

# CARBON DIOXIDE TRANSPORT

Carbon dioxide also relies on the blood for transportation. It is a critical physiological process, as CO<sub>2</sub> is a waste product of cellular metabolism. Efficient removal of CO<sub>2</sub> from tissues to the lungs, where it can be exhaled, is essential for maintaining acid-base balance and overall homeostasis in the body.

## Mechanisms of CO<sub>2</sub> Transport

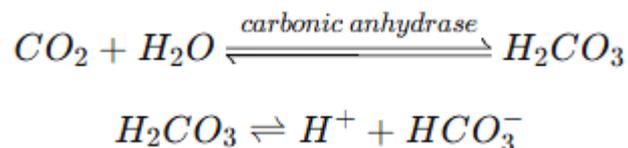
Once carbon dioxide is released from the cells, it is carried in the blood primarily in three forms:

- As bicarbonate ions resulting from the dissociation of carbonic acid
- Dissolved in plasma
- Bound to hemoglobin (called carbaminohemoglobin)

### 1. Bicarbonate Ion Formation

The majority (about 60-70%) of CO<sub>2</sub> is transported in the blood as bicarbonate (HCO<sub>3</sub><sup>-</sup>). This occurs through a series of reactions that involve the enzyme carbonic anhydrase:

- **CO<sub>2</sub> diffuses into red blood cells** from the tissues, where it reacts with water (H<sub>2</sub>O) in the presence of the enzyme carbonic anhydrase to form carbonic acid (H<sub>2</sub>CO<sub>3</sub>).
- **Carbonic acid** is unstable and quickly dissociates, freeing a hydrogen ion (H<sup>+</sup>) and forming a bicarbonate ion (HCO<sub>3</sub><sup>-</sup>). The reaction is as follows:

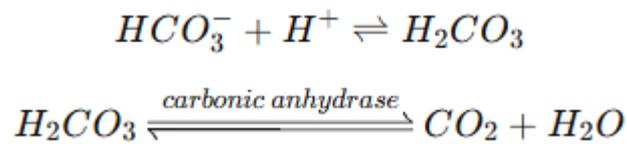


### Exchange of Chloride Ions:

- To maintain electrical neutrality in the red blood cell, bicarbonate (HCO<sub>3</sub><sup>-</sup>) ions are transported out of the RBC into the plasma.
- For each bicarbonate ion (HCO<sub>3</sub><sup>-</sup>) that exits the red blood cell, a chloride ion (Cl<sup>-</sup>) moves into the RBC from the plasma. This exchange occurs via a **chloride-bicarbonate exchanger** (also known as the **anion exchanger**).
- This process helps maintain the **electrical neutrality** of the red blood cell as the negatively charged bicarbonate ions leave the cell and are replaced by chloride ions from the plasma.
- This exchange is referred as the **chloride shift** (also called the **Hamburger phenomenon**).

### **In the lungs, the reverse process occurs:**

- Bicarbonate ions are transported back into red blood cells in exchange for chloride ions.
- Bicarbonate then reacts with hydrogen ions to form carbonic acid, which is rapidly converted back to CO<sub>2</sub> and water by carbonic anhydrase.
- The CO<sub>2</sub> is then released from the red blood cells and diffuses into the alveolar airspaces, where it is expelled during exhalation.



## **2. Dissolved CO<sub>2</sub> in Plasma**

Part of the carbon dioxide released from the tissues is dissolved in plasma; but only a small amount, typically just 7% to 10%, is transported this way. This dissolved carbon dioxide comes out of solution where the PCO<sub>2</sub> is low, as in the lungs. There it diffuses from the pulmonary capillaries into the alveoli to be exhaled.

## **3. Carbaminohemoglobin**

Carbon dioxide transport also can occur when the gas binds with hemoglobin, forming carbaminohemoglobin. The compound is so named because carbon dioxide binds with amino acids in the globin part of the hemoglobin molecule, rather than with the heme group as oxygen does. Because carbon dioxide binding occurs on a different part of the hemoglobin molecule than does oxygen binding, the two processes do not compete. However, carbon dioxide binding varies with the oxygenation of the hemoglobin (deoxyhemoglobin binds carbon dioxide more easily than oxyhemoglobin) and the partial pressure of CO<sub>2</sub>, a phenomenon known as the **Haldane effect**. Carbon dioxide is released from hemoglobin when PCO<sub>2</sub> is low as it is in the lungs. Thus, carbon dioxide is readily released from the hemoglobin in the lungs, allowing it to enter the alveoli to be exhaled.

## **Carbon Dioxide removal**

Carbon dioxide exits the cells by simple diffusion in response to the partial pressure gradient between the tissue and the capillary blood. For example, muscles generate carbon dioxide through oxidative metabolism, so the PCO<sub>2</sub> in muscles is relatively high compared with that in the capillary blood. Consequently, CO<sub>2</sub> diffuses out of the muscles and into the blood to be transported to the lungs.

## **Physiological Relevance of CO<sub>2</sub> Transport**

The transport of CO<sub>2</sub> is crucial for several physiological reasons:

- **Acid-Base Balance:** The formation of bicarbonate (HCO<sub>3</sub><sup>-</sup>) helps to buffer blood pH. The reaction between CO<sub>2</sub> and water, leading to the production of carbonic acid,

influences the pH of the blood. If CO<sub>2</sub> levels rise (e.g., during exercise), more H<sup>+</sup> ions are produced, lowering pH (acidosis), and if CO<sub>2</sub> levels fall, pH rises (alkalosis).

- **Efficient Gas Exchange:** The Haldane effect ensures that hemoglobin can pick up CO<sub>2</sub> more efficiently in tissues where oxygen is being released and expel it in the lungs where oxygen binds more effectively.
- **Oxygen Delivery:** The Bohr effect enhances the delivery of oxygen to tissues by promoting oxygen release when CO<sub>2</sub> levels are high (as seen in metabolically active tissues).

## References:

1. Guyton, A. C., & Hall, J. E. (2016). *Textbook of Medical Physiology* (13th ed.). Elsevier.
2. West, J. B. (2012). *Respiratory Physiology: The Essentials* (9th ed.). Lippincott Williams & Wilkins.
3. Berkowitz, A. (2018). *Human Physiology: An Integrated Approach* (9th ed.). Pearson Education.
4. Forster, H. V., & Dempsey, J. A. (2019). "The Transport of CO<sub>2</sub>." In *Handbook of Physiology: Environmental Physiology* (Vol. 2, pp. 529-561). Academic Press.