Mechanics of pulmonary ventilation

Dr. Aida Korish
Associate Prof. Physiology
KSU

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 sub atmospheric 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.

Dr.Aida Korish (akorish@ksu.edu.sa)

Mechanics of breathing

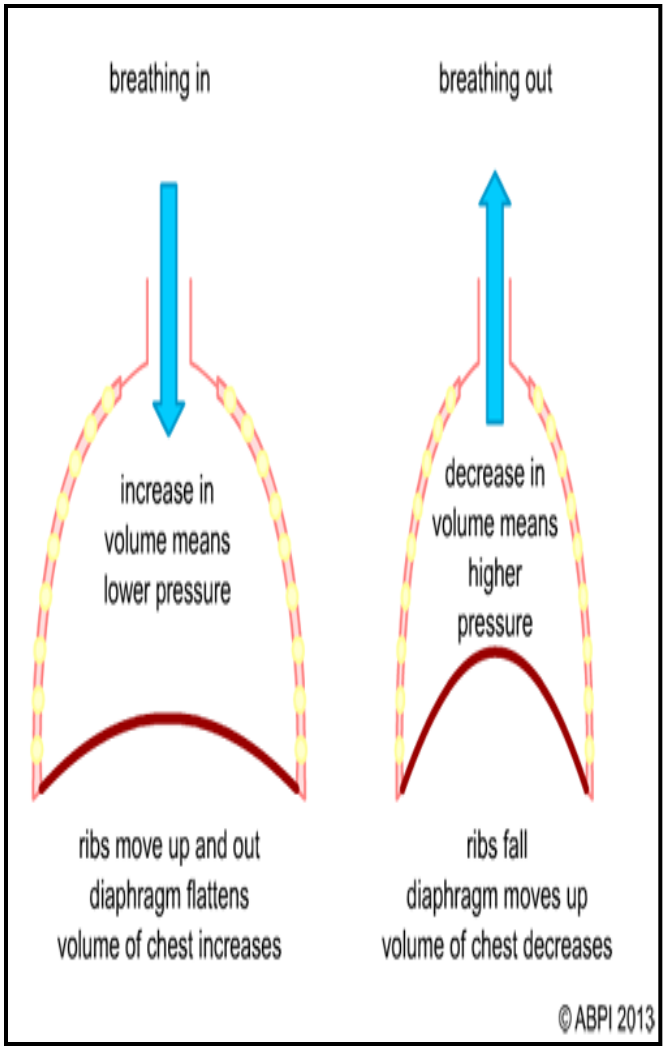
- Pulmonary Ventilation : The physical movement of air into and out of the lungs
- Air movement depends upon: Boyle's Law:

  PxV=K

  P1xV1=P2xV2

  P= pressure V= volume, K = constant

- Volume depends on movement of diaphragm and ribs.



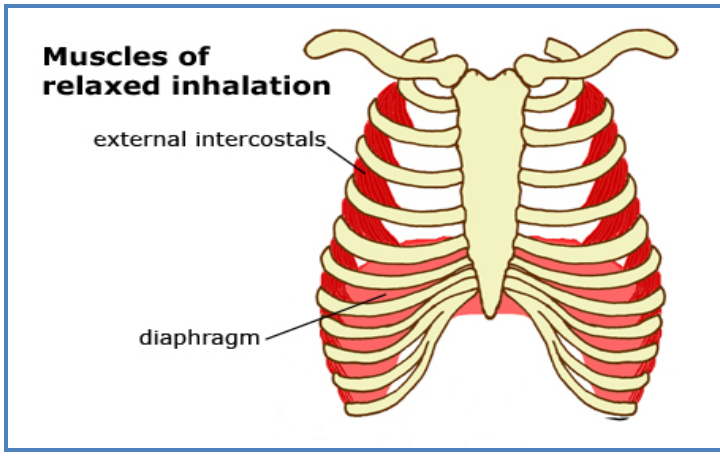
Respiratory muscles

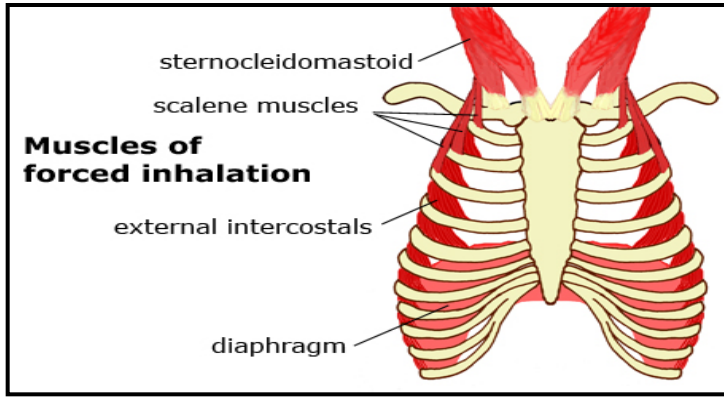
- ***Inspiratory muscles:***

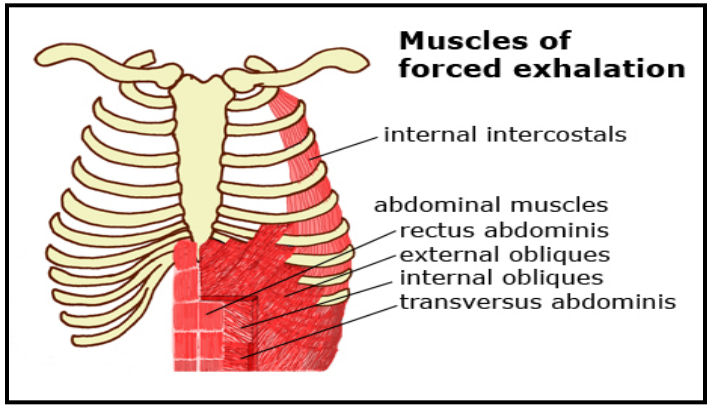
  - During resting inspiration are the diaphragm, external intercostal.

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

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

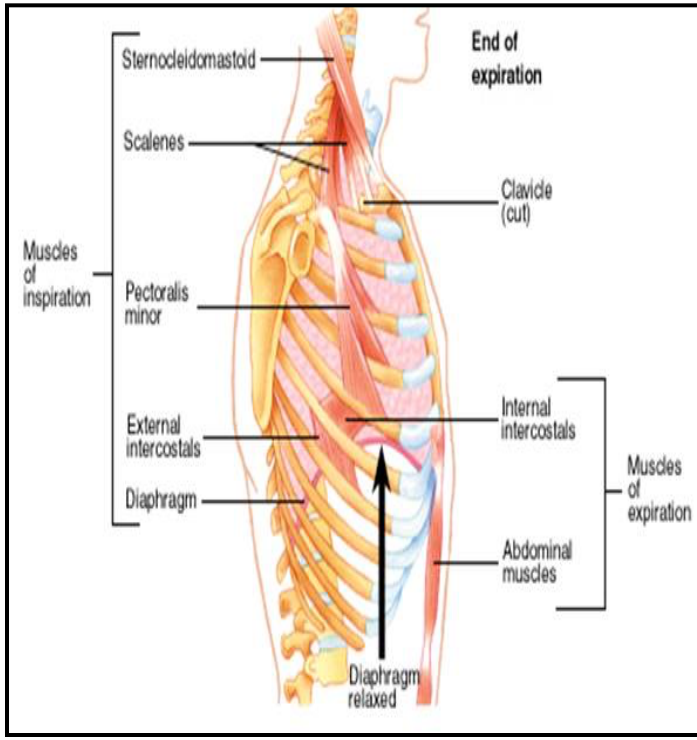






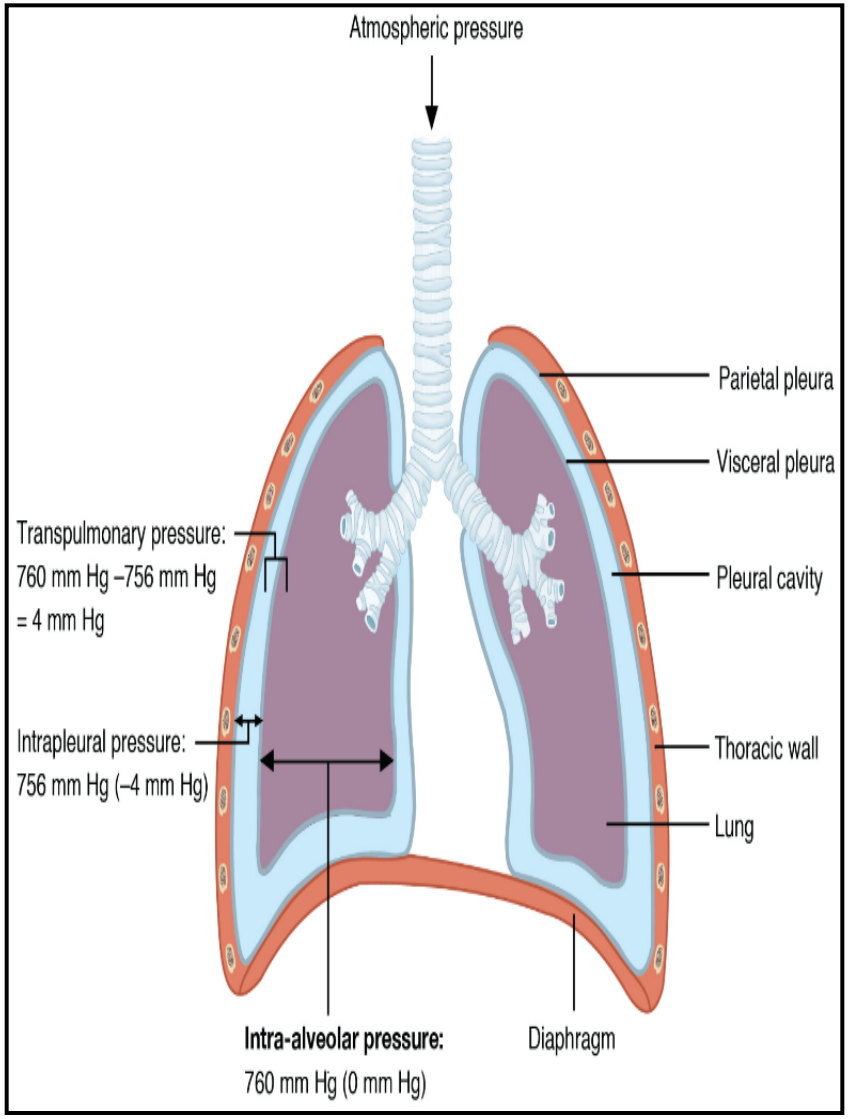
Deep Forceful Breathing

- 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.
    - Anterior serrati; elevates many of the ribs.
    - Pectoralis minor – elevate 3rd–5th ribs
- Deep Expiration
  - Expiration during forceful breathing is an active process.
  - Muscles of exhalation increase pressure in abdomen and thorax
    - Abdominal muscles.
    - Internal intercostals.



Different pressures that affect respiration

1. Atmospheric pressure
2. Alveolar pressure
3. Intraplural pressure
4. Transpumonary pressure



Intra-alveolar pressure
(intrapulmonary pressure

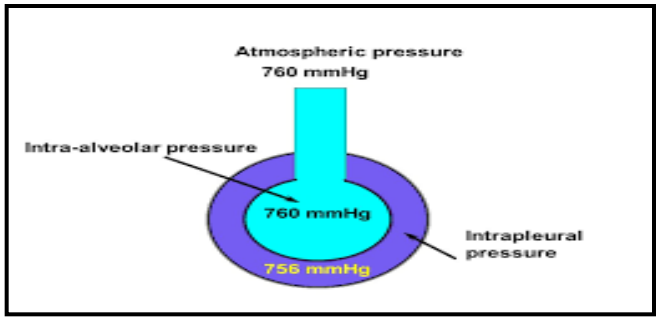
1-Intra-alveolar

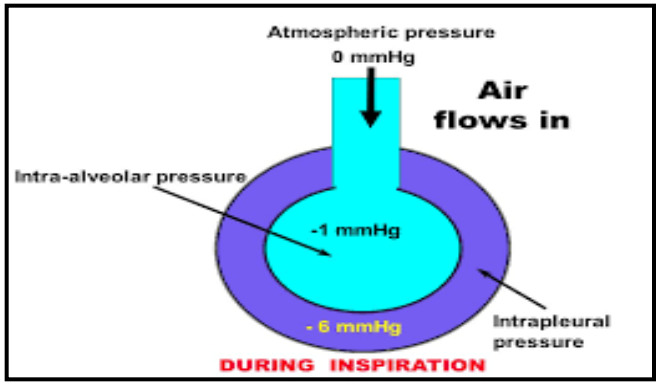
Between breathes = zero pressure

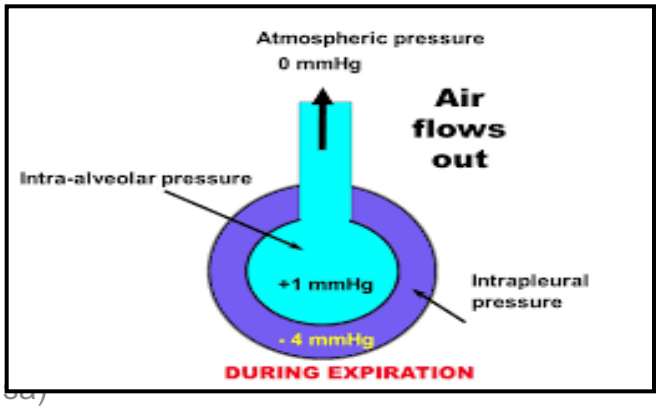
During inspiration = (-1 mmHg) and air (tidal volume) flows from outside to inside the lungs).

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

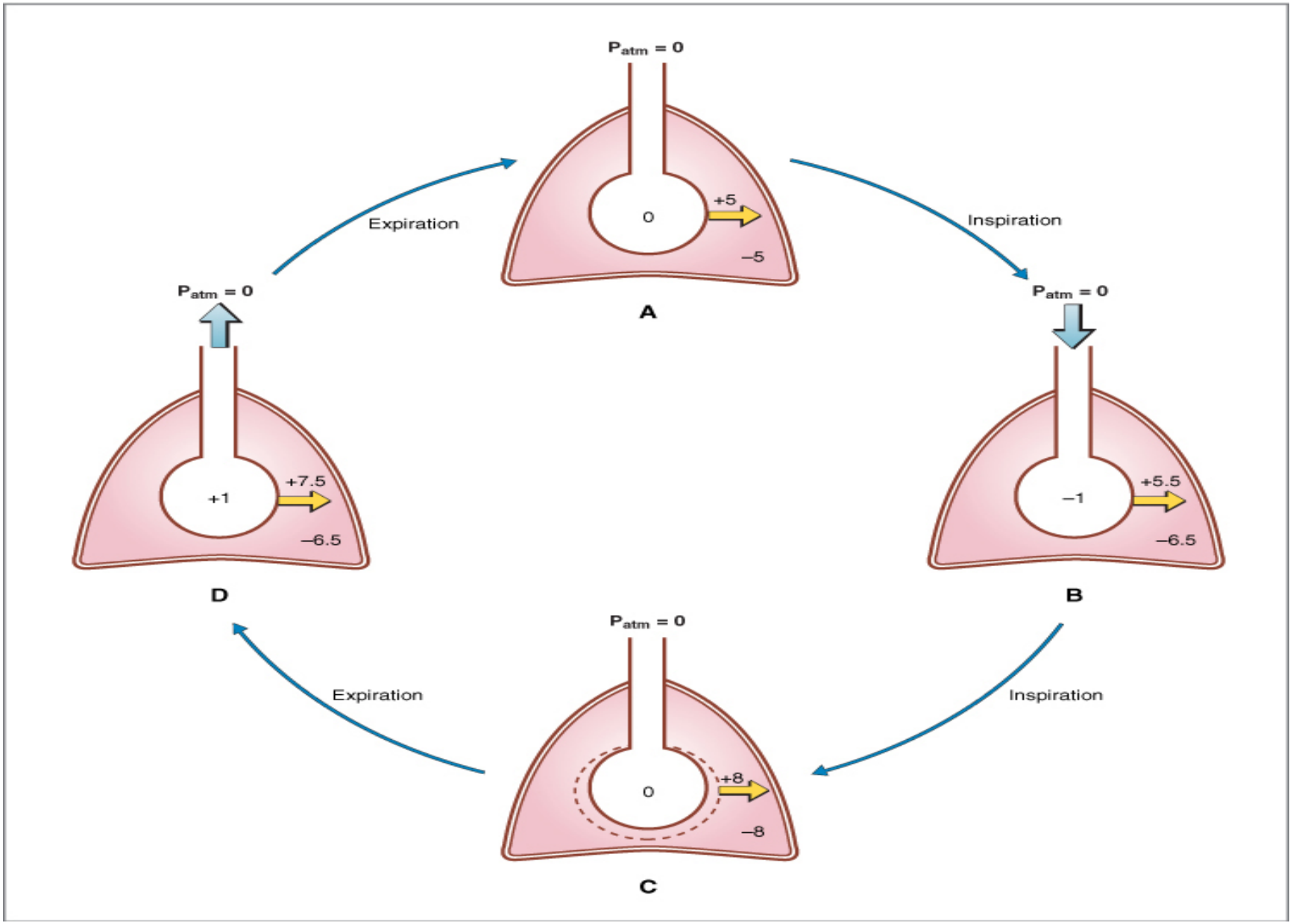
During expiration = (+1 mmHg) and air flows out of the Lungs



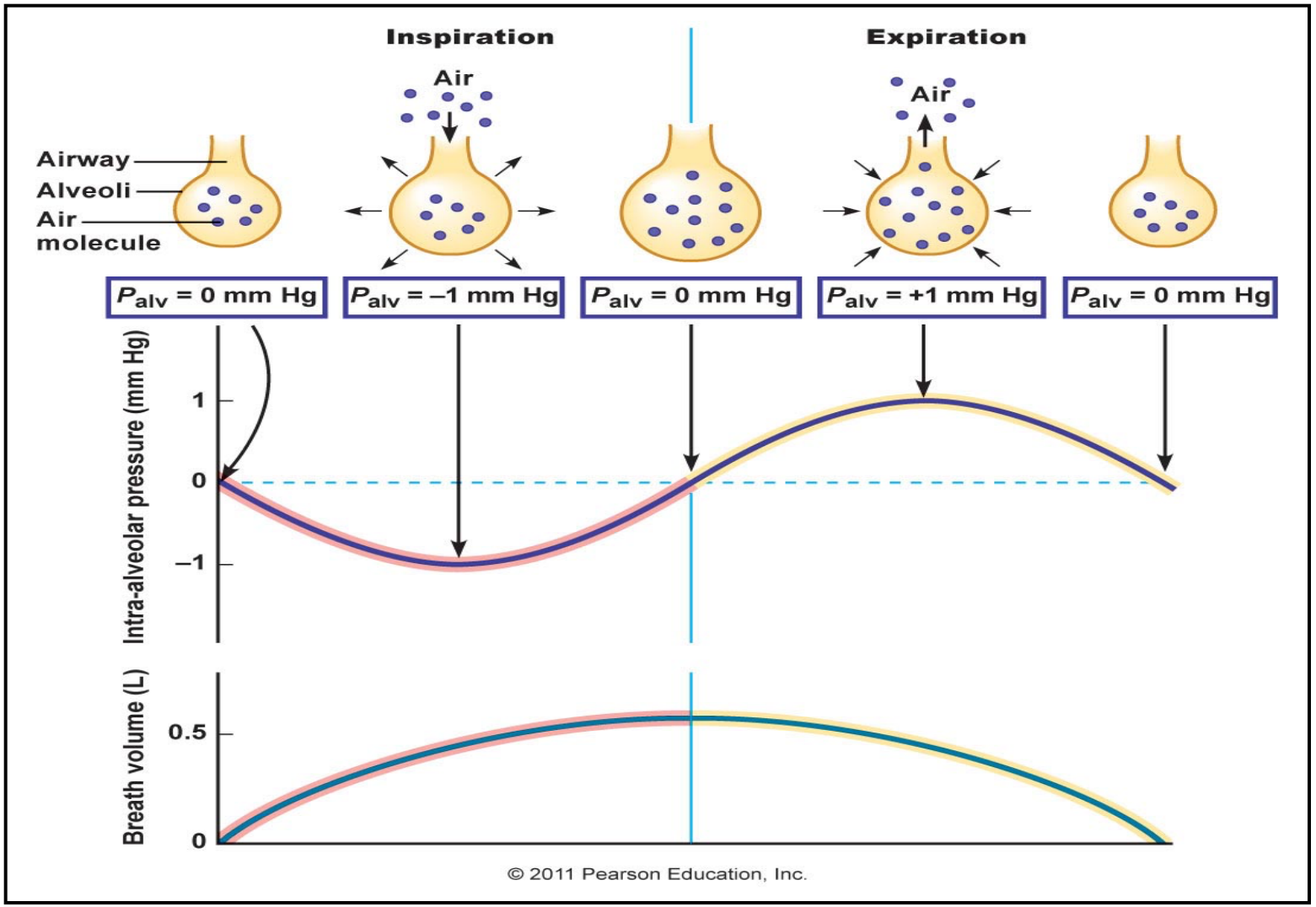




Cont…. Mechanics of ventilation



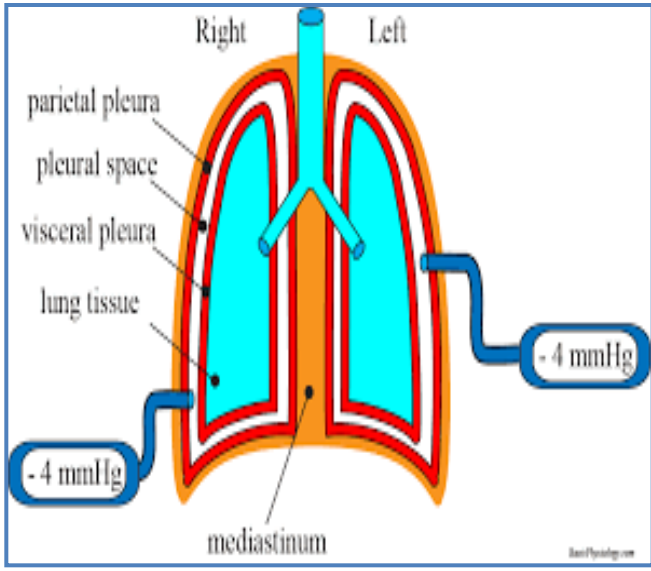
Relation between inta-alveolar pressure and lung volume



Intrapleural pressure

Negative Pressure" in Pleural Fluid.

- A negative force is always required on the outside of the lungs to keep the lungs expanded.
- This force is provided by negative pressure in the normal pleural space.
- Because the normal collapse tendency of the lungs is about −4 mm Hg, the pleural fluid pressure must always be at least as negative as −4 mm Hg to keep the lungs expanded.
- Actual measurements have shown that the pressure is usually about −7 mm Hg, which is a few millimeters of mercury more negative than the collapse pressure of the lungs.
- The negativity of the pleural fluid pressure keeps the normal lungs pulled against the parietal pleura of the chest cavity, except for an extremely thin layer of mucoid fluid that acts as a lubricant.



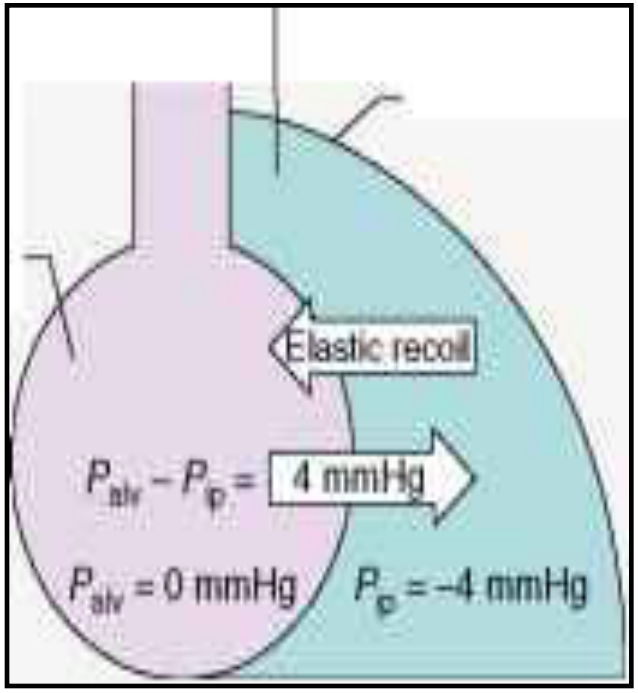
- **2-Intrapleural pressure (IPP):**

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 space) due to continuous suction of fluids by lymphatic vessels. (which is also the basis of the negative pressure found in most tissue spaces of the body).



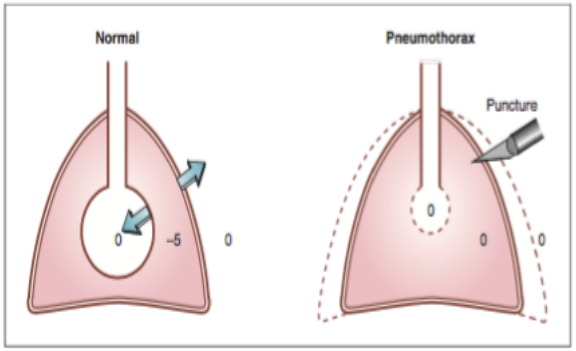
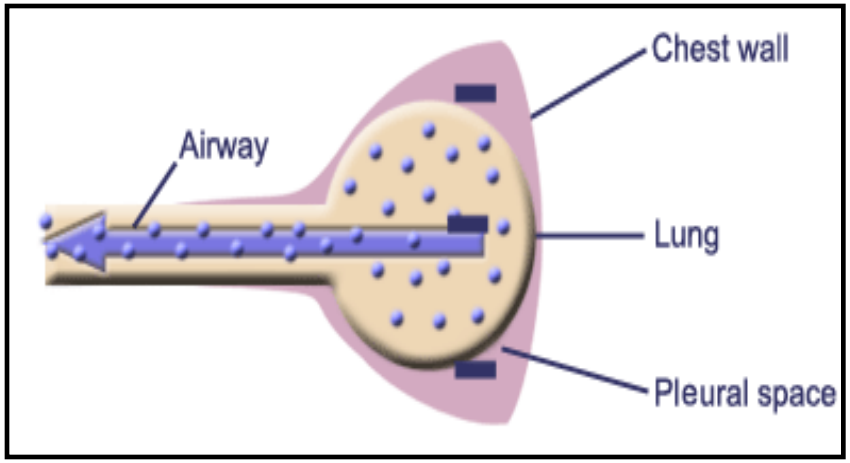


Fig. 5.9 Intrapleural pressure in a normal person and in a person with a pneumothorax. The numbers are pressures in centimeters of water. Pressures are referred to atmospheric pressure; thus zero pressure means equal to atmospheric pressure. The arrows show expanding or collapsing elastic forces. Normally, at rest, intrapleural pressure is –5 cm H_2O because of equal and opposite forces trying to collapse the lungs and expand the chest wall. With a pneumothorax, the intrapleural pressure becomes equal to atmospheric pressure, causing the lungs to collapse and the chest wall to expand.

Values of IPP

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

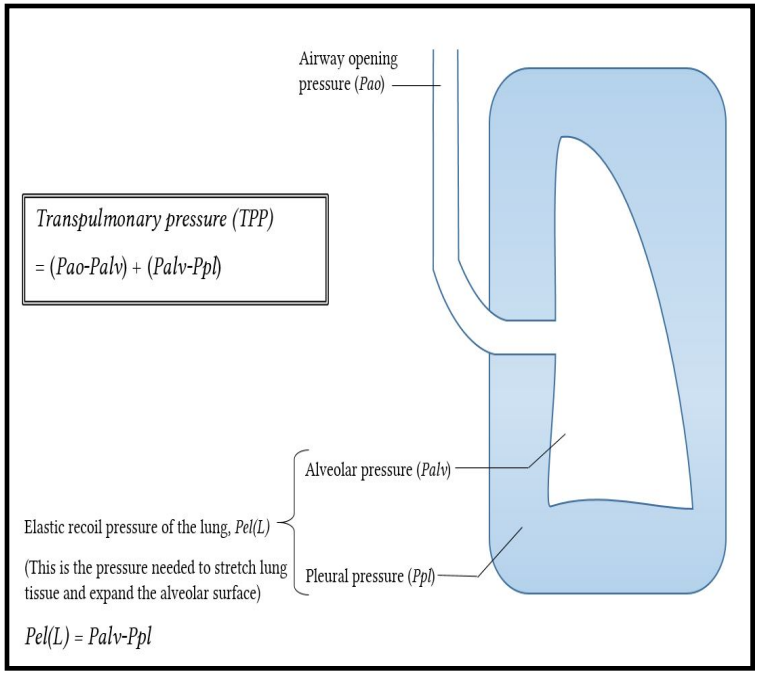


3-Transpulmonary pressure (TPp) (Extending Pressure)

- *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 the 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.

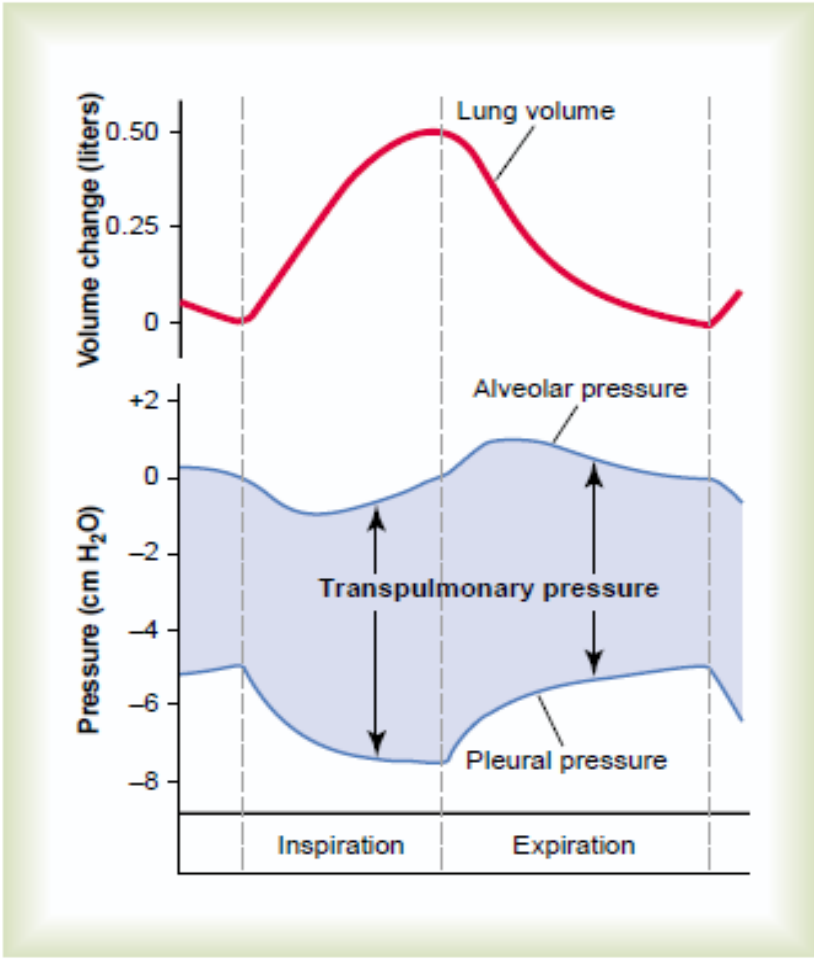


Figure 37–2

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) 1/3 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.

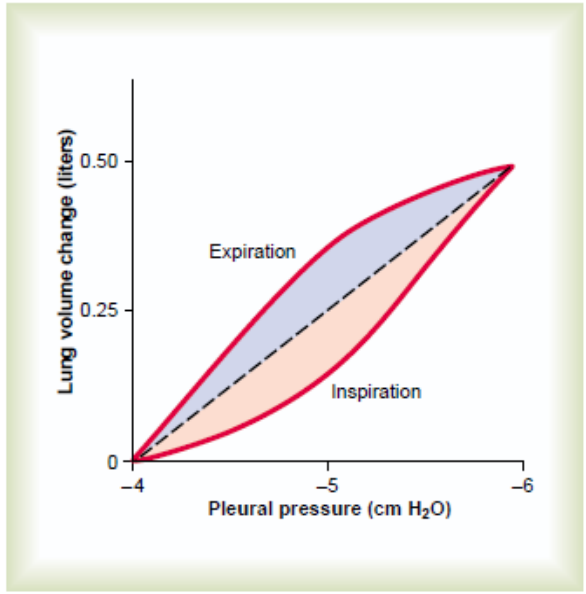


Figure 37–3

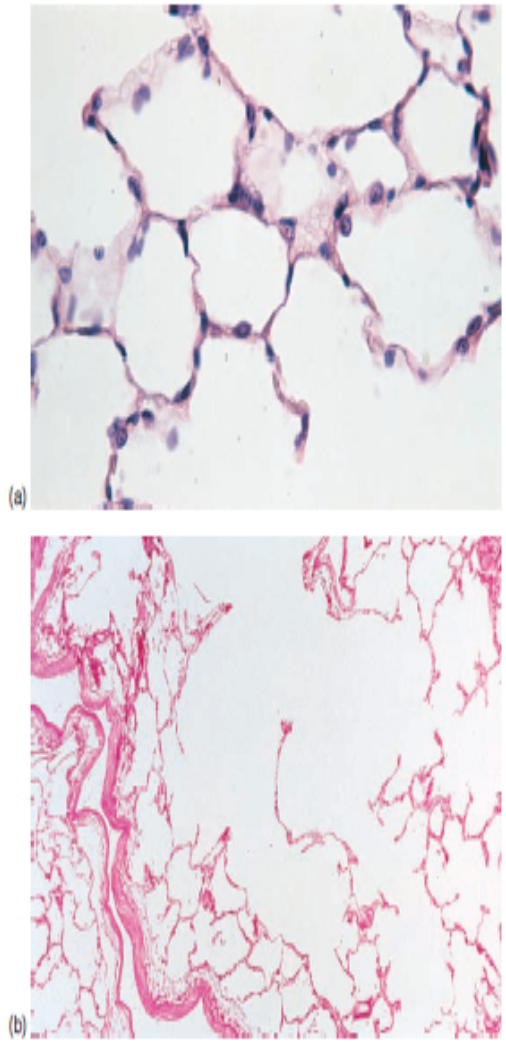
Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone.

Diseases that affect compliance of lung

- Lung compliance is reduced in pulmonary fibrosis , pulmonary edema, diseases of the chest wall

(kyphosis, scoliosis, paralysis of the muscles, etc…).

- Emphysema increases the compliance of the lungs because it destroys the alveolar septal tissue rich with elastic fibers that normally opposes lung expansion.



The work of *inspiration* can be divided into three parts

Compliance work or elastic work (expand the lungs against the lung and chest elastic forces.

Tissue resistance work to overcome the viscosity of the lung and chest wall structures)

Airway resistance work (required to overcome airway resistance *during the movement of air in the lungs.*

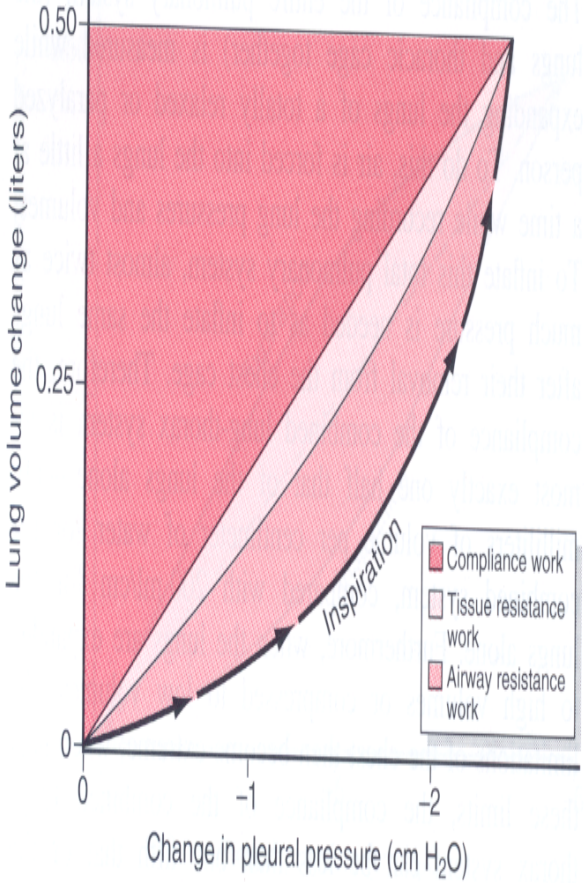


FIGURE 37-5

Energy required for respiration

- 3-5% of total energy expended by the body
- Can increase 50 folds during heavy exercise especially if the person has any degree of increased airway resistance or decreased pulmonary compliance.

➢ One of the major limitations on the intensity of exercise that can be performed is the person's ability to provide enough muscle energy for the respiratory process alone.

➢ During ***pulmonary disease*** all the three types of work are increased.