MEDICAL EDUCATION RESOURCE

Ventilation and Perfusion in Lungs

Ventilation and Perfusion in Lungs: Diffusion

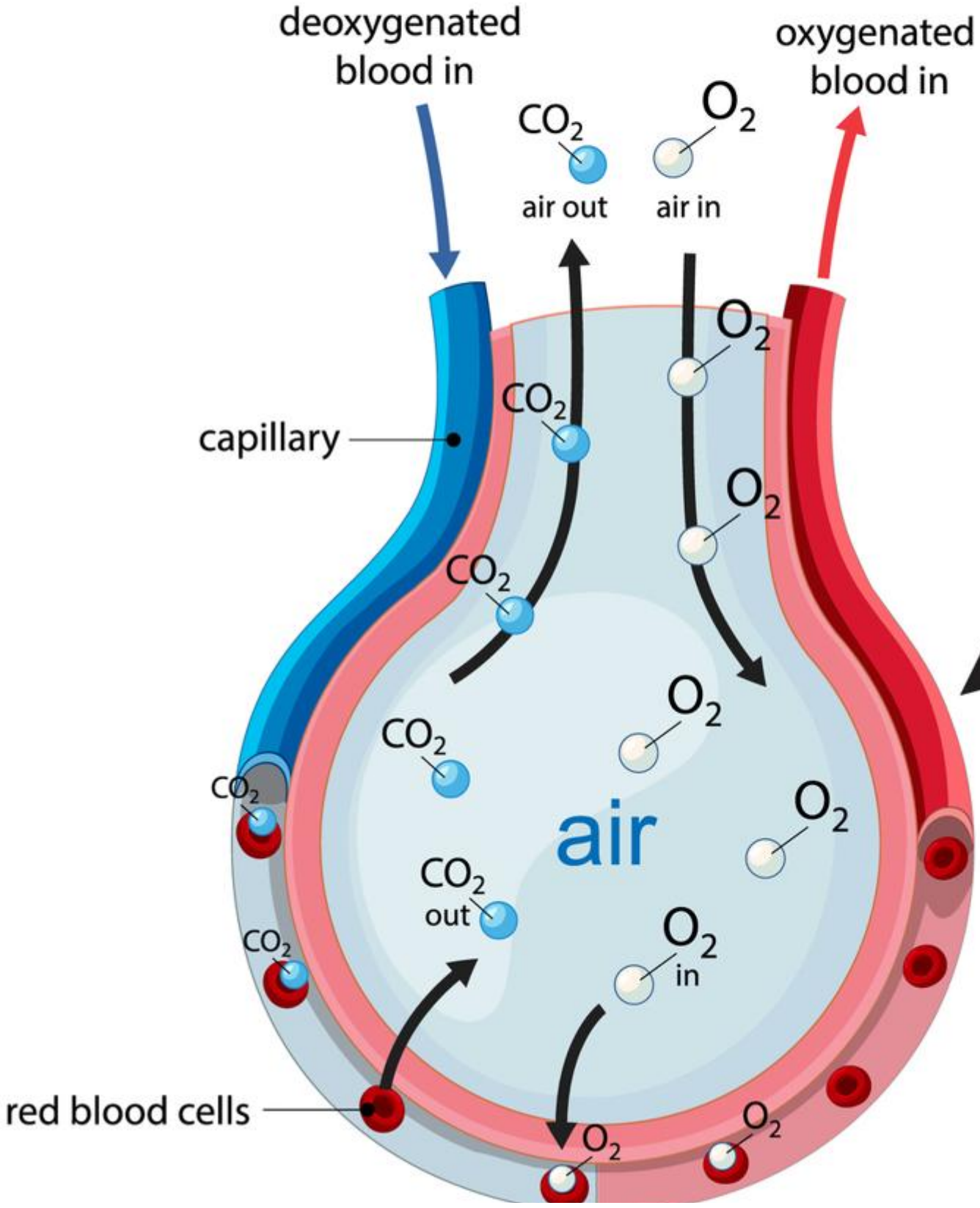
Introduction

• Gas exchange in lungs occurs by diffusion across the respiratory membrane
• Oxygen diffuses from alveoli into pulmonary capillary blood
• Carbon dioxide diffuses from blood into alveoli
• Efficient gas exchange requires proper matching of ventilation and perfusion
• Important for maintaining normal oxygenation of blood

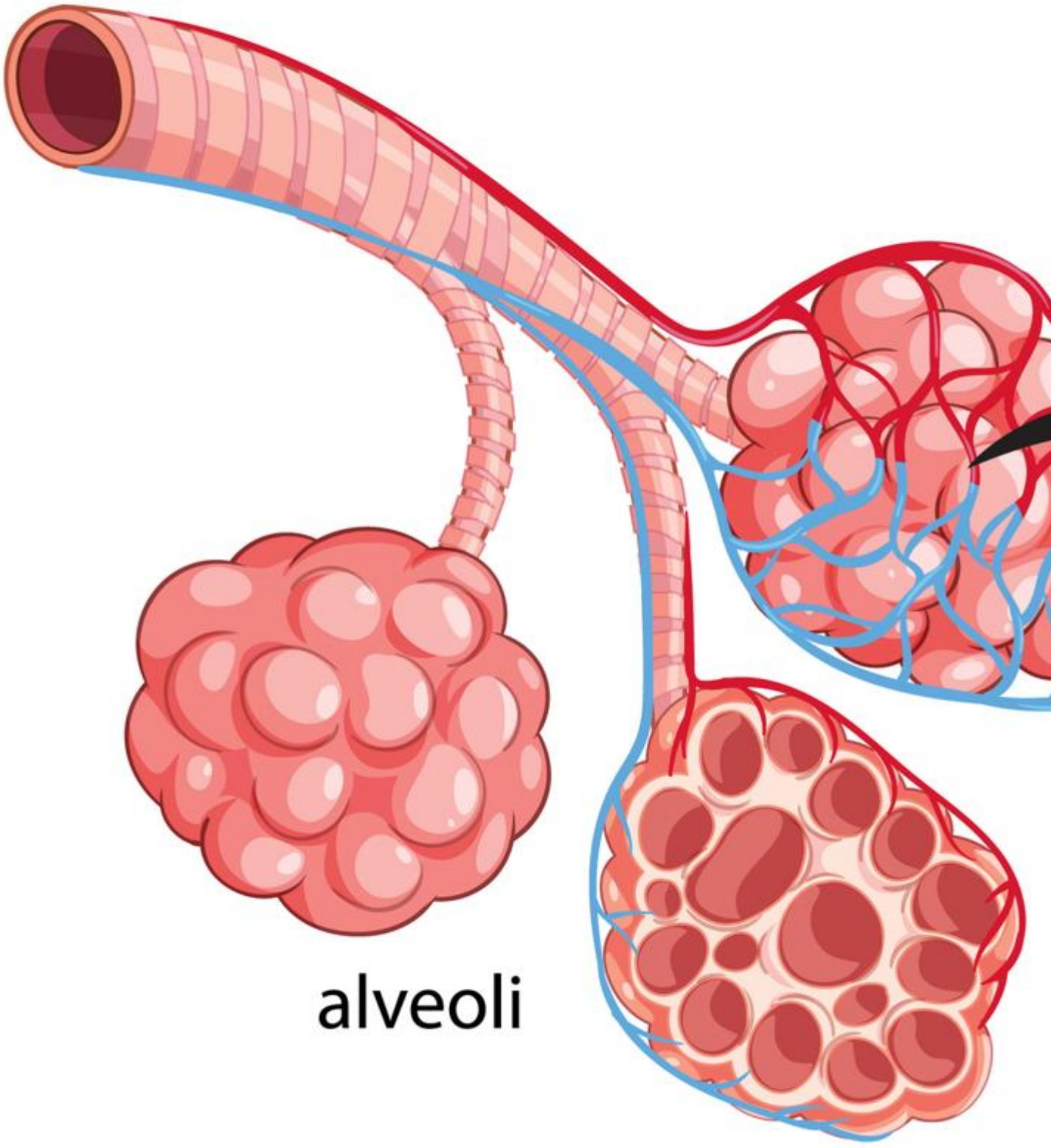
Diffusion Across the Respiratory Membrane


Air in/out

Alveo


deoxygenated blood in
oxygenated blood in
CO_2
air out
O_2
air in
capillary
air
CO_2 out
O_2 in
red blood cells

Alveolus Ga



• **Process of diffusion in lungs**
• Diffusion refers to the **movement of gases from an area of higher partial pressure to lower partial pressure**

• **Oxygen diffusion**
• Oxygen moves from **alveolar air (higher PO?) ? pulmonary capillary blood (lower PO?)**.

• **Carbon dioxide diffusion**
• Carbon dioxide moves from **blood (higher PCO?) ? alveoli (lower PCO?)**.

• **Respiratory membrane**
• Diffusion occurs across a very thin membrane consisting of:
• Alveolar epithelium
• Interstitial space
• Capillary endothelium

• **Importance of ventilation–perfusion matching**
• Effective gas exchange requires **adequate air reaching alveoli and adequate blood flow in pulmonary capillaries**

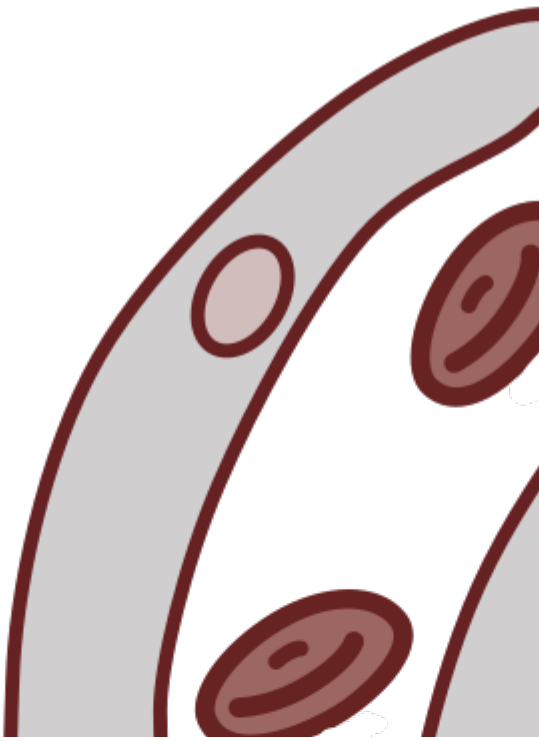
The respiratory membrane is astonishingly thin—about **0.5 micrometers**. Nature essentially stretched a delicate film between air and blood to make diffusion extremely efficient.

Factors Controlling Diffusion

• Several physical and physiological factors determine the rate of gas diffusion in lungs

Factors Affecting Diffusion of Gases


Air in/out



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• **Partial pressure gradient**
• Diffusion rate depends on the **difference in partial pressure of gases between alveoli and blood**.

• **Surface area of respiratory membrane**
• Larger surface area increases diffusion.
• Human lungs provide about **70–100 square meters of exchange surface**.

• **Thickness of respiratory membrane**
• Diffusion decreases if membrane thickness increases.
• Seen in diseases like **pulmonary fibrosis and pulmonary edema**.

• **Solubility of gases**
• Carbon dioxide diffuses **about 20 times faster than oxygen** because of greater solubility.

• **Molecular weight of gases**
• Diffusion rate is inversely proportional to the **square root of molecular weight**.

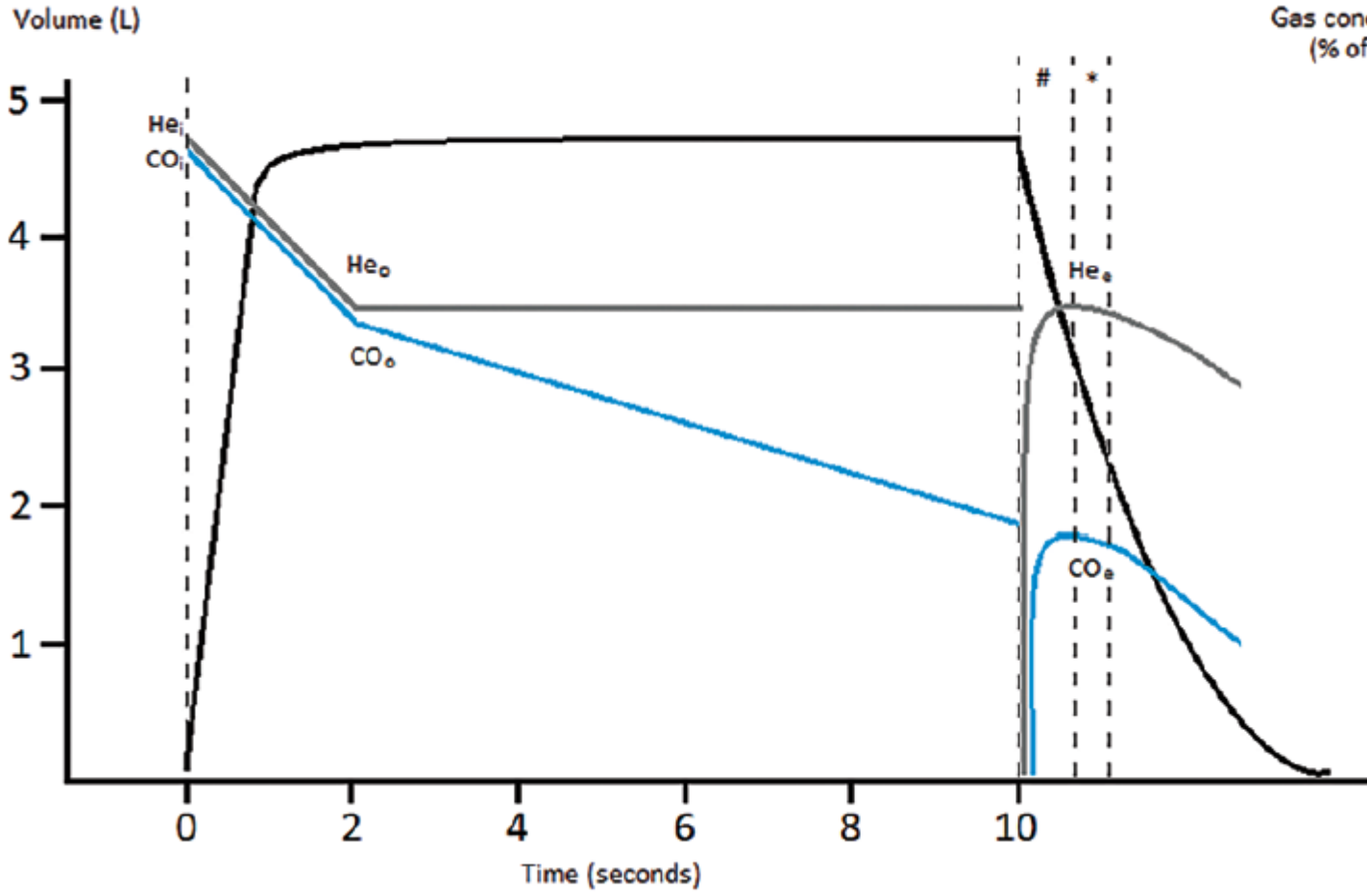
This relationship is summarized by **Fick's law of diffusion**, which governs how gases move across membranes.

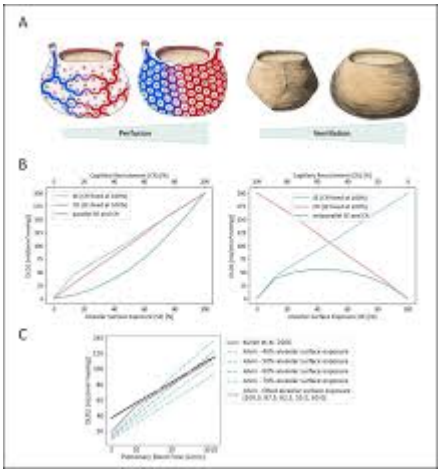
Pulmonary Diffusing Capacity for O?

• Measure of efficiency of lungs in transferring oxygen from alveoli to blood
• Reflects functional status of respiratory membrane

Pulmonary Diffusing Capacity


Air in/out





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• **Definition**

• Pulmonary diffusing capacity refers to the **volume of oxygen that diffuses through the respiratory membrane per minute**

for each mmHg difference in pressure.

• **Normal diffusing capacity**
• Diffusing capacity of oxygen at rest is approximately **20–25 mL/min/mmHg**.

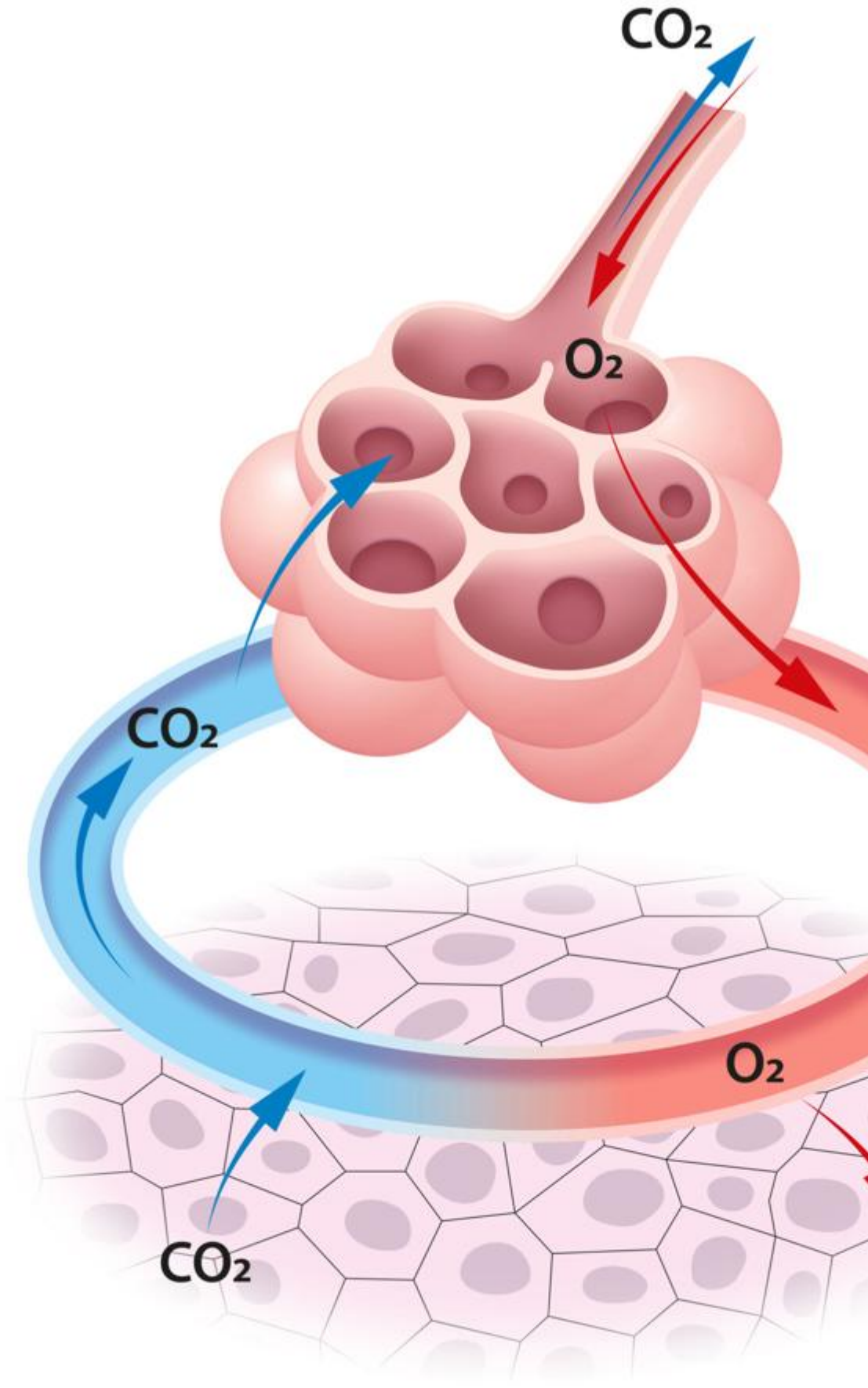
• **Factors influencing diffusing capacity**
• Surface area of alveoli
• Thickness of respiratory membrane
• Pulmonary blood flow
• Hemoglobin concentration

• **Clinical significance**
• Diffusing capacity decreases in:
• Pulmonary fibrosis
• Emphysema
• Pulmonary edema

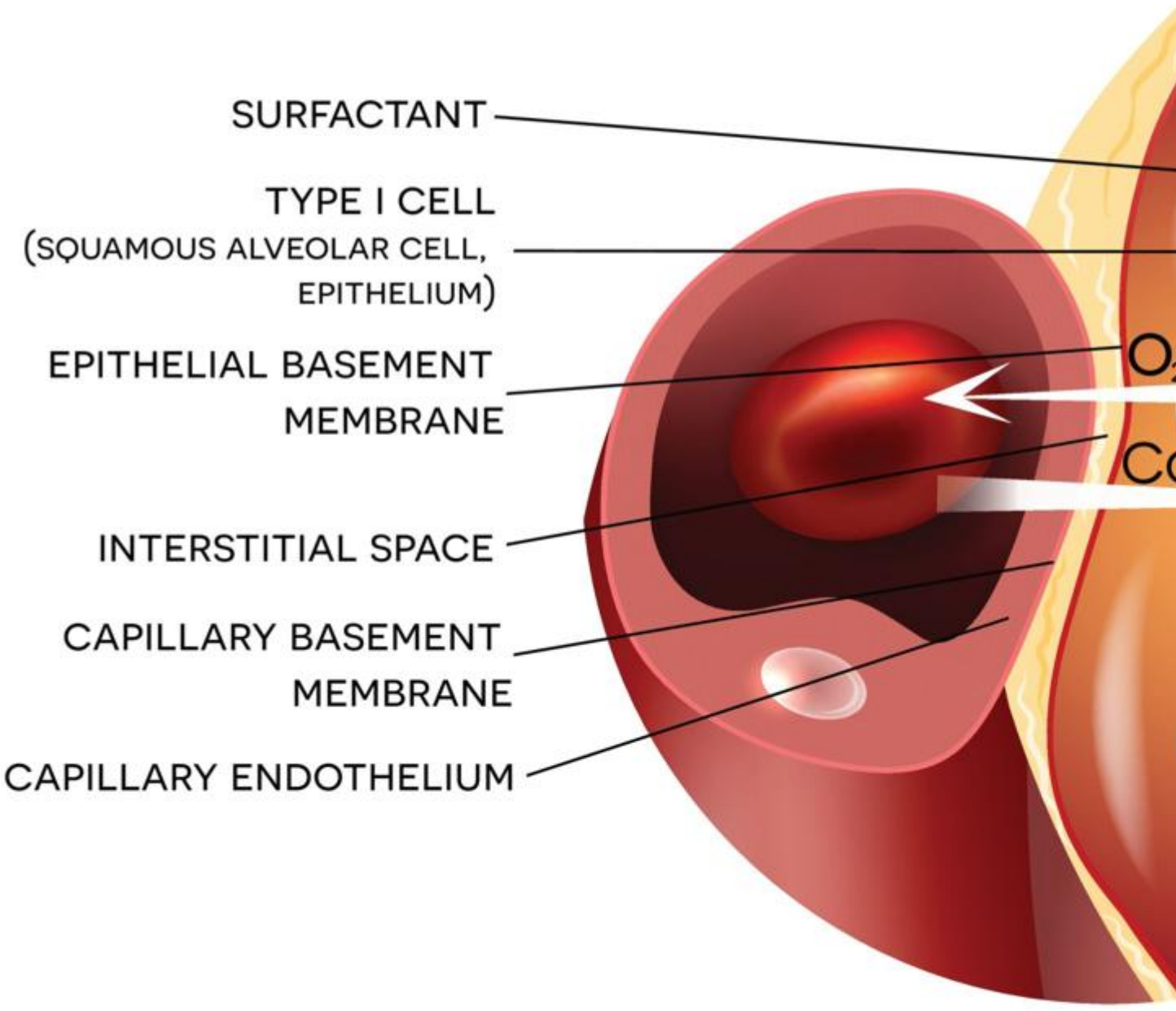
Diffusion of CO?

• Movement of carbon dioxide from pulmonary capillary blood to alveolar air
• Occurs across the respiratory membrane by diffusion
• Driven by partial pressure gradient between blood and alveoli
• Important for elimination of metabolic carbon dioxide

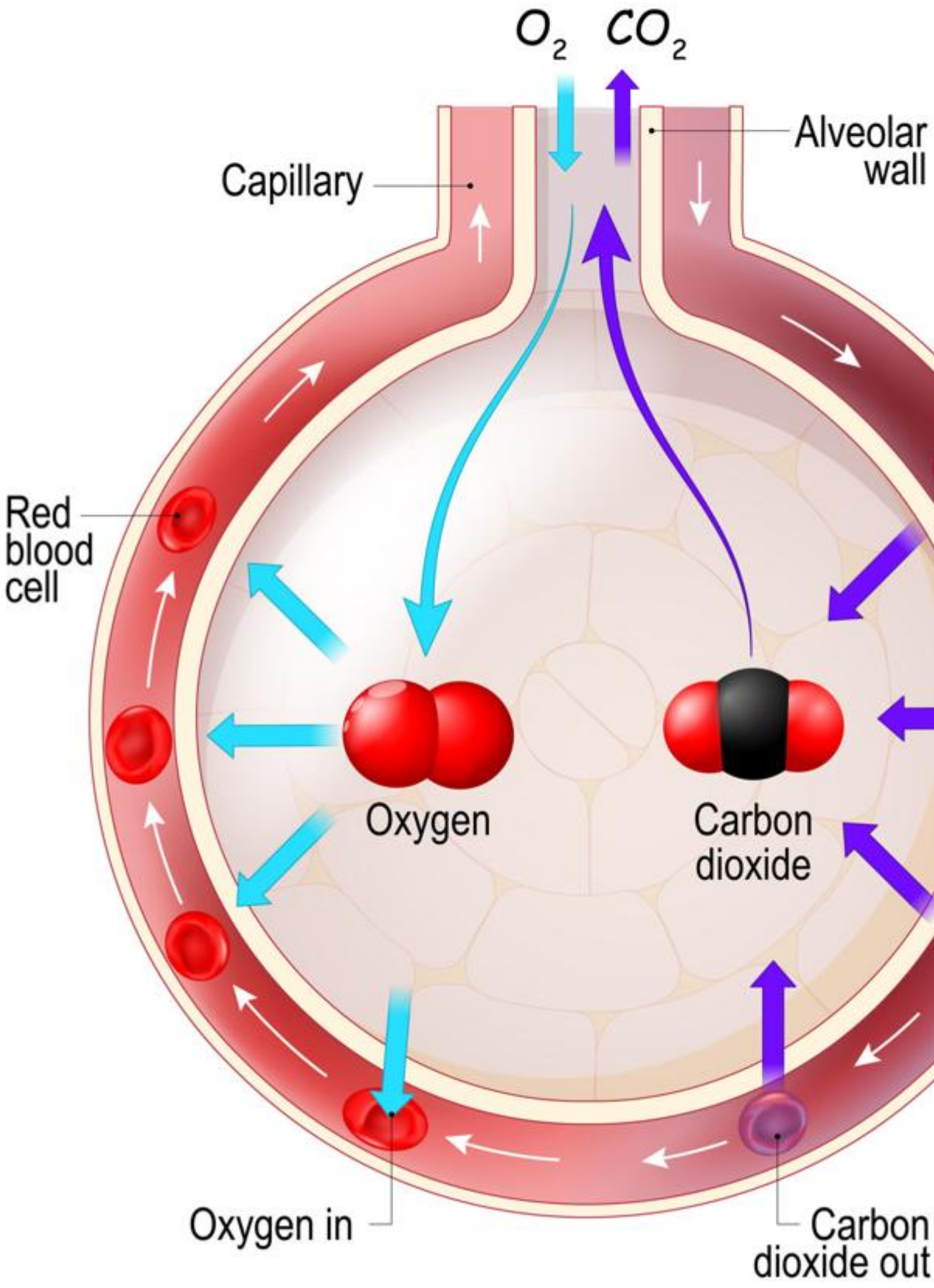
Diffusion of Carbon Dioxide in Lungs


CO2
O2
CO2
O2
CO2

RESPIRATORY MEMBR



Pulmonary alveolus



• **Direction of diffusion**
• Carbon dioxide diffuses from **pulmonary capillary blood (higher PCO?)** to **alveolar air (lower PCO?)**.

• **High solubility of CO?**
• Carbon dioxide is **about 20 times more soluble than oxygen**, so it diffuses very rapidly across the respiratory membrane.

• **Small pressure gradient required**
• Only a small pressure difference is needed:
• Pulmonary capillary PCO? ? **45 mmHg**
• Alveolar PCO? ? **40 mmHg**

• **Efficiency of carbon dioxide removal**
• Because of its high diffusibility, CO? elimination remains effective even if the respiratory membrane becomes slightly thickened.

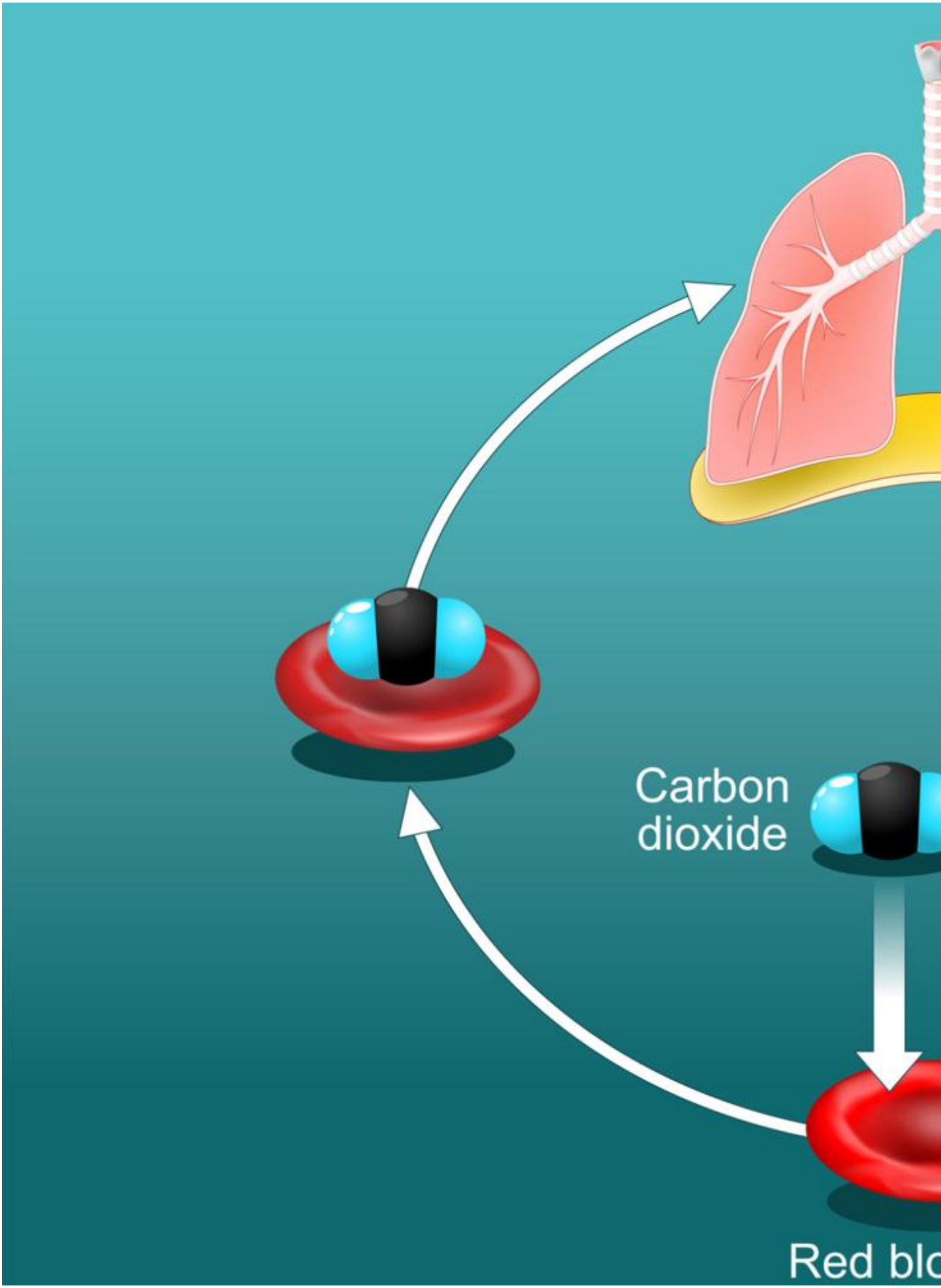
This is a clever piece of evolutionary engineering. Carbon dioxide leaves the blood easily, even when the lungs are not working perfectly.

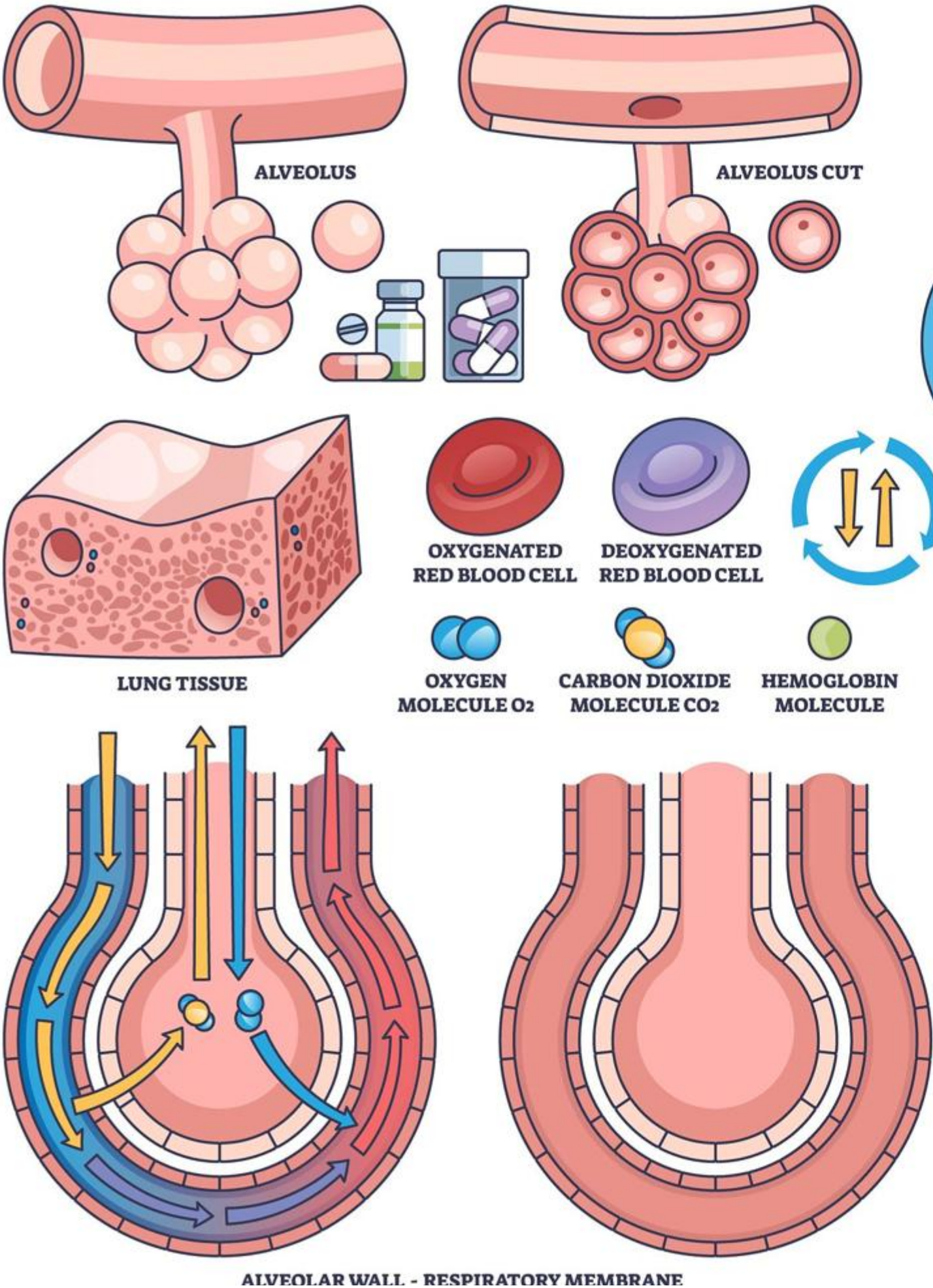
Perfusion

• Refers to blood flow through pulmonary capillaries surrounding alveoli
• Essential for effective gas exchange
• Must be properly matched with ventilation

Pulmonary Perfusion


Air in/out




ALVEOLUS
ALVEOLUS CUT
LUNG TISSUE
OXYGENATED RED BLOOD CELL
DEOXYGENATED RED BLOOD CELL
OXYGEN MOLECULE O2
CARBON DIOXIDE MOLECULE CO2
HEMOGLOBIN MOLECULE
ALVEOLAR WALL - RESPIRATORY MEMBRANE

• **Definition of perfusion**
• Perfusion refers to the **flow of blood through pulmonary capillaries available for gas exchange**.

• **Importance in gas exchange**
• Oxygen uptake and carbon dioxide removal require **adequate blood flow around ventilated alveoli**.

• **Relationship with ventilation**
• Efficient respiration depends on proper **matching between ventilation (airflow) and perfusion (blood flow)**.

• **Ventilation–perfusion ratio (V/Q ratio)**
• The ratio between alveolar ventilation and pulmonary blood flow.
• Normal average **V/Q ratio ? 0.8**.

• **Clinical importance**
• Mismatch between ventilation and perfusion can lead to:
• Hypoxemia
• Pulmonary diseases such as **embolism, COPD, and pneumonia**