HUMAN PHYSIOLOGY AND CLINICAL BIOCHEMISTRY

Topic: Respiration

Lecture 4

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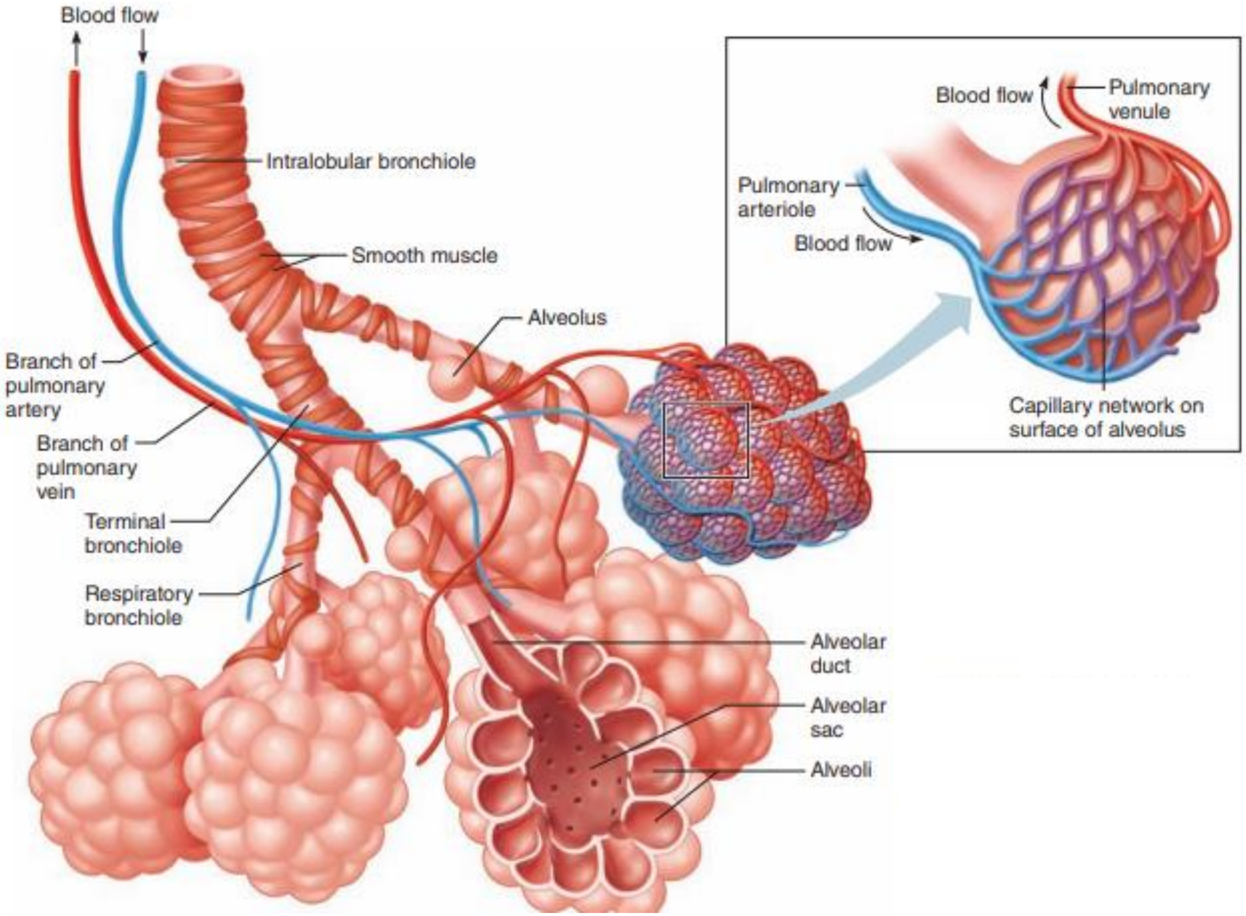
REFERENCE: OPEN ACCESS



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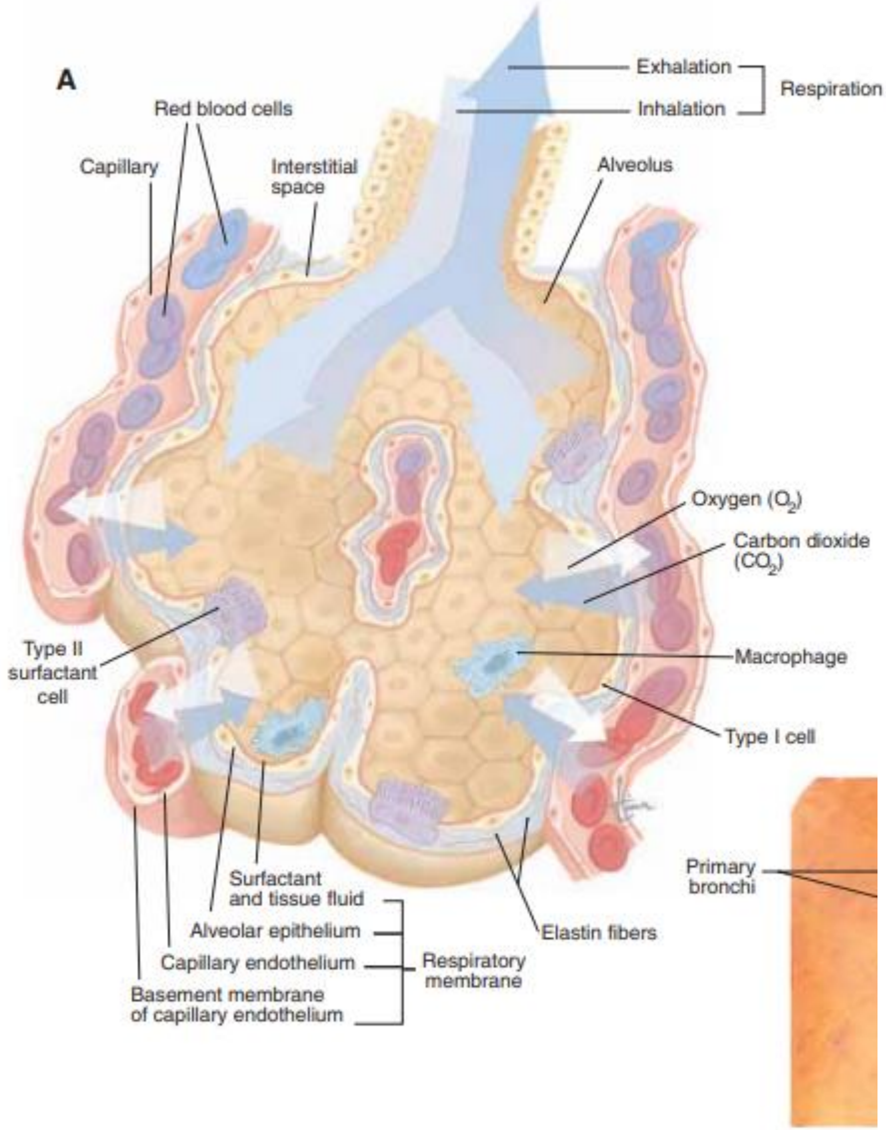

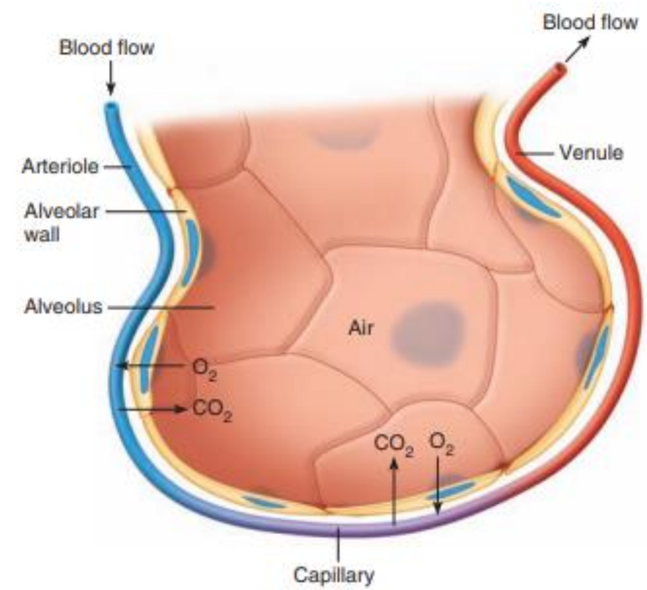

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Alveolar Gas Exchanges

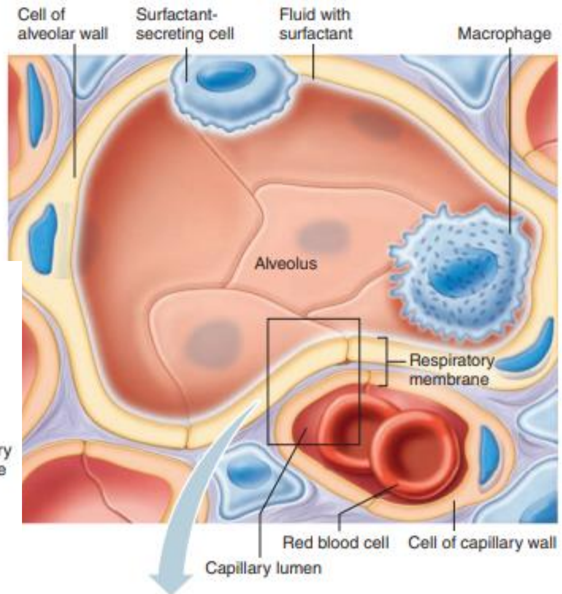
The tubelike parts of the respiratory system move air in and out of the air passages. The alveoli are the sites of the vital process of gas exchange between the air and the blood.

Respiratory Membrane

Part of the wall of an alveolus is made up of cells (type II cells) that secrete pulmonary surfactant, described earlier. However, the bulk of the wall of an alveolus consists of a layer of simple squamous epithelium (type I cells).

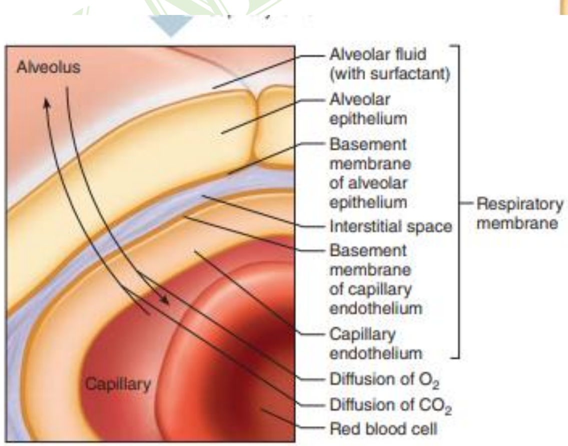
Each alveolus is associated with a dense network of capillaries with walls of simple squamous epithelial cells

Thin basement membranes separate the walls of the alveoli from the walls of the capillaries, and in the spaces between them elastic and collagen fibers help support the alveolar walls.



Thus, two thicknesses of epithelial cells and basement membranes separate the air in an alveolus and the blood in a capillary.

These layers make up the respiratory membrane (alveolarcapillary membrane), through which gas exchange occurs between the alveolar air and the blood



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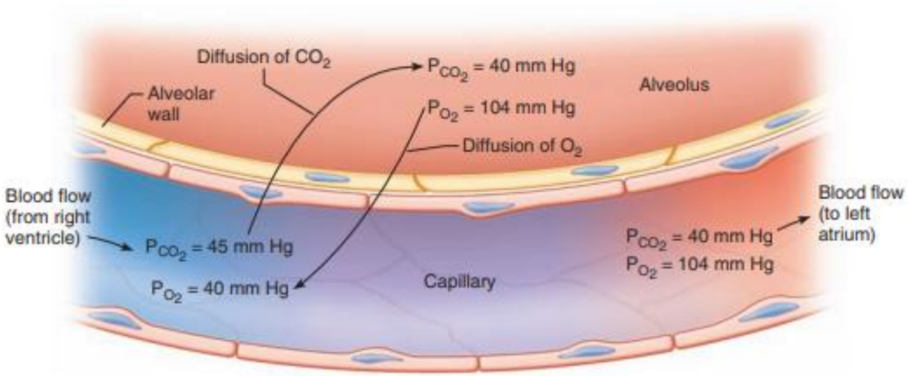
Diffusion Through The Respiratory Membrane



The respiratory membrane is normally so thin that certain soluble chemicals other than CO2 may diffuse into alveolar air and be exhaled. This is why breath analysis can reveal alcohol in the blood or acetone can be smelled on the breath of a person who has untreated diabetes mellitus. Breath analysis may also detect substances associated with kidney failure, certain digestive disturbances, and liver disease.

Gas Transport

- The blood carries oxygen and carbon dioxide between the lungs and the body cells.
- As these gases enter the blood, they dissolve in the liquid portion, the plasma, or combine chemically with other atoms or molecules.
- Oxygen Transport Almost all the oxygen (over 98%) is carried in the blood bound to the protein hemoglobin in red blood cells.
- The oxygen bound to iron in hemoglobin provides the color of these blood cells.
- The remainder of the oxygen is dissolved in the blood plasma.
- **Hemoglobin** consists of two types of components called heme and globin
- Globin is a protein of 574 amino acids in four polypeptide chains.
- Each chain is associated with a heme group, and each heme group surrounds an atom of iron.
- Each iron atom can loosely bind an oxygen molecule.
- As oxygen dissolves in blood, it rapidly combines with hemoglobin, forming a new compound called oxyhemoglobin
- Each hemoglobin molecule can bind up to four oxygen molecules.

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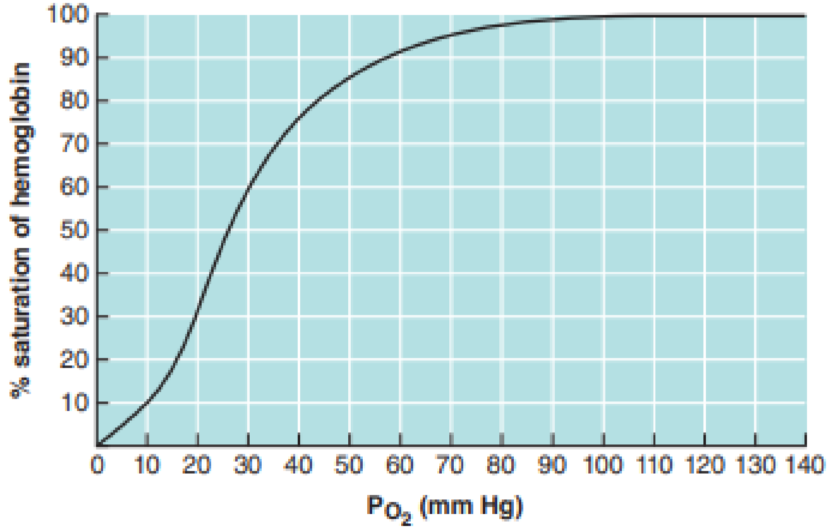
- The PO2 determines the amount of oxygen that hemoglobin binds.
- The greater the PO2 , the more oxygen binds until the hemoglobin molecules are completely loaded with oxygen, or saturated
- At normal arterial PO2 (95 mm Hg), hemoglobin is essentially completely saturated.
- As the PO2 decreases, oxyhemoglobin releases oxygen molecules



Oxyhemoglobin dissociation at 38°C

Hemoglobin is completely saturated at normal systemic arterial PO2 but readily releases oxygen at the PO2 of the body tissues.

- This happens in tissues in which cells have used oxygen in respiration
- The free oxygen diffuses from the blood into nearby cells,
- Increasing the blood level of carbon dioxide (PCO2), acidity, and temperature all increase the amount of oxygen that oxyhemoglobin releases
- These influences help release more oxygen from the blood to the skeletal muscles during exercise.

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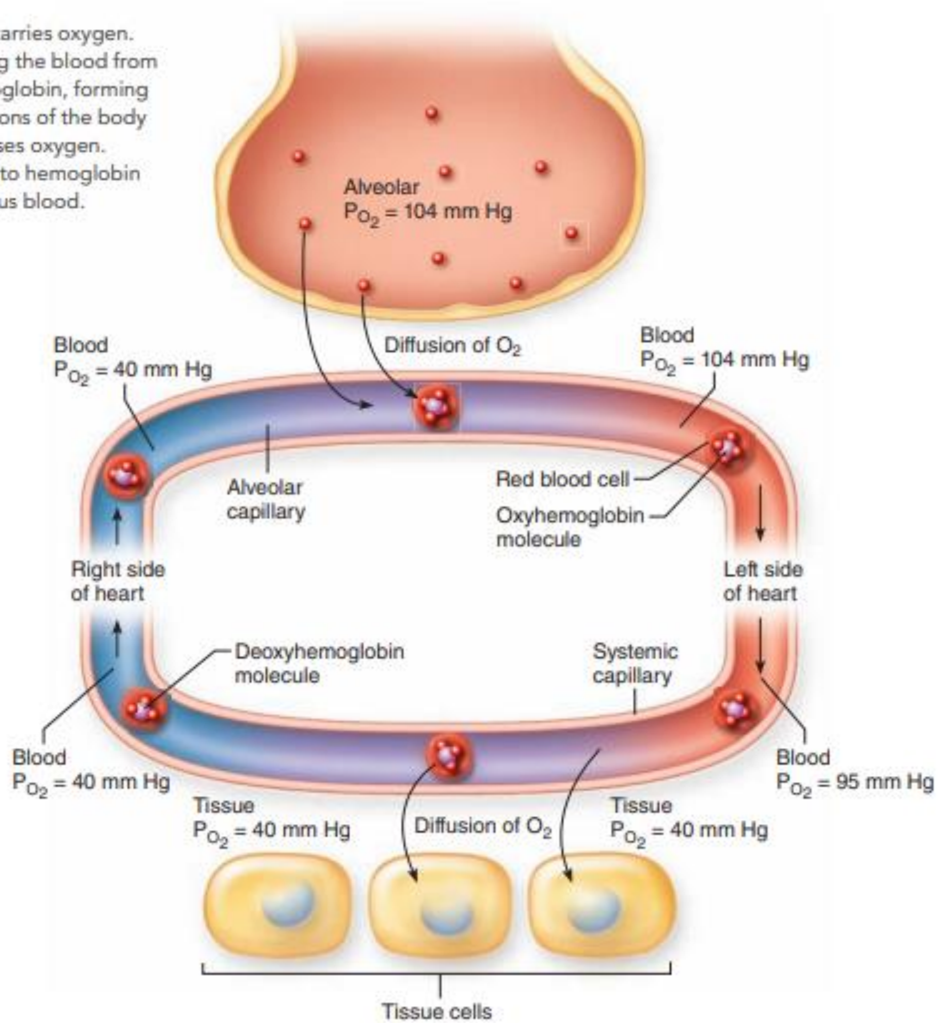
Blood carries oxygen.
Oxygen molecules, entering the blood from the alveolus, bond to hemoglobin, forming oxyhemoglobin. In the regions of the body cells, oxyhemoglobin releases oxygen. Much oxygen is still bound to hemoglobin at the P_{O_2} of systemic venous blood.



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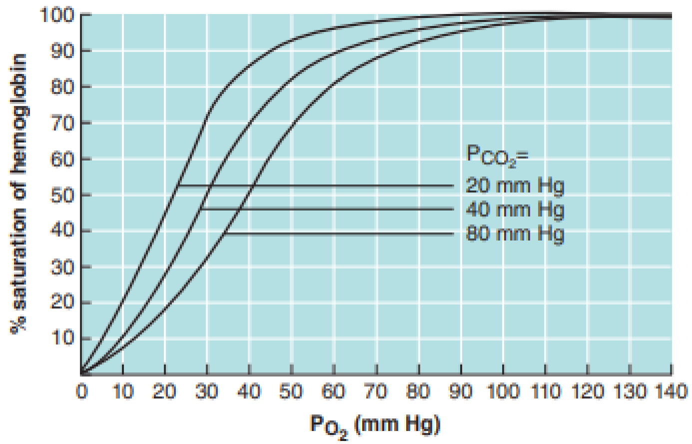
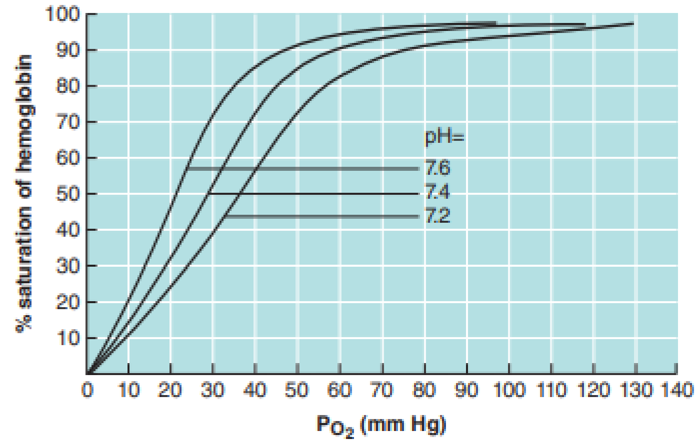


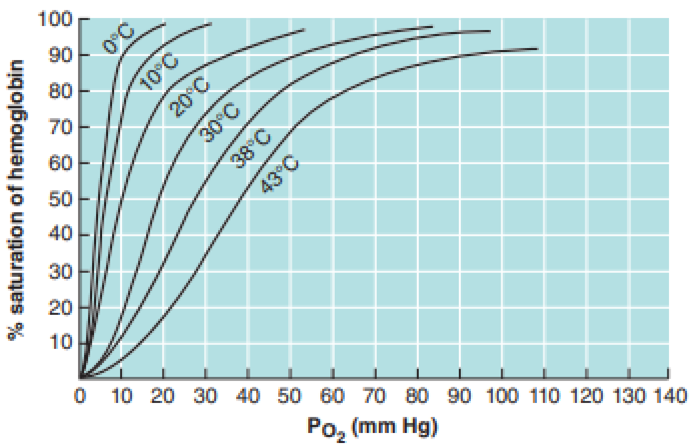
Oxyhemoglobin dissociation at 38°C

The amount of oxygen released from oxyhemoglobin increases as the P_{CO_2} increases.



Oxyhemoglobin dissociation at 38°C

The amount of oxygen released from oxyhemoglobin increases as the blood pH decreases.



Oxyhemoglobin dissociation at various temperatures

'he amount of oxygen released from oxyhemoglobin increases as the blood temperature increases.

Unlike oxygen, which binds the iron atoms of hemoglobin molecules, carbon dioxide bonds with the amino groups (—NH2) of these molecules.

Consequently, oxygen and carbon dioxide do not directly compete for binding sites—a hemoglobin molecule can transport both gases at the same time.

Carbon dioxide binding hemoglobin forms a loosely bound compound called carbaminohemoglobin

This molecule readily decomposes in regions where the pCO2 is low, releasing its carbon dioxide

Although this method of transporting carbon dioxide is theoretically quite effective, carbaminohemoglobin forms relatively slowly

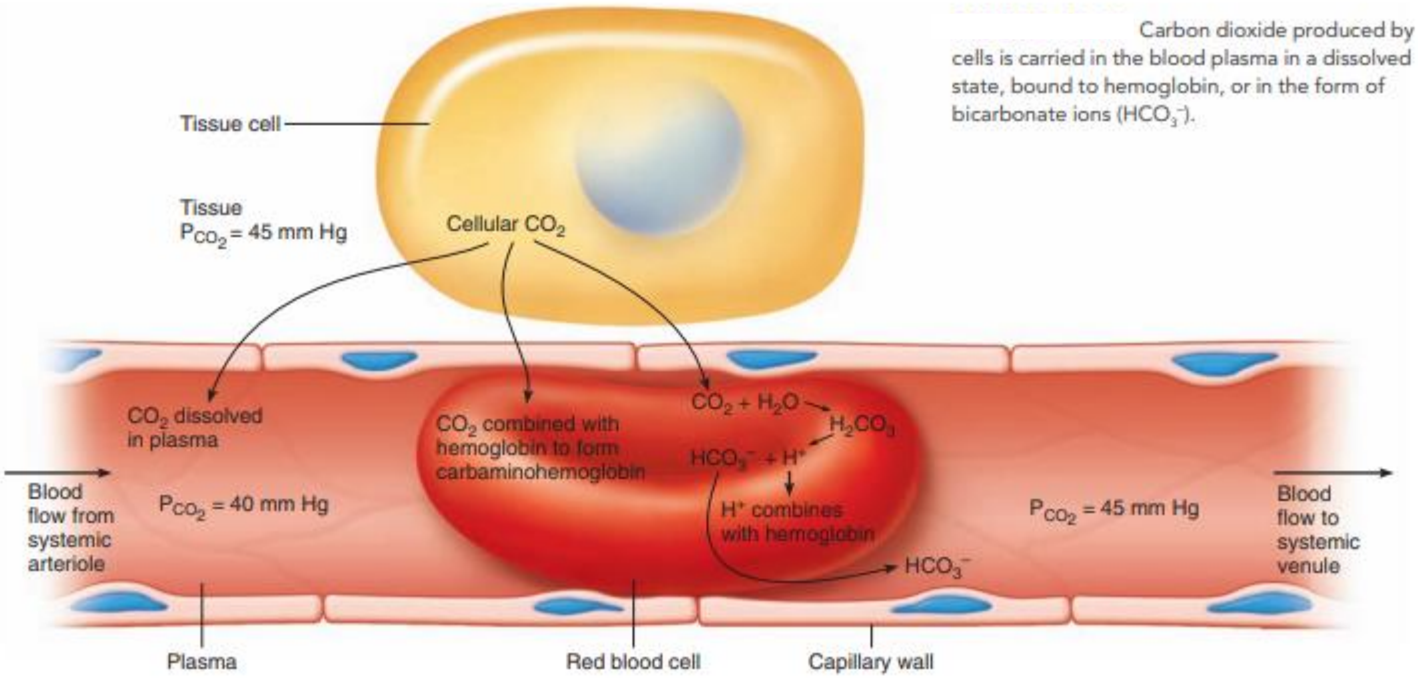
About 15% to 25% of the CO2 that enters the blood is carried this way

In the most important CO2 transport mechanism bicarbonate ions (HCO3 –) form

- This reaction occurs slowly in the blood plasma, but much of the CO2 diffuses into the red blood cells.
- These cells contain an enzyme, **carbonic anhydrase** which speeds the reaction between CO2 and water. The resulting carbonic acid dissociates almost immediately, releasing hydrogen ions (H+) and bicarbonate ions (HCO3 –):

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

- This is the reverse of the reaction described above. Carbonic anhydrase catalyzes this reaction in either direction, depending on the levels of CO2 and H+ . Carbaminohemoglobin also releases its CO2 , and both of these events contribute to the PCO2 of the alveolar capillary blood.
- CO2 diffuses out of the blood until an equilibrium is established between the PCO2 of the blood and the PCO2 of the alveolar air.



Carbon dioxide produced by cells is carried in the blood plasma in a dissolved state, bound to hemoglobin, or in the form of bicarbonate ions (HCO_3^-).

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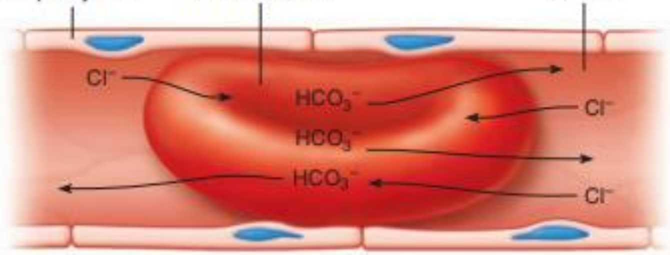
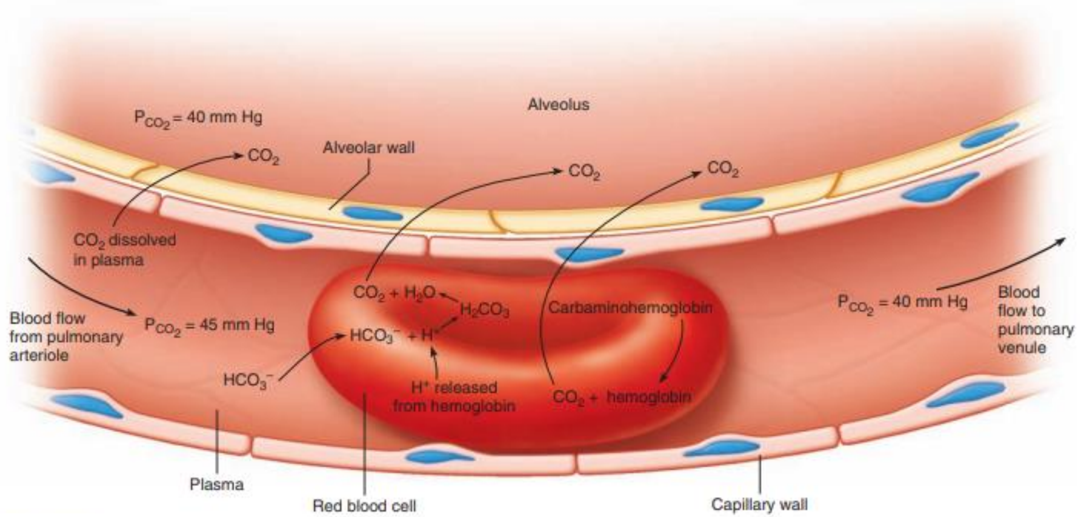


As bicarbonate ions (HCO_3^-) diffuse out of the red blood cell, chloride ions (Cl^-) from the plasma diffuse into the cell, maintaining the electrical balance between ions. This exchange of ions is called the chloride shift.



In the lungs, carbon dioxide diffuses from the blood into the alveoli.