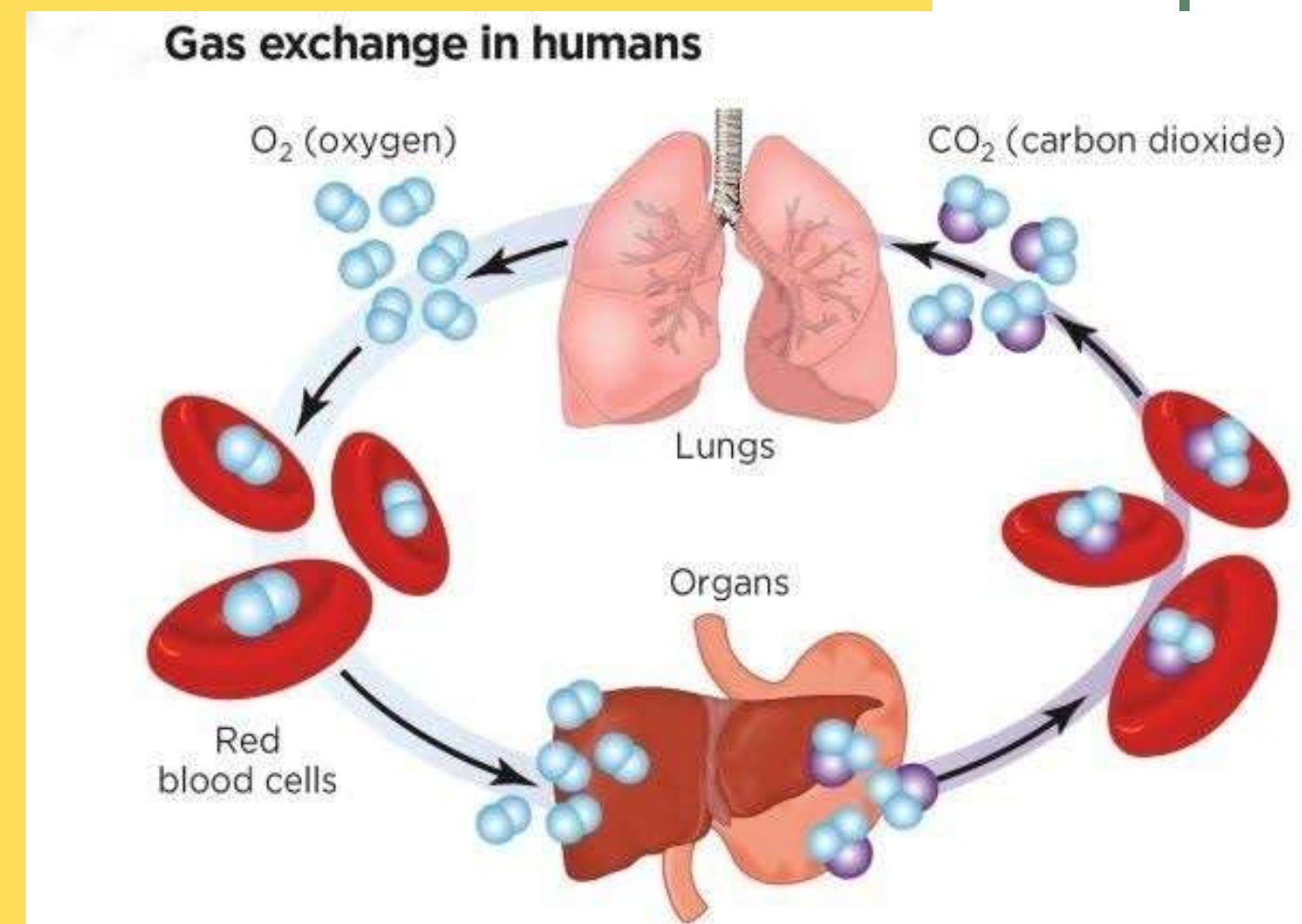


# EXCHANGE OF RESPIRATORY GASES

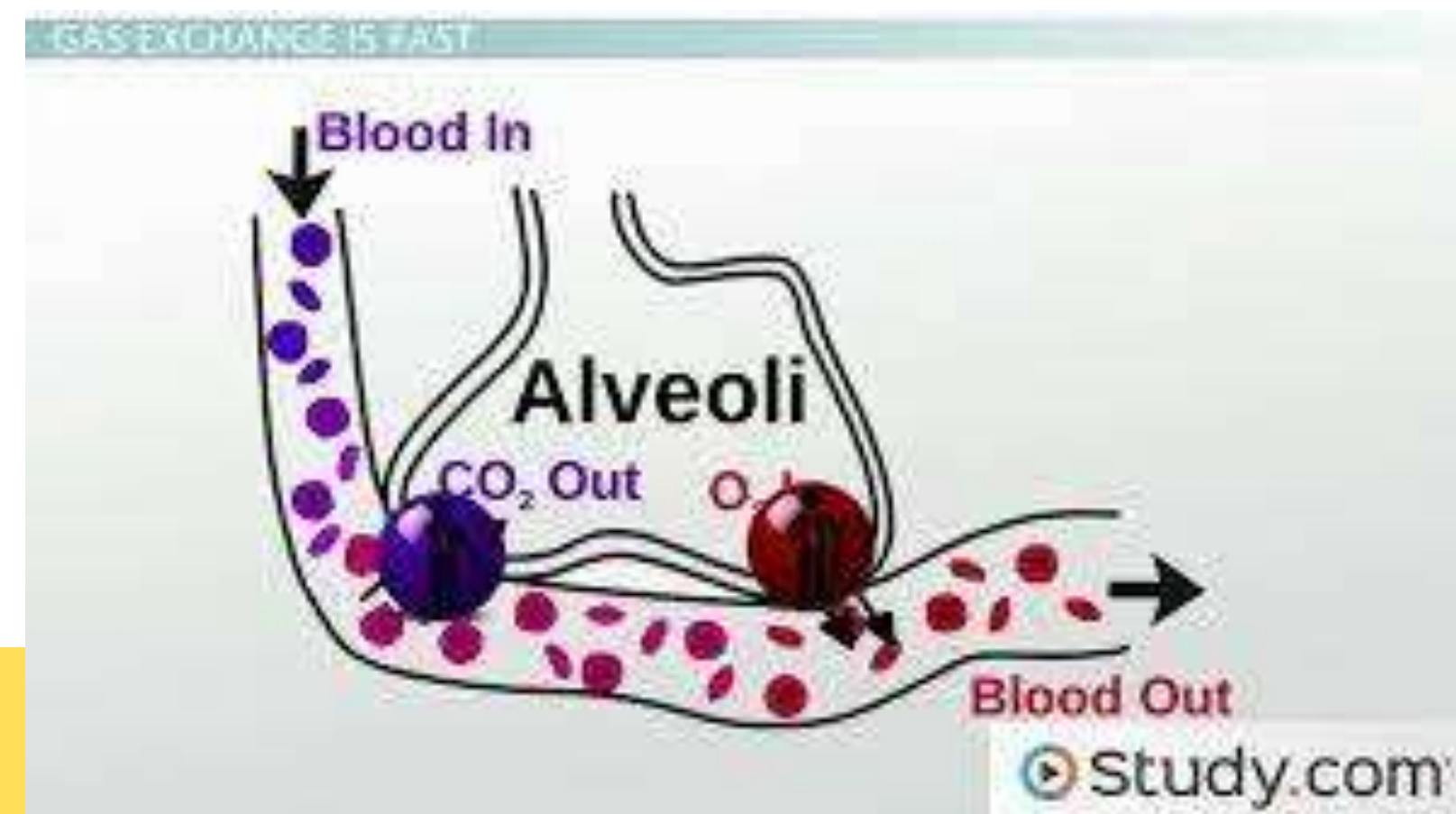


## INTRODUCTION

Oxygen is essential for the **cells**.

Carbon dioxide, which is produced as waste product in the cells must be **expelled from the cells and body**.

Lungs serve to exchange these two gases with blood.







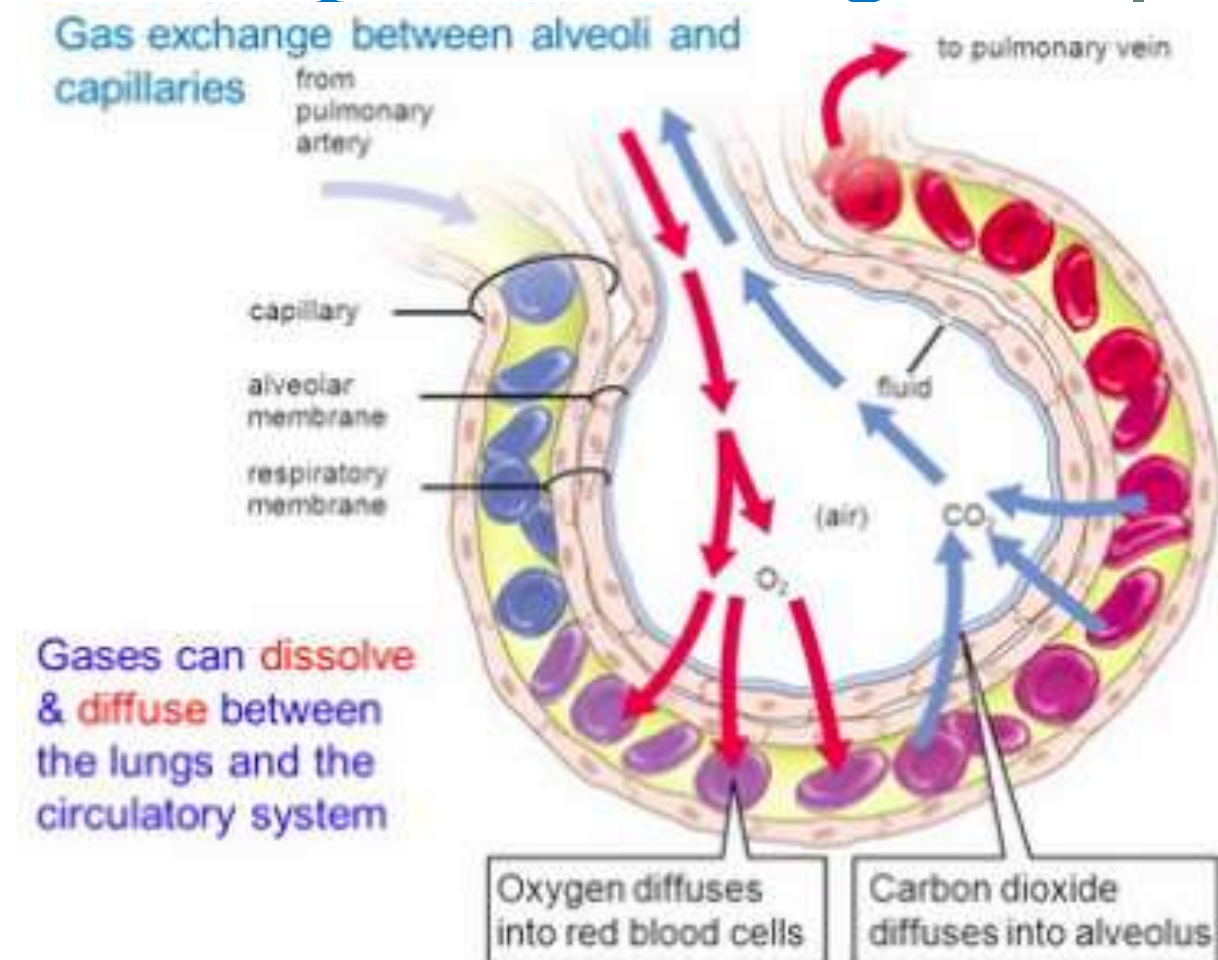
# EXCHANGE OF RESPIRATORY GASES IN LUNGS

In the lungs, exchange of respiratory gases takes place between the **alveoli of lungs and the blood.**

Oxygen enters the blood from alveoli and carbon dioxide is expelled out of blood into alveoli.

Exchange occurs through **bulk flow diffusion.**

Exchange of **gases between blood and alveoli** takes place through **respiratory membrane.**





## RESPIRATORY MEMBRANE

Respiratory membrane is a membranous structure through which **exchange of respiratory gases takes place.**

It is formed by epithelium of respiratory unit and endothelium of pulmonary capillary.

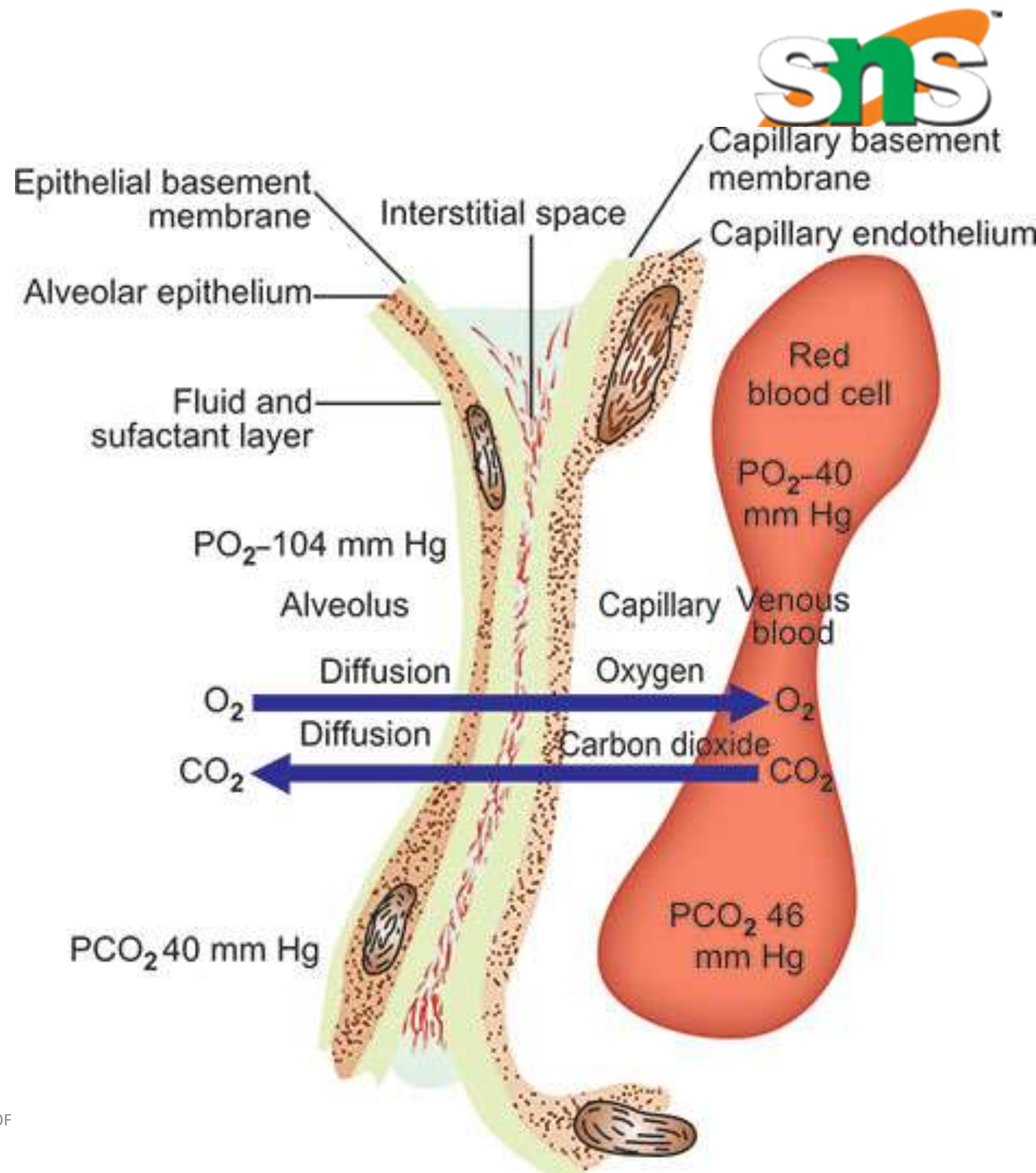
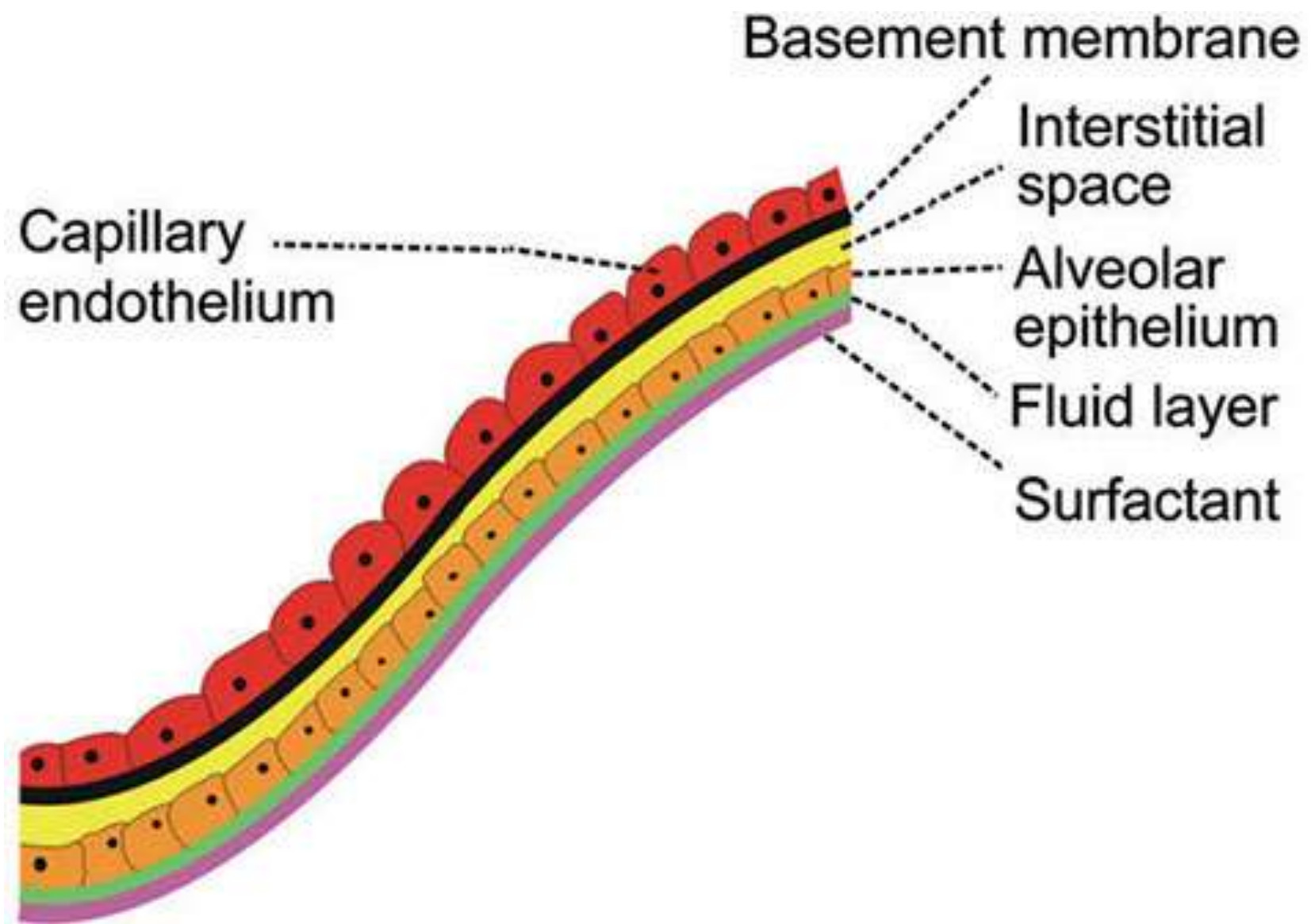
Epithelium of respiratory unit is a **very thin layer .**

Since, the capillaries are in close contact with this membrane, alveolar air is in close proximity to capillary blood.

This facilitates **gaseous exchange between air and blood .**

Respiratory membrane is formed by different layers of structures belonging to the alveoli and capillaries.

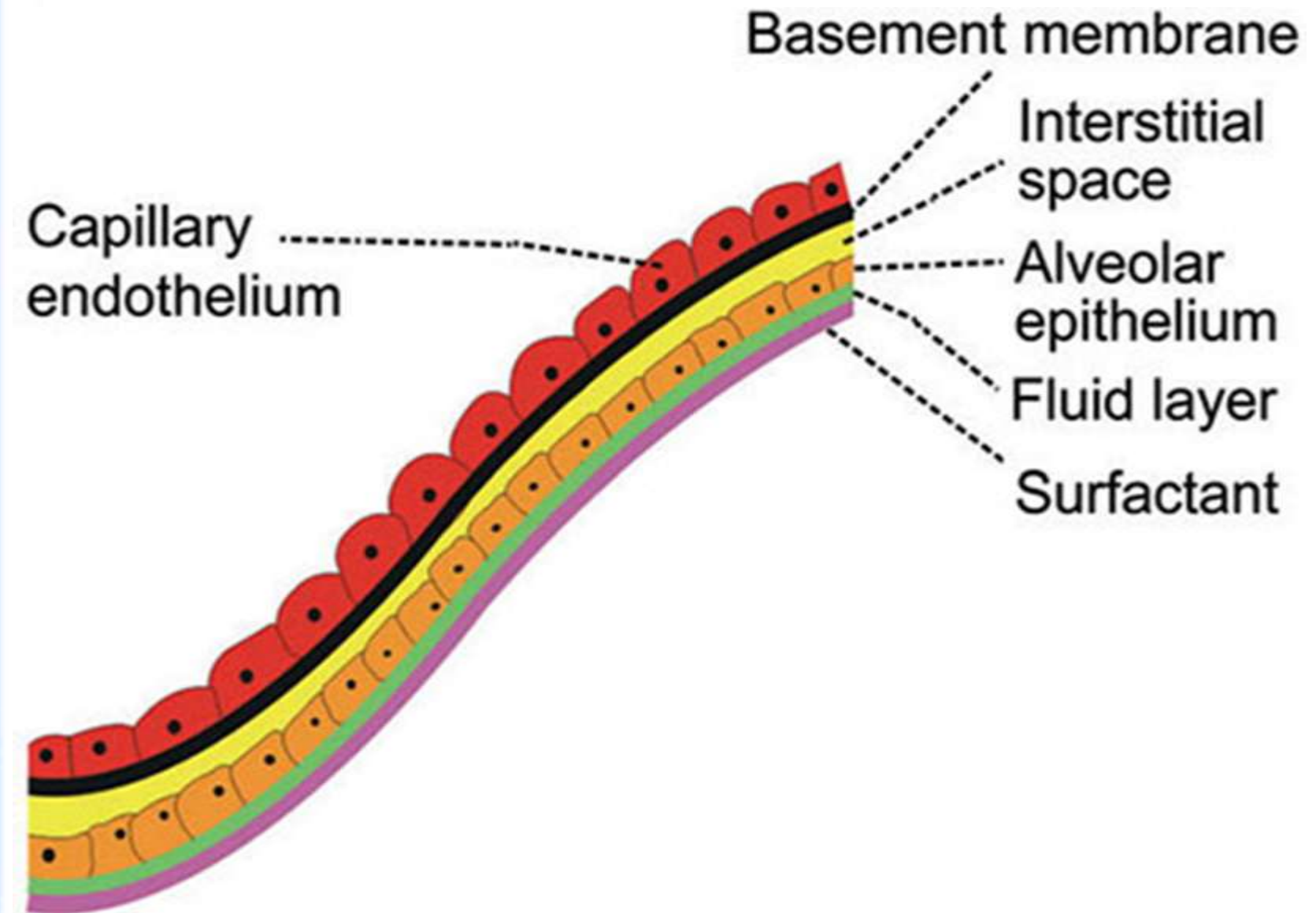






**TABLE 124.1: Layers of respiratory membrane**

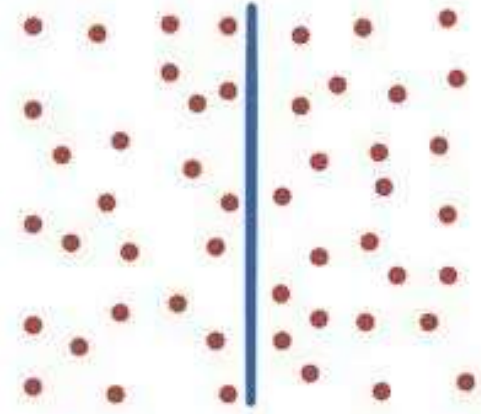
Portion	Layers
Alveolar portion	<ol style="list-style-type: none"><li>1. Monomolecular layer of surfactant, which spreads over the surface of alveoli</li><li>2. Thin fluid layer that lines the alveoli</li><li>3. Alveolar epithelial layer, which is composed of thin epithelial cells resting on a basement membrane</li></ol>
Between alveolar and capillary portions	<ol style="list-style-type: none"><li>4. An interstitial space</li></ol>
Capillary portion	<ol style="list-style-type: none"><li>5. Basement membrane of capillary</li><li>6. Capillary endothelial cells</li></ol>





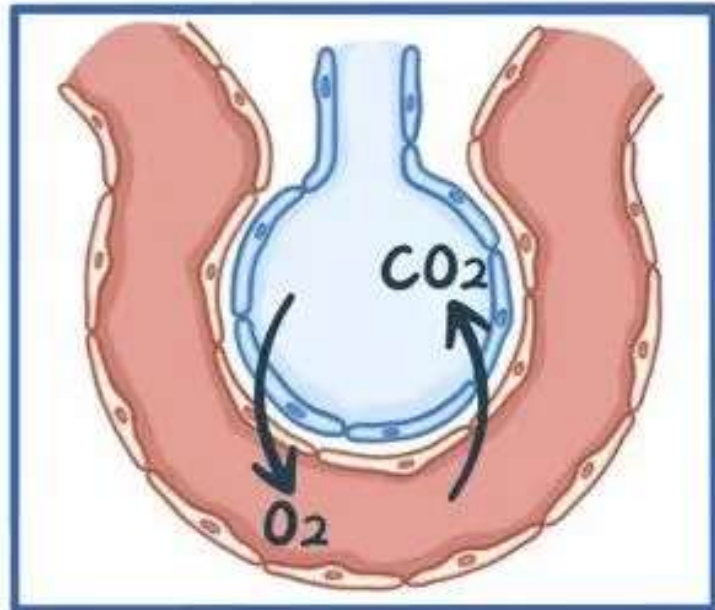
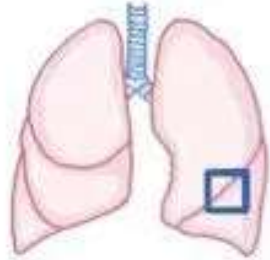
# GAS EXCHANGE

- GASES MOVE PASSIVELY



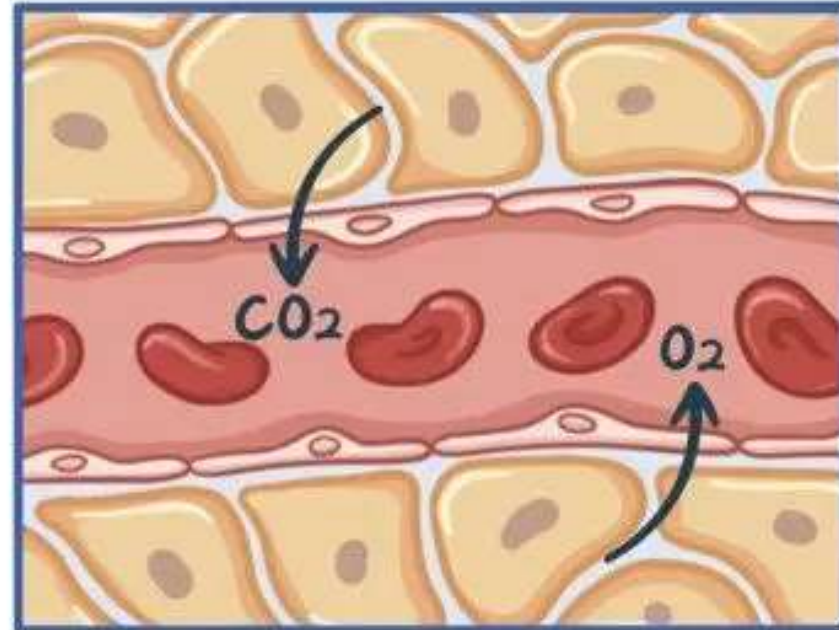
## EXTERNAL RESPIRATION

- BULK FLOW of AIR INTO & OUT of the LUNGS



## INTERNAL RESPIRATION

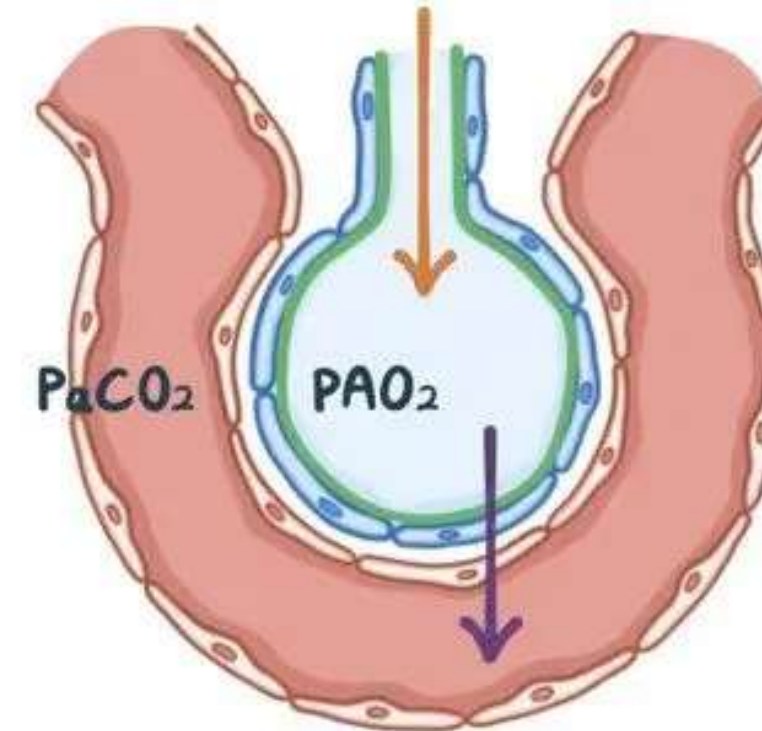
- CAPILLARY GAS EXCHANGE in BODY TISSUES



\* FLOW of AIR from the EXTERNAL ENVIRONMENT HAPPENS DUE to PRESSURE CHANGES in the LUNGS

## \* ALVEOLAR GAS EXCHANGE

1. SURFACE AREA
2. PARTIAL PRESSURE GRADIENTS of GASES
3. MATCHING of VENTILATION & PERFUSION





## **LAYERS OF RESPIRATORY MEMBRANE**

Different layers of respiratory membrane from within outside.

In spite of having many layers, respiratory membrane is very thin with an average thickness of  $0.5 \mu$ .

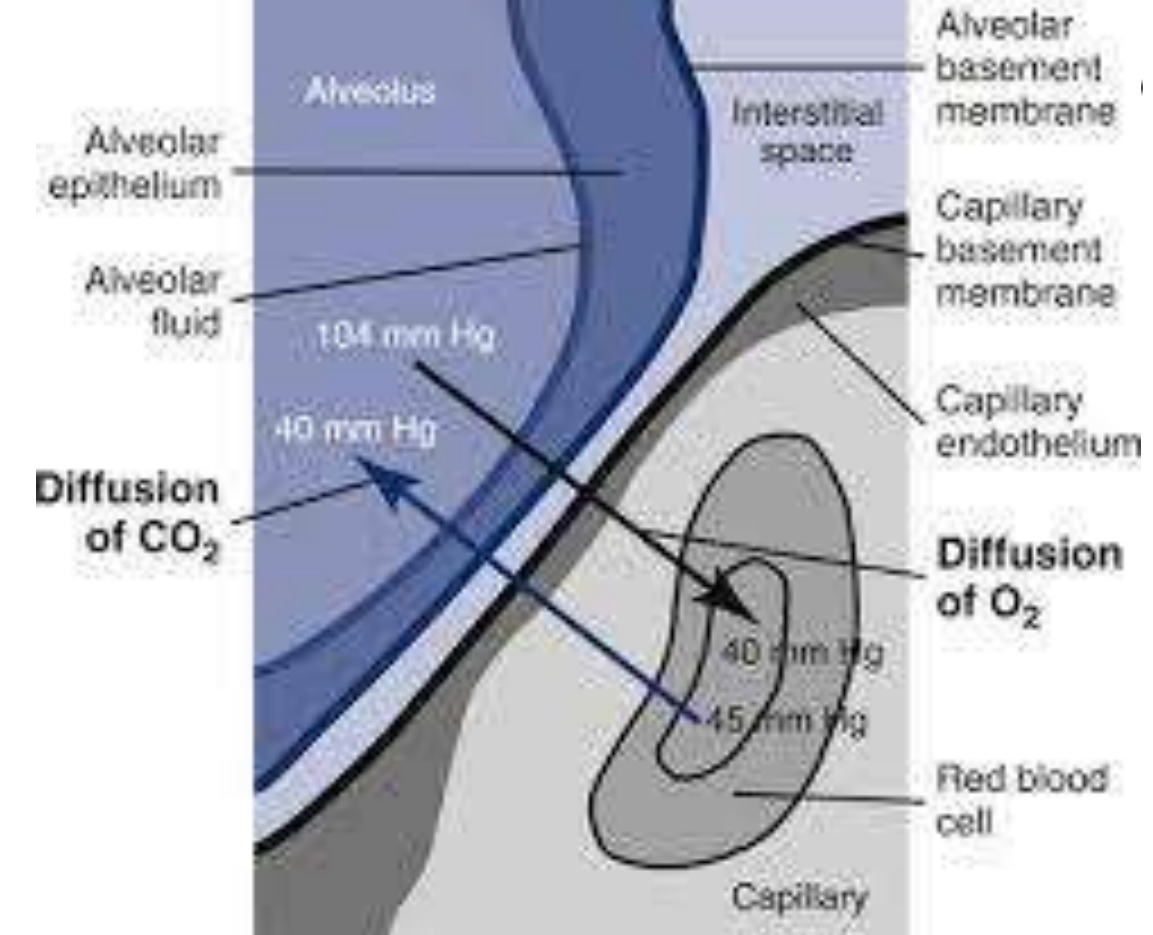
Total surface area of the respiratory membrane in both the lungs is about 70 square meter.

Average diameter of pulmonary capillary is only  $8 \mu$ , which means that the RBCs with a diameter of  $7.4 \mu$  actually squeeze through the capillaries.

Therefore, the membrane of RBCs is in close contact with capillary wall.

This facilitates quick exchange of oxygen and carbon dioxide between the blood and alveoli.





## DIFFUSING CAPACITY

Diffusing capacity is defined as the volume of gas that diffuses through the **respiratory membrane** each minute for a pressure gradient of 1 mm Hg.

### Diffusing Capacity for Oxygen and Carbon Dioxide

Diffusing capacity for **oxygen** is 21 mL/minute/1 mm Hg.

Diffusing capacity for **carbon dioxide** is 400 mL/minute/1 mm Hg.

Thus, the **diffusing capacity** for carbon dioxide is about 20 times more than that of **oxygen**.



## Factors Affecting Diffusing Capacity

### 1. Pressure gradient

Diffusing capacity is directly proportional to **pressure gradient**.

Pressure gradient is the difference between the partial pressure of a gas in alveoli and pulmonary capillary blood

It is the major factor, which affects the diffusing capacity.

### 2. Solubility of gas in fluid medium

Diffusing capacity is directly proportional to **solubility of the gas**.

If the **solubility of a gas is more in the fluid medium**, a large number of **molecules dissolve in it and diffuse easily**





### **3. Total surface area of respiratory membrane**

Diffusing capacity is directly proportional to **surface area of respiratory membrane.**

Surface area of respiratory membrane in each lung is about **70 sq m.**

If the **total surface area of respiratory membrane decreases**, the diffusing capacity for the gases is decreased.

Diffusing capacity is **decreased in emphysema** in which many of the **alveoli are collapsed because of heavy smoking or oxidant gases**



#### 4. Molecular weight of the gas

Diffusing capacity is **inversely proportional to molecular weight** of the gas. If the **molecular weight is more**, the density is more and the **rate of diffusion is less**.

#### 5. Thickness of respiratory membrane

Diffusion is **inversely proportional to the thickness of respiratory membrane**. More the thickness of respiratory **membrane less is the diffusion**. It is because the distance through which the diffusion takes place is long. In conditions like **fibrosis and edema, the diffusion rate is reduced, because the thickness of respiratory membrane is increased**.



## Relation between Diffusing Capacity and Factors Affecting it

Relation between diffusing capacity and the factors affecting it is expressed by the following formula:

$$DC \propto \frac{P_g \times S \times A}{M_w \times D}$$

DC = Diffusing capacity

P<sub>g</sub> = Pressure gradient

S = Solubility of gas

A = Surface area of respiratory membrane

M<sub>w</sub> = Molecular weight

D = Thickness of respiratory membrane.



# **DIFFUSION COEFFICIENT AND FICK LAW OF DIFFUSION**

## **Diffusion Coefficient**

Diffusion coefficient is defined as a constant (a factor of proportionality), which is the measure of a substance diffusing through the concentration gradient.

It is also known as diffusion constant.

It is related to size and shape of the molecules of the substance.



# Fick Law of Diffusion

Diffusion is well described by Fick law of diffusion.

According to this law, amount of a substance crossing a given area is directly proportional to the area available for diffusion, concentration gradient and a constant known as diffusion coefficient.

## Fick's First Law

Movement of particles (diffusion flux) from high to low concentration is directly proportional to the particle's concentration gradient

$$J \propto \frac{d\phi}{dx} \quad \text{or} \quad J = -D \frac{d\phi}{dx}$$

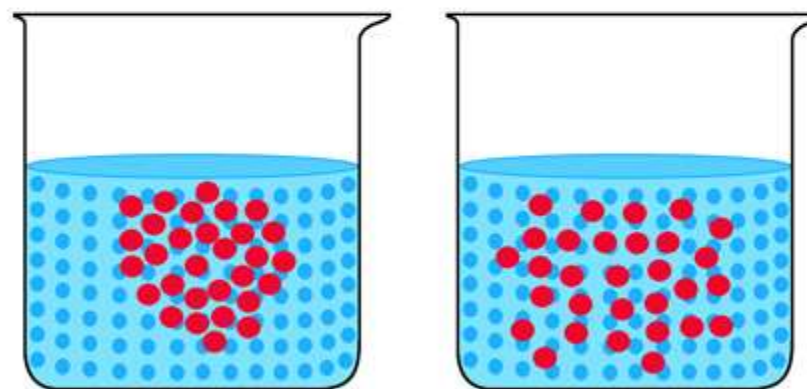
$J$  = diffusion flux

$D$  = diffusion coefficient or diffusivity

$d\phi$  = change in concentration of the particle

$dx$  = change in position

$\frac{d\phi}{dx}$  = concentration gradient of the particle



Particles diffusing from high to low concentration

Thus,  
Amount diffused = Area × Concentration gradient × Diffusion coefficient

Formula of Fick law:

$$J = -D \times A \times \frac{dc}{dx}$$

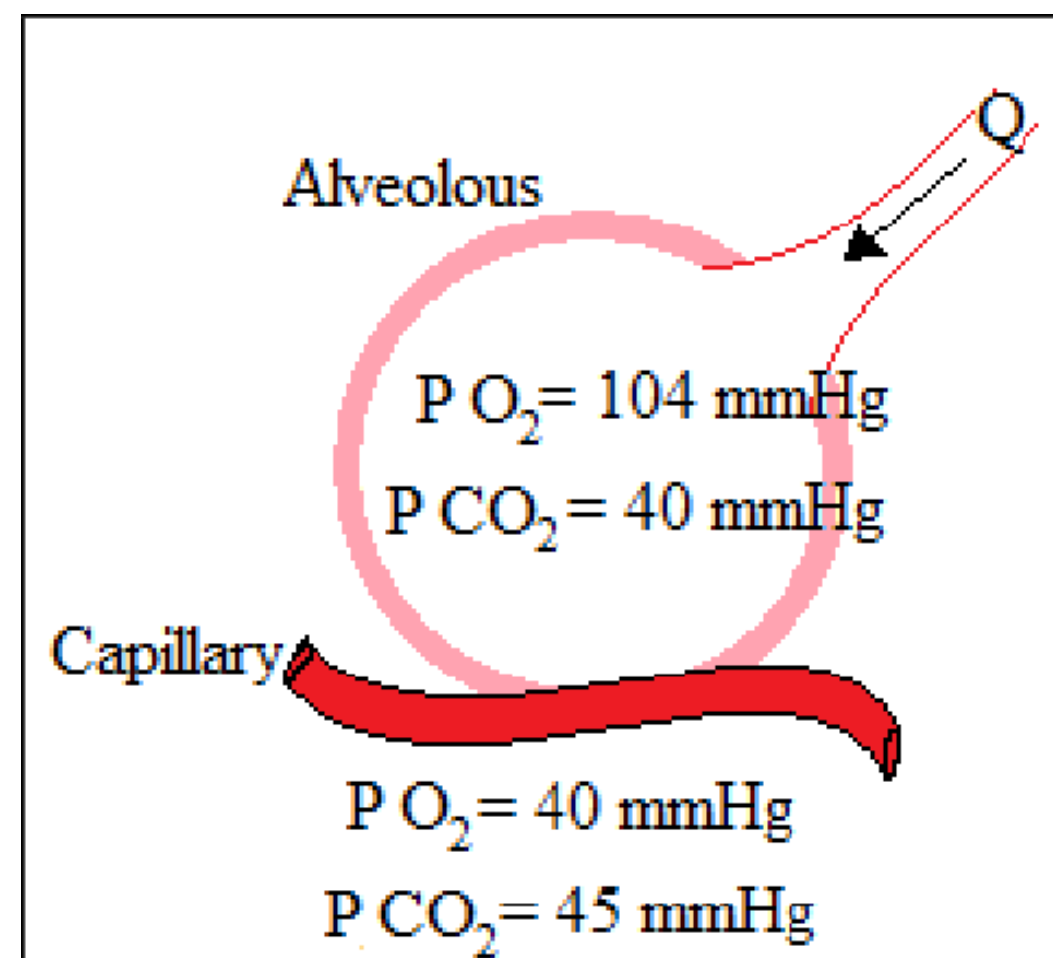
Where,

$J$  = Amount of substance diffused

$D$  = Diffusion coefficient

$A$  = Area through which diffusion occurs

$dc/dx$  = Concentration gradient.



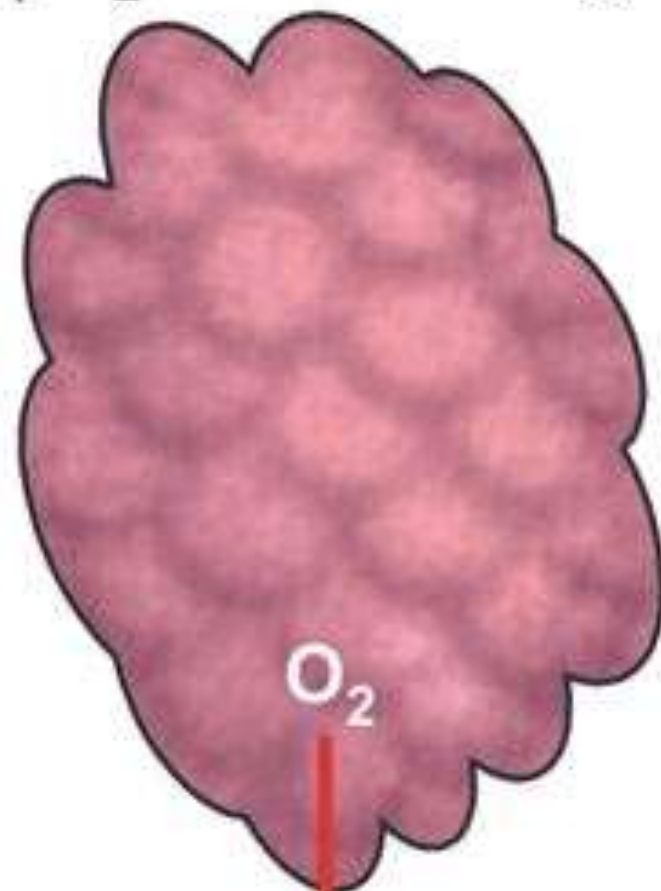
## DIFFUSION OF OXYGEN

Diffusion of Oxygen from Atmospheric Air into Alveoli Partial pressure of oxygen in the atmospheric air is 159 mm Hg and in the alveoli, it is 104 mm Hg.

Because of the pressure gradient of 55 mm Hg, oxygen easily enters from atmospheric air into the alveoli.

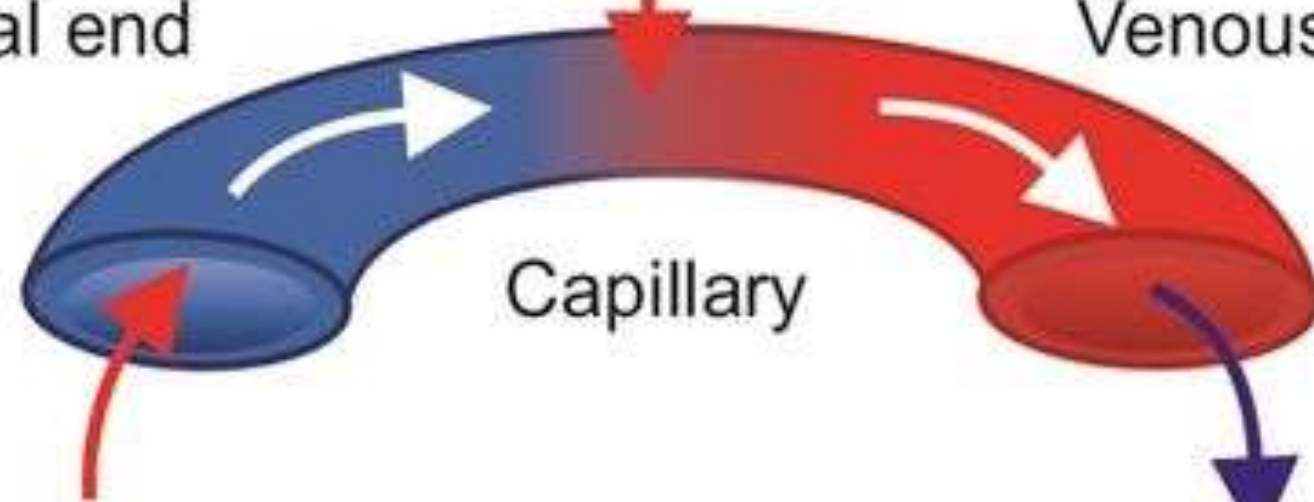


Alveolus  
 $pO_2 = 104 \text{ mm Hg}$



Arterial end

Venous end



Capillary

$pO_2 = 40 \text{ mm Hg}$   
 $O_2 \text{ content} = 14 \text{ mL\%}$

$pO_2 = 104 \text{ mm Hg}$   
 $O_2 \text{ content} = 19 \text{ mL\%}$



## **Diffusion of Oxygen from Alveoli into Blood**

When blood passes through pulmonary capillary, RBC is exposed to oxygen only for **0.75 second at rest** and only for **0.25 second during severe exercise**.

So, diffusion of **oxygen must be quicker and effective**.

Fortunately, this is possible because of pressure gradient.

Partial pressure of oxygen in the pulmonary capillary is 40 mm Hg and in the alveoli, it is 104 mm Hg.

Pressure gradient is 64 mm Hg.

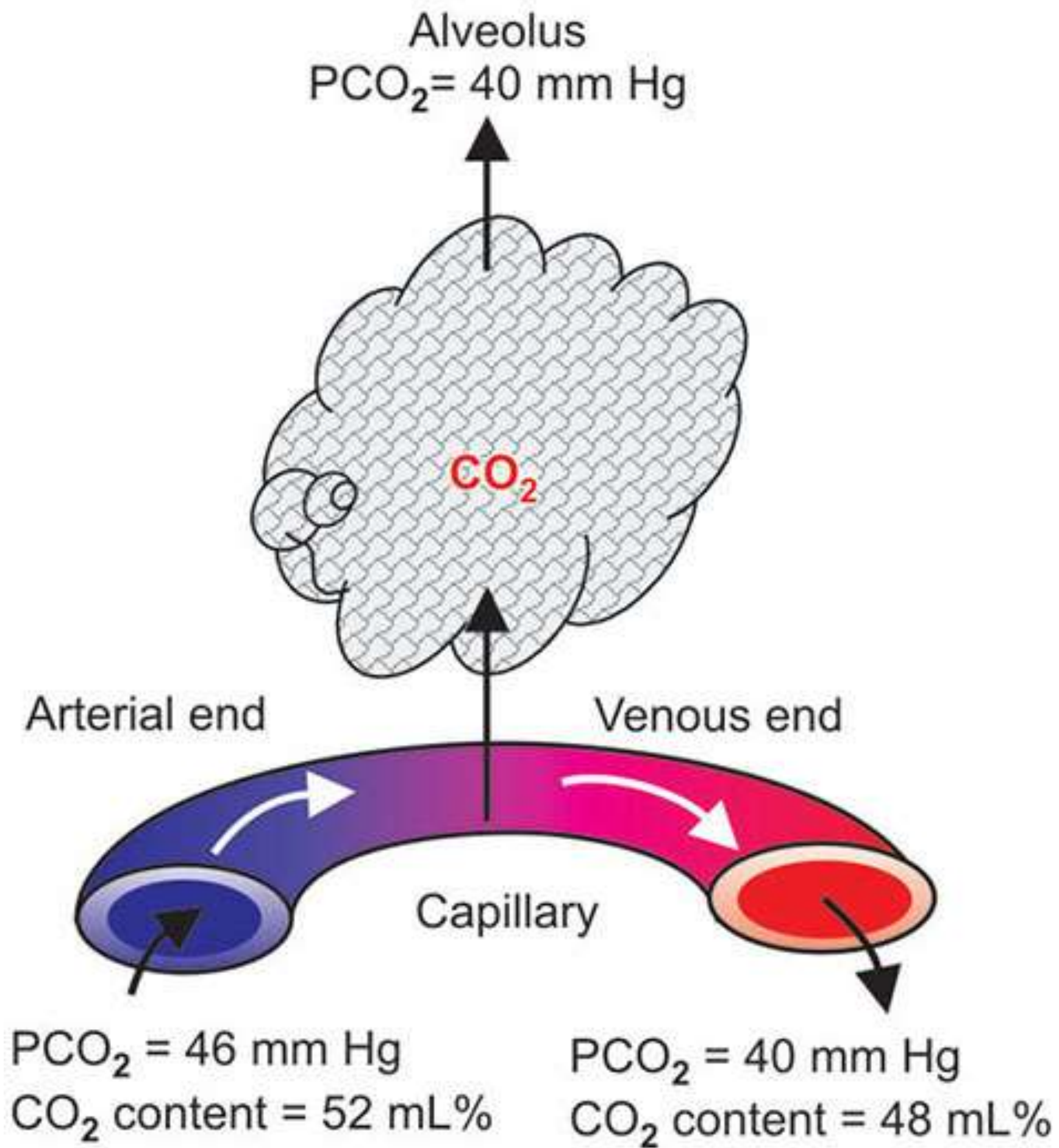
It facilitates the diffusion of oxygen from alveoli into the blood



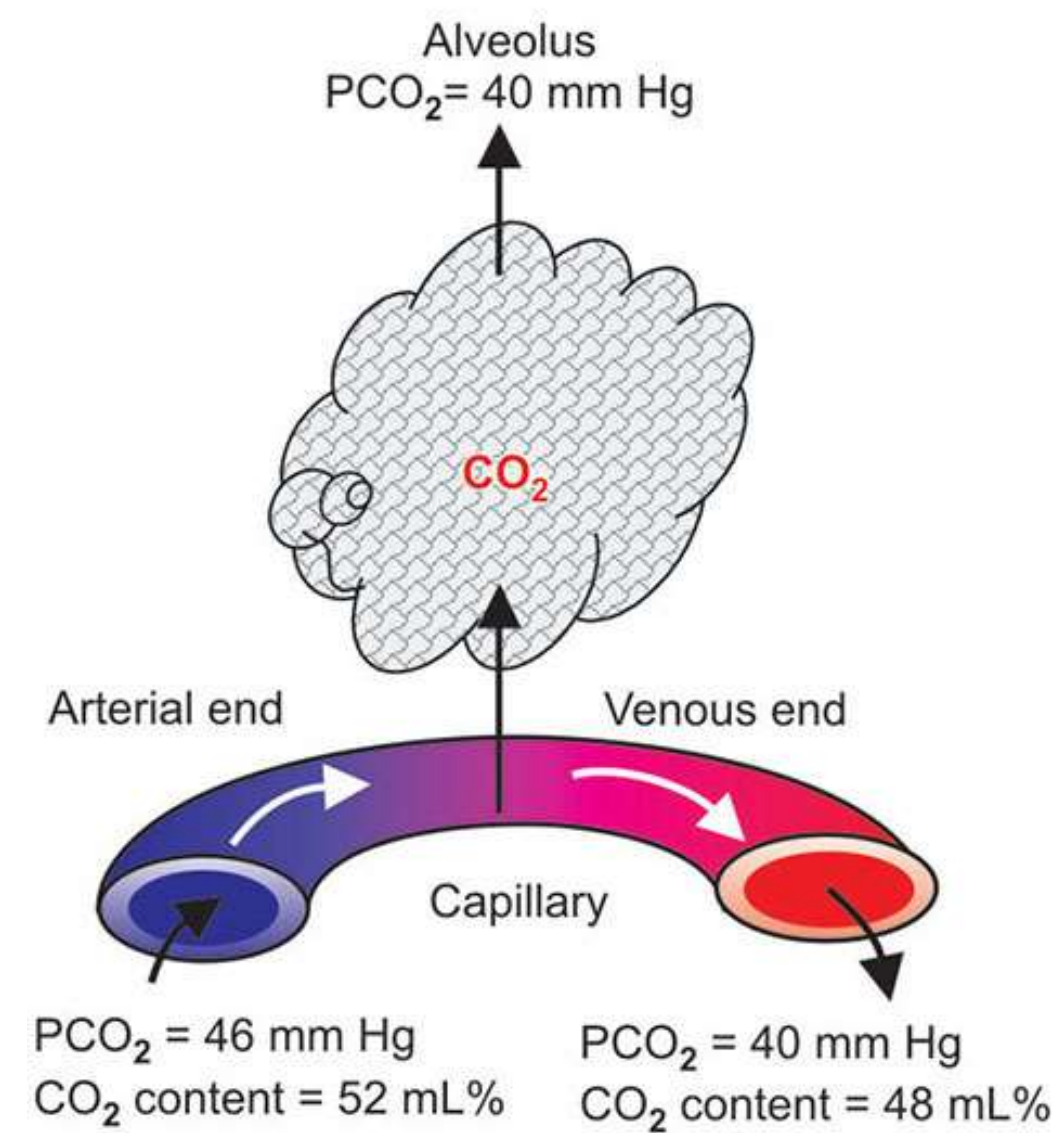


## **DIFFUSION OF CARBON DIOXIDE**

Diffusion of Carbon Dioxide from Blood into Alveoli Partial pressure of carbon dioxide in alveoli is 40 mm Hg whereas in the blood it is 46 mm Hg. Pressure gradient of 6 mm Hg is responsible for the diffusion of carbon dioxide from blood into the alveoli







## **Diffusion of Carbon Dioxide from Alveoli into Atmospheric Air**

In atmospheric air, partial pressure of carbon dioxide is very insignificant and is only about 0.3 mm Hg whereas, in the alveoli, it is 40 mm Hg.

So, carbon dioxide enters passes to atmosphere from alveoli easily

