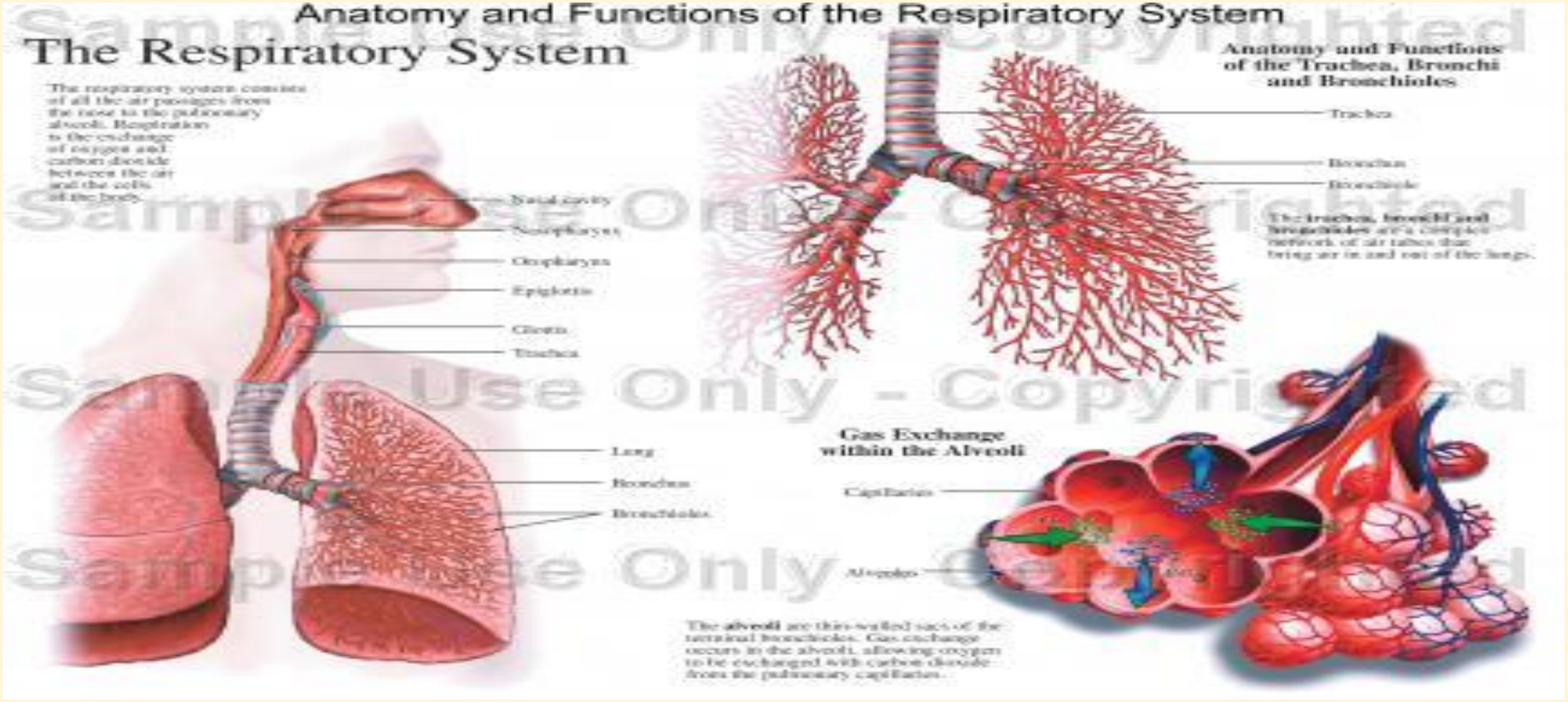
Respiratory Physiology



Functions and organization of the respiratory system

Learning Objectives

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

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

2-Understand the difference between internal and external respiration.

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

Functions of the respiratory system include

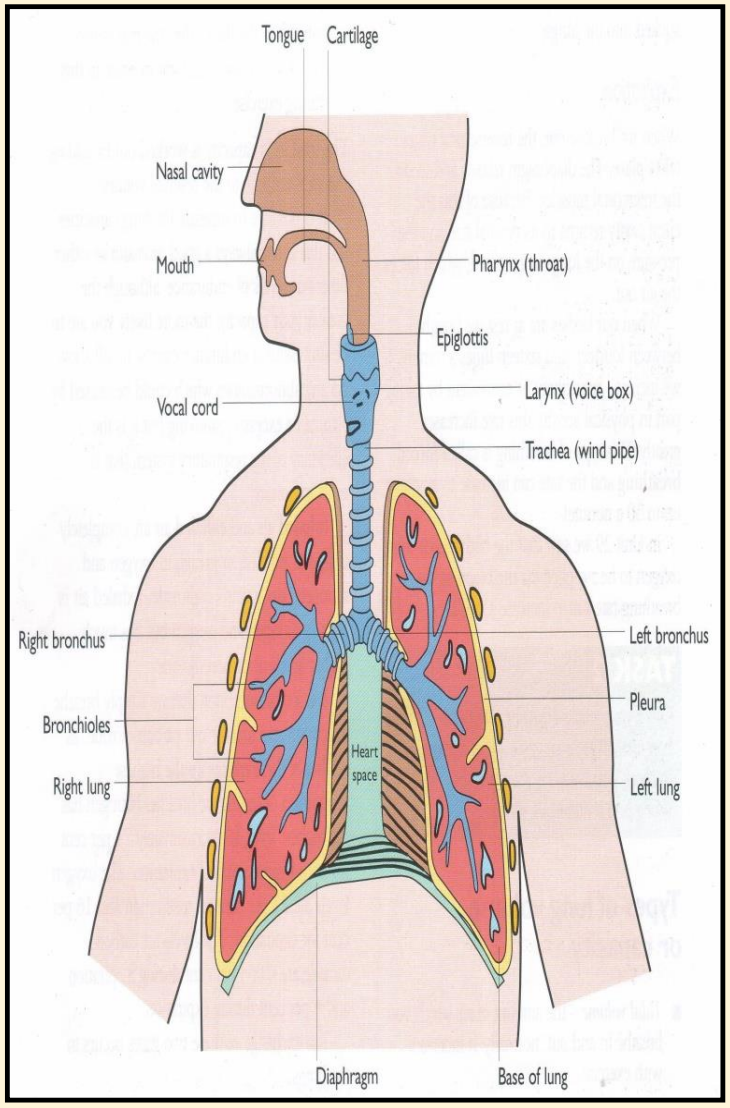
- Gas exchange (respiratory function).
- Phonation: is the production of sounds by the movement of air through the vocal cords.
- Pulmonary defense

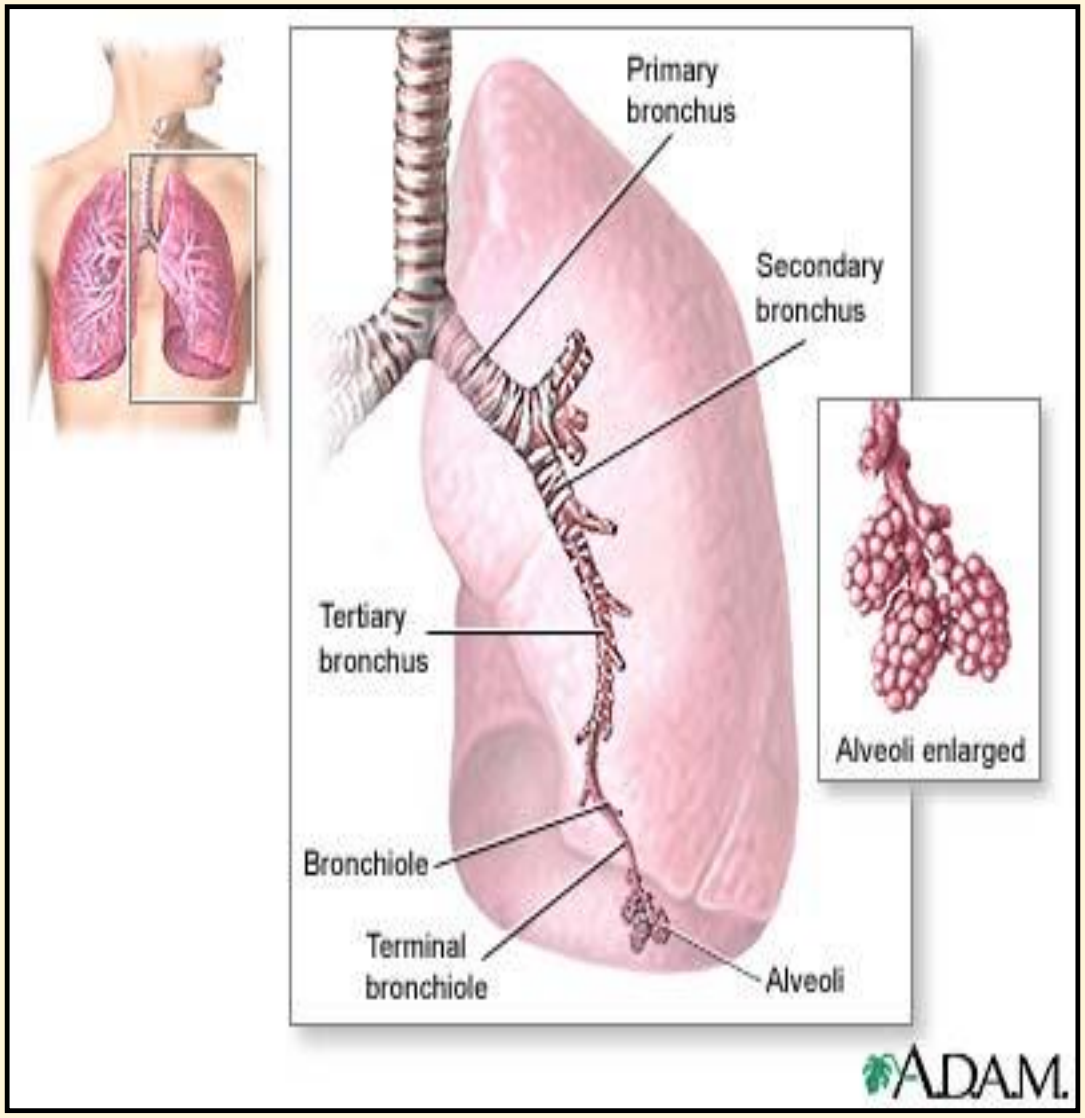
- Immunoglobulin A (IgA),
- Alpha-1 antitrypsin
- *The pulmonary macrophages in the alveoli: engulf* smaller particles which pass through the muco-cilliary barrier filter.

Cont..non respiratory functions of lung

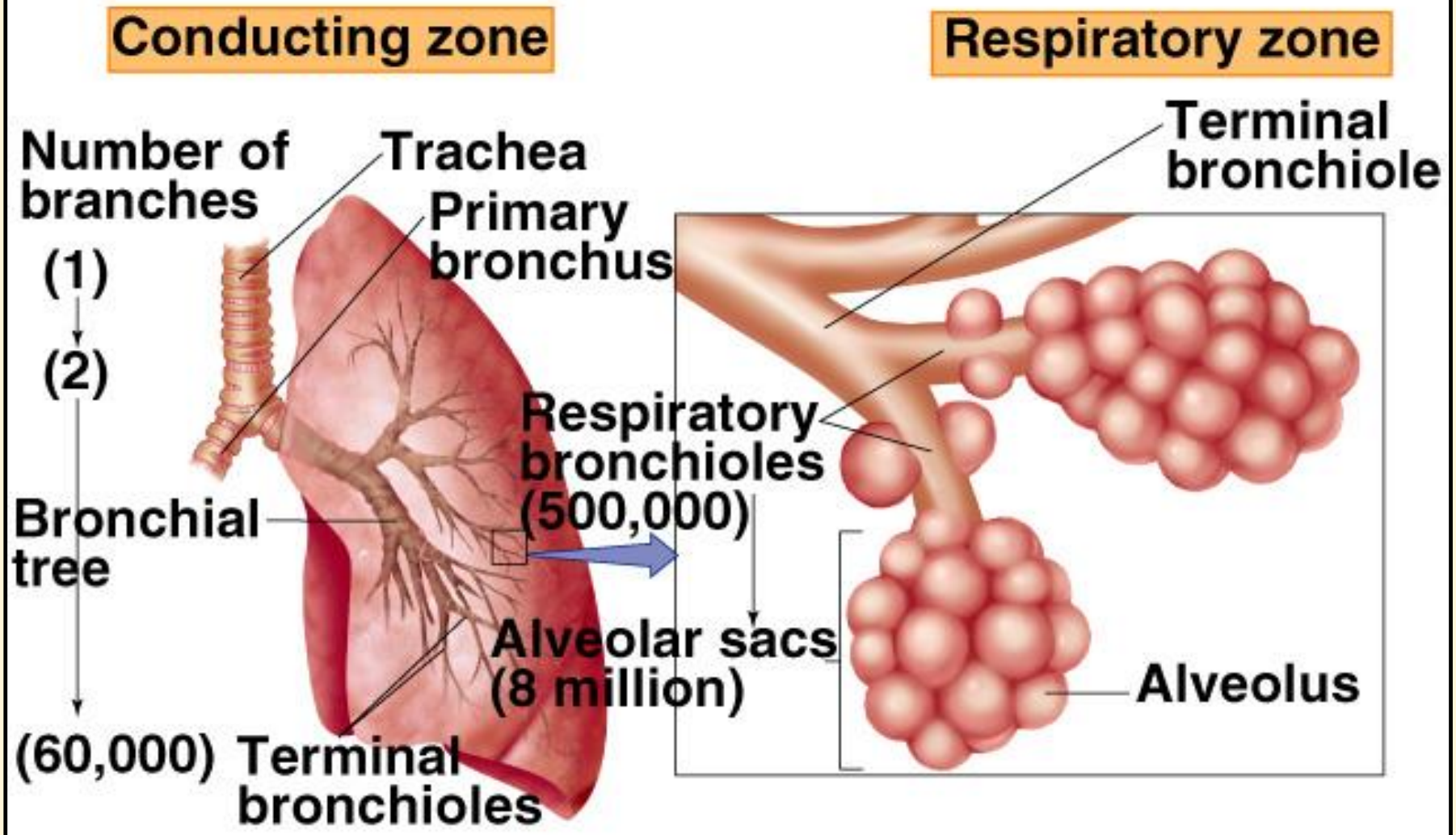
- Angiotensin I is converted to angiotensin II with the help of angiotensin converting enzymes formed by the lungs.
- Regulating the acid- base status of the body by washing out extra carbon dioxide from the blood.
- Secretion of important substances like surfactant .

Respiratory passages (airways)





Respiratory passages airways can be divided into



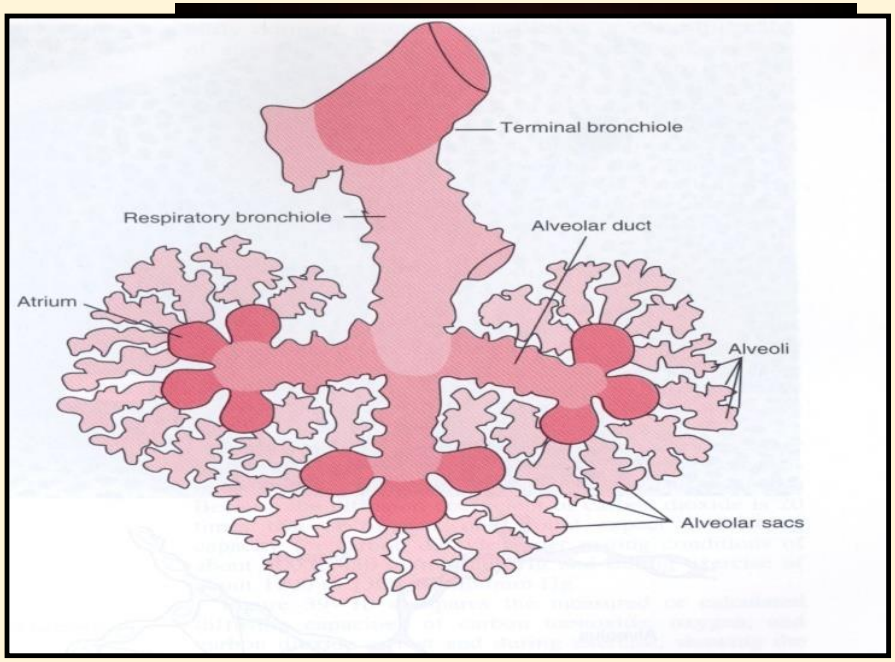
I- Conductive Zone

- 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.

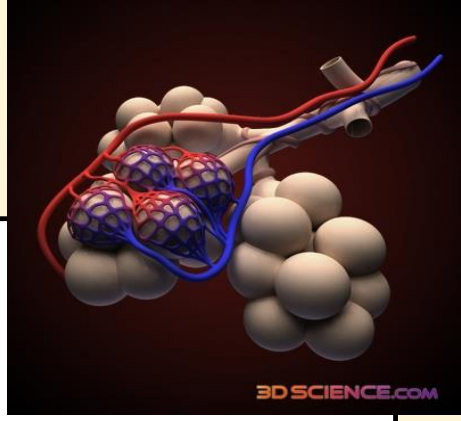
II- Respiratory Zone (Respiratory unit)

- Includes:

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



Internal & External Respiration



Atmospheric air:
P_{O_2} = 159 mm Hg
P_{CO_2} = 0.3 mm Hg

CO_2 exhaled

O_2 inhaled

Alveoli

CO_2 O_2

Alveolar air:
P_{O_2} = 105 mm Hg
P_{CO_2} = 40 mm Hg

Pulmonary capillaries

(a) External respiration: pulmonary gas exchange

To lungs

To left atrium

Deoxygenated blood:
P_{O_2} = 40 mm Hg
P_{CO_2} = 45 mm Hg

Oxygenated blood:
P_{O_2} = 100 mm Hg
P_{CO_2} = 40 mm Hg

To right atrium

To tissue cells

(b) Internal respiration: systemic gas exchange

Systemic capillaries

CO_2 O_2

Systemic tissue cells:
P_{O_2} = 40 mm Hg
P_{CO_2} = 45 mm Hg

23.18

Internal & *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

Respiration could be either

Resting : normal breathing during resting conditions

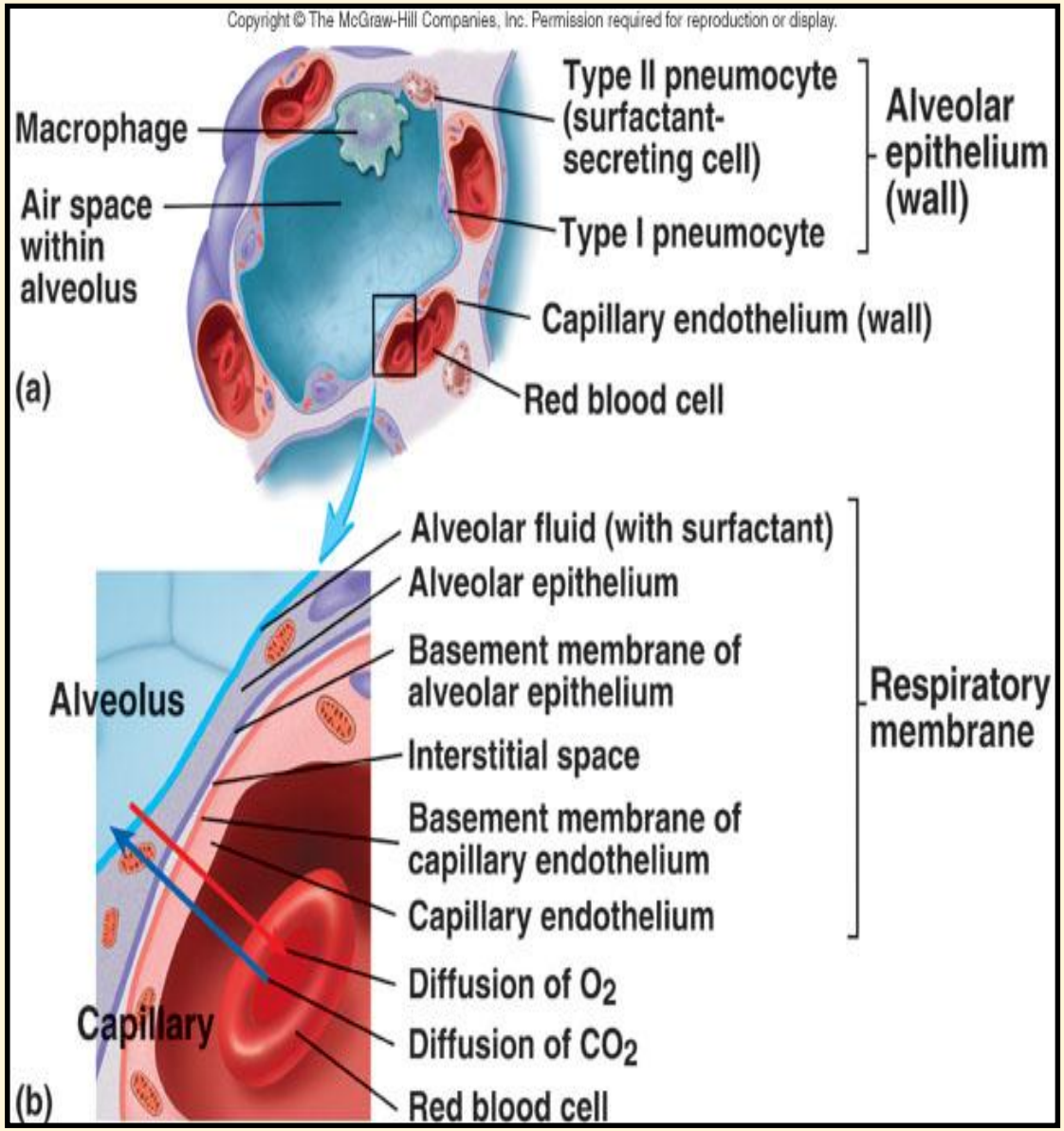
Forced (maximal): during exercise, in patients with asthma, allergy,…

Lining cells of the alveoli

1- Type I alveolar cells
(type I pneumocytes)

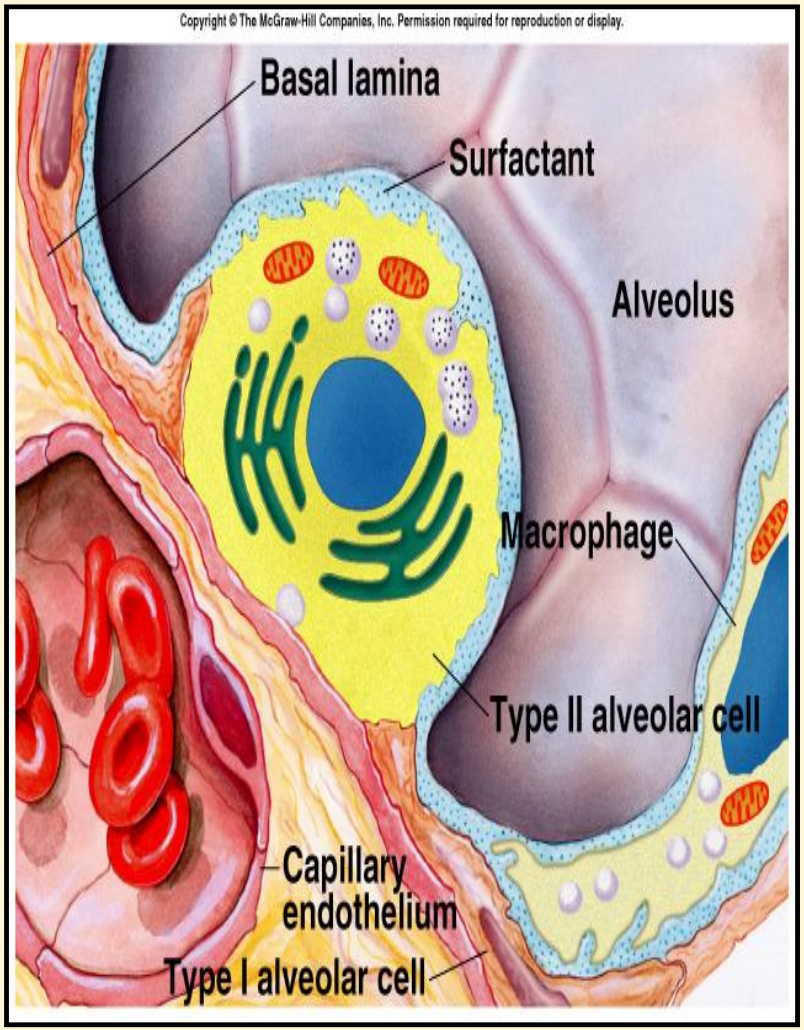
2- Type II alveolar cells
(type II pneumocytes)
(Secrete surfactant)

3- Alveolar macrophages



Surface Tension

- H_2O molecules at the surface are attracted to other H_2O molecules by attractive forces that resist distension (inflation)called surface tension.
- Surface tension tends to oppose alveoli expansion
- Pulmonary surfactant reduces surface tension



Surfactant

- Surfactant is a complex substance containing phospholipids and a number of apoproteins.
- Secreted by the Type II alveolar cells { the earliest detection begins between 6-7th month much as the earliest detection but this could be delayed in others} at wk 35 of intrauterine life from fetal alveoli.
- Surfactant reduces surface tension throughout the lung, prevents alveolar collapse, decreases airway resistance and the work of breathing.

Cont…surfactant

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

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

example of deficiency of surfactant.

In **neonatal respiratory distress syndrome** surfactant is lacking. In the developing fetus Infants born before week 24 will *never* have surfactant Without surfactant, small alveoli have increased surface tension and increased pressures, and will collapse (**atelectasis**). Collapsed alveoli are not ventilated and, therefore, cannot participate in gas exchange

Alveoli with and without surfactant

Innervations of lungs and bronchi

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

Mechanics of pulmonary ventilation

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- Understand the importance of the following pressures in respiration: atmospheric, 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.

Muscles That Cause Lung Expansion and Contraction

- lungs can be expanded and contracted:
- (1) downward and upward movement of the diaphragm to lengthen or shorten the chest cavity
- (2) by elevation and depression of the ribs to increase and decrease the anteroposterior diameter of the chest cavity

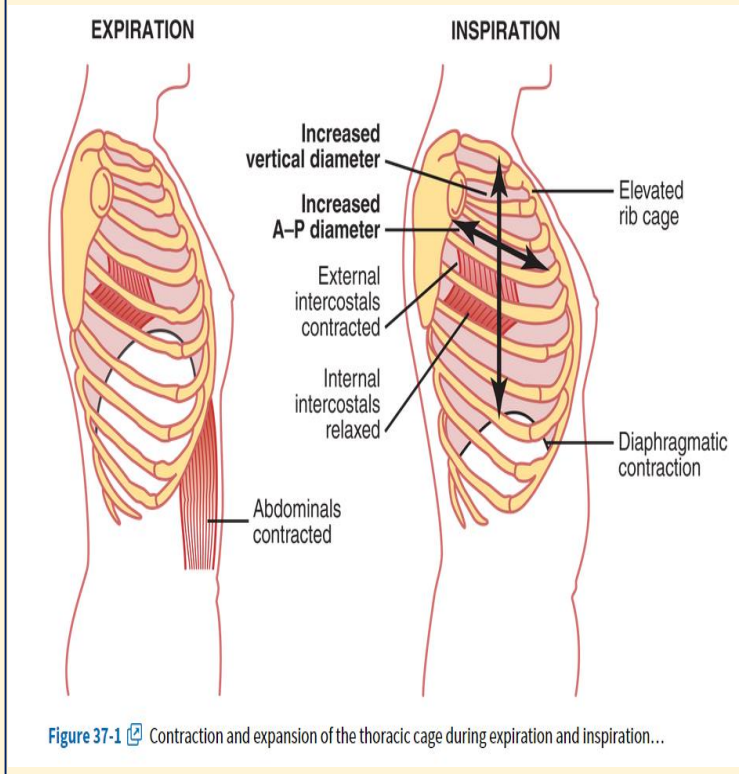


Figure 37-1 Contraction and expansion of the thoracic cage during expiration and inspiration...

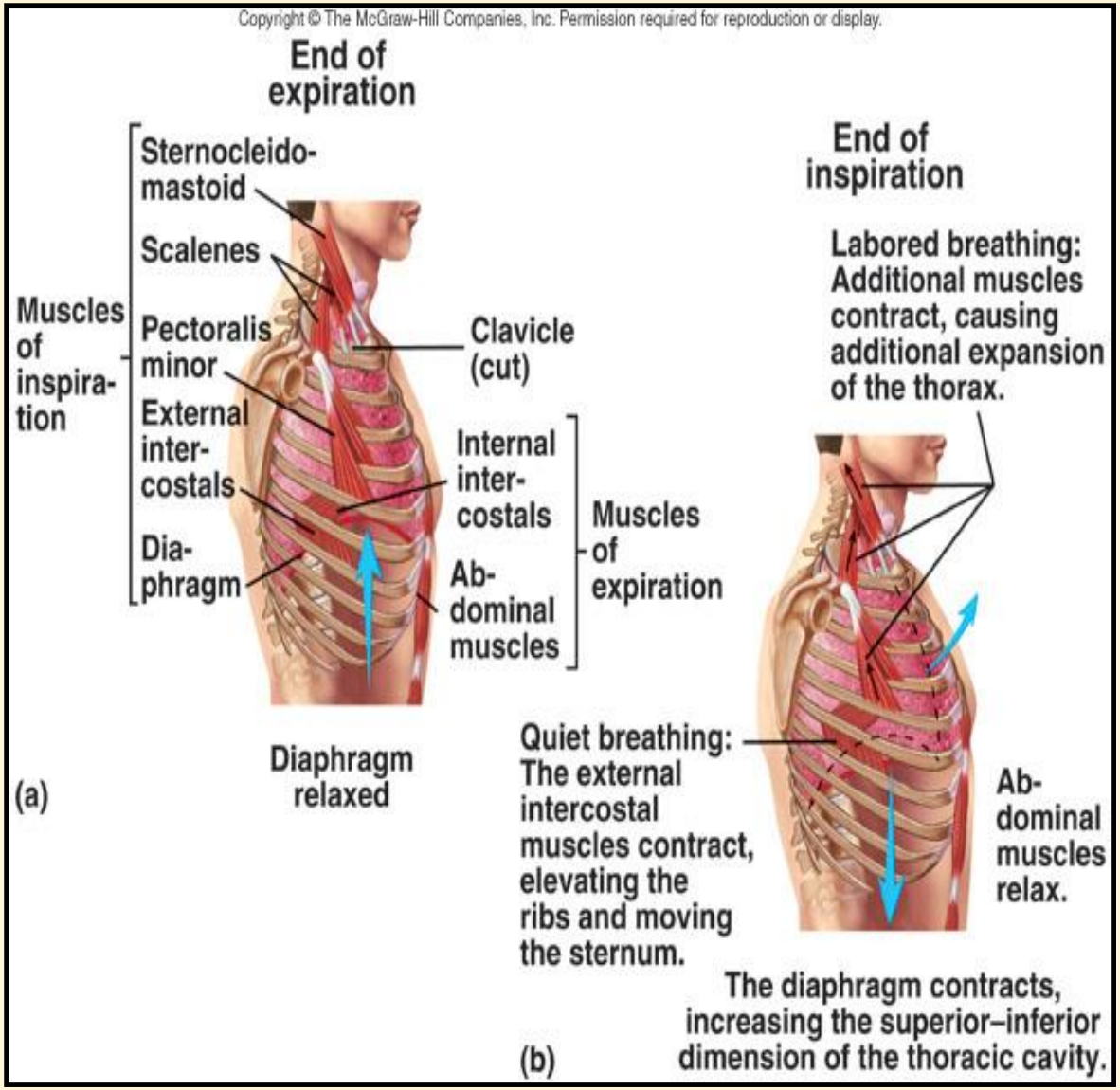
Respiratory muscles

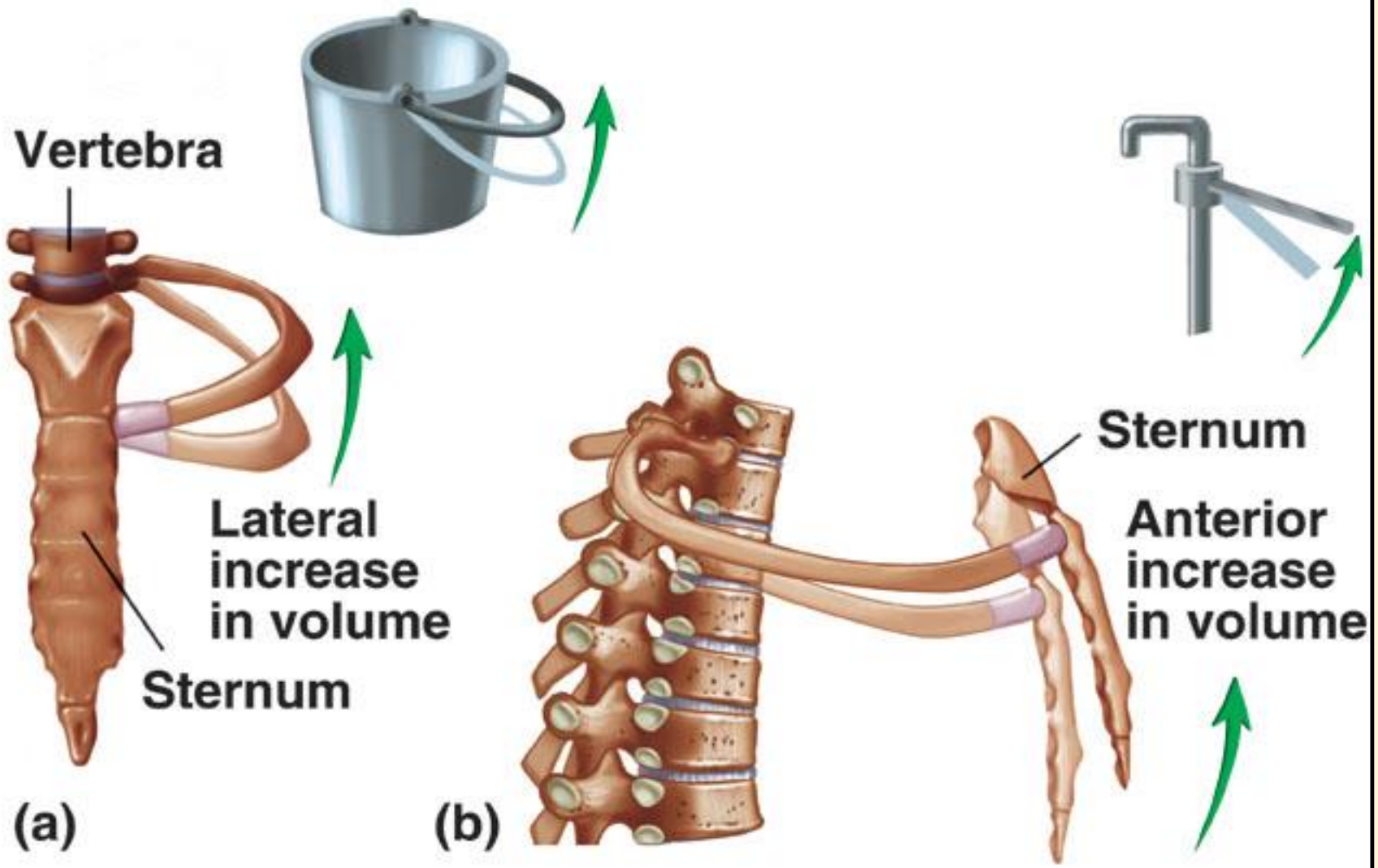
Inspiratory muscles

(resting- forced)

Expiratory muscles

(forced expiration- muscles that depress the rib cage)

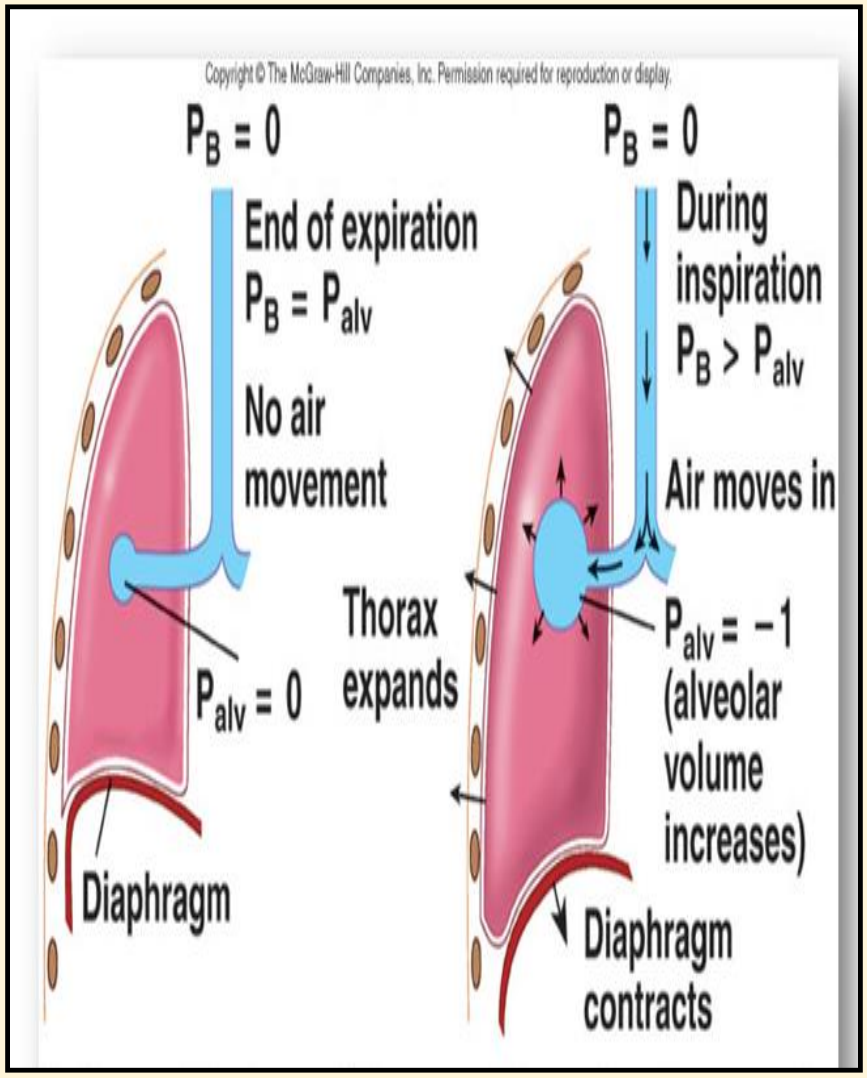


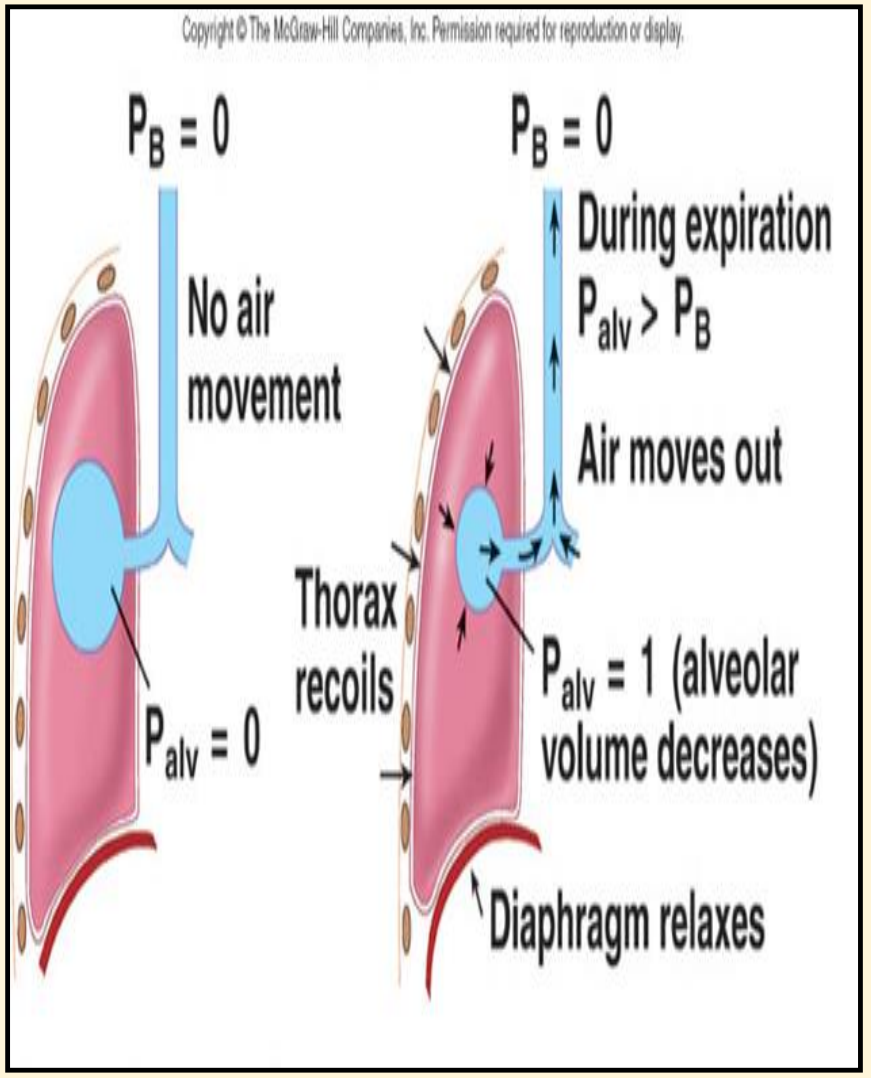


Deep Forceful Breathing

- Deep Inspiration
  - During deep forceful inhalation accessory muscles of inspiration participate to increase size of thoracic cavity
    - Sternocleidomastoid – elevate sternum
    - Scalenes – 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

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





Pressure changes in the lungs during breathing

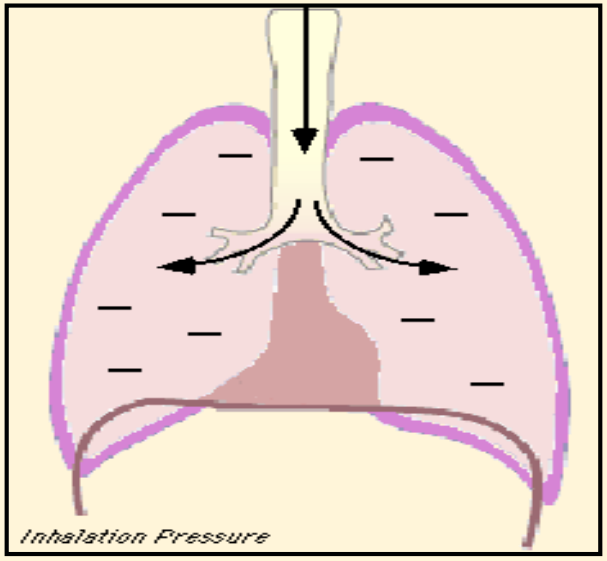
1-Intra-alveolar (intrapulmonary pressure

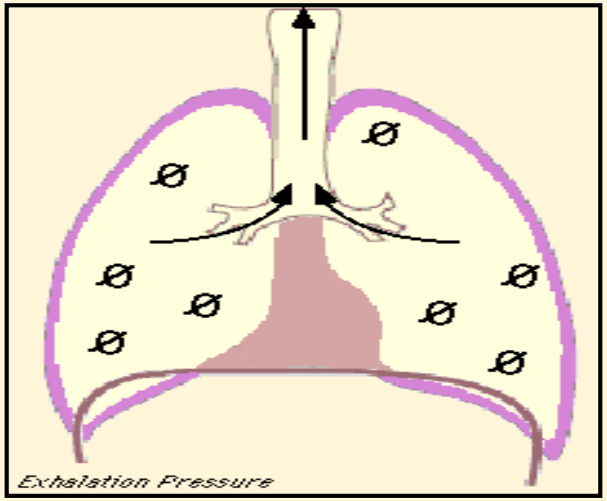
Between breathes = zero pressure

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

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

During expiration = (+1 mmHg). air flow out of the Lungs





- **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 2 opposing forces the pressure in the pleural cavity becomes negative.

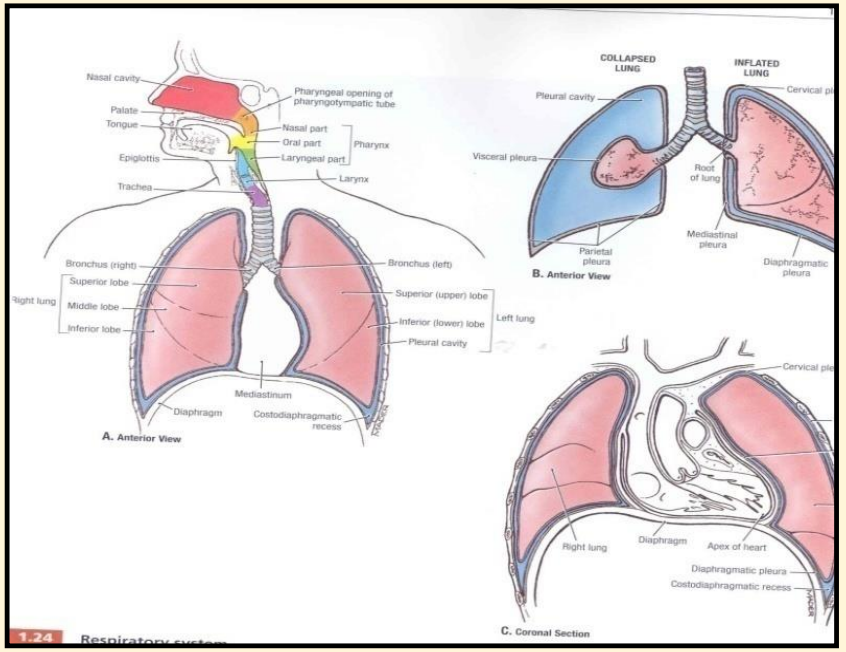
2-The pleural space is a potential space, empty due to continuous suction of fluids by lymphatics.

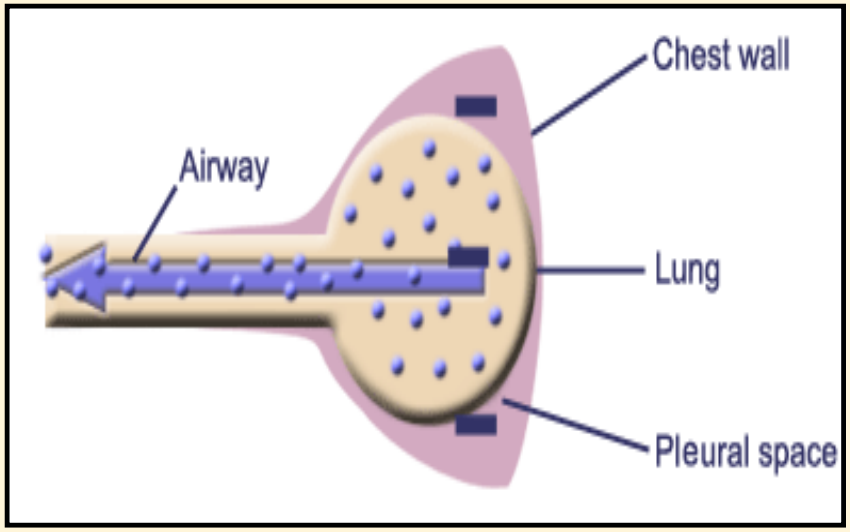
Values of IPP

- (-5) cm H2O during resting position between breathes, and it becomes more –ve (-7.5) cm H2O during resting inspiration.
- Forced ventilation

  Insp. :-20 to -40 cm H2O

  Exp. : + 30 cm H2O





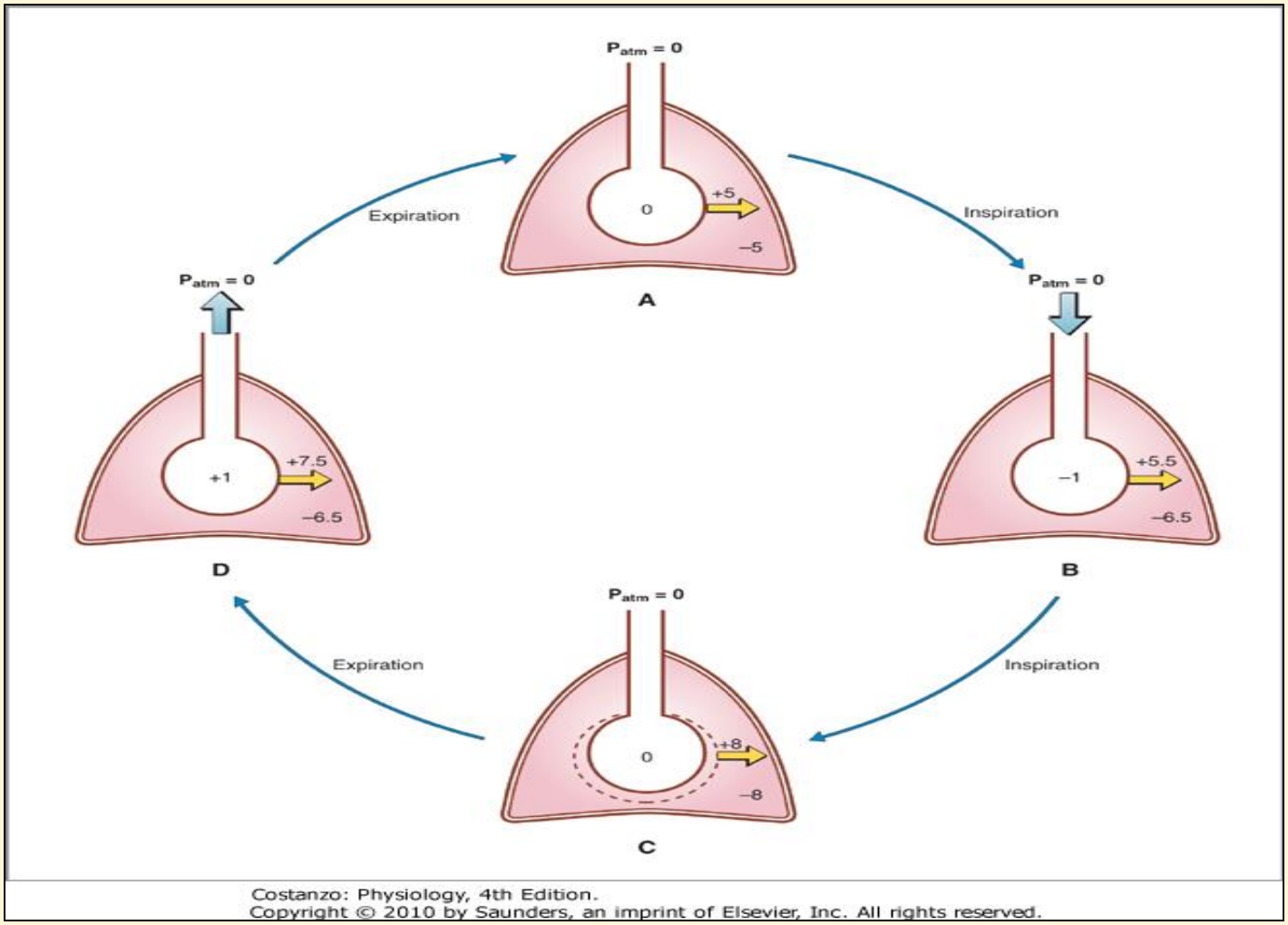
3-Transpulmonary pressure (TPp) (Extending Pressure)

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

$$TPp = \text{Palv-Ppl}$$

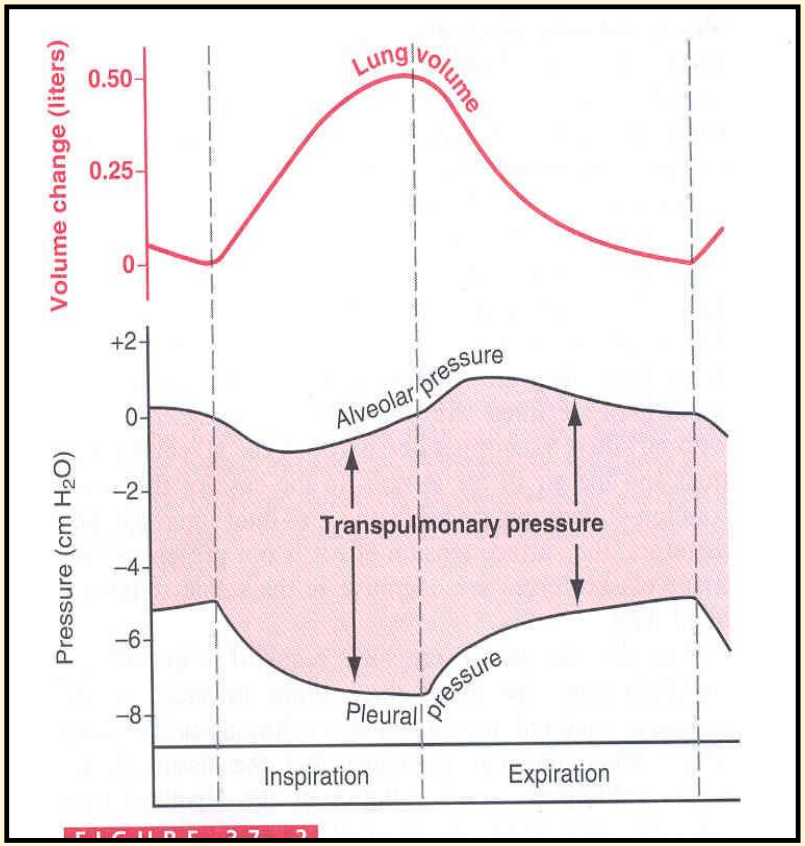
- *It is a measure of the elastic forces in the lungs that tend to collapse the lungs (**the recoil pressure).***
  - It prevents lung collapse.
- The bigger the volume of the lung the higher will be its tendency to recoil.

pressure and volume relationships in a single respiratory cycle.



Vo(Compliance of the lung) in a single respiratory cycle

E.g. two rubber bands, thin and thick. The thin rubber band easily stretched, and is very distensible and compliant. The thick rubber band difficult to stretch and is less distensible and compliant.



Compliance of the lungs

- Is defined as, the ratio of the change in the lung volume produced per unit change in the distending pressure.
- The extent to which the lungs expand for each unit increase in the transpulmonary pressure.

- CL= $\frac{\text{Volume change } (\Delta V)}{\text{Transpulmonary pressure change } (\Delta P)}$

- CL = $\frac{(\Delta V)}{(\Delta P)}$

Cont…compliance of lung

- For both lungs in adult = 200 ml of air /cm H20.
- For lungs and thorax together = 110 ml/cm H20.
- 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.