Respiration

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Objectives

- **1-The concept of anatomic dead space.**
- **2-Pulmonary ventilation and alveolar ventilation.**
- **3-The gas exchange between alveoli and pulmonary blood and factors affect the movement of gases across alveolar wall.**
- **4-How oxygen and carbon dioxide are transported to and from tissues in the blood .**
- **5-O2 dissociation curve and physiologic factors that can influence it.**
- **6-The transport of carbon dioxide by blood**

Respiration is divided into:

1) **External respiration, consists of:**

   a) **Pulmonary ventilation** i.e renewal of air from atmosphere.

   b) **Exchange of gases** between alveolar air and venous blood.

2) **Respiratory function of blood:**

   a) **Carriage of O2 from the lung to tissues.**

   b) **Carriage of CO2 from the tissue to lung.**

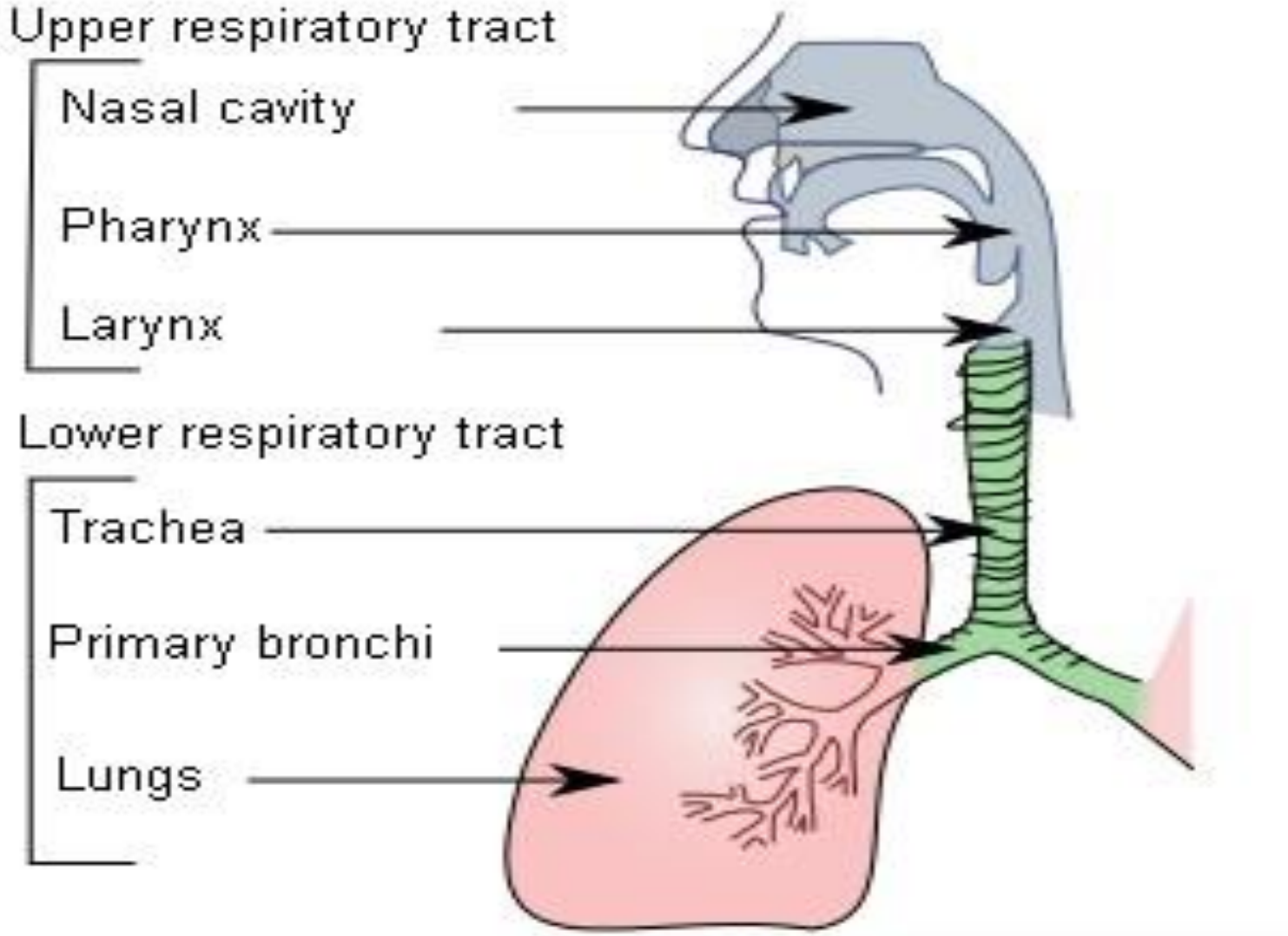
3) **Internal respiration:**

   - It's utilization of 02 in oxidation of food stuffs and production of energy.

Physiological anatomy of respiratory system:

- respiratory system is consist of :

1) **air passage and lungs:** which is divided into conducting zone and respiratory zones.
2) **respiratory muscles.**
3) **respiratory centers controlling respiration.**


Upper respiratory tract
Nasal cavity
Pharynx
Larynx
Lower respiratory tract
Trachea
Primary bronchi
Lungs

A) Conducting zone

- It includes : nose , nasopharynx , trachea , bronchi, terminal bronchioles ,**till** the end of terminal bronchiole and the start of respiratory bronchioles.
- walls of conducting zone are thick and **don't allow** gas exchange (Dead space)

Function of conducting zone:

1) **Conduction** of air to the respiratory zone.
2) **Air conditioning:**

- **adjusting the temperature** of inspired air to be **equal to that of body** by adding heat to cold air and remove of excess heat from hot air.
- this is achieved by the **rich blood supply** in the mucosa of nose , mouth and pharynx.

3) Humidification:

- means **saturation of inspired air with water vapour** to protect the delicate lung tissues from injury.
- **this occurs by transcapillary fluid in the mucous membrane.**

4) Filtration:

- means **filtering air from foreign particles** and bacteria , so that:
- large **particles > 4-6 microns are trapped by hairs** of the nose while **small particles are trapped by mucous secreted by goblet cells**.

5) **Protective reflexes:**

- **for removal of F.B and irritant sub. from respiratory passages, they include:**

  a) cough reflex b) sneezing reflex

6) **Non respiratory function:**

a) **Smell:** by the olfactory epithelium in the nose.

b) **Phonation:** by vibration of vocal present in the larynx.

B) respiratory zone

- Thes includes respiratory bronchioles and alveoli
- The membrane separating blood in pulmonary capillaries and air in alveoli is very thin so gas exchange occurs freely and rapidly.

External respiration

- Consists of: 1) Pulmonary ventilation.

  2) Exchange of gases.

1-Pulmonary ventilation (Minute respiratory volume)

- **Definition:** It is the total amount of air inspired per minute
- It equals **the respiratory rate per minute(respiratory cycles) x tidal volume**
- **Tidal volume**:The volume of air inspired or expired with each normal quite breath
- **It equals 500ml in the normal young adult male**

I) Pulmonary ventilation

The respiratory cycle, each cycle **consists of:**

a) Inspiration = 1.3 sec.:

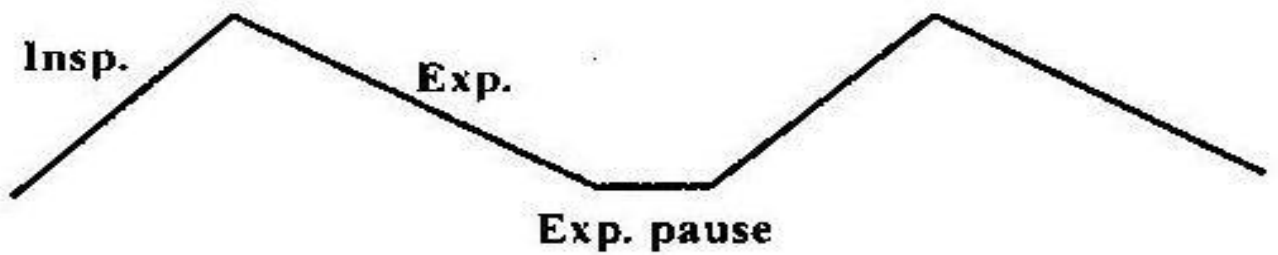
- active process , the thoracic cavity ↑ in all dimensions → the lung distends and air rushes into the lungs .

b) Expiration = 1.7 sec (longer than inspiration):

- passive process , the thoracic cavity ↓ in all dimensions → the lung recoils and the air is forced outside the lung .

c) Expiratory pause = 0.7 sec. :

- some time present specially during rest and sleep.
- **disappears during rapid respiration** e.g **exercise.**



N.B: - Respiratory cycle = 1.7+1.3+0.7 = 3.7 sec.

- **Respiratory rate (number of respiratory cycle/min.):**

$$= \frac{60}{3.7} = \text{about } \mathbf{16} \text{ cycle / min.}$$

It ranges from 12-16 cycles per minute

-In children the rate is about 25 /min

So pulmonary ventilation =12 x 500=6 L per minute

Mechanism of Respiration

a) Inspiration:

- **Occurs as a result of contractions of the diaphragm and external intercostal ms.**
- Contraction of the diaphragm →↑ the vertical diameter of chest cavity.
- **Contraction of external intercostal ms→↑the transverse and antero-posterior diameters**.
- So the chest cavity increases in all its dimensions → ↑in the lung volume → ↓ pressure inside the lung alveoli → rush of air into the lung.

b) Expiration:

- **Relaxation of diaphragm and external intercostal ms decrease the chest in all diameters → ↓ in the lung volume → ↑ pressure inside the lung alveoli → rush of air out of the lung.**

Factors affecting pulmonary ventilation

1) **Resistance of air passage:**

- The resistance **depend on the diameter of respiratory passages:** ***↓ diameter of the air way →↑ resistance →↓ pulmonary ventilation***

- ***Diameter of air passages is affected by:***

- ***1-Bronchomotor tone****:-affected by* ***autonomic nervous system*** *and inflammatory mediators such as histamine and prostaglandins*

- ***2-Bronchial mucosa*** *:Prescence of secretions (mucus) or* ***increased thickness increase the resistance***

- ***3-Lung volumes*** *:* ***the diameter increases as lung expands***

Factors affecting pulmonary ventilation

2) Surfactant:

- **Surfactant is a complex substance secreted by the alveolar epithelium and acts mainly to ↓ surface tension (when the water forms a surface with air ,the water molecules on the surface are strongly attracted to each other) inside the lung alveoli(due to thin water film lines the alveoli in contact with air). So prevent lung collapse**
- **Decrease of surfactant e.g. respiratory distress syndrome →↑ surface tension inside alveoli →↓ pulmonary ventilation. (alveolar collapse)**

3) Lung and chest compliance:

- **Def:** ***is*** *the extent to which the lung expands for each unit increase in the pulmonary pressure.*

$$\textbf{Compliance} = \frac{\textbf{Change in volume } (\Delta V)}{\textbf{Change in pressure } (\Delta P)}$$

- **The normal compliance** of the lungs in the average adult human is approximately **200 ml / cm of water pressure.**

Significance of measuring compliance:

- **it is a measure of the expansibility of the lung.**
- ***any condition that decreases lung compliance e,g pulmonary fibrosis →↓pulmonary ventilation.***

4--Intra pleural pressure

Each lung is enclosed in a double walled sac called pleura :

-The part that lines the thoracic cavity is called parietal layer

-the part that covers the lung firmly is called visceral pleura

- The cavity in between is filled with serous fluid that prevent friction between the 2 layers and cause the lung to slide on the chest wall and resist their separation

Definition It **is the pressure** inside the pleural cavity.

Value:

It is **a negative pressure**

Causes of negative intrapleural pressure:

a. **No air in the pleural cavity.**
b. Continuous traction of the lung against a rigid chest wall.

4--Intra pleural pressure

Importance of negativity of IPP:

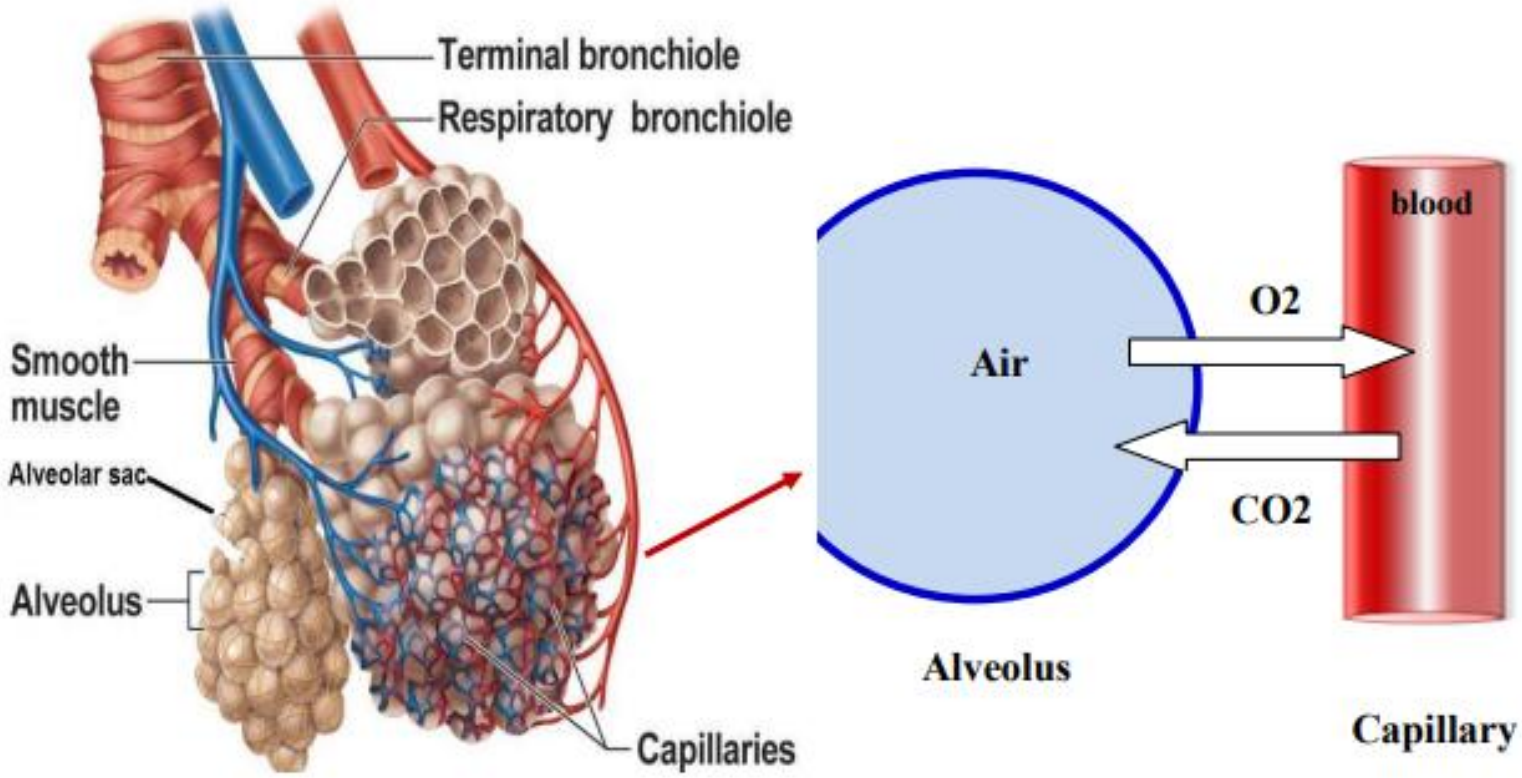
a. It helps expansion of the lungs.(so help pulmonary ventilation)

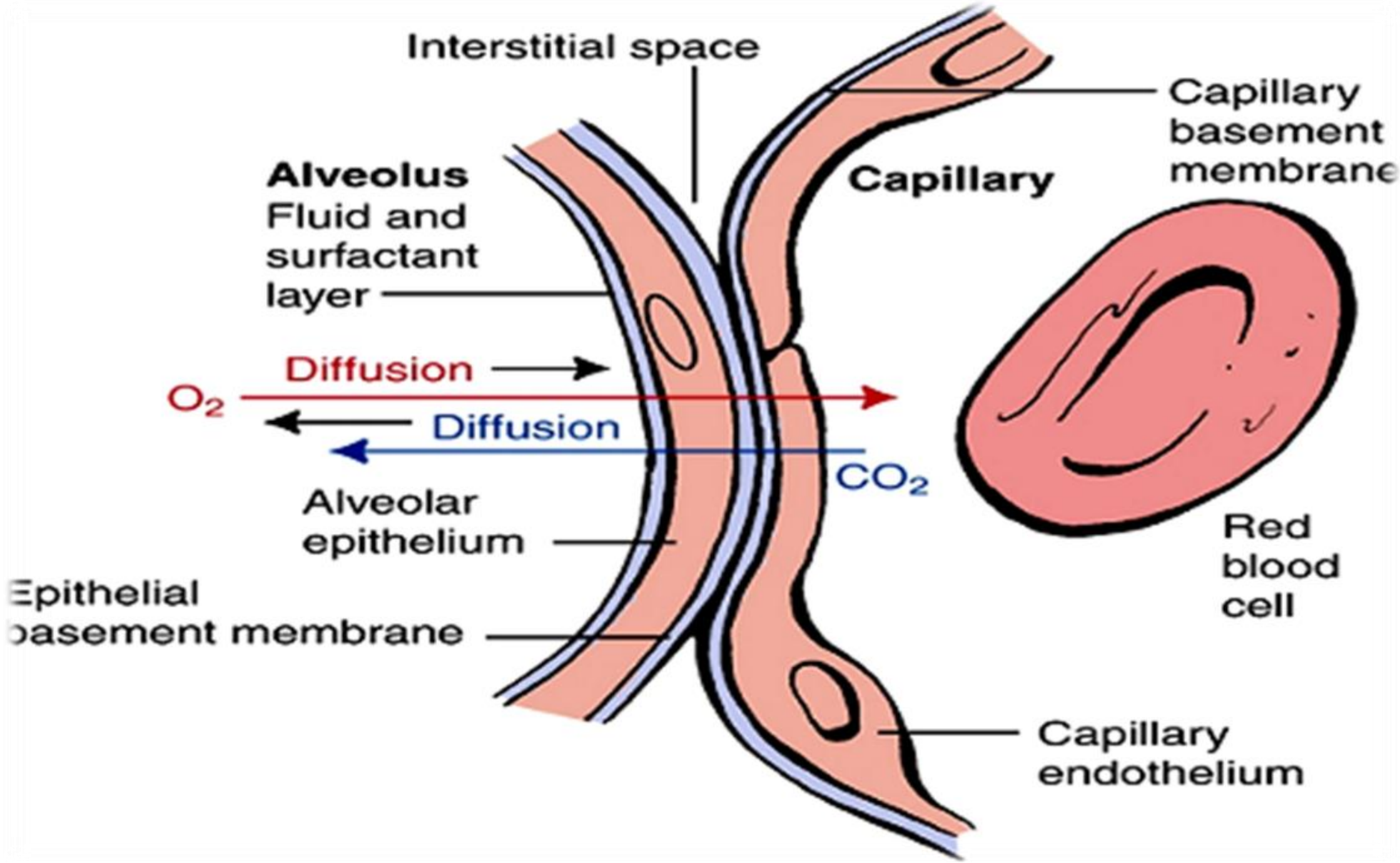
b. It helps venous return.

c. It helps flow of lymph.

II- Exchange of gases

- is the change of O2 for Co2 through the respiratory membrane.




Interstitial space
Capillary basement membrane
Alveolus
Fluid and surfactant layer
Capillary
Diffusion
O_2
Diffusion
CO_2
Alveolar epithelium
Red blood cell
Epithelial basement membrane
Capillary endothelium

Factors affecting gas exchange:

1) **Properties of respiratory membrane.**
2) **Properties of respiratory gases.**
3) **Ventilation / perfusion ratio.**

1-Properties of respiratory membrane.

a) Thickness of the respiratory membrane:

- **normal thickness** of resp. memb. = **0.6** micro-meter.
- the **rate of gas diffusion** → is **inversely proportional** to the **thickness.** so any factor that ↑ **the thickness** of resp. memb → ↓ **gas** exchange .
- Any factor that increases the thickness (such as pulmonary edema and pulmonary fibrosis) can interfere with exchange of gases.

b) Surface area of the respiratory membrane:

- **Normal** surface area = **60 m^2 .**
- the **rate** of gas diffusion → is **directly proportional** to the **surface area** of the Respiratory.

II- Properties of the respiratory gases:

- the **rate of diffusion** of respiratory gases is **affected by :**

a) Pressure gradient:

	Alveolar air	Venous blood
O2 pressure	100 mmHg	40 mmHg
Co2 pressure	40 mmHg	46 mmHg

- according to conc. **Gradient :**
  i. O_2 diffuses from the alveoli **into pulmonary capillaries**
  ii. CO_2 diffuses from pulmonary capillaries **into alveoli .**

b) Lipid solubility & molecular weight (M.W):

- all respiratory gases are lipid soluble.
- the **rate** of gas diffusion is :

i-directly proportional to lipid solubility.

ii-inversely proportional to M.W of the gas.

The solubility of Co2 is greater than O2but have larger molecular weight

The net result is that the diffusion rate of CO_2 through the respiratory membrane is about 20 times that of O_2

Diffusion capacity

- **Def: It is the volume of a gas that diffuses through the membrane each minute for a pressure difference of 1 mmHg.**

- For O_2 is 20ml./ min./ mmHg.
- for CO_2 is 400 ml./min./mmHg.
- **This capacity increases during muscular exercise to 80 for O2 and 1200 for CO2**
- This increase is due to increase surface area for diffusion (expansion of **alveoli and opening of more pulmonary capillaries and increase pulmonary blood flow) a**nd also better ventilation perfusion ratio

3-Ventilation / perfusion ratio.

Def: it is the ratio between alveolar ventilation and pulmonary blood flow per minute. ✓

Alveolar ventilation(Effective pulmonary ventilation) ✓

Defintion: The volume of air that enters the alveoli per minute and undergo gas exchange with blood in the pulmonary capillaries ✓

It equals 350 of the 500 ml inspired with each breath ✓

So alveolar ventilation =resp rate x(MRV-Dead space ventilation)=12x(500-150)= 4.2Lper min ✓

Anatomic versus physiological dead space ✓

Anatomic :Air conducting part ✓

Physiologic :include anatomic +non functioning alveoli ✓

3-Ventilation / perfusion ratio.

- The normal alveolar ventilation in an adult is 4 L / min.
- The total perfusion (the blood flow through the lungs) is equal to the cardiac output = 5L/min.
- So the ratio is about 0.8.
- This ratio differ from one part of the lung to another

3-Ventilation / perfusion ratio.

The lung is divided into three zones according to its blood flow.(change in blood flow is **due to effect of gravity on the blood column from the top of the lung to its base)**

Zone I

Present at the apex of the lung.

It is hyper ventilated (ventilation is high).

Blood flow is little so it is called hypoperfused.

This area is more liable to be infected with T.B.

V/P ratio = 3.3.

3-Ventilation / perfusion ratio.

Zone 2 :- ➢

The blood flow begins to occur at the top of the zone increasing down its length.

Zone 3:-this region is hyper perfused and hypo ventilated. ➢

This unequal distribution of blood flow can be explained by the hydrostatic pressure difference(effect of gravity) between the top and bottom of the lung.

V/P mismatch

Local autoregulatory mechanism contribute to match alveolar air flow and blood flow:

I. Pulmonary vessels

- **Low PO_2 causes V.C. of pulmonary blood vessels and decrease in pulmonary blood flow.**
- **While, high PO_2 causes V.D. of pulmonary blood vessels and increase in pulmonary blood flow.**
- **This helps to redistribute blood flow from areas poor in O_2 to areas rich in O_2 producing normal V/P ratio.**
- **II. Respiratory air way**
- **High CO_2 level dilates the airways and increases airflow in the alveoli.**
- **While low CO_2 level constricts the airways and decrease airflow in the alveoli.**
- **This helps to match alveolar air with the pulmonary blood flow.**

Questions

1-Mention 3 functions of the respiratory conducting zone of the respiratory tract

2-Which of the following is considered internal respiration?

Carriage of O2 by the blood (a

Carriage of Co2 by the blood (b

Pulmonary ventilation (c

Oxidation of food stuff by the tissues (d

Exchange of gases (e

2- which of the following is considered part of the respiratory zone of the respiratory system ?

The nose (a

The nasopharynx (b

The larynx (c

The respiratory bronchioles (d

The terminal bronchioles (e

4- which of the following values is considererd the value of respiratory rate?

30cycles per min (a

16 cycles per minute (b

5cyclesper minute (c

10 cycles per min (d

40 cycles per minute (e

5- Describe factors affecting pulmonary ventilation

- 6-Which of the following defects in pulmonary ventilation is considered the cause of respiratory distress syndrome?

Decreased surfactant (a

-ve intrapleural pressure (b

Decreased lung compliance (c

Decreased chest compliance (d

Narrowing of air passages (e

6- Enumerate 3 causes of –ve intrapleural pressure and mention the significance of these negativity

7-Which is considered the value of O2 pressure in alveolar air?

- 40 mmHg (a
- 100mmHg (b
- 46mmHg (c
- 80mmHg (d
- 20mmHg (e

7-Mention how mismatch between pulmonary and alveolar ventilation is autoregulated

8--Discuss factors affecting gas exchange through the respiratory membrane

Thank You