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.

Mechanics of breathing

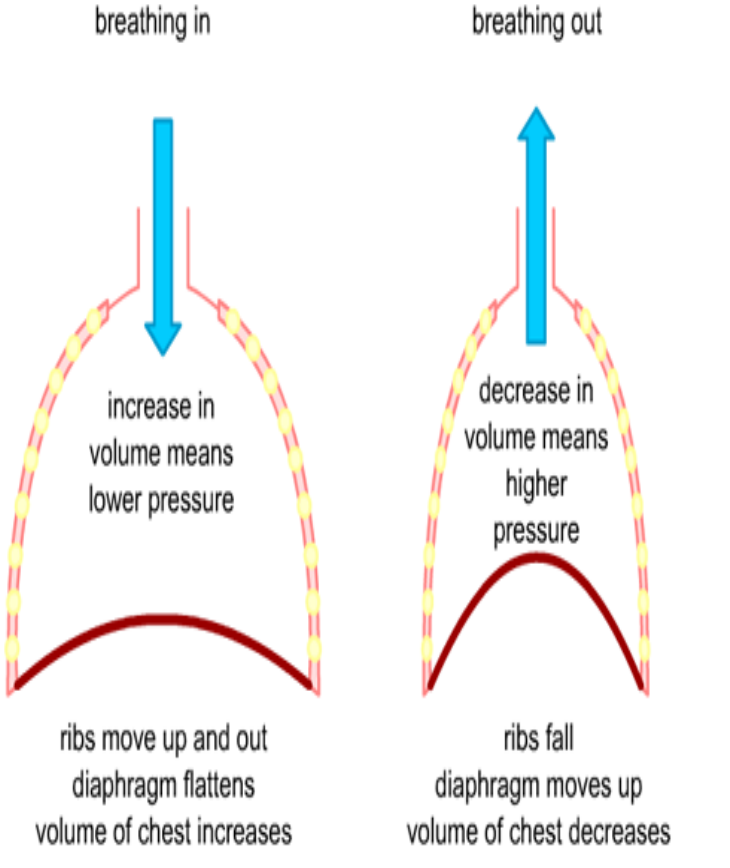
- Pulmonary Ventilation : The physical movement of air into and out of the lungs.
- Air movement depends upon:

Boyle's Law:

PxV=K P1xV1=P2xV2

P= pressure V= volume, K = constant

- Volume depends on movement of diaphragm and ribs.



Muscle of breathing

Normal Inspiration: diaphragm+ external intercostal muscles.

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 ribs.
- Pectoralis minor – elevate 3rd–5th ribs

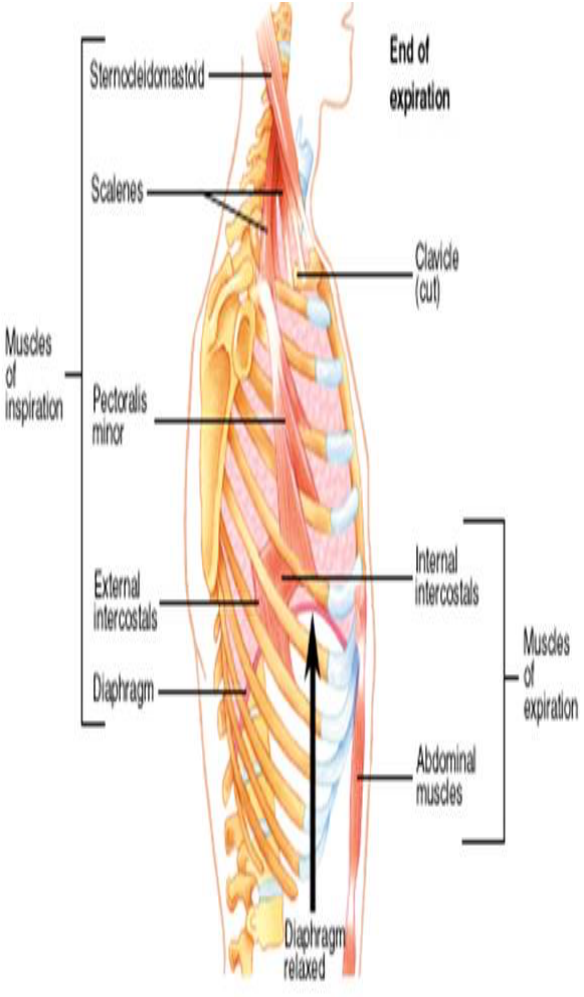
During normal expiration: passive process.

During forceful Expiration:

Expiration during forceful breathing is an active process.

Muscles of exhalation increase pressure in abdomen and thorax:

Abdominal muscles+ Internal intercostal.



Respiratory muscles

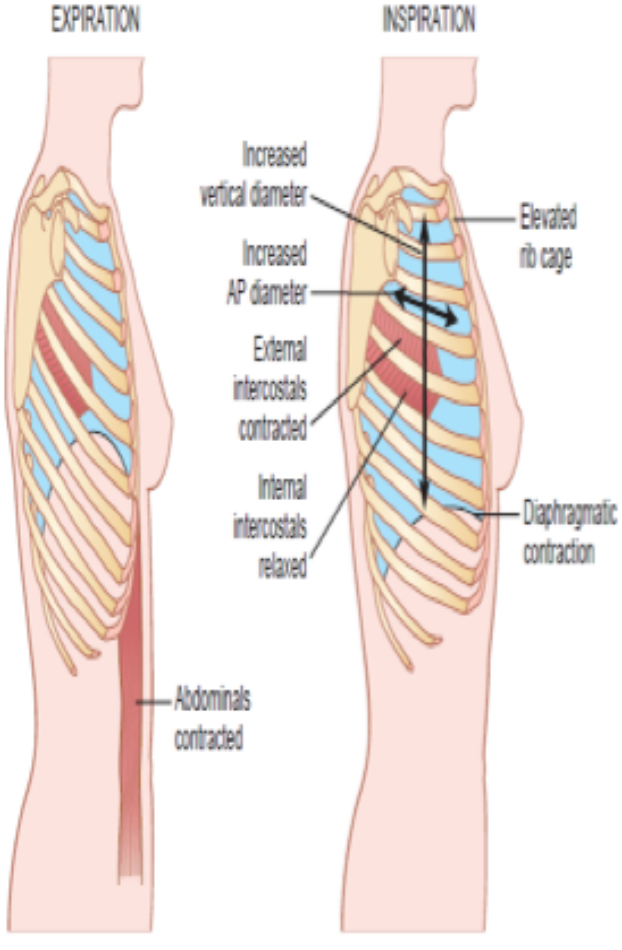
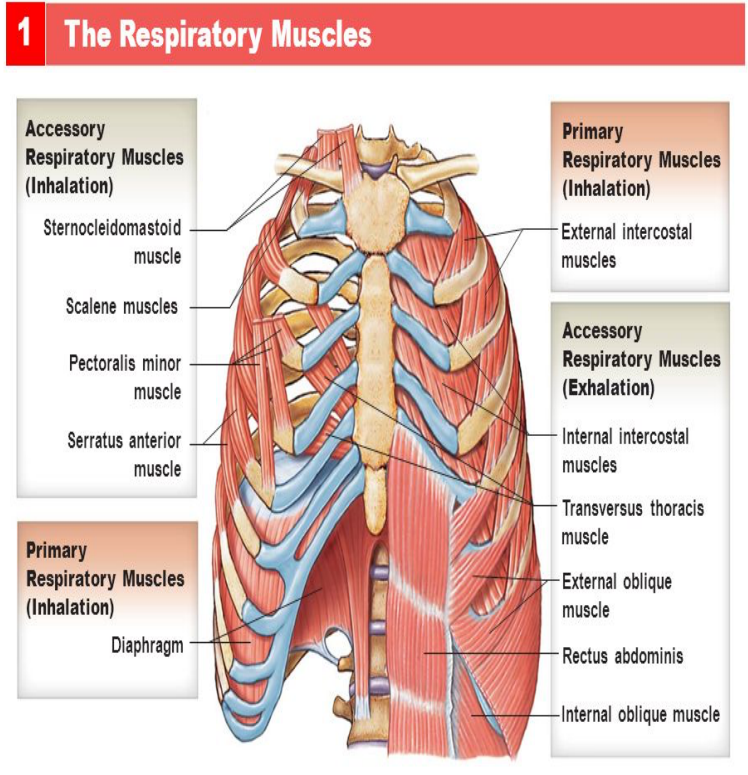


Figure 24.16 Respiratory Muscles and Pulmonary Ventilation (1 of 4)



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Different pressures that affect respiration

1. Atmospheric pressure
2. Alveolar pressure
3. Intrapleural pressure
4. Transpulmonary pressure

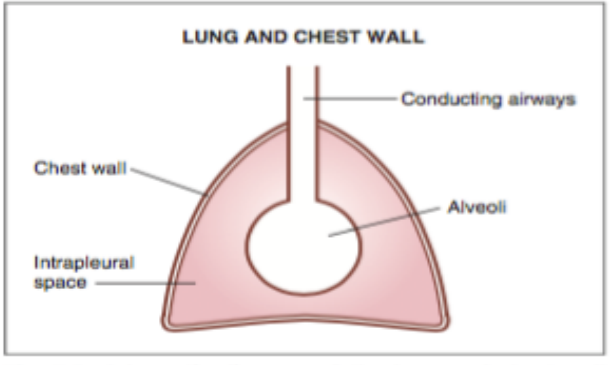
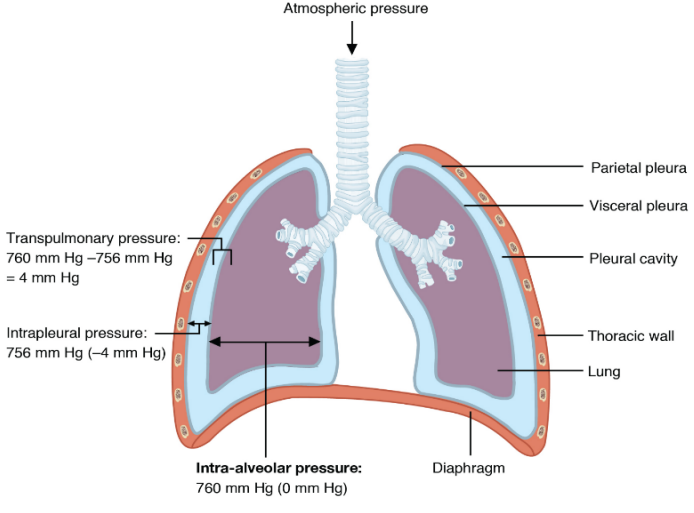
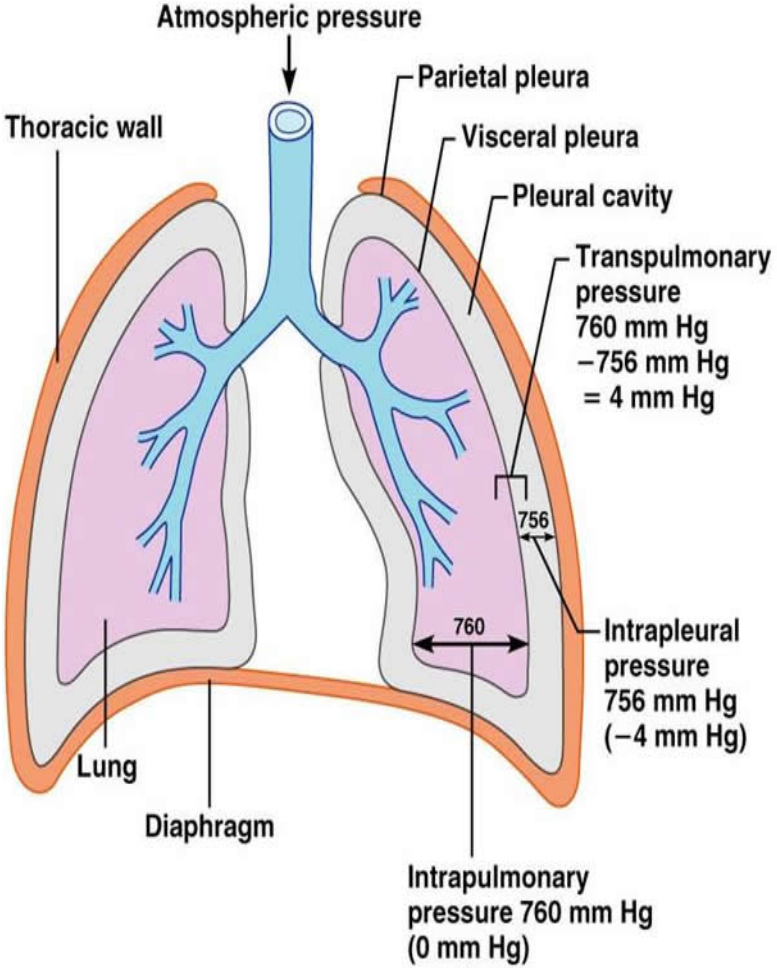
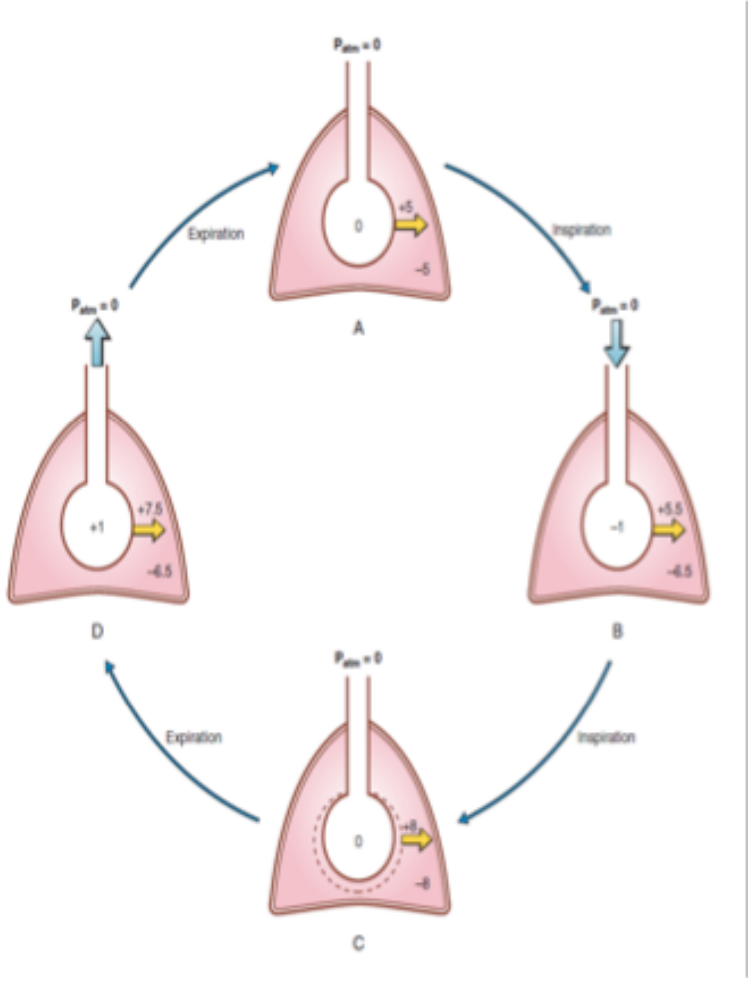


Fig. 5.8 Schematic diagram of the lung and chest-wall system. The intrapleural space is exaggerated and lies between the lungs and the chest wall.



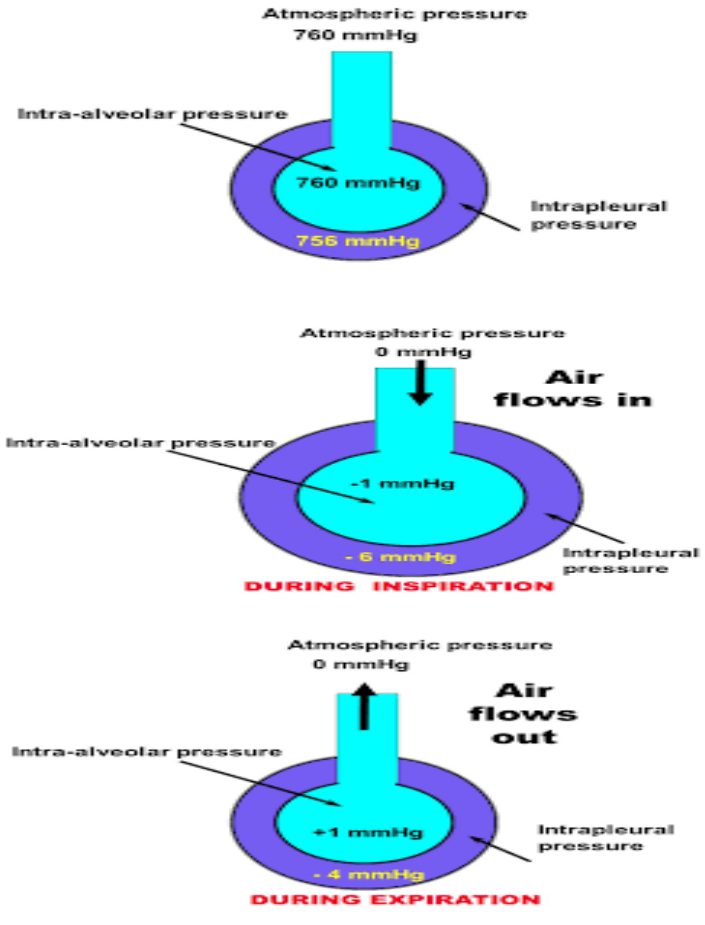
Pressures during normal breathing cycle.



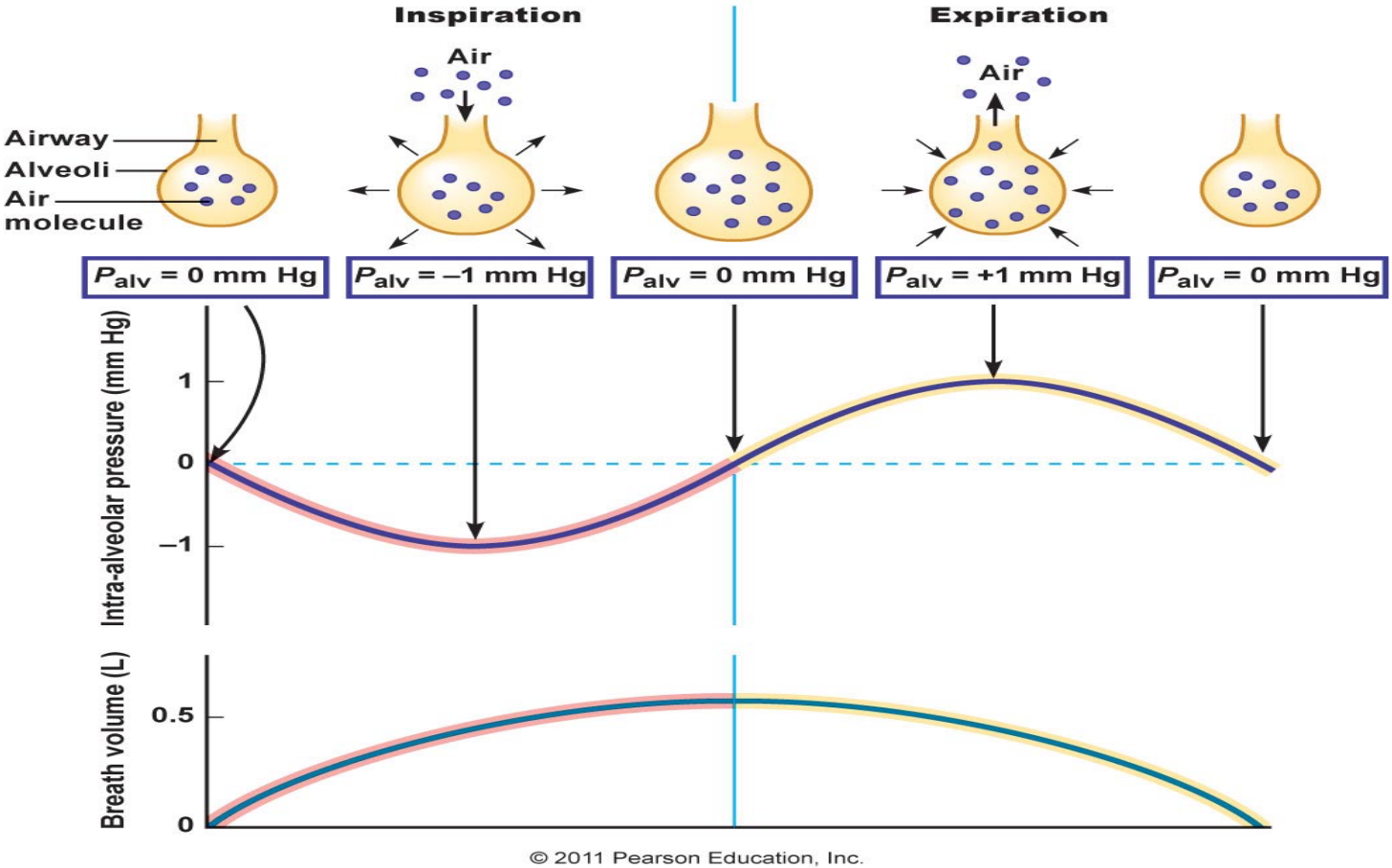


Intra-alveolar pressure

- 1-Intra-alveolar: (Intrapulmonary)
- Between breathes = <u>zero</u> 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



Relation between Intra-alveolar pressure and lung volume



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.

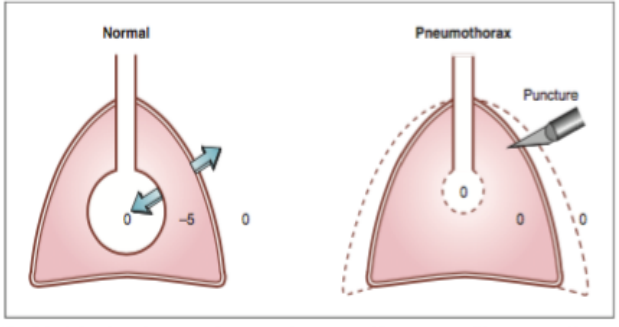
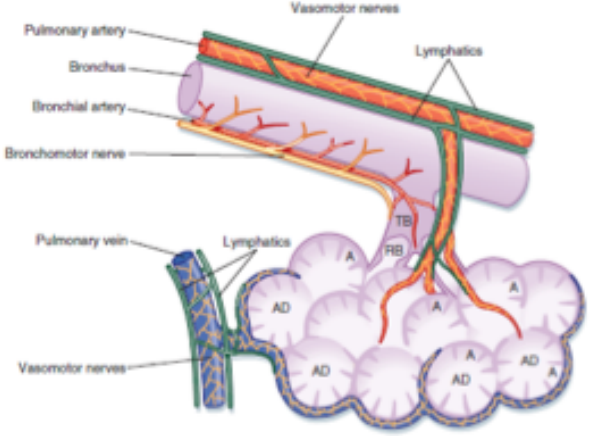


Fig. 5.9 Intrapleural pressure in a normal person and in a person with a pneumothorax. The numbers are pressures in centimeters of water. Pressures are referred to atmospheric pressure; thus zero pressure means equal to atmospheric pressure. The *arrows* show expanding or collapsing elastic forces. Normally, 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.



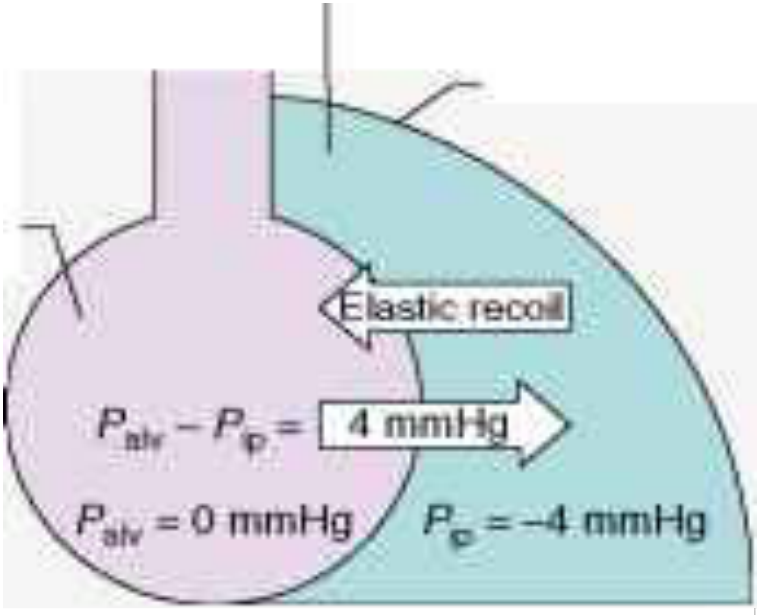
Values of IPP

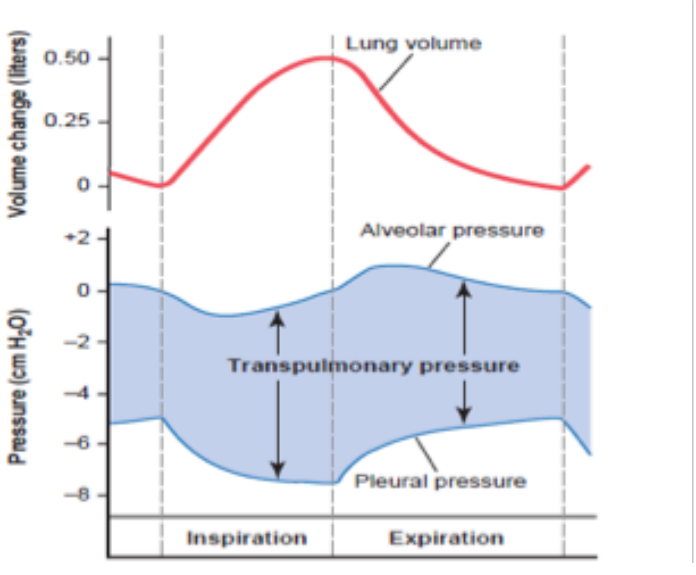
- During resting position (between breathes):

= -5 cm H2O (-4 mmHg).

- During resting inspiration: it becomes more –ve,

= -8 cm H2O.



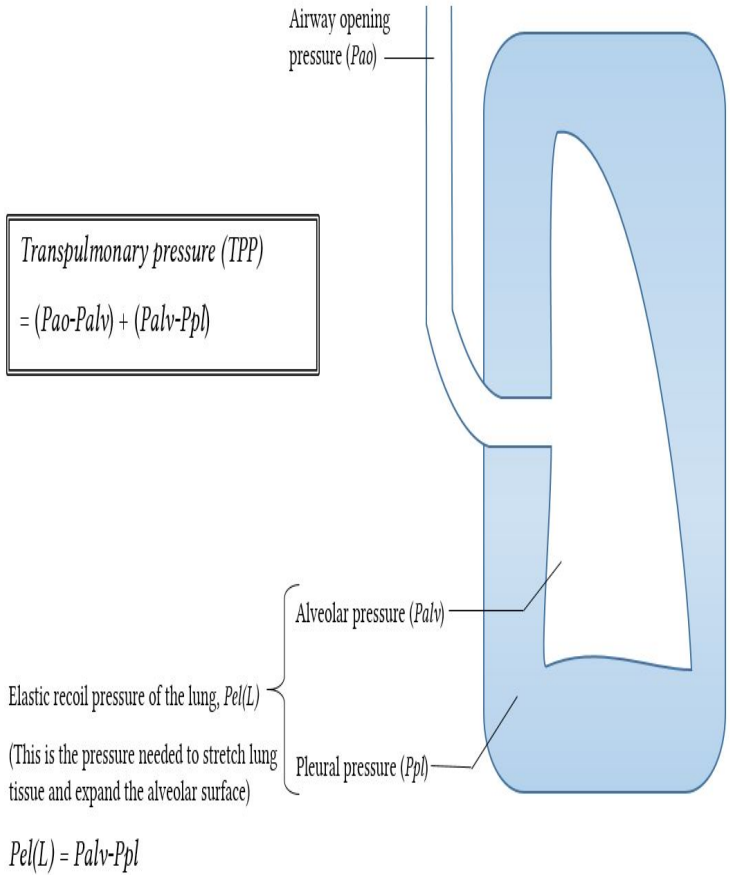


3-Transpulmonary pressure (TPp)
(Extending Pressure)

- 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).**
- 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 alone in adult = 200 ml of air /cm H20.

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

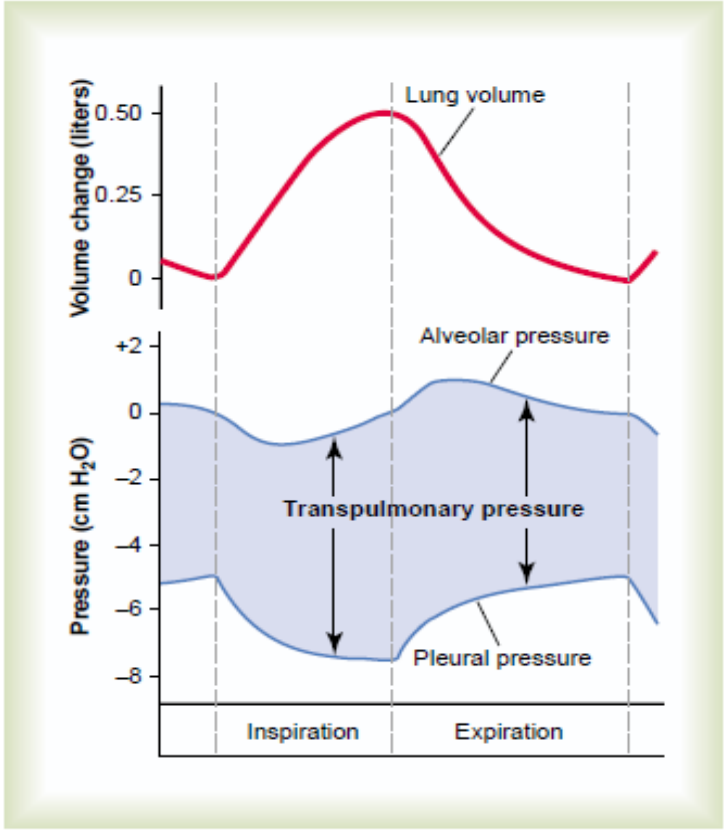


Figure 37–2

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

Lung Compliance diagram

- The characteristics of the compliance diagram are determined by the elastic forces of the lungs. These can be 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.

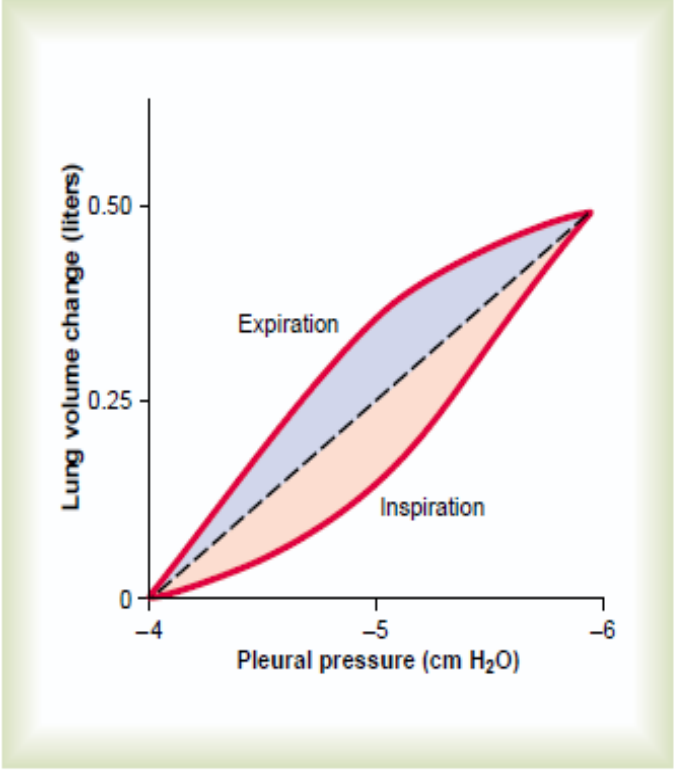


Figure 37–3

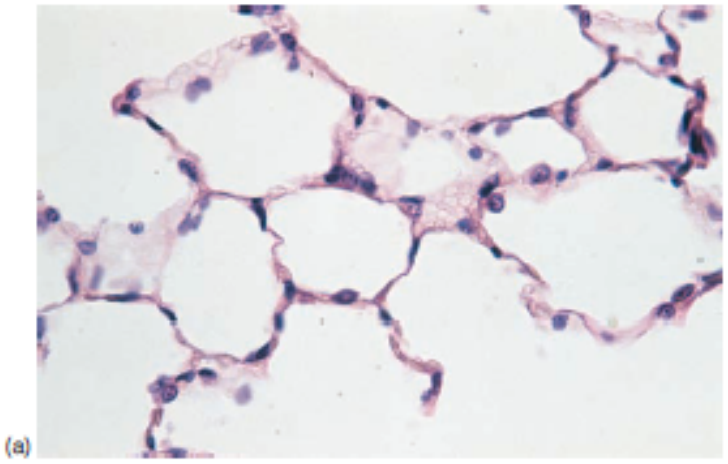
Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone.

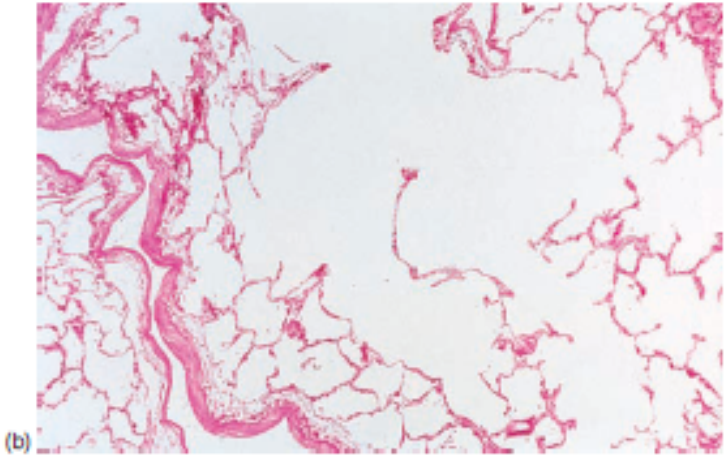
Diseases that affect compliance of lung:

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.





Work of inspiration can be divided into three parts:

1. Compliance work or elastic work: (expand the lungs against the lung and chest elastic forces (65%).
2. Tissue resistance work: to overcome the viscosity of the lung and chest wall structures (7%).
3. Airway resistance work: required to overcome airway resistance during the movement of air in the lungs (28%).

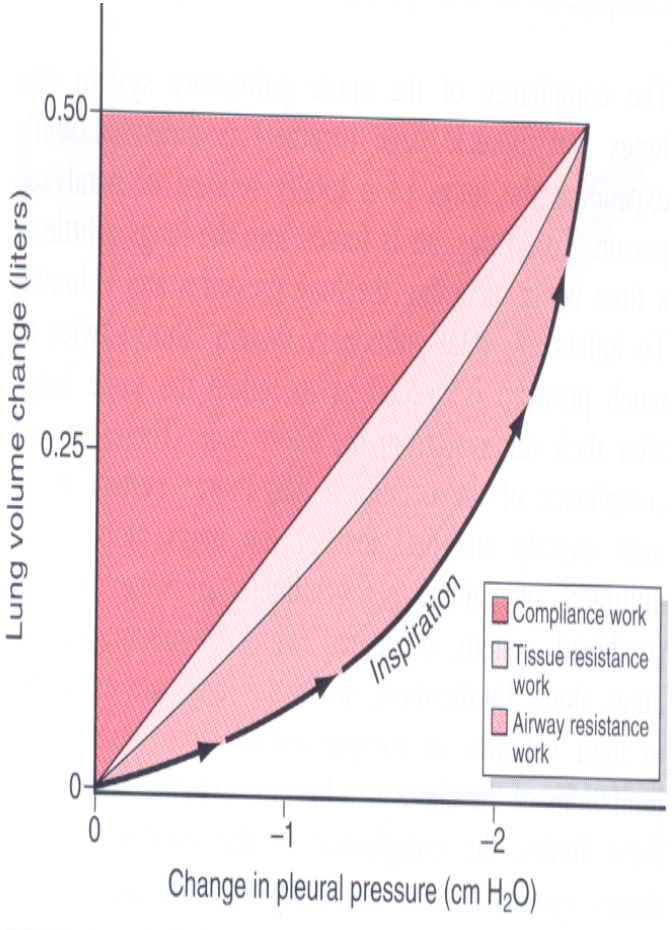


FIGURE 37-5

Energy required for respiration

- 3-5% of total energy expended by the body.
- Can be increased to 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.