Transport of Oxygen from the Lungs to the Body Tissues

- Diffusion of Oxygen from the Alveoli to the Pulmonary Capillary Blood

Fig. 40.1 Uptake of oxygen by the pulmonary capillary blood
Physics of Gas Diffusion and Gas Partial Pressure

a. Uptake of oxygen during exercise may increase as much as 20x

b. During non-exercising conditions, the blood almost becomes saturated with oxygen by the time it passes through 1/3 of the pulmonary capillary
Physics of Gas Diffusion and Gas Partial Pressure

- Transport of Oxygen in the Arterial Blood

Fig. 40.2 Changes in the $P_{O_2}$ in the pulmonary capillary blood, systemic arterial blood, and systemic capillary blood, demonstrating the effect of "venous admixture"
Physics of Gas Diffusion and Gas Partial Pressure

• Diffusion of Oxygen from the Peripheral Capillaries into the Tissue Fluid

Fig. 40.3  Diffusion of oxygen from a peripheral tissue capillary to the cells
Physics of Gas Diffusion and Gas Partial Pressure

• Diffusion of Carbon Dioxide from the Peripheral Tissue Cells into the Capillaries and from the Pulmonary Capillaries into the Alveoli

  a. When oxygen is used by the cells, virtually all of it becomes carbon dioxide, and thus increases the intracellular $P_{CO_2}$

  b. Carbon dioxide diffuses about 20x as rapidly as oxygen
Physics of Gas Diffusion and Gas Partial Pressure

c. Carbon dioxide pressures are approximately:

1. Intracellular $P_{CO_2}$, 46 mm Hg; interstitial $P_{CO_2}$, 45 mm Hg

2. $P_{CO_2}$ of the arterial blood entering the tissues, 40 mm Hg; $P_{CO_2}$ of the venous blood leaving the Tissues, 45 mm Hg

3. $P_{CO_2}$ of blood entering the pulmonary capillaries at the arterial end, 45 mm Hg; $P_{CO_2}$ of the alveolar air, 40 mm Hg
Fig. 40.5 Uptake of carbon dioxide by the blood in the tissue capillaries
Fig. 40.6 Diffusion of carbon dioxide from the pulmonary blood into the alveolus.
Physics (cont.)

- **Effect of Rate of Tissue Metabolism and Tissue Blood Flow on Interstitial $P_{CO_2}$**

Fig. 40.7 Effect of blood flow and metabolic rate on peripheral tissue $P_{CO_2}$
• **Role of Hb in Oxygen Transport** - normally 97% of the oxygen transported from the lungs is bound to hemoglobin

• **Reversible Combination of Oxygen with Hb** - dependent on concentration differences

• **Oxygen-Hemoglobin Dissociation Curve**
Physics (cont.)

Fig. 40.8 Oxygen-hemoglobin dissociation curve
Physics (cont.)

a. Usual oxygen saturation of systemic arterial blood is 97%

b. Normal venous blood, the oxygen saturation of Hb is 75%
Physics (cont.)

- **Maximum Amount of Oxygen That Can Combine with Hemoglobin**— usually expressed as volume per cent of oxygen (Fig. 40.8)

- **Amount of Oxygen Released from Hb When Systemic Arterial Blood Flows Through Tissues**— reduced from 19.4 ml (97%) to 14.4 ml
Transport of Oxygen During Strenuous Exercise

Fig. 40.9  Effect of blood $P_{O_2}$ on the quantity of oxygen bound with Hb /$100$ ml blood
Physics (cont.)

- **Utilization Coefficient** - % of blood that gives up oxygen as it passes through the tissue capillaries
  
a. Normal value is about 25%

b. During strenuous exercise it may increase to 75-85%
Physics (cont.)

- **Effect of Hb to “Buffer” the Tissue $P_{O_2}$; the Role of Hb in Maintaining Constant $P_{O_2}$ to the Tissues**
  
a. Under basal conditions, the tissue requires 5 ml oxygen/100 ml of blood; $P_{O_2}$ must be $<40$ mmHg
  
b. Cannot rise above 40 mm pressure, the oxygen needed would not be released by the Hb
  
c. During exercise, the extra oxygen needed can be delivered by (1) steep slope of dissociation curve, and (2) increased blood flow
  
d. Also remains constant when atmospheric oxygen content changes
• Factors That Shift the Oxygen-Hb Dissociation Curve
  a. pH; acidic it shifts to the right and if basic, it shifts to the left
  b. Increased carbon dioxide concentration
  c. Increased blood temperature
  d. Increased BPG (2,3 biphosphoglycerate), metabolic compound found in the blood
Shift to right:
(1) Increased hydrogen ions
(2) Increased CO₂
(3) Increased temperature
(4) Increased BPG
• **Bohr Effect** - a shift of the dissociation curve to the right due to increased CO$_2$ and H ions enhances the release of oxygen from the blood into the tissues and enhances the oxygenation of the blood in the lungs.

As blood passes through the tissues, carbon dioxide diffuses from the tissue cells into the blood. This increases $P_{CO_2}$ which in turn raises the blood H$_2$CO$_3$ (carbonic acid) and the hydrogen ion concentration.

This forces oxygen away from Hb and delivers increased amounts to the tissues.
• **Bohr Effect (cont.)**

  Exactly the opposite happens in the lungs

• **Metabolic Use of Oxygen by the Cells**

  a. **Effect of intracellular P_{O_2}** on the rate of oxygen usage

  b. **Effect of diffusion distance from the capillary to the Cell on oxygen usage**

  c. **Effect of blood flow on the metabolic use of oxygen**
Fig. 40.11  Effect of intracellular ADP and $P_{O_2}$ on the rate of oxygen usage by the cells
Transport of Carbon Dioxide in the Blood

- **Chemical Forms in Which CO₂ is Transported**

![Diagram of CO₂ transport in blood](image)

CO₂ transported as:
1. CO₂ = 7%
2. Hgb • CO₂ = 23%
3. HCO₃⁻ = 70%

Fig. 40.13 Transport of carbon dioxide in the blood
Transport of Carbon Dioxide in the Blood

a. Transport of carbon dioxide in the dissolved state—normally about 7% of the total

b. Transport in the form of the bicarbonate ion—(70%)

1. Reaction of carbon dioxide with water in the RBCs—effect of carbonic anhydrase

2. Dissociation of carbonic acid into bicarbonate and hydrogen ions; also involves the “chloride shift”
Transport of Carbon Dioxide in the Blood

c. Transport in combination with Hb and plasma proteins-carbaminohemoglobin (25-30%)
Transport of Carbon Dioxide in the Blood

- **Carbon Dioxide Dissociation Curve**

![Carbon dioxide dissociation curve](image)
Transport of Carbon Dioxide in the Blood

• When Oxygen Binds with Hb, Carbon Dioxide is Released to Increase CO$_2$ (Haldane Effect)
  a. Binding of oxygen with Hb tends to displace carbon dioxide from the blood (more important than the Bohr Effect)
  b. Oxygen plus Hb in the lungs causes Hb to become a stronger acid
Transport of Carbon Dioxide in the Blood

Fig. 40.15
Transport of Carbon Dioxide in the Blood

- **Respiratory Exchange Ratio**: ratio of carbon dioxide output to oxygen uptake

\[ R = \frac{\text{Rate of carbon dioxide output}}{\text{Rate of oxygen uptake}} \]