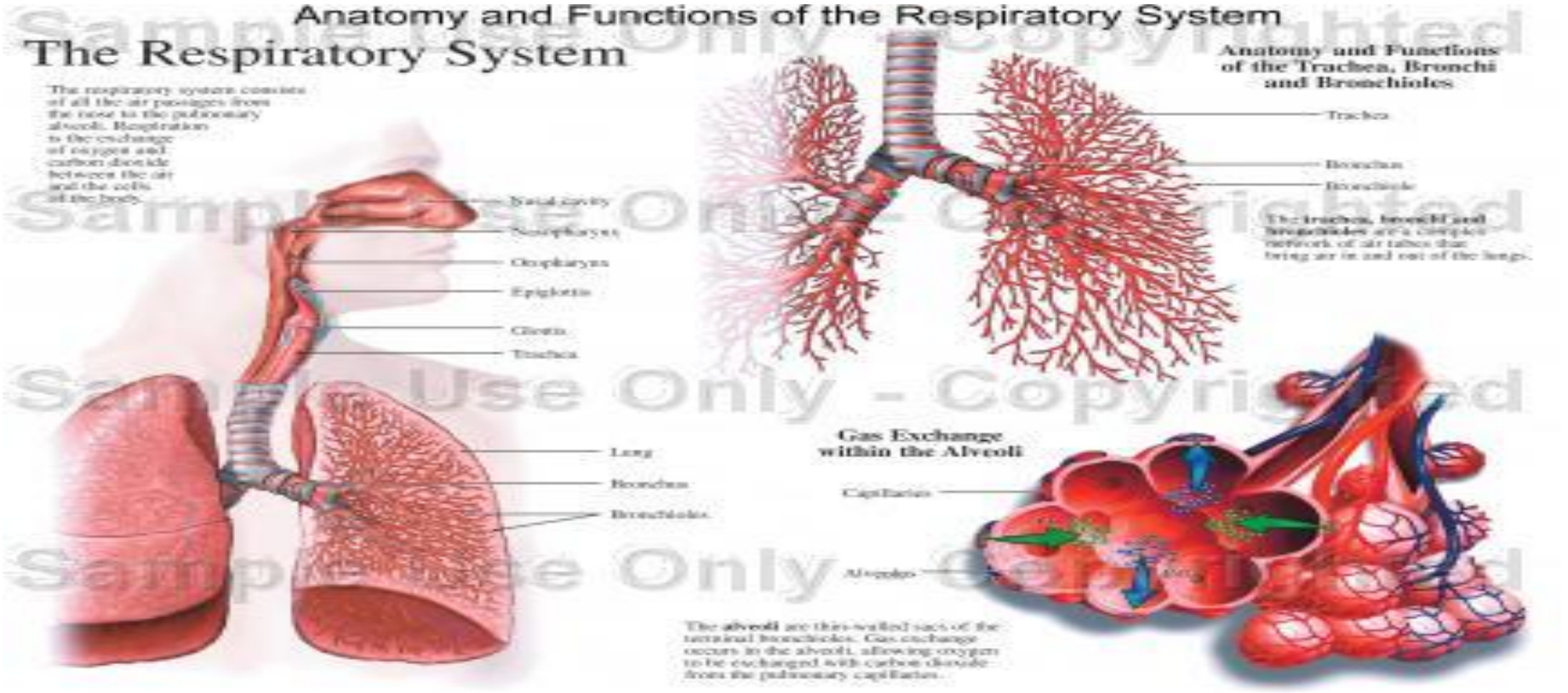
Respiratory Physiology



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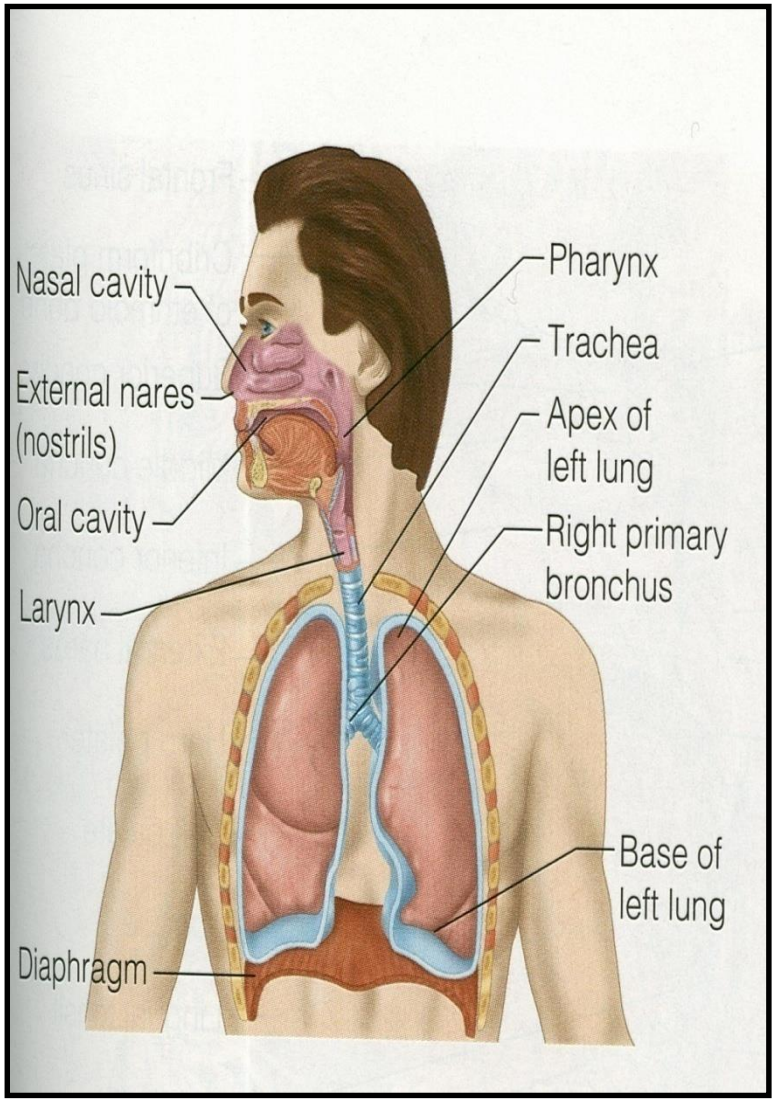
The main goal of respiration is to

1-Provide oxygen to tissues

2- Remove CO2 from the body.

Respiratory system consists of:

- Passages (airways)
- Muscles
- Centers



Functions and organization of the respiratory system

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Learning Objectives

- **By the end of this lecture you will be able to:-**

1-Describe the structures and functions of the conductive and respiratory zones of airways.

2-Distinguish the difference between internal and external respiration.

3-Discuss the functions of the respiratory system, including non-respiratory functions, like clearance mechanism by mucus and cilia, production of surfactant and its physiological significance.

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Functions of the respiratory system include

- Gas exchange (respiratory function).
- Phonation: is the production of sounds by the movement of air through the vocal cords.
- Pulmonary defense: the respiratory mucus membrane has muco-cilliary barrier filter and it produces

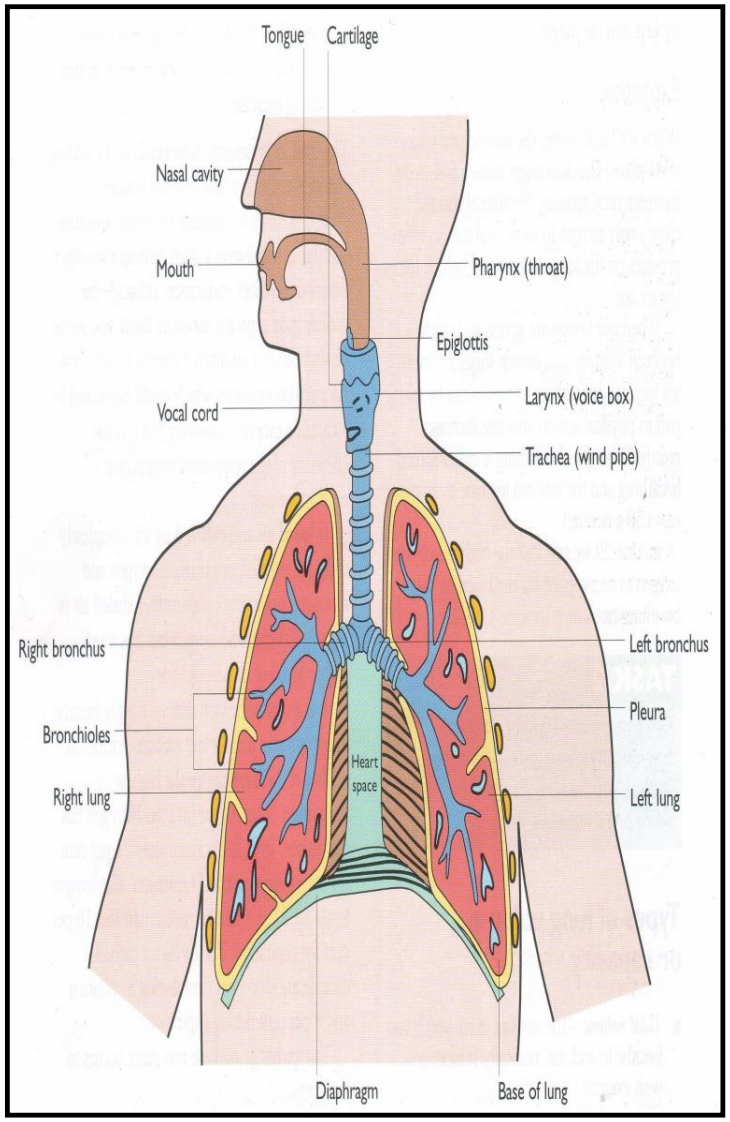
- *Immunoglobulin A (Ig A),*
- *Alpha-1 antitrypsin,*

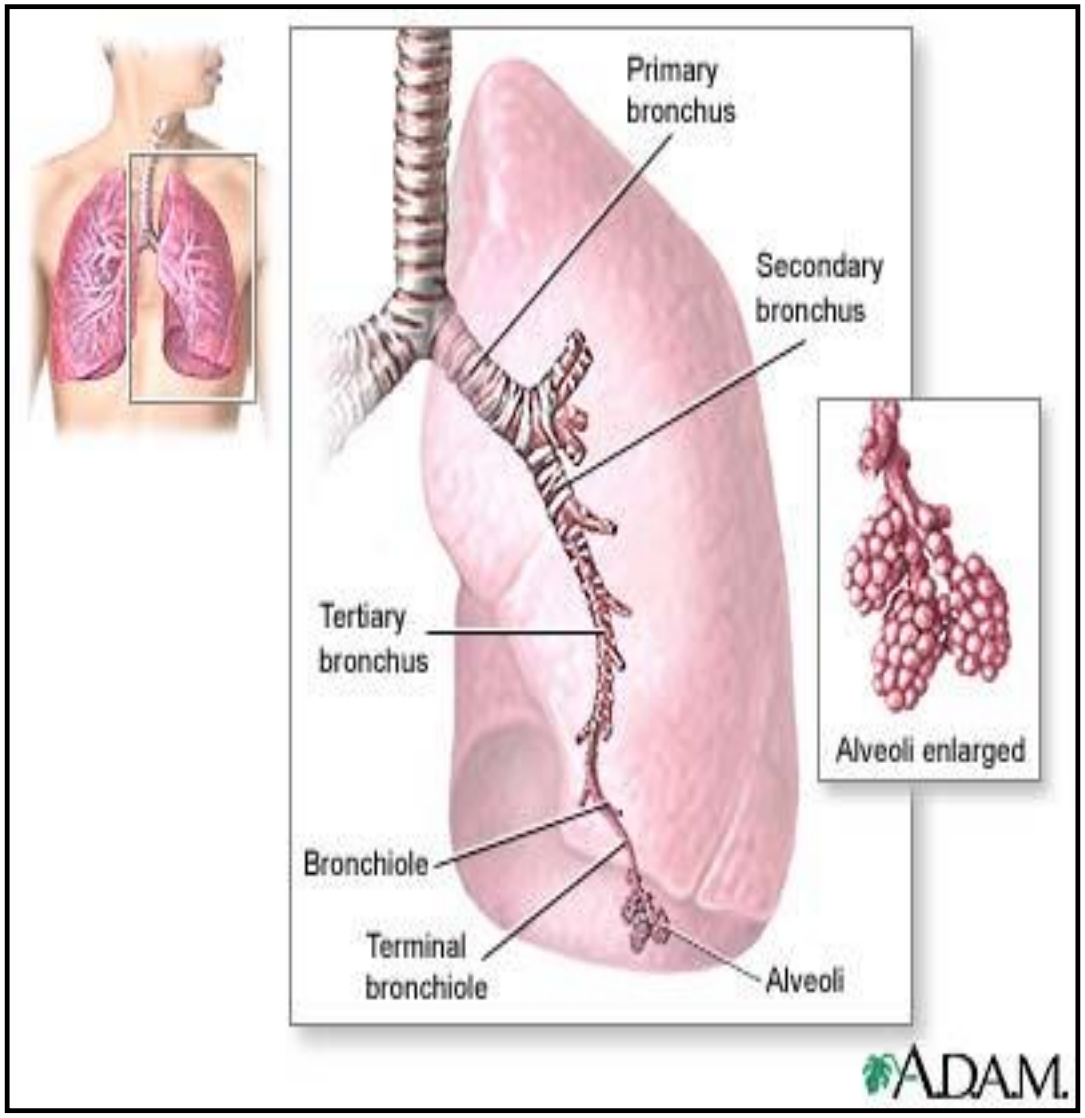
In addition, the pulmonary macrophages in the alveoli: engulf smaller forign particles which pass through the muco-cilliary barrier filter.

Cont..non respiratory functions of lung

- Angiotensin I is converted to angiotensin II with the help of angiotensin converting enzyme formed by the lungs.
- Regulating the acid- base status of the body by washing out extra carbon dioxide from the blood.
- Secretion of important substances like surfactant.

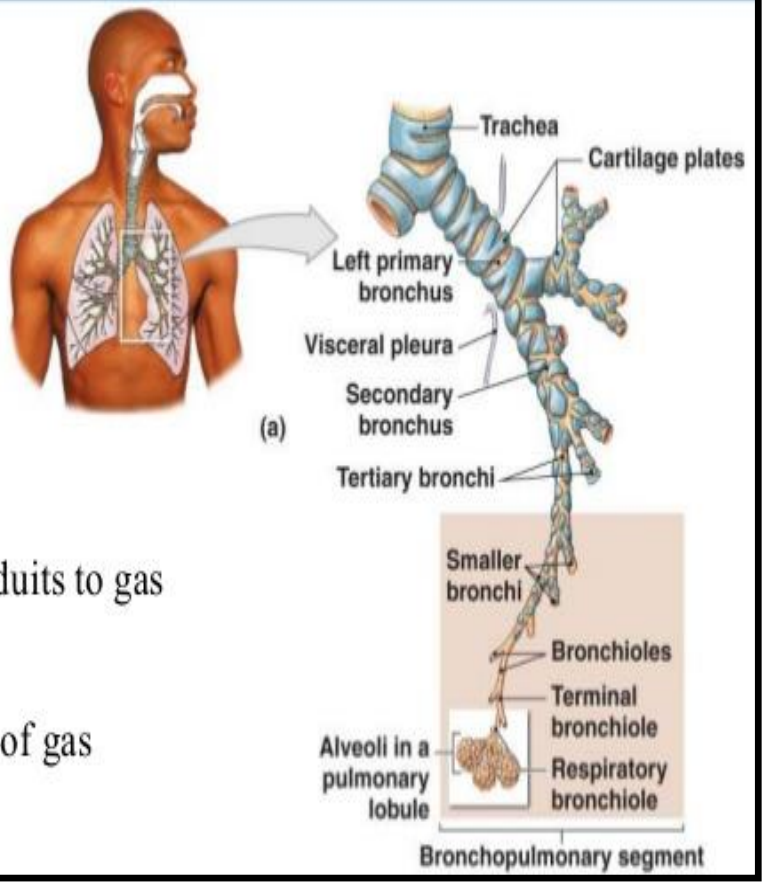
Respiratory passages (airways)





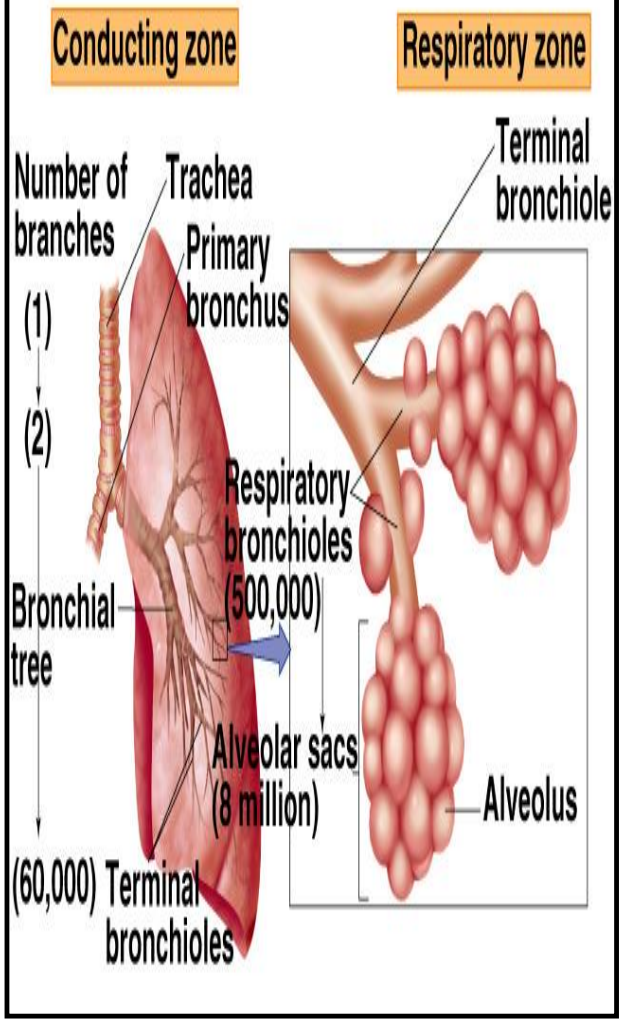
Respiratory passages airways can be divided into

Functional Anatomy



Conducting zone-conduits to gas exchange sites

Respiratory zone-site of gas exchange



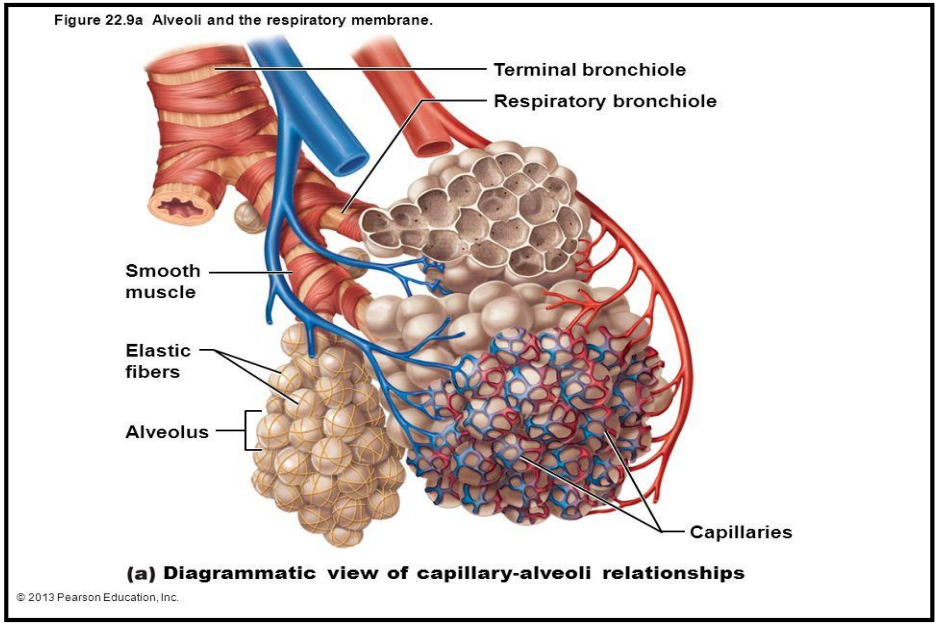
I- Conductive Zone

- Starts from nose to the end of terminal bronchioles.
- Help *warming, humidification, filtration* of inspired air.
- Contains the *olfactory receptors* for smell sensation.
- *Conducts the sound* during speech.
- Protective function by cough and sneezing reflexes.

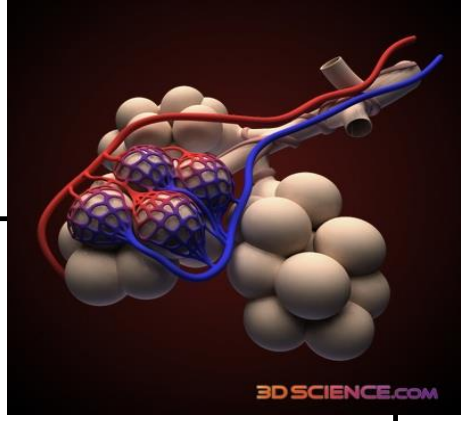
II- Respiratory Zone (Respiratory unit)

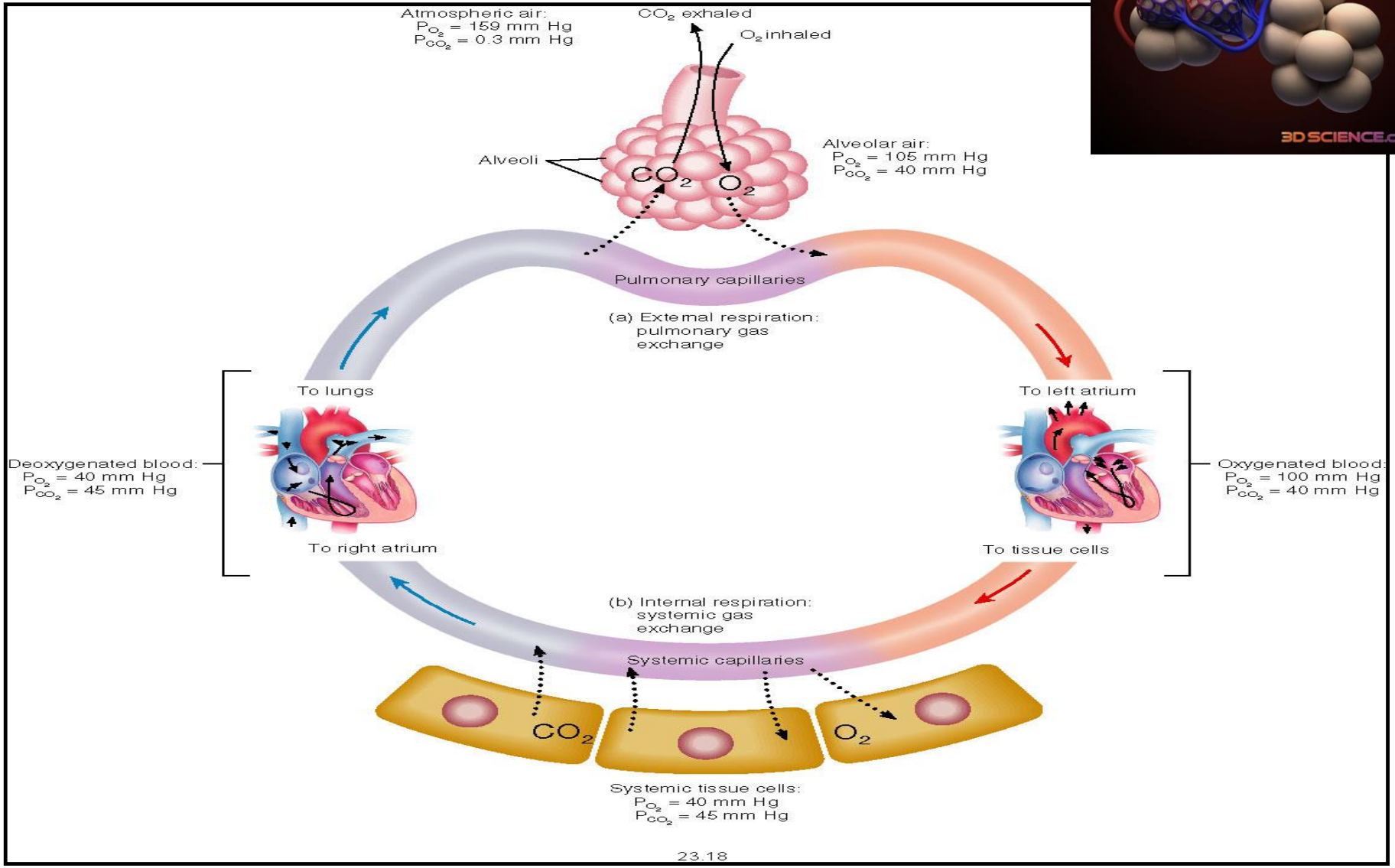
- Includes:

  Respiratory bronchioles, alveolar ducts, alveolar sacs, alveoli
- Function in gas exchange.



External & Internal Respiration





External respiration

3 major functional events occurs during it:

1-Pulmonary ventilation: inward and outward movement of air between lung and atmosphere.

2- ***Diffusion*** of oxygen and CO2 between the alveoli and the pulmonary capillary blood.

3- ***Transport*** of O2 & Co2 in the blood and body fluids to and from the cells.

<u>Respiration could be either:</u>

Resting: normal breathing during resting conditions.

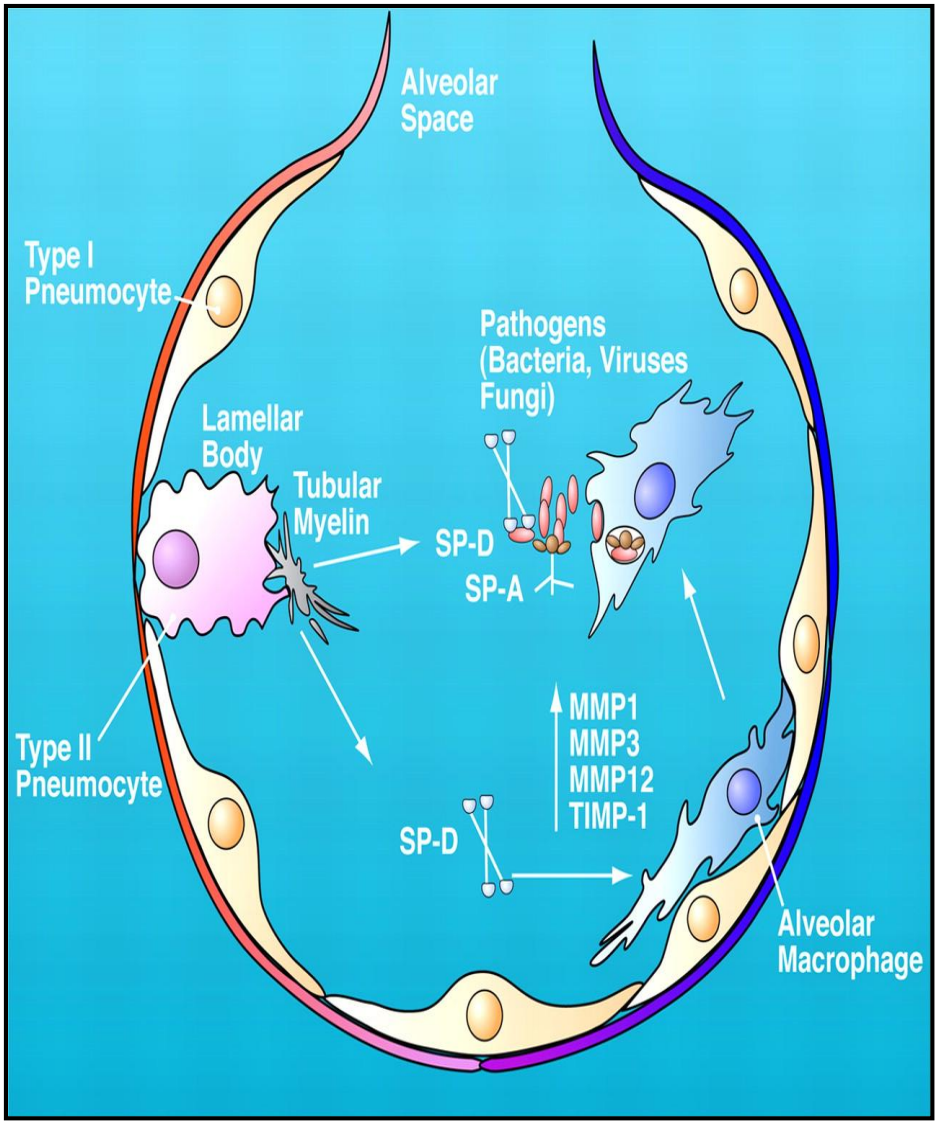
Forced (maximal): normally during exercise and in patients with bronchial asthma, allergy,…etc.

Lining cells of the alveoli

1- Type I alveolar epithelial cells
(type I pneumocytes)
*Participate in the respiratory membrane.

2- Type II alveolar epithelial cells
(type II pneumocytes)
*Secrete surfactant.

3- Alveolar macrophages
*Engulf the foreign bodies that reach the alveoli.



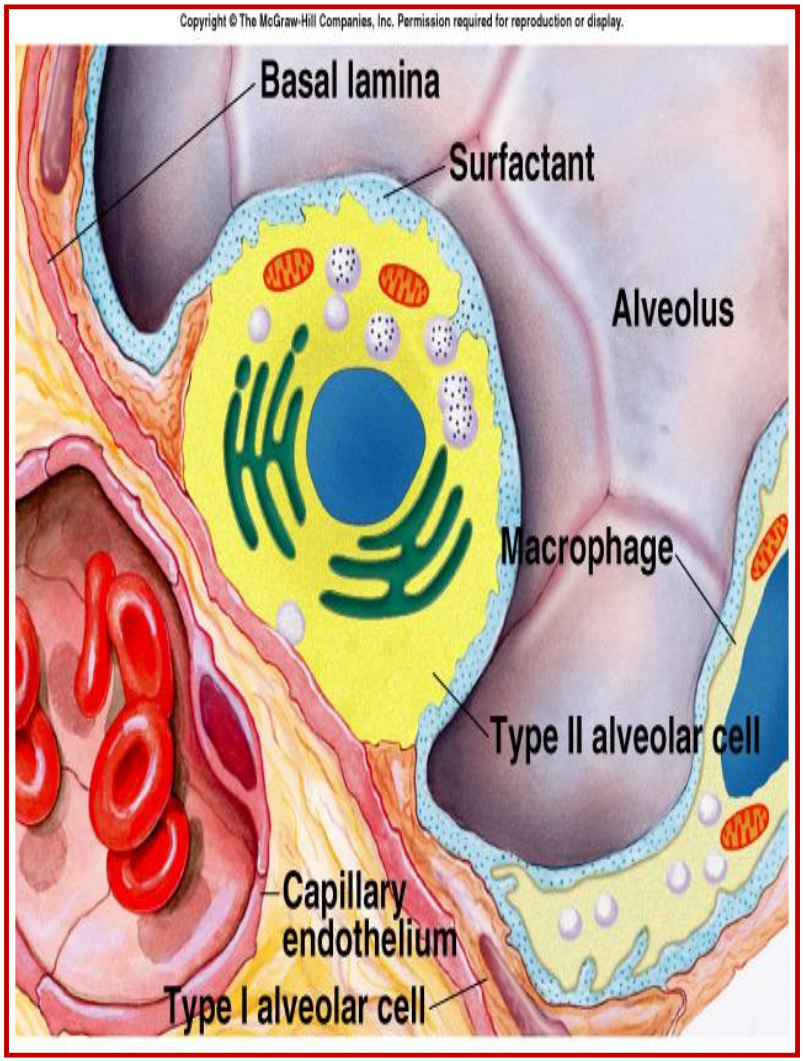
Surface Tension

H_2O molecules at the surface of alveoli are attracted to each other by attractive forces that resist distension called surface tension.

- Surface tension tends to oppose alveoli expansion.

$$\text{Pressure} = \frac{2 \times \text{Surface tension}}{\text{Radius of alveolus}}$$

- Pulmonary surfactant reduces the surface tension of the fluid lining the alveoli.



Surfactant

- Surfactant is a complex compound containing phospholipids esp. dipalmitoylphosphatidyl choline and a number of Apo proteins.
- The earliest detection of surfactant from fetal alveoli begins between 6-7th month but this could be delayed in others to wk 35 of intrauterine life.
- Surfactant reduces surface tension throughout the lung, reducing the effort required by the respiratory muscles to expand the lungs, prevents alveolar collapse, decreases airway resistance and the decreases work of breathing.

Surfactant deficiency

- Deficiency in premature babies causes respiratory distress syndrome of the new born (RDS) (hyaline membrane disease).

- Smoking in adults, hypoxia or hypoxemia (low oxygen in the arterial blood) or both, decrease the secretion of surfactant and cause adult respiratory distress syndrome.

Innervations of lungs and bronchi

- Is by autonomic nerves.
- Sympathetic stimulation causes dilatation of the bronchi.
- Parasympathetic stimulation causes constriction of the bronchi.
- Locally secreted factors :histamine, slow reacting substances of anaphylaxis (SRSA) secreted by the mast cells due to allergy (as in patients with asthma) often cause bronchiolar constriction and increased airway resistance leading to forced breathing.

Mechanics of pulmonary ventilation

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Learning Objectives

- By the end of this lecture you will be able to:

1- List the muscles of respiration and describe their roles during inspiration and expiration.

2- Identify the importance of the following pressures in respiration: atmospheric, intra-alveolar, intrapleural, and transpulmonary.

3- Explain why intrapleural pressure is always subatmospheric under normal conditions, and the significance of the thin layer of the intrapleural fluid surrounding the lung.

4- Define lung compliance and list the determinants of compliance.

Respiratory muscles

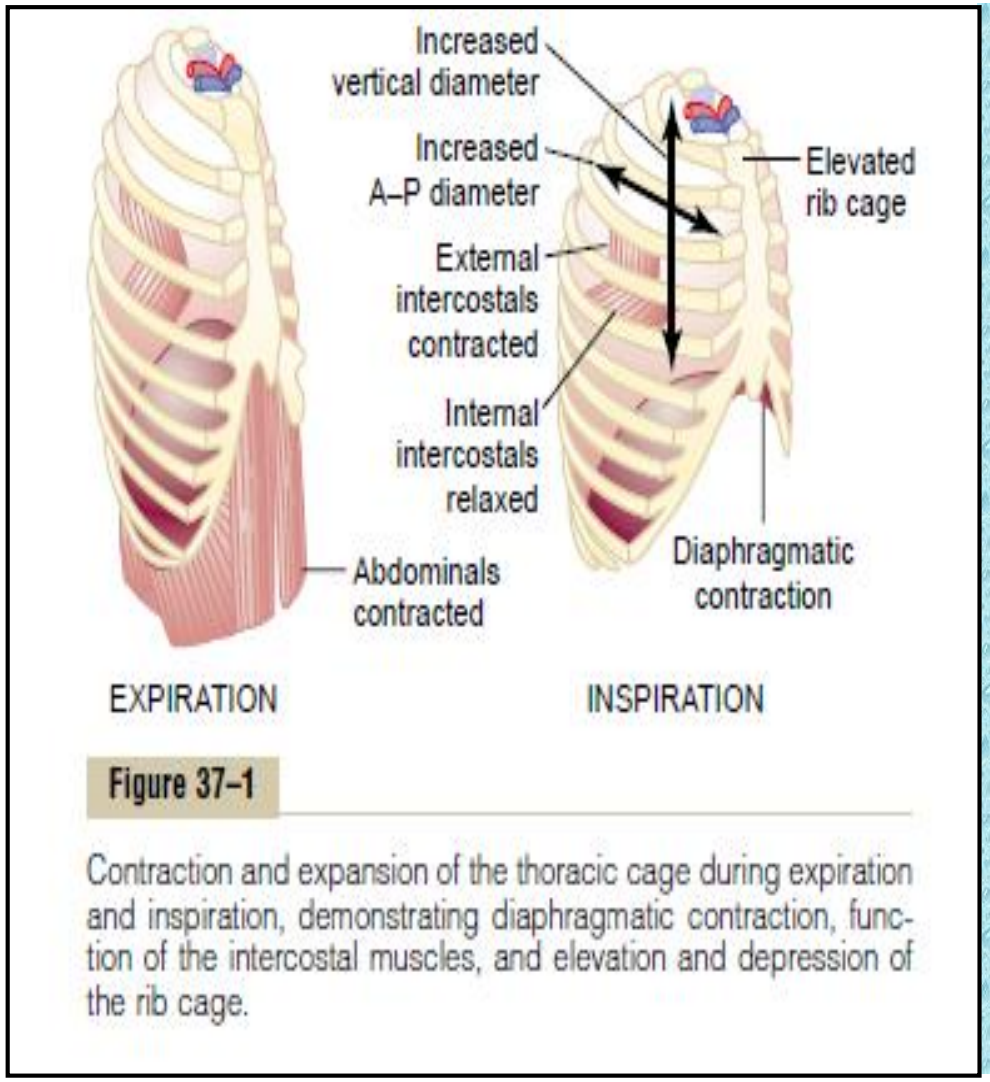
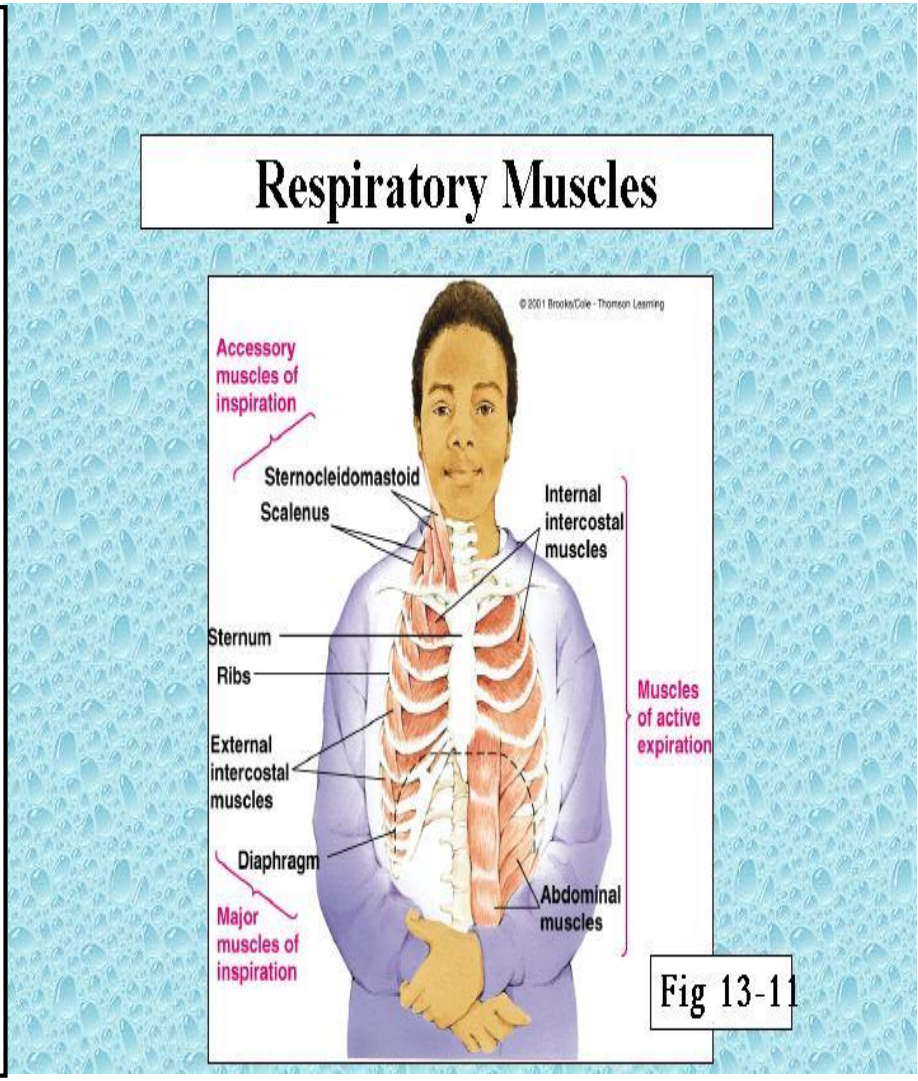


Figure 37–1

Contraction and expansion of the thoracic cage during expiration and inspiration, demonstrating diaphragmatic contraction, function of the intercostal muscles, and elevation and depression of the rib cage.



Cont…respiratory muscles

- ***Inspiratory muscles***

- During resting inspiration are the diaphragm, external intercostals.

- During forced inspiration the Accessory muscles of inspiration e.g sternomastoid, anterior serratus, scalene muscles contract in addition to ms. of resting inspiration.

- ***Expiratory mussles:*** Resting expiration is a passive process that depends on the recoil tendency of the lung and need no muscle contraction. However, forced expiration is active and need contraction of the 1-*Abdominal muscles* . 2-*internal intercostal muscles*.

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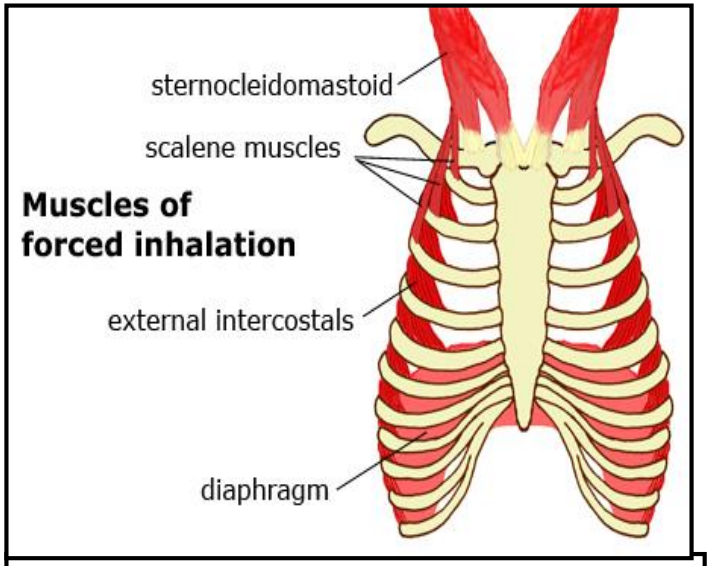
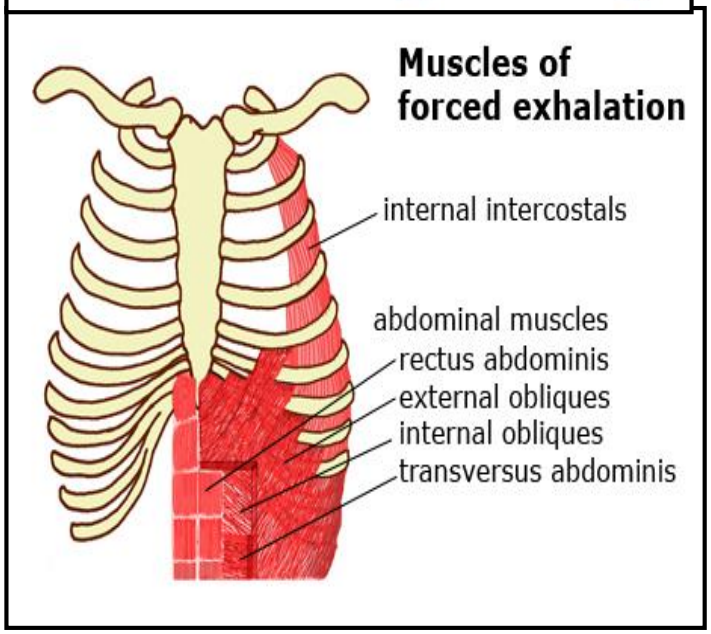


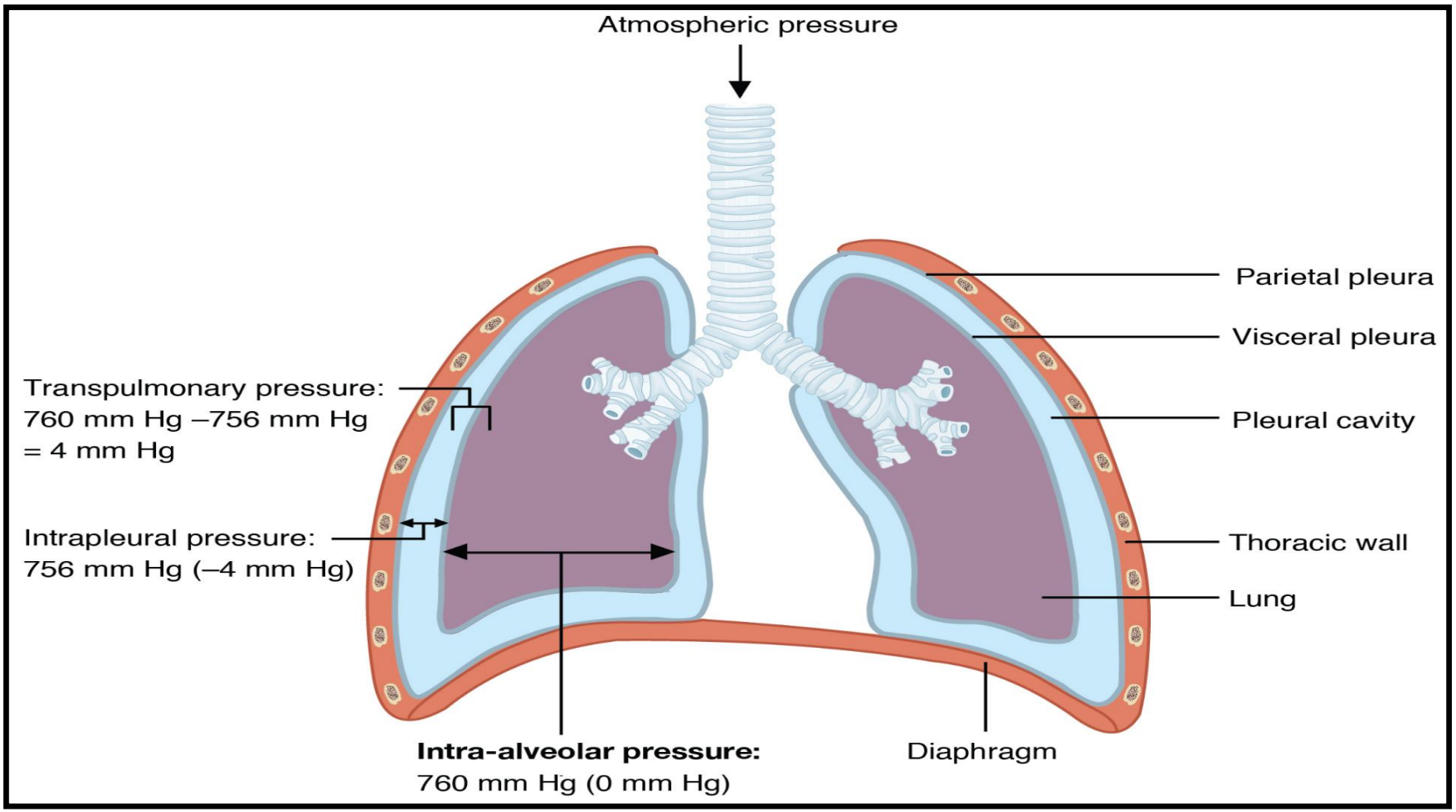


Deep Forceful Breathing

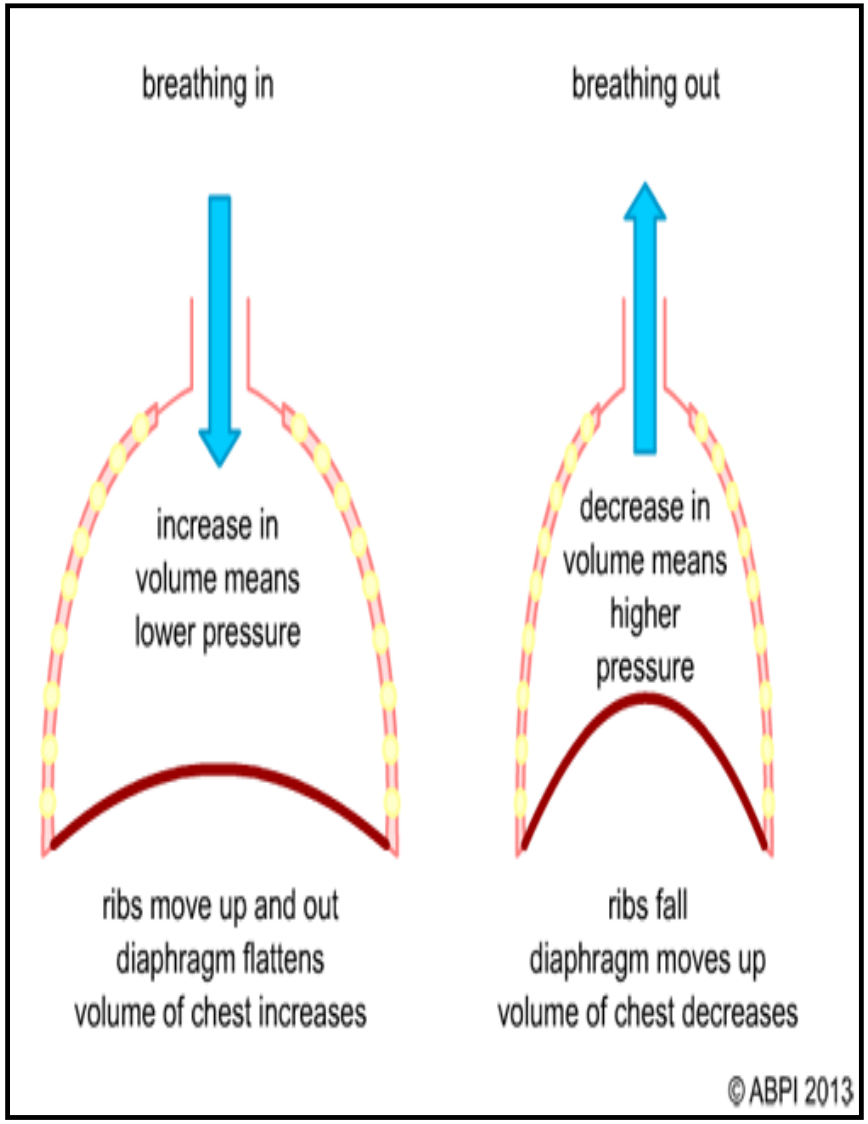
- Deep Inspiration
  - During deep forceful inhalation accessory muscles of inspiration participate to increase size of the thoracic cavity
    - Sternocleidomastoid – elevate sternum
    - Scalene – elevate first two ribs
    - Pectoralis minor – elevate 3rd–5th ribs
- Deep Expiration
  - Expiration during forceful breathing is active process.
  - Muscles of exhalation increase pressure in abdomen and thorax
    - Abdominal muscles.
    - Internal intercostals.

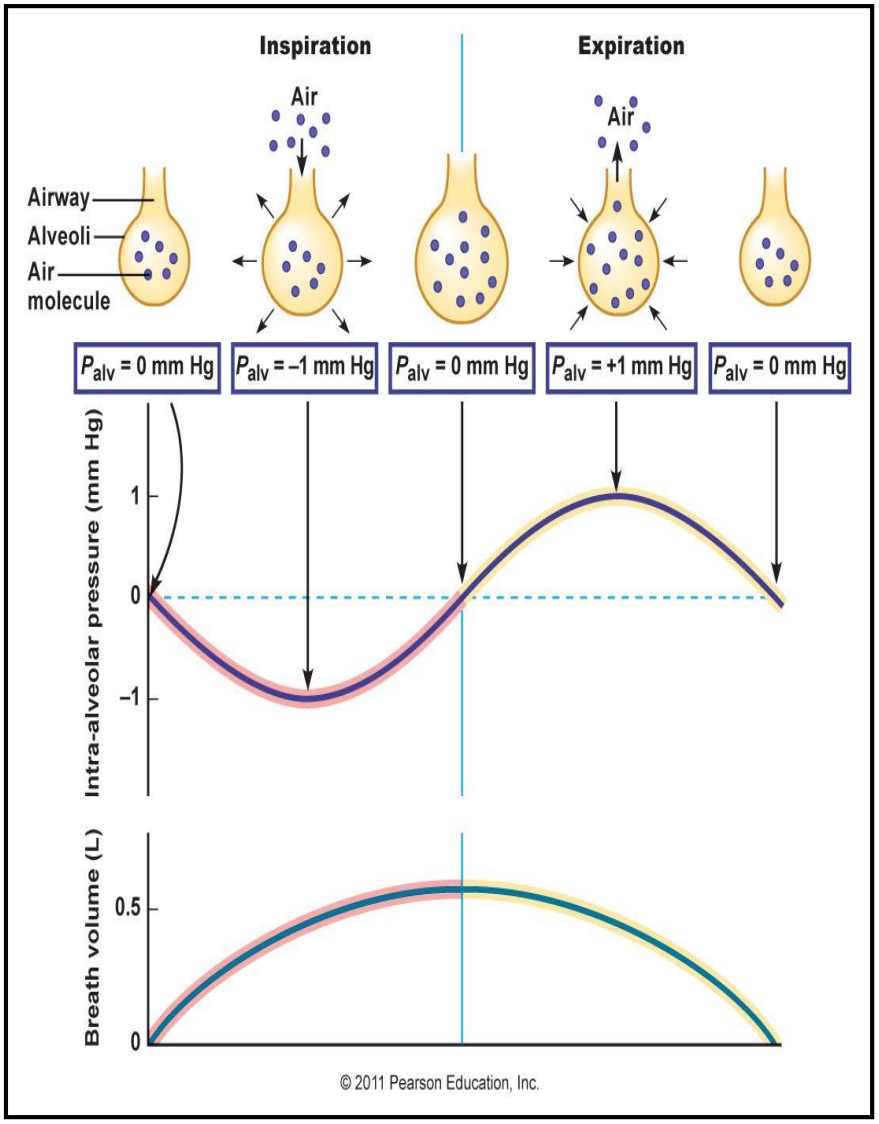
Pressure changes in the lungs during breathing

Air will flow from a region of high pressure to one of low pressure-- the bigger the difference, the faster the flow



Intra-alveolar pressure
(intrapulmonary pressure





Cont.. Inta-alveolar pressure

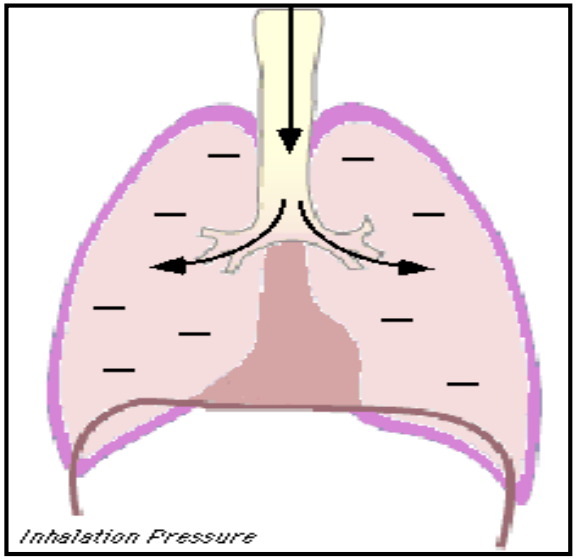
1-Intra-alveolar

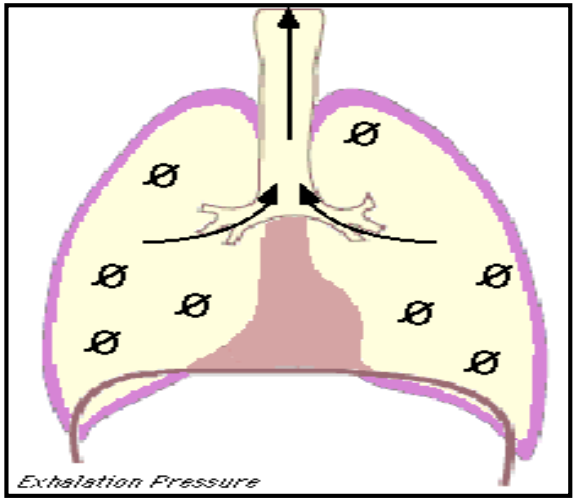
Between breathes = zero pressure

During inspiration = (-1 mmHg) and air (tidal volume) flows from outside to inside the lungs).

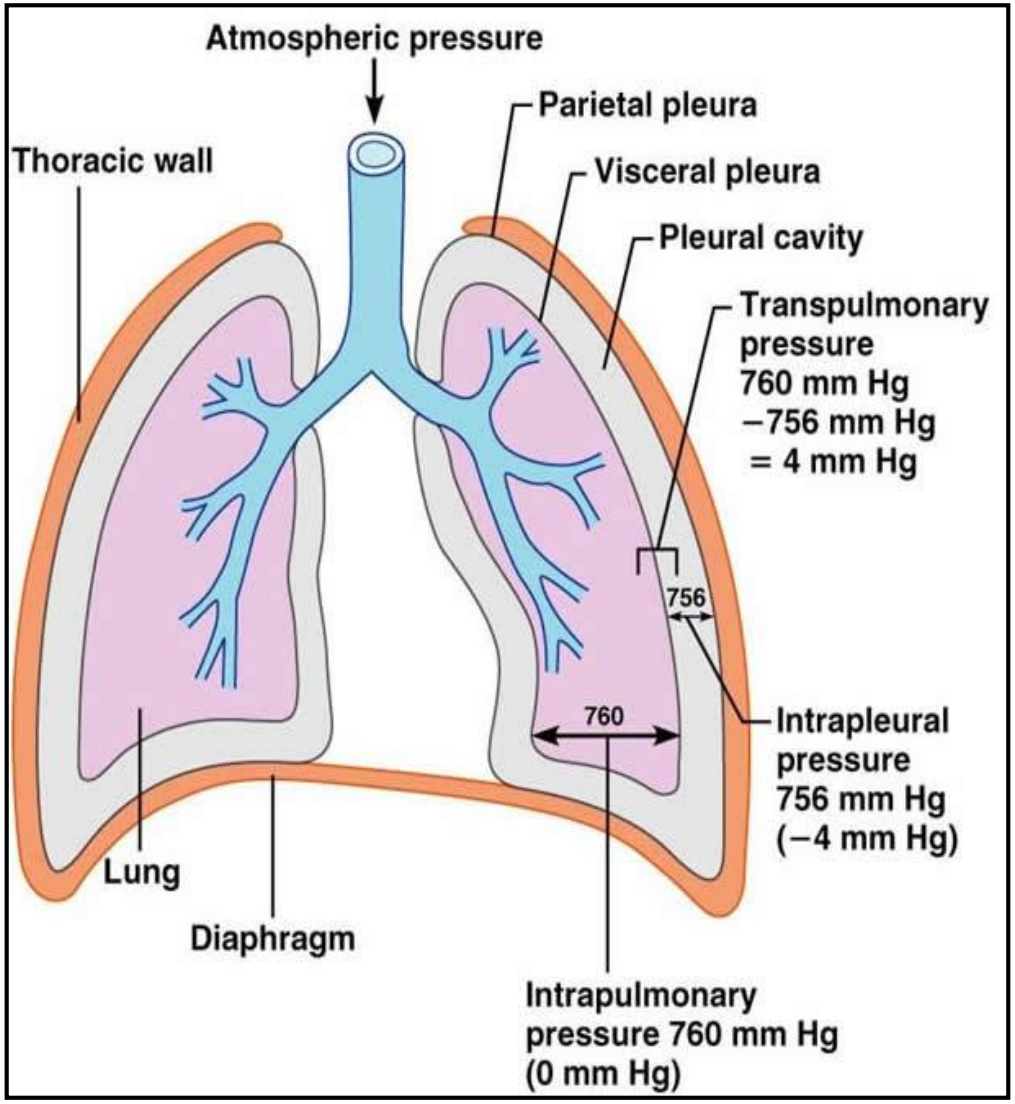
At the end of inspiration = zero and air flow stops.

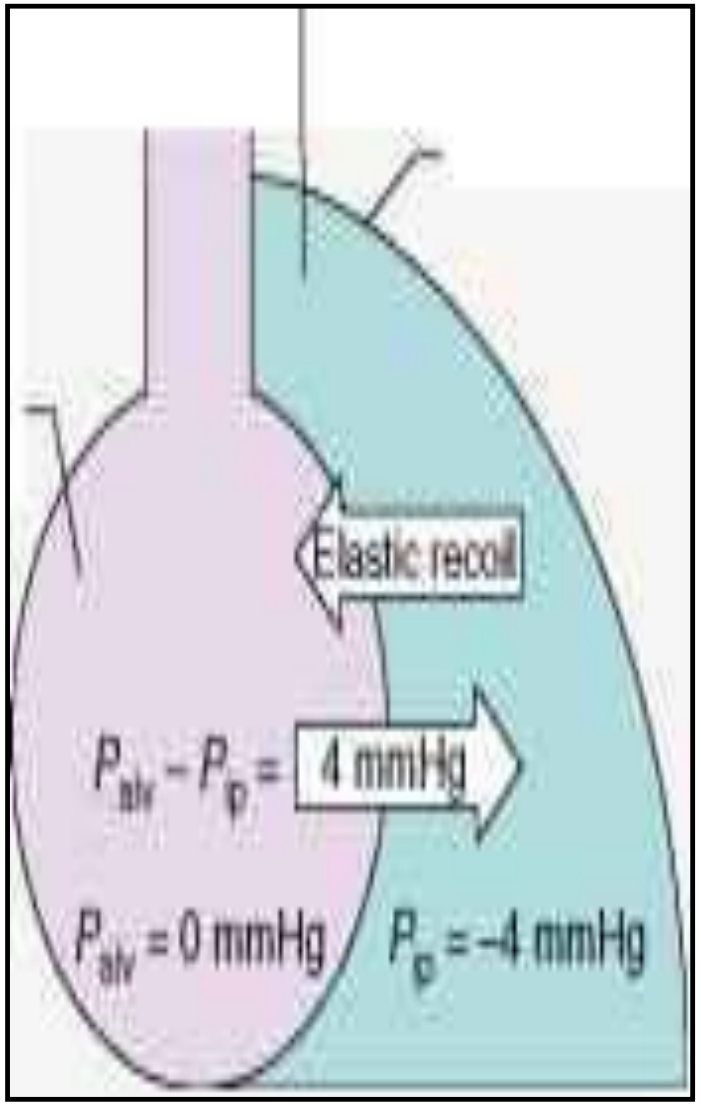
During expiration = (+1 mmHg) and air flows out of the Lungs





Intrapleural pressure





- **2-Intrapleural pressure (IPP):**

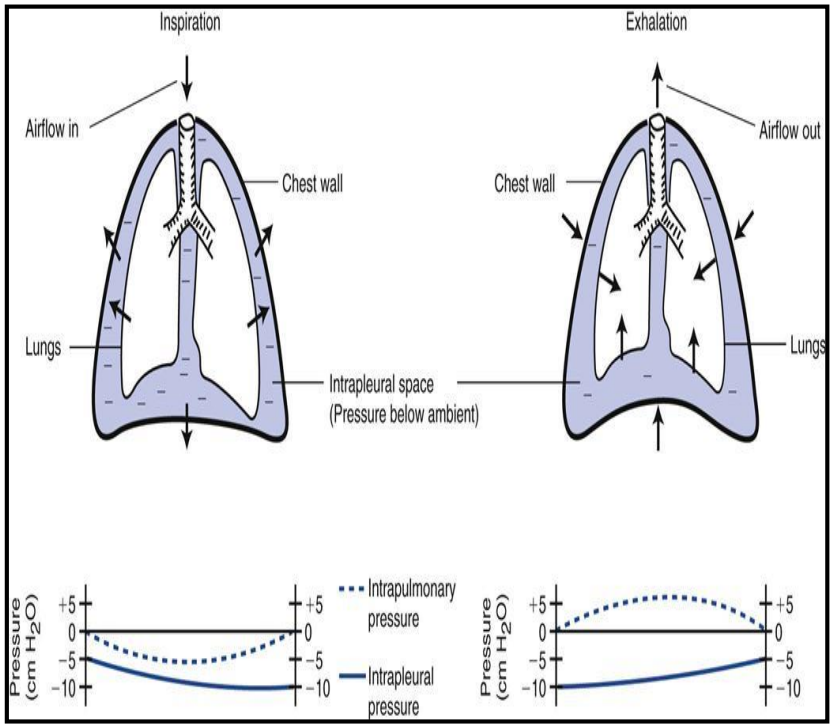
Pressure in the pleural space

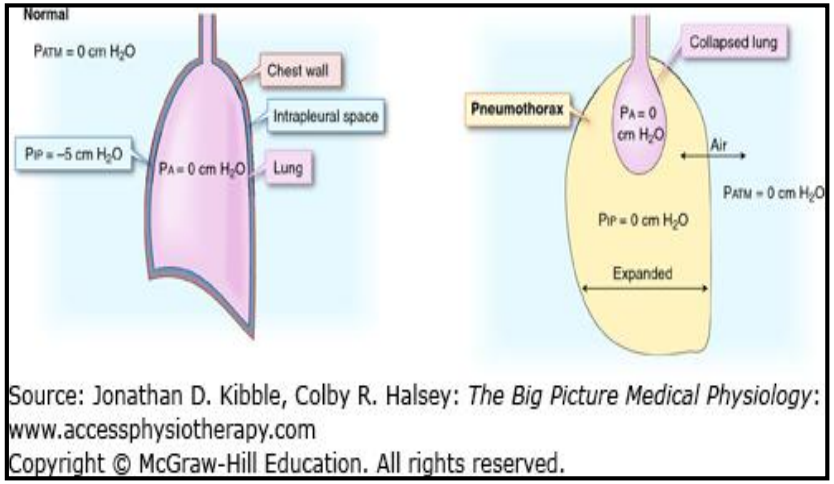
is negative with respect to atmospheric pressure at the end of normal expiration (-5cmH2O).

- Why negative??:

1- The lung's elastic tissue causes it to recoil, while that of the chest wall causes it to expand. Because of these two opposing forces the pressure in the pleural cavity becomes negative.

2-The pleural space is a potential space, (empty) due to continuous suction of fluids by lymphatic vessels.





Source: Jonathan D. Kibble, Colby R. Halsey: *The Big Picture Medical Physiology*: www.accessphysiotherapy.com

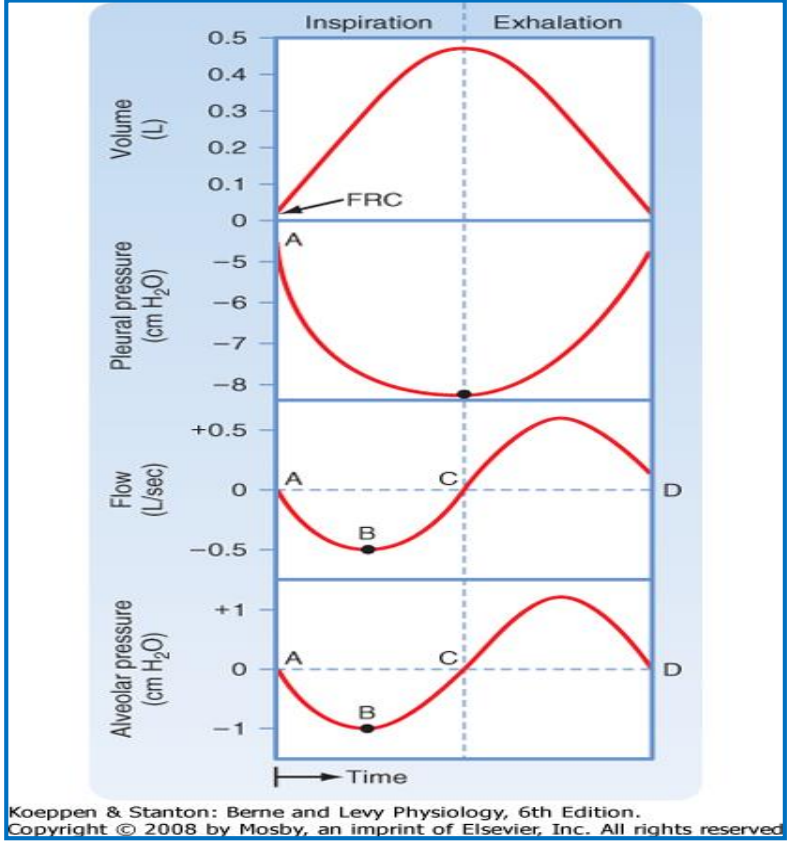
Values of IPP

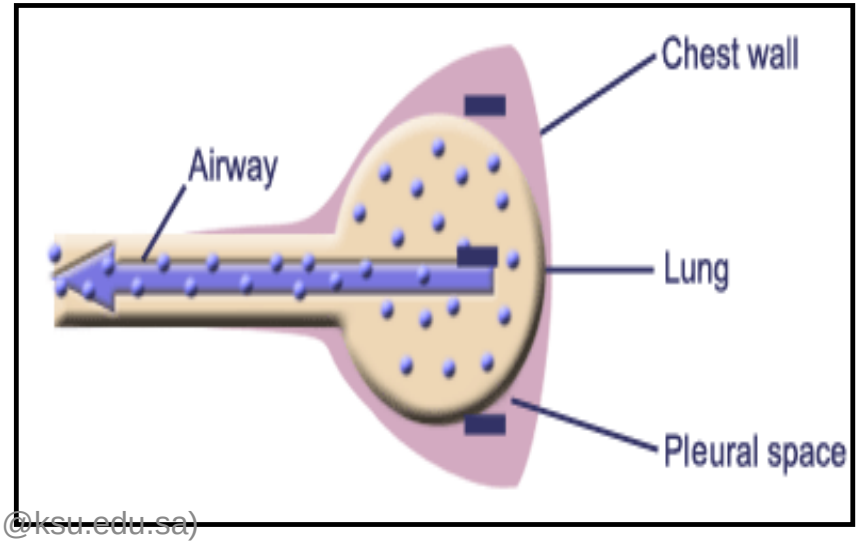
- During resting position between breathes it = (-5) cm H2O. During resting inspiration it becomes more –ve (-7.5) cm H2O.

- Forced ventilation

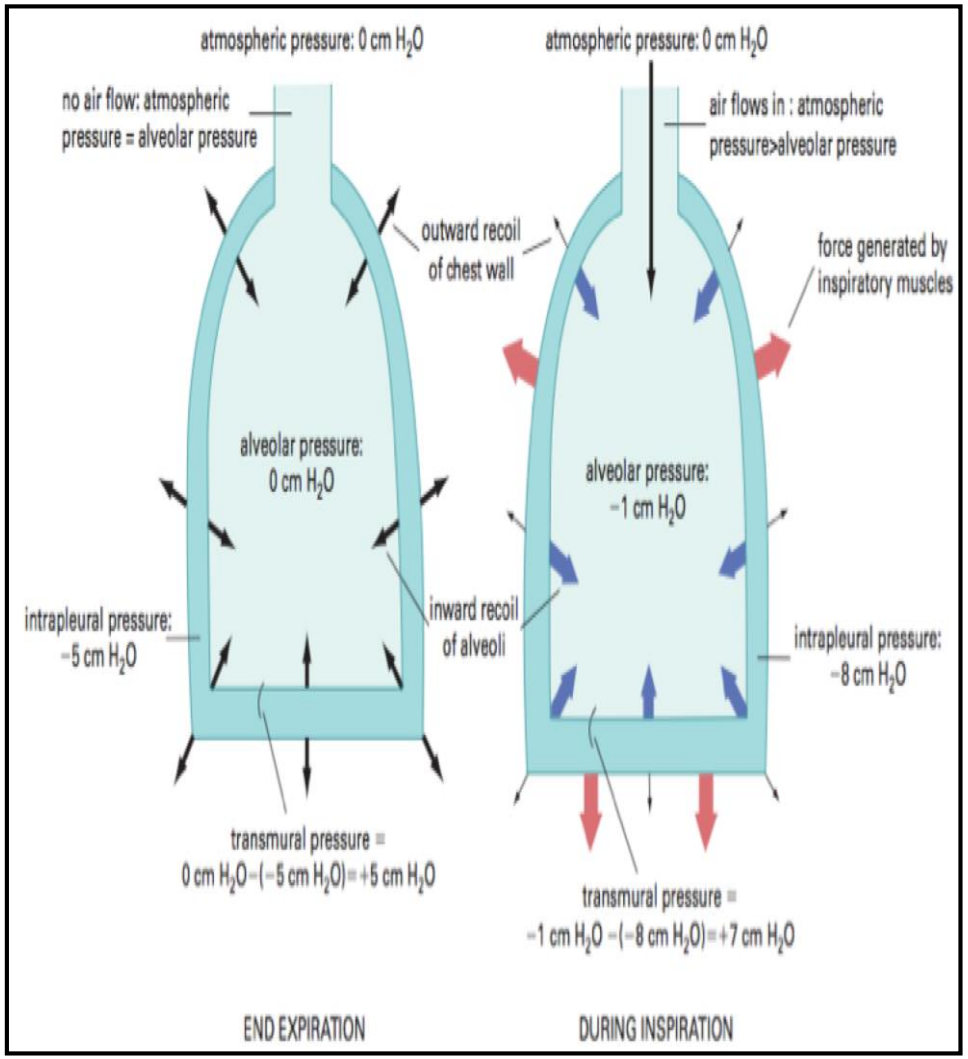
  Insp. :-20 to - 40 cm H2O

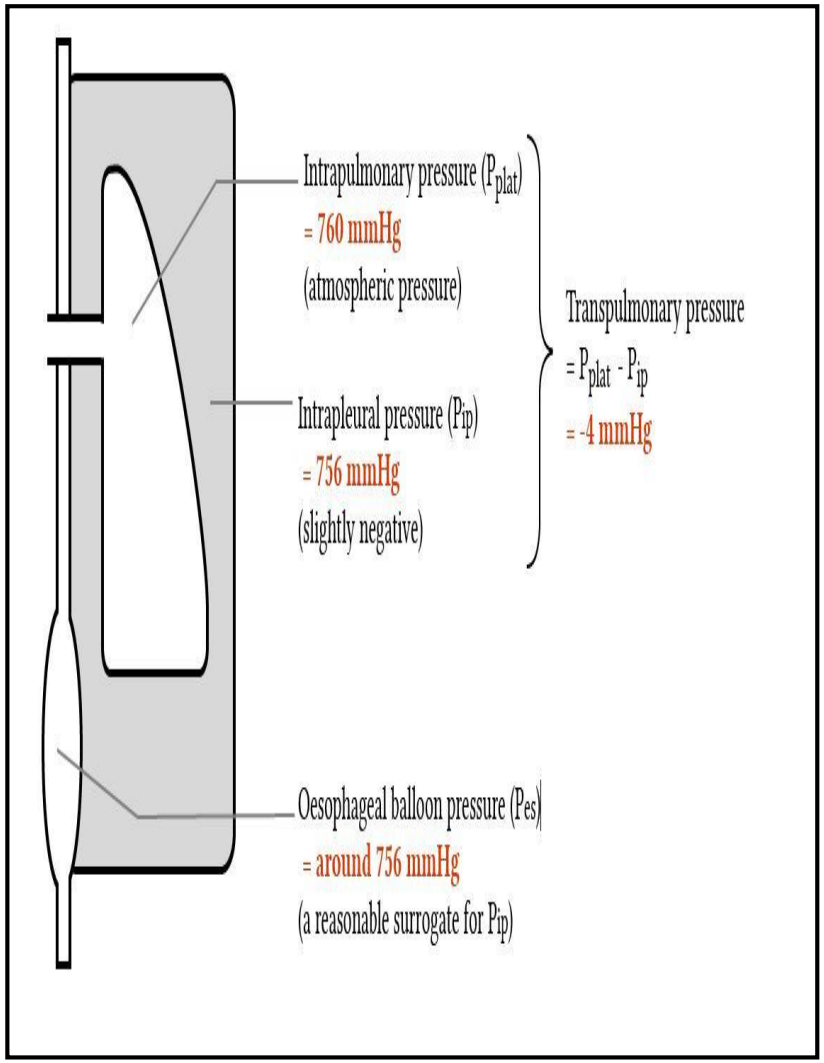
  Exp. : + 30 cm H2O





Transpulomnary pressure TPP



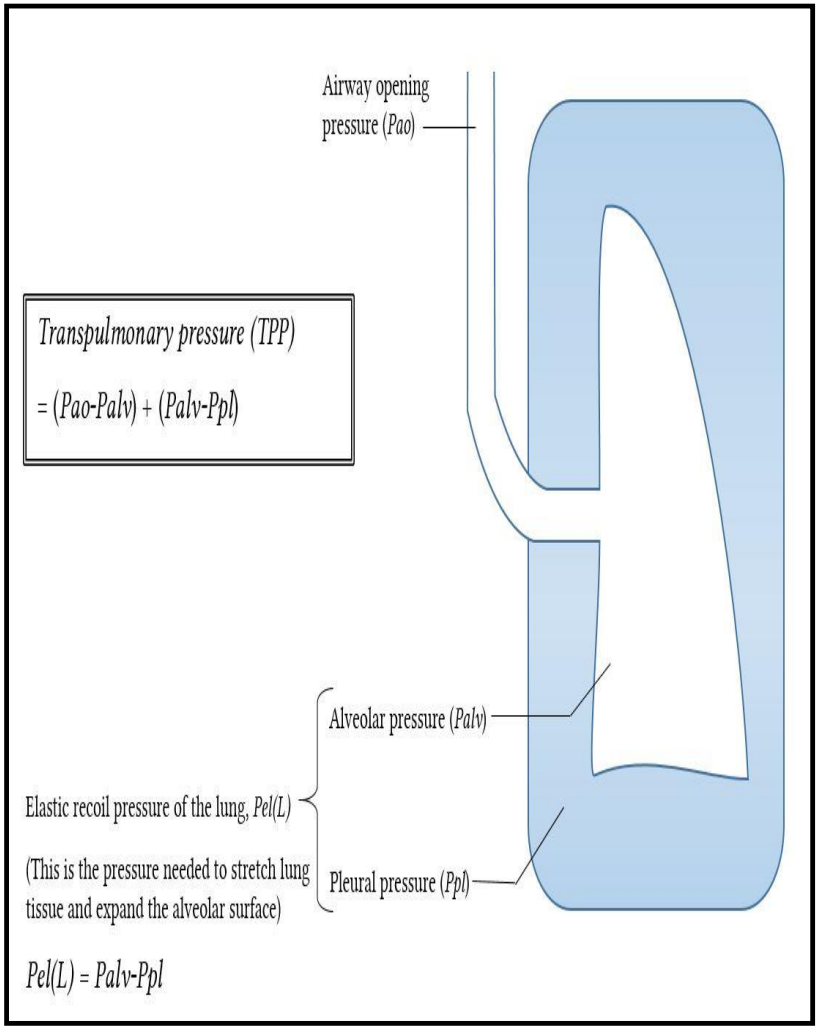


3-Transpulmonary pressure (TPp) (Extending Pressure)

- *The difference between the alveolar pressure (Palv) and the pleural pressure(Ppl).*

  TPp = Palv-Ppl

- *It is a measure of the elastic forces in the lungs that tend to collapse the lungs (**the recoil pressure).***
  - *It prevents lung collapse.*
- *The bigger the volume of the lung the higher will be its tendency to recoil.*



Compliance of the lung (CL)

The extent to which the lungs will expand for each unit increase in transpulmonary pressure is called the *lung compliance*. $CL = \frac{(\Delta V)}{(\Delta P)}$

i.e the ratio of the change in the lung volume produced per unit change in the distending pressure.

For both lungs in adult = 200 ml of air /cm H20.

For lungs and thorax together = 110 ml/cm H20.

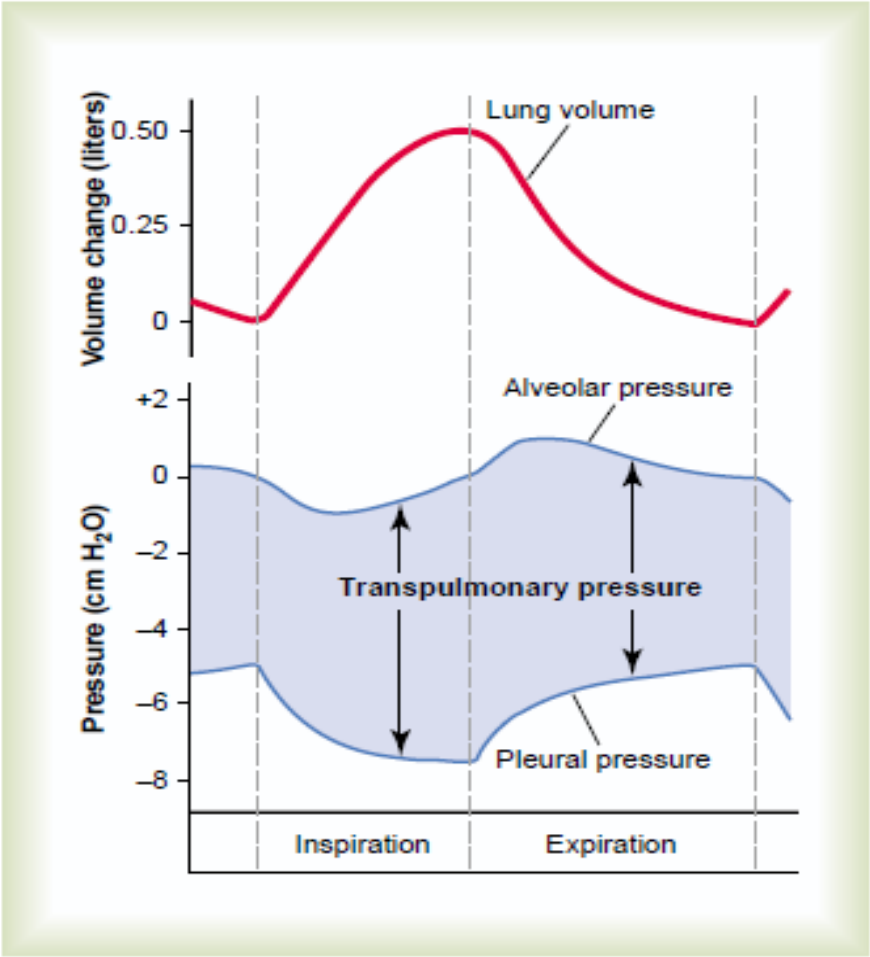


Figure 37–2

Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing.

- **Compliance Diagram of the Lungs..**

•The characteristics of the compliance diagram are determined by the elastic forces of the lungs. These can divided into

(1) 1l3 is due to *elastic forces of the lung tissue* itself (elastin, collagen).

(2)2/3 of the *elastic forces caused by surface tension of the fluid that lines the inside walls of the alveoli* and other lung air spaces.

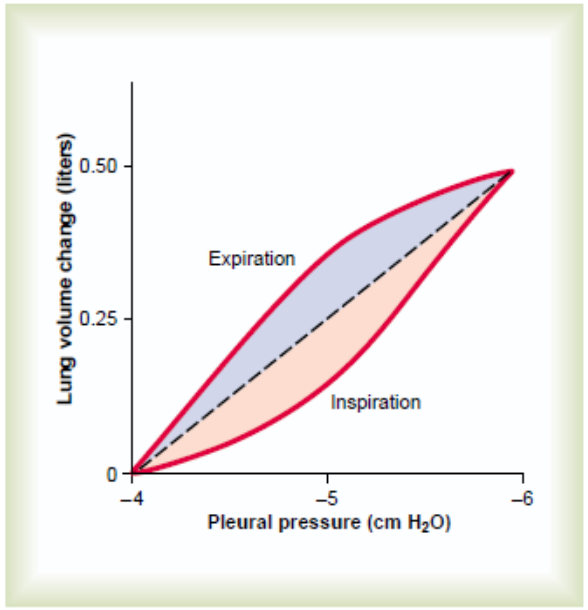


Figure 37–3

Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone.

Diseases that affect compliance of lung

- Lung compliance is reduced in pulmonary fibrosis , pulmonary edema, diseases of the chest wall (kyphosis, scoliosis)
- Emphysema increases the compliance of the lungs because it destroys the alveolar septal tissue rich with elastic fibers that normally opposes lung expansion.