?

Model 2: Hemoglobin (Hb) Values and Their Effect on Oxygen Carrying Capacity

Hemoglobin is found in very high numbers within red blood cells, and there are lots of red blood cells in our blood. Because dealing with such large numbers can be challenging, hemoglobin is typically measured by mass and oxygen is measured by volume. The following table provides information about common parameters used in calculating blood oxygen levels.

Parameter	Normal Value
Number of hemoglobin molecules per red blood cell	250 million molecules
Number of red blood cells per deciliter (dL) of blood (There are 10 deciliters in 1 liter of blood)	500 billion cells
Mass of hemoglobin in a deciliter (dL) of blood	15 grams (g)
Amount of oxygen that 1 gram of hemoglobin can hold (carry) when 100% saturated	1.34 milliliters (mL)

QUESTIONS:

8. How many molecules of oxygen can one red blood cell carry?

9. Is it possible for the <u>total hemoglobin</u> inside a red blood cell to be 82% saturated? Explain your answer.

10. Set up a mathematical equation that illustrates how to calculate the number of oxygen molecules that could be carried in 1 dL of blood when it is fully saturated with oxygen (you do not have to solve your calculation):

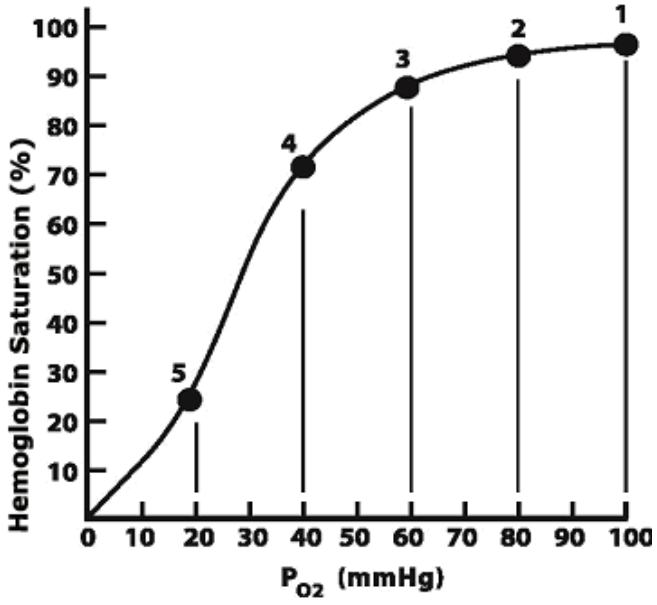
11. Calculate the amount (in mL) of oxygen that could be carried in 1 dL of blood when the hemoglobin is 100% saturated:

12. Calculate the amount (in mL) of oxygen carried in 1 dL of blood when the hemoglobin is 50% saturated:

Model 3: Oxyhemoglobin Dissociation Curve

A major determinant of how much oxygen is found in blood is the saturation of hemoglobin (which determines the amount of "bound" oxygen). This saturation level is mainly determined by the amount of oxygen dissolved in the blood plasma, because the dissolved and bound oxygen are in chemical equilibrium. The amount of dissolved oxygen is indirectly measured as PO_2, the partial pressure of oxygen in plasma. When the PO_2 increases, saturation typically increases as well. This relationship is illustrated by the oxyhemoglobin dissociation curve, as shown below.

Oxyhemoglobin Dissociation Curve



QUESTIONS:

13. What is the label on the X-axis?

14. What are the units specified on the X-axis?

15. What is the label on the Y-axis?

16. What are the units specified on the Y-axis?
17. As partial pressure of oxygen (PO_2) increases, what happens to hemoglobin saturation?

18. At PO_2 of 100 mm Hg, what is the hemoglobin saturation?

19. At PO_2 of 20 mm Hg, what is the hemoglobin saturation?

20. Answer questions a, b, and c assuming the numbered points on the graph in Model 3 represent:

    1: Blood at the distal end of alveolar capillaries in a normal individual.
    2: Blood in the distal end of alveolar capillaries in a person with slightly impaired oxygen exchange in their lungs.
    3: Blood in the middle of a capillary of systemic organs.
    4: Blood at the distal end of a typical (resting) capillary of systemic organs.
    5: Blood at the distal end of a metabolically active (working) capillary.

    a) What is the "distal end" of a capillary?

    b) Where are the distal ends of alveolar capillaries located?

    c) Where might you find the distal end of a metabolically active (working) capillary?

21. Complete the following table. Assume a "normal" individual with a Hb concentration of 15 g/dL. There is space for your calculations after the table.

Vessel	**PO_2 (mmHg)**	**Hb Saturation (%)**	**Oxygen content (mL/dL)**
Pulmonary vein			
Distal end of resting capillaries			
Distal end of working capillaries			
Vena Cava	*40*		
Pulmonary Artery			

22. Using the results of your calculations in Question #21, complete the following table. *(Assume all references to capillaries refer to the distal end of the capillary)*

Relationship	Difference (number)
PO_2 difference between the pulmonary and resting capillaries	
PO_2 difference between the pulmonary and working capillaries	
Oxygen content difference between the pulmonary and resting capillaries	
Oxygen content difference between the pulmonary and working capillaries	

23. When a person exercises, what happens to the oxygen saturation of hemoglobin in capillaries leaving muscle tissue? Discuss with your group and write one answer.

24. Does a change in PO_2 always correspond to a proportional change in oxygen content? Explain why or why not:

Extension Questions:

25. There is an oxygen bar in town where you can pay to breathe air with higher than normal oxygen content. The owners claim it will improve your alertness and ability to function. Using data from the graph in Model 2, discuss with your group whether you think this statement is true or not. Explain your answer in complete sentences below:

26. A person with anemia has a decreased concentration of hemoglobin in the blood.

    a) Would this affect the person's oxyhemoglobin dissociation curve? Explain:

    b) Would it affect their blood oxygen content? Explain:

27. Describe a specific situation or circulatory location that could be represented by point 3 in Model 3: