

# Pulmonary & Alveolar Ventilation

*By*

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# Respiration

➤ **Respiration:** 

It is the complex process by which **O<sub>2</sub>** is taken from the atmosphere by **inspiration**, carried by the blood to reach to cells to be used in food oxidation and energy production and then **CO<sub>2</sub>** resulted is extruded from the body by **expiration**.

## ➤ Steps of respiration

**1) *Pulmonary ventilation***: it is inflow of O<sub>2</sub> from the atmosphere to alveoli and CO<sub>2</sub> outflow to atmosphere.

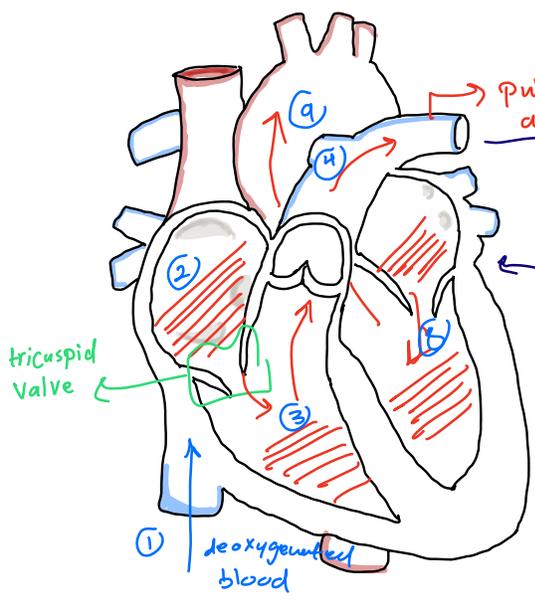
**2) *Pulmonary perfusion*** : it is the cardiac output of right ventricle (5 lit/min) to the lung to take O<sub>2</sub> and get rid of CO<sub>2</sub>.

It's a process which blood reach the lung to take oxygen and transfer it to tissue, and take the carbon dioxide from tissue to lung

**3) *Exchange of gases*** between pulmonary ventilation and perfusion via *pulmonary membrane* by **Simple Diffusion**

**4) *Gas carriage by the blood*** to the left heart and then to all body.

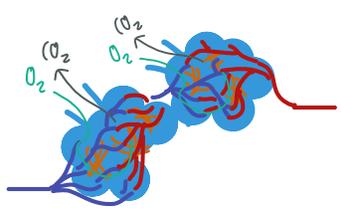
cardiac output: amount of blood pumped by each ventricle per min



pulmonary artery

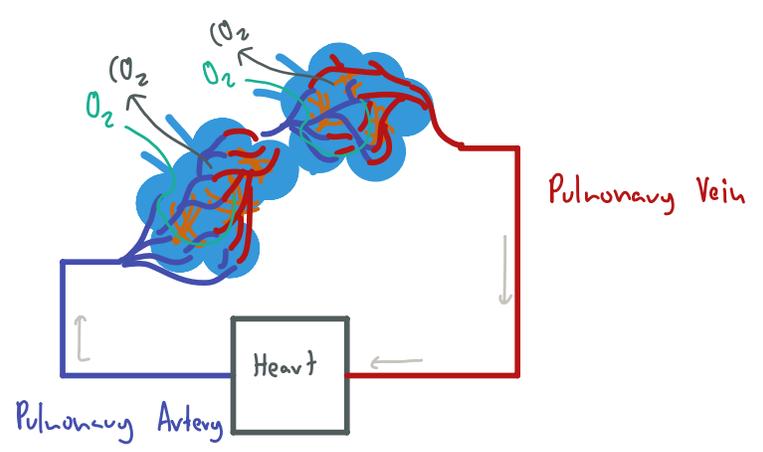
⑤ pulmonary capillary

alveoli → where gas exchange occur



4 pulmonary veins bring gas exchange oxygenated blood

القلية بـسـاـفـة



- ***Another classification of respiration:***

A- External respiration: is the gas exchange at lung level. (between atmosphere & alveoli)

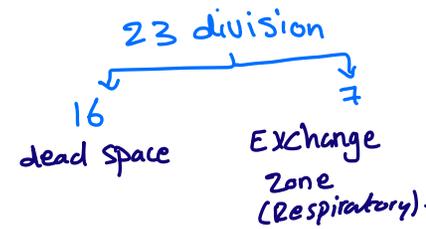
B- Carriage of gases by blood. (between alveoli & pulmonary capillaries)

C- Internal respiration: is gas exchange at tissue level. (between tissue & blood)

➤ **The respiratory system consists of:**

- 1) The respiratory passages.
- 2) The respiratory muscles.
- 3) The respiratory centers.
- 4) The pulmonary circulation.

# Respiratory passages



## I. Air conducting zone (Dead space):

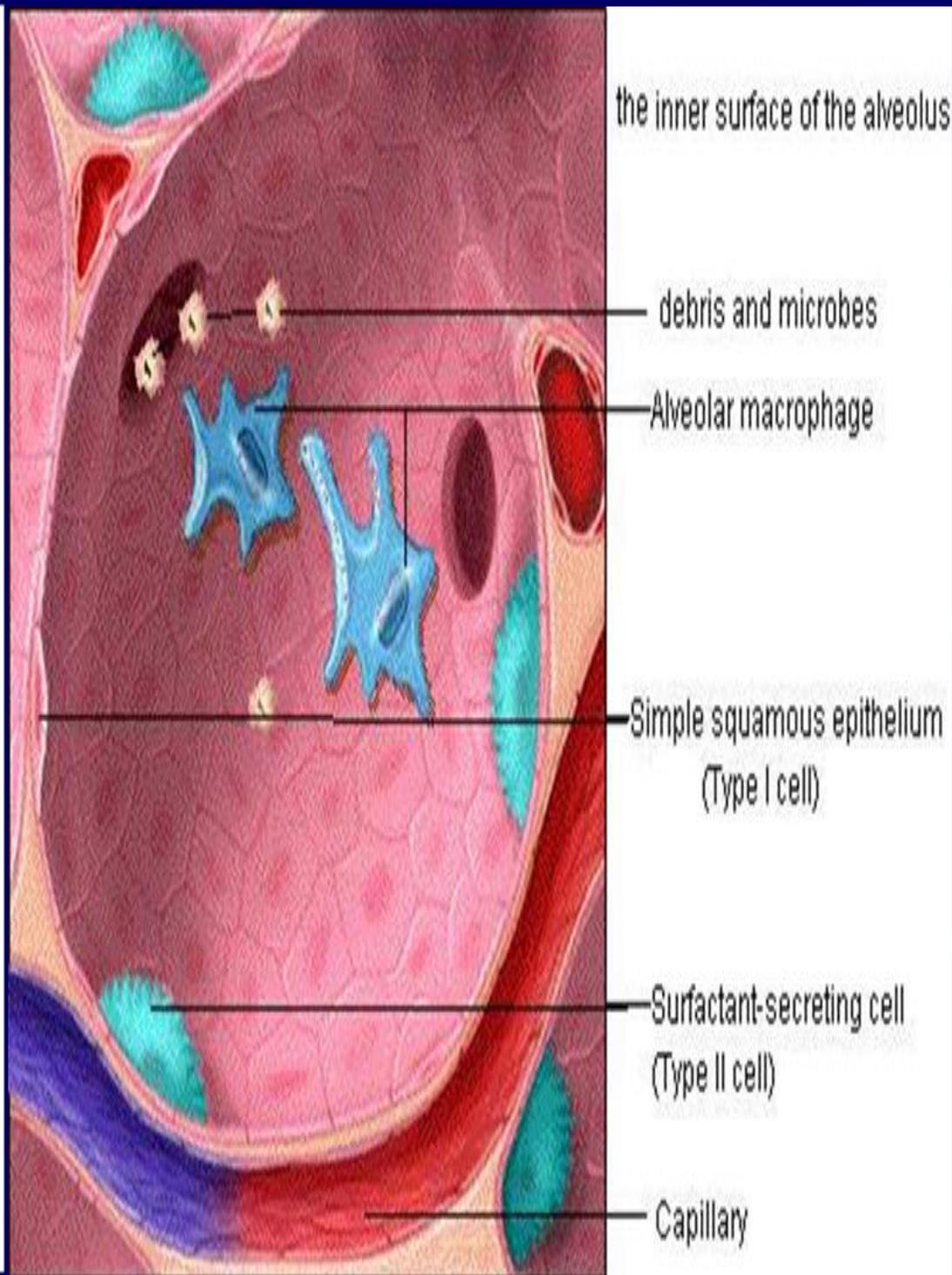
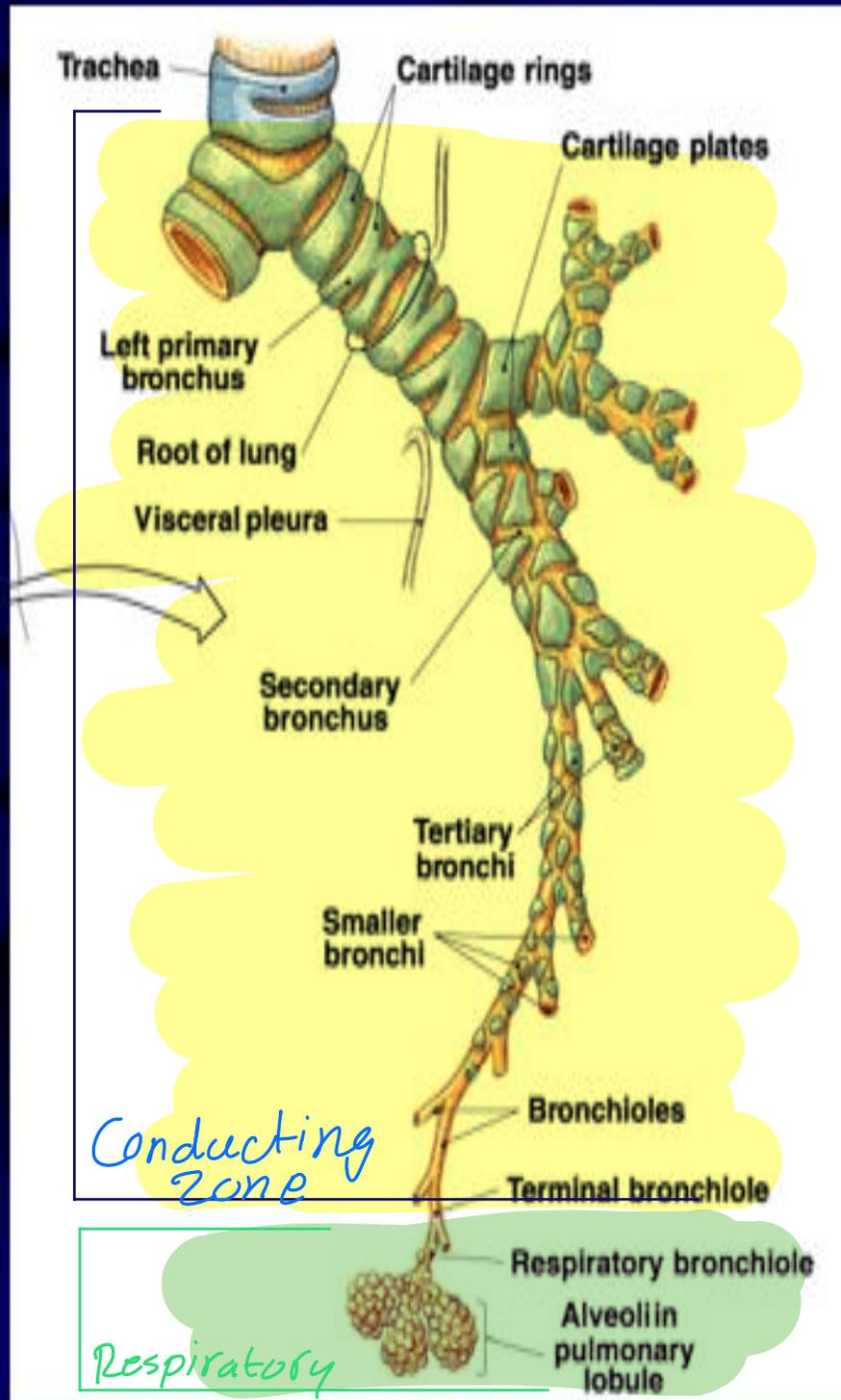
- ❑ Nose ð Pharynx ð larynx ð trachea ð bronchi ð bronchiole ð terminal bronchiole. (16 divisions)
- ❑ No gas exchange due to thick wall.
- ❑ It contains circular cartilaginous rings to prevent its collapse and contains longitudinal elastic fibers to allow lengthening and shortness of bronchi with lung expansion and collapse.
- ❑ It has an important protective functions

عسان أتر أحركت  
chest wall  
up & down  
أثناء عملية التنفس

## II. Respiratory zone (Exchange zone):

- ❑ Respiratory bronchioles ð alveolar duct ð alveoli. (7 divisions)
- ❑ Gas exchange occurs with blood.
- ❑ Structure of alveoli: alveoli have **3 types** of cells:
  - 1) Type I cells (squamous pneumocyte).
  - 2) Type II cells (granular pneumocyte) **secrete surfactant**.
  - 3) Type III cells (alveolar macrophages or dust cell) they are highly phagocytic cells .

thickness of pulmonary membrane (0.5 - 0.6)µ



# Non respiratory functions of respiratory system

**Smell:** By olfactory receptors present in the posterior nasal cavity.

**Taste:** By oral cavity & pharynx. *\* because taste bud located in the respiratory route*

**Voice production:** (phonation & articulation of speech)

- By changes in thickness & vibration & position of vocal cords in larynx.

**Regulation of body temperature:** By heat loss in expiration.

**Regulation of pH (Acid-base balance):**

- By controlling CO<sub>2</sub> level. *\*\* The most imp function of Rs is to control CO<sub>2</sub>*

**Many drugs may be used by inhalation:**

- As anesthetics & bronchodilators.

# Protective functions

protection of particles

Size	By
$>10\mu$	nasal hair
$<10\mu$	Mucous blanket
$<2\mu$	Macrophage

## 1) Air conditioning:

By warming & moistening of air due to rich blood supply & mucous so, prevent bad effect of cold air or dry air on the alveoli.

## 2) Protective reflexes:

- Irritation of nose causing **sneezing reflex**.
- Irritation of larynx, trachea or bronchi causing **cough reflex**.

## 3) Presence of Lymphoid tissue: in oro- pharynx & naso- pharynx.

imp. for immunity  
Such: adenoid

## 4) Filtration of Large particles: ( $> 10 \mu$ ) by nasal hair.

## 5) Mucous blanket:

- It is produced by goblet cells under effect of **vagal nerve** in a range of 100ml/day.
- It prevents dust particles (less than  $10 \mu$ ) to reach alveoli. → increase the secretion
- It contains **immunoglobulin A**

## 6) Muco-ciliary escalator mechanism:

- It is a wave of movement of cilia of respiratory mucosa, which drives mucus with particles to pharynx to be expelled. + معكن يهبطها وتدخل Swallowing stomach
- It is **inhibited by**: cigarette smoking, hypoxia, general anesthesia & dehydration

## 7) Alveolar macrophages (Dust cells):

- They engulf dust particles ( $< 2 \mu$ ) and kill bacteria by its lysosomes.

# Metabolic functions

1) **Synthesis of surfactant**

2) **Release of** prostaglandins & interleukins & histamine & serotonin.

3) **Activation** of angiotensin I to form **angiotensin II** (important VC substance) by (ACE) convertase enzyme.   
 → potent vasoconstriction

4) **Removal of some substances** as noradrenaline & serotonin.

5) **Contains fibrinolytic system** for lysis of any intra-vascular thrombus. So, protect systemic circulation from emboli.

# Lung surfactant

- **Definition:** It is lipoprotein mixture containing phospholipid , dipalmitoyl lecithin.
- **Secreted from:** Type II alveolar cells.

## Functions:

1. **Decrease the Surface tension of the fluid lining the alveoli** Surfactant forms a layer between alveolar fluids & air inside alveoli So, prevent air – water interface. (make it air – surfactant interface).

This leads to decrease surface tension .

2. **Decrease muscular effort during inspiration**

Surfactant causes easy gradual expansion during inspiration.

يمنع انهيار alveoli إنهما تسكر  
بشكل كامل عن طريق تقليل  
ال Surface tension  
بالتالي يسهل ال  
inspirational  
expirational

Surfactant also prevents rapid expiration and collapse.

Surfactant ↓ alveolar surface tension → ↓ collapsing force → keeps alveoli open & prevents fluid from entering → prevents pulmonary edema ✓

### 3. Safety factor against pulmonary edema

Surfactant **decreases the alveolar fluid surface tension suction force** causing dry alveoli & prevents formation of pulmonary edema.

(As increased surface tension in alveoli leads to filtration of fluid from pulmonary capillaries into the alveoli) → *causing edema...*

### 4. Stabilization of alveolar size

It is **Less** concentrated in **Large** alveoli so, prevent their rupture, while it is more concentrated in small alveoli so, prevent their collapse.

\* Air move from higher pressure to lower pressure  
\* if the pressure is equal no movement will occur

\* حجم كل alveoli مختلف عن الثاني، وعشانه يحافظ على ال pressure وكاف على ال Volume  
small size → pressure ↑ → *بسكون ال* Surfactant → *عشان* يقل ال Surface tension → prevent collapse

# Factors affecting surfactant formation

- Surfactant formation starts from **24th weeks** of intrauterine life.
- Surfactant formation completes at **35th weeks**.
- Surfactant formation needs **Cortisol & Thyroxin**

## *Factors diminish surfactant:*

- 1- Prematurity in infants.
- 2- Decrease thyroxine and cortisone.
- 3- Increase insulin as it inhibits surfactant protein formation.
- 4- Hypoxia.
- 5- Heavy cigarette smoking.
- 6- Acidosis.
- 7- Lung diseases.



السبب ممكن يكون:-

1. tumor in B cell
2. diabetic mother →

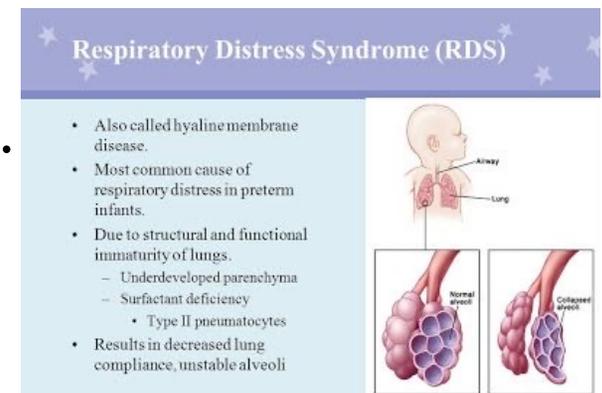
عندما glucose عالي يروح ال placenta عن طريق ال baby as a response to a high level of glucose insulin is produced

# Hyaline membrane diseases (Infantile respiratory distress syndrome)

- Decrease surfactant formation in **newly born** leading to failure of lung expansion & alveolar collapse & pulmonary edema & respiratory failure then death.
- It occurs in premature babies due to (low cortisol & low thyroxin) & infant of diabetic mother due to (high insulin).
- **Diagnosis** Decreased ratio between **lecithin / sphingomyelin** in amniotic fluid ( $< 1$ ).
- Normally = 1 at 24 weeks & = 2 at 35 weeks of pregnancy.

- **Treatment**

- a) Artificial respiration and cortisone & thyroxin.
- b) Artificial surfactant.



in → out → Pause

Respiratory cycle...

# Respiratory mechanics

## Mechanism of inspiration

**Active** process under effect of inspiratory center + short duration.

Contraction of inspiratory muscles.

**Normal inspiration:**

a) Diaphragm ⇒ ↑ vertical diameter.

( responsible for 75% of normal inspiration)

b) External intercostal ⇒ ↑ transverse diameter.

**Forced inspiration:**

Sternomastoid & Serratus anterior

& Scaleni & Elevator Scapule

& Erector Spine.

↑ Size of thoracic cavity.

Distention of the lung.

↓ Intrapulmonary pressure. (-1 mmHg).

Air flow to inside the lung.

zero is equal to atmospheric...  
سوی صفر است  
هو جو

## Mechanism of expiration

**Passive** process due to stoppage of the activity of the inspiratory center.

**Normal expiration** by:  
Relaxation of inspiratory muscles.

**Forced expiration** by:

- a) Internal intercostals.
- b) Abdominal muscles.

*inversion*  
*descend*

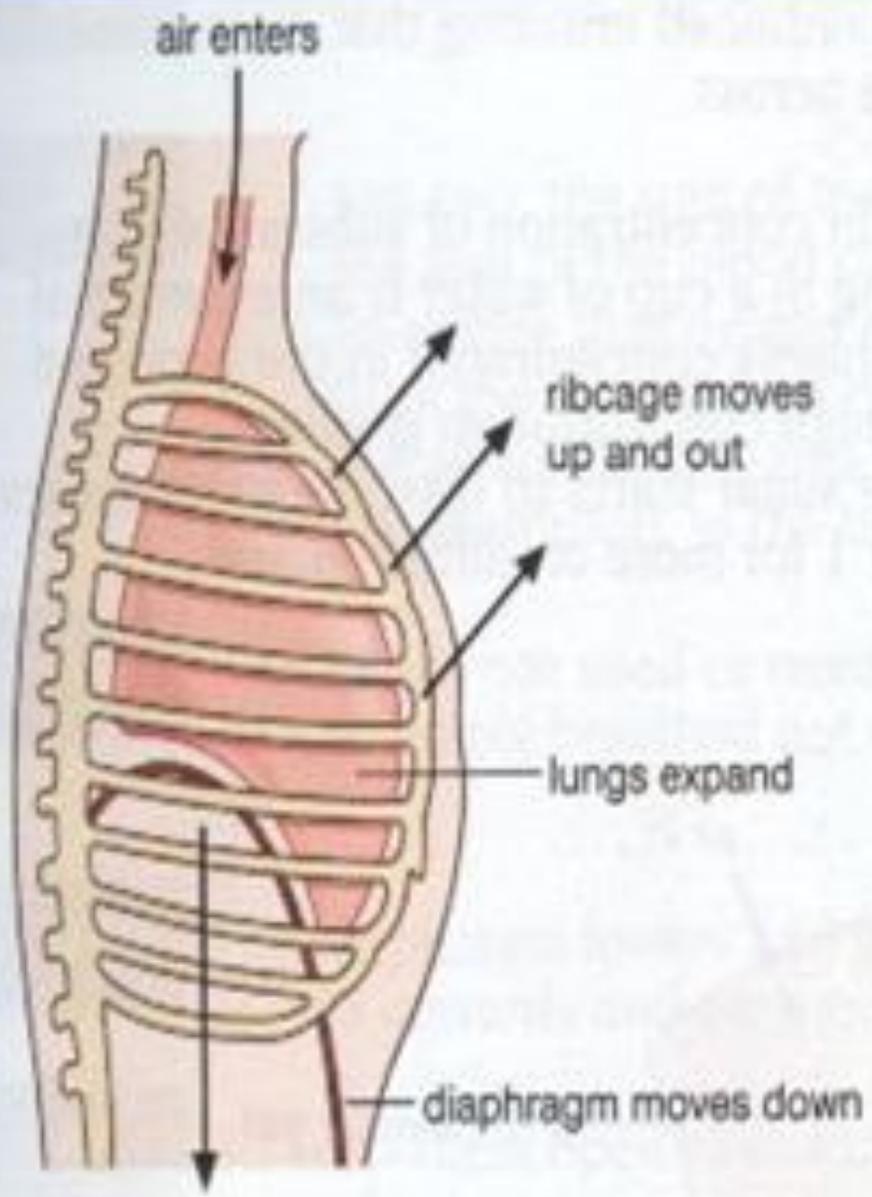
↓ Size of thoracic cavity.

Recoil of the lung.

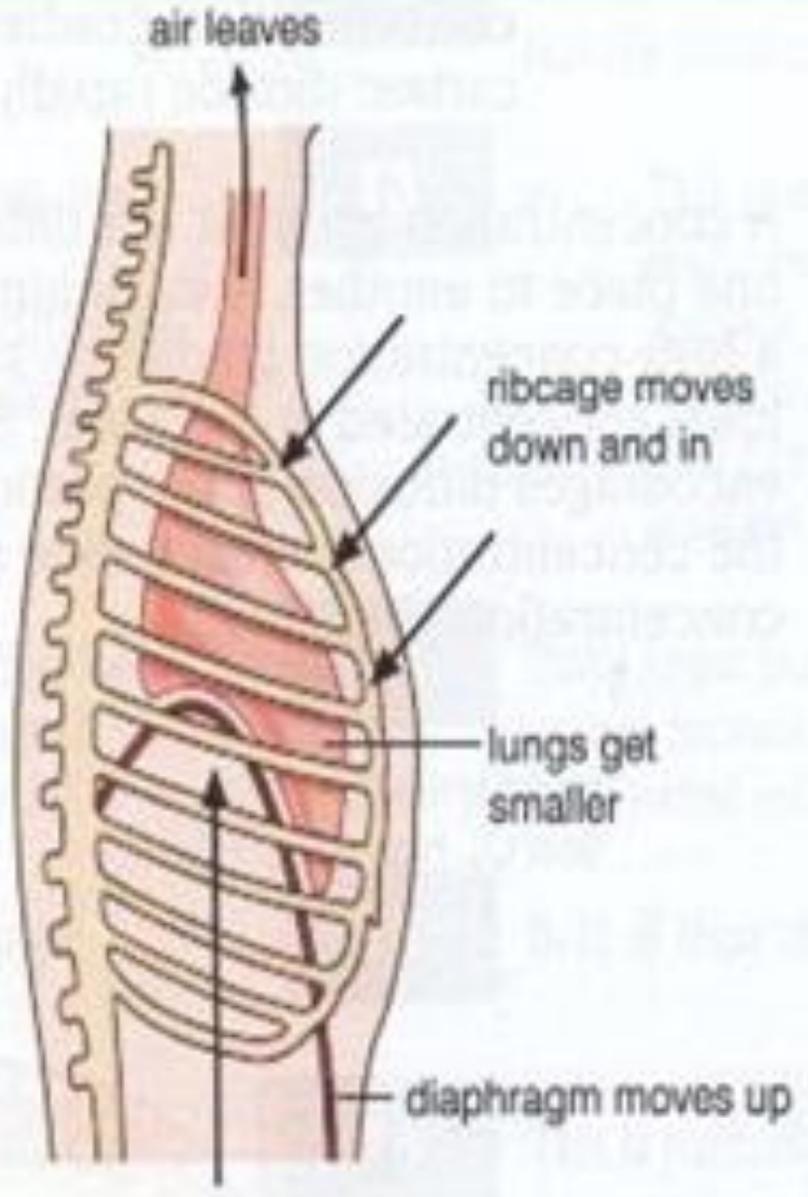
↑ Intrapulmonary pressure. (+1 mmHg).

Air flow to outside the lung.

**N.B** Expiration is active in forced expiration



Inhalation



Exhalation

➤ **N.B:** *Respiratory cycle is composed of* active inspiration and passive longer expiration followed by expiratory pause in a rate of 12-16 cycles/min.

➤ **N.B:** *The expiratory pause is caused by:*

1- reflex stoppage of the activity of the inspiratory centers.

2- the time required for re-accumulation of  $\text{CO}_2$  after its wash by expiration to stimulate new inspiration.

*$\text{CO}_2$  is the main stimulus of Respiratory process.*

# Respiratory pressures

## 1. Intra alveolar (Intra pulmonary) pressure:

**Definition:** It is the pressure inside the alveoli during respiratory cycle.

<b>Value:</b>	<b>Inspiration</b>	<b>Expiration</b>
<b>Normal</b>	- 1 mmHg	+1 mmHg
<b>Forced</b>	- 30 mmHg	+ 40 mmHg
<b>Forced with closed glottis</b>	- 80 mmHg (Muller maneuver)	+ 100 mmHg (Valsalva maneuver)
During respiratory pause = zero (atmospheric).		

No flow of air neither out nor in

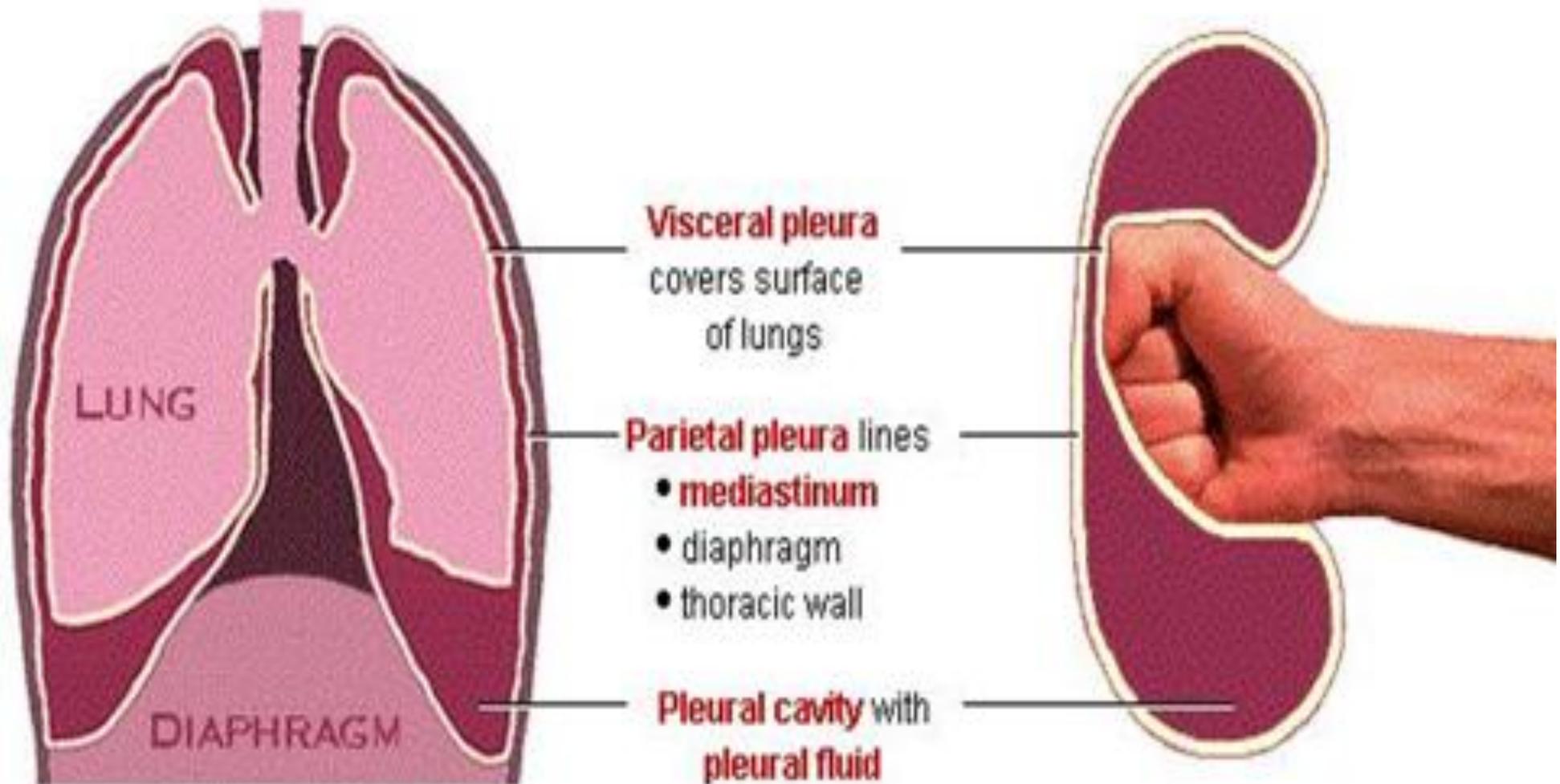
this change in pressure is due to muscle work

# PLEURAE AND THE LUNGS

Each lung is surrounded by two layers of **serous membrane** known as the **pleurae**.

The visceral and parietal pleurae are actually a continuation of the same membrane.

The relationship between the pleurae and the lungs can be demonstrated by pushing a fist into a water-filled balloon.



## 2. Intra pleural (intra thoracic) pressure (IPP):

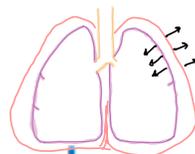
➤ **Definition:** It is the pressure in the space between the two layers of pleura.

➤ **Value:**

	Inspiration	Expiration
Normal	- 6 mmHg	- 3 mmHg
Forced	- 12 mmHg	
Forced with closed glottis	- 30 mmHg (Muller maneuver)	+ 40 mmHg (Valsalva maneuver)

→ +ve  
عشان يضغو  
على ال lung  
ويطلع الهواء

➤ **Cause of negativity of IPP:**



pleura → expansion  
lung → recoil

- It is due to continuous tendency of the lung to recoil against continuous tendency of the chest wall to expand. So, the two opposing forces cause negativity in pleural sac.

## The recoil tendency of lung

- At end of normal expiration when respiratory muscles are relaxed the volume of lung and thorax = 2.5 liters, But the relaxation volume of the lungs = 1 liter.
- So, the lung is distended from 1L to 2.5L and has tendency to recoil.

This **recoil tendency** is caused by:

- 1) Stretched elastic fibers of the lung (1/3 recoil tendency).
- 2) Surface tension of the fluid lining the alveoli (2/3 recoil tendency).

## The expansion tendency of chest wall

- At end of normal expiration when respiratory muscles are relaxed the volume of lung and thorax = 2.5 liters.
- But the relaxation volume of chest = 5 liters So, the chest is compressed from 5L to 2.5L and has tendency to expand.

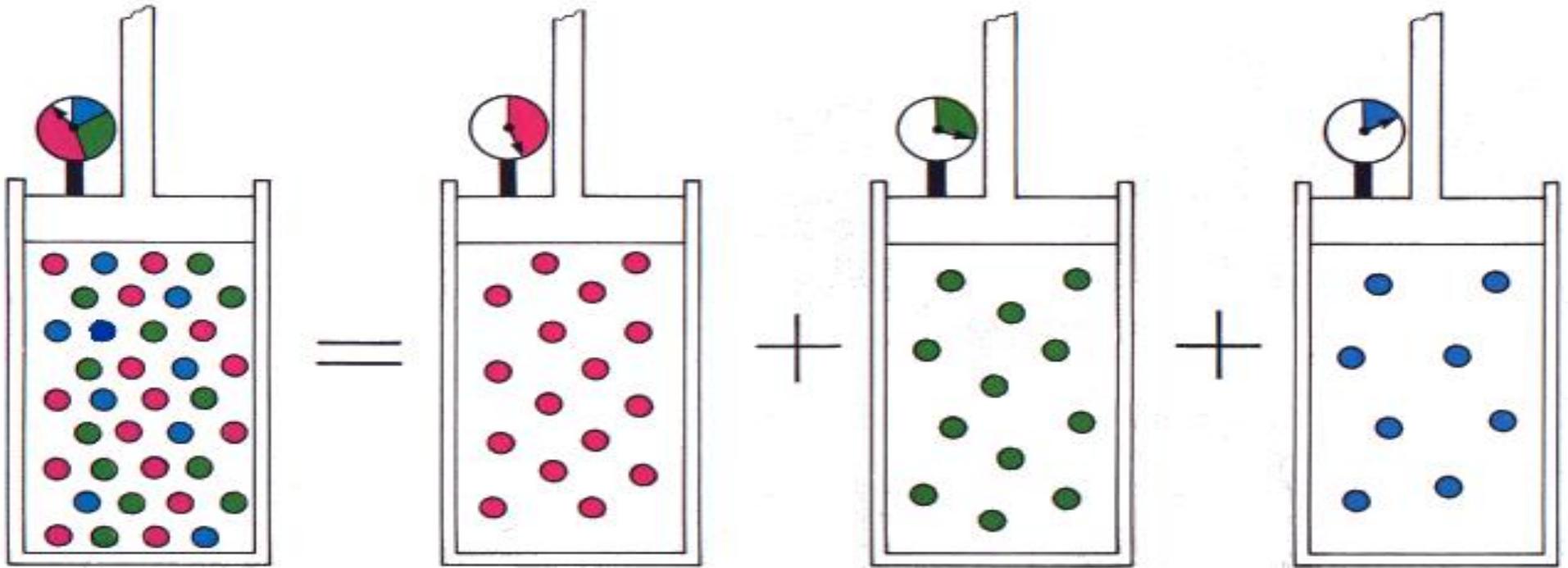
This **expansion tendency** is caused by:

Elasticity of muscles, tendons and tissue of chest.

## Functions of IPP

- 1) It helps venous and lymph return against gravity.
- 2) It helps the **Expansion** of the lungs during inspiration.
- 3) Maintains the lung inflated & prevents its collapse specially during expiration.

# Dalton's Law of Partial Pressure



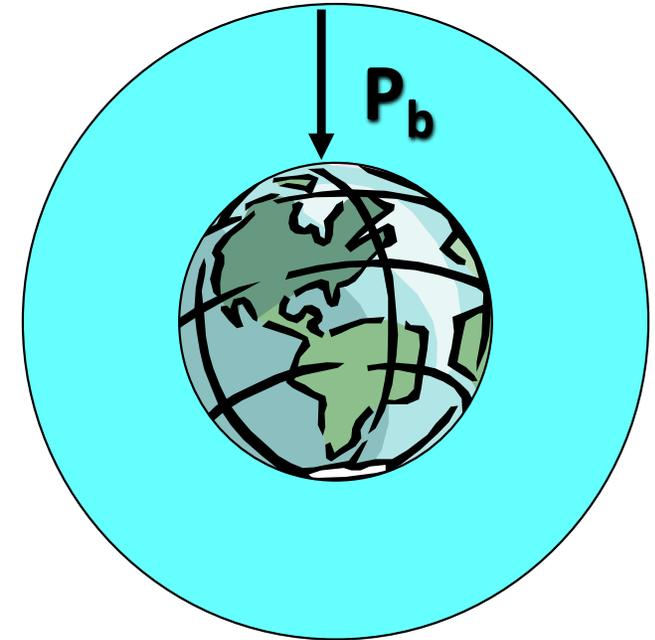
- Partial Pressure = Pressure that each gas would exert if it were alone.
- Total Pressure = Sum of individual gas pressures.

# Partial Pressures of Gases

## Basic Composition of Dry Air

- 78.98 % Nitrogen & inert gases
- 20.98 % Oxygen
- 0.04 % Carbon Dioxide

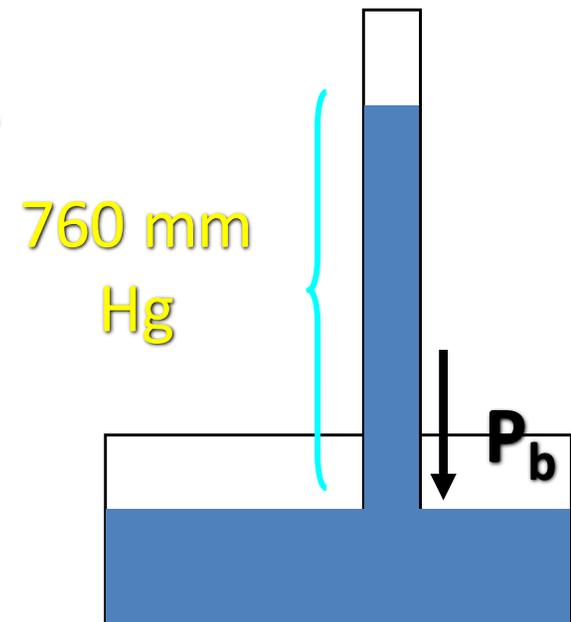
➤ In **a mixture of gases**, each gas exerts a partial pressure proportional to its fraction.



➤ Total Pressure = sum of the partial pressure of each gas

➤ Total Pressure (**at sea level**)

$$P_{\text{barometric}} = 760 \text{ mm Hg}$$



# Partial Pressures of Gases

$P_{\text{gas}} = P_{\text{baro}} \times F_{\text{gas}}$       **where**  $F_{\text{gas}}$  is the gas fraction

$P_{\text{N \& inert gases}} = 760 \times 78.98 \% = 600.2 \text{ mm Hg}$

$P_{\text{O}_2} = 760 \times 20.98 \% = 159.44 \text{ mm Hg}$

$P_{\text{CO}_2} = 760 \times 0.04 \% = 0.30 \text{ mm Hg}$

**N.B Partial Pressure** of a gas is a major determinate of gas exchange in the alveoli.

# Alveolar Gases

Nitrogen- 74.9% or 569 mm Hg

Oxygen- 13.7% or 104 mm Hg

Carbon dioxide- 5.2% or 40 mm Hg

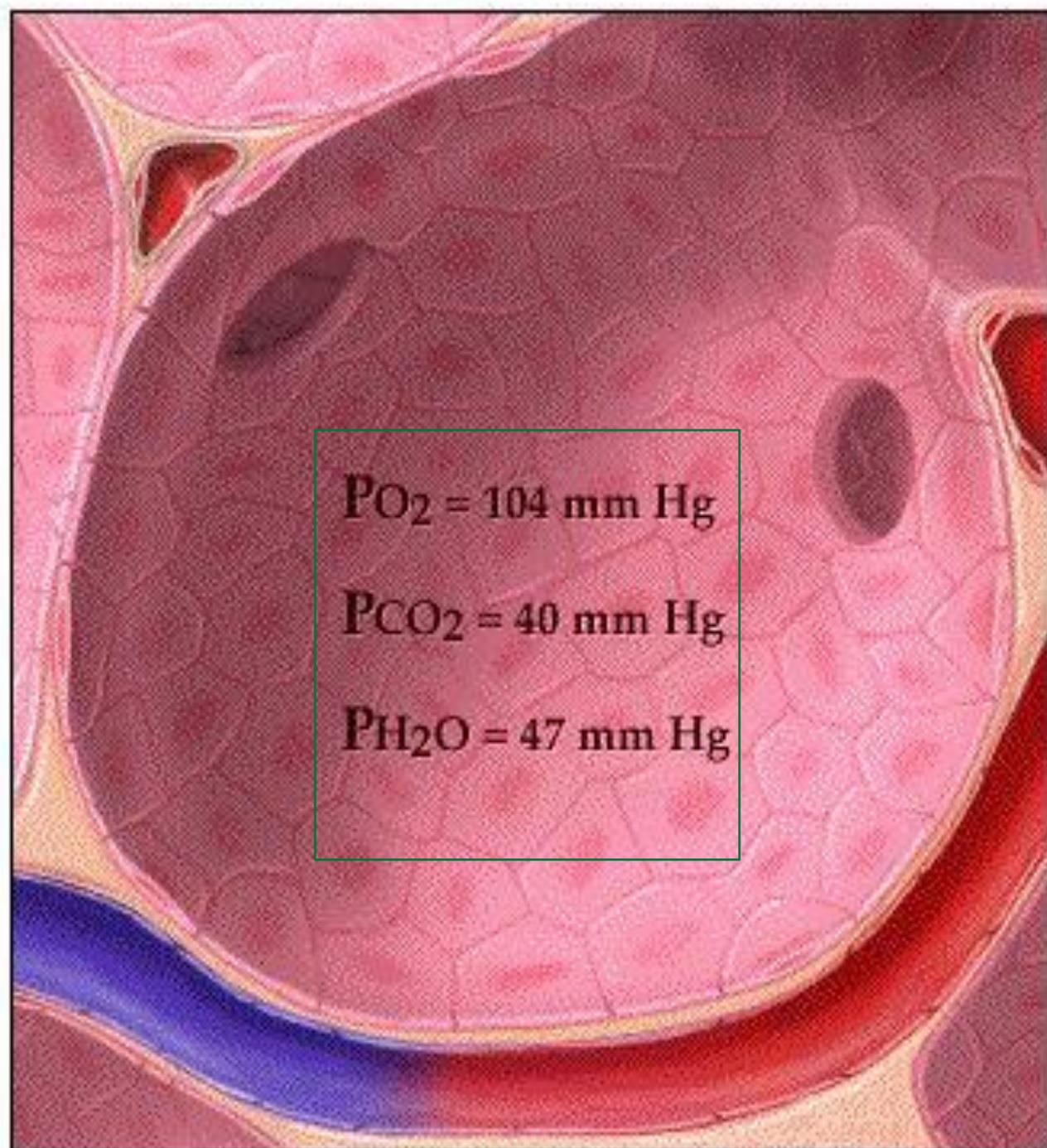
زاد لانه اجي  
مع ال blood

Water vapor- 6.2% or 47 mm Hg

سبب الاختلاف بين ال alveolar وال atmospheric

1. humidification
2. gas exchange

# PARTIAL PRESSURES



The partial pressures of gases in the alveoli differ from those in the atmosphere.

This difference is caused by a combination of several factors:

- Humidification of inhaled air
- Gas exchange between alveoli and pulmonary capillaries
- Mixing of new and old air

# Effects of Humidity on Partial Pressures

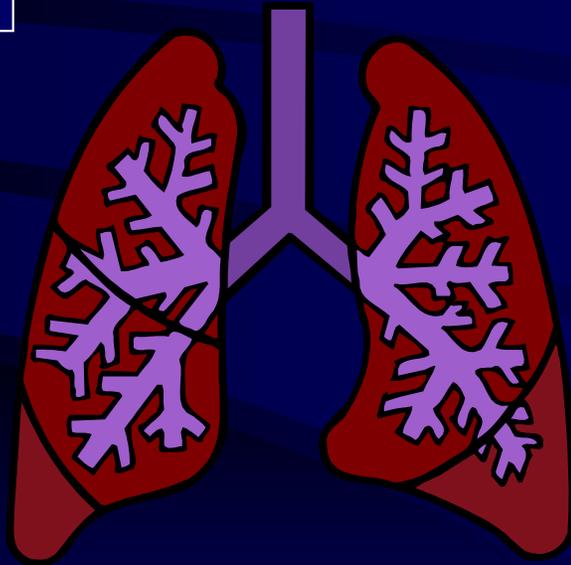
Your Nose



Humidified  
warm Air



Cold  
Dry Air



Saturated air at  $37^{\circ}\text{C}$  has  $\text{H}_2\text{O}$  vapor that exerts a partial pressure of **47 mm Hg**

Total Pressure remains 760 mm Hg

## Basic Fact

The addition of water to the air has diluted the oxygen concentration of the air entering the lungs.

**THANK YOU**

