Lecture 2

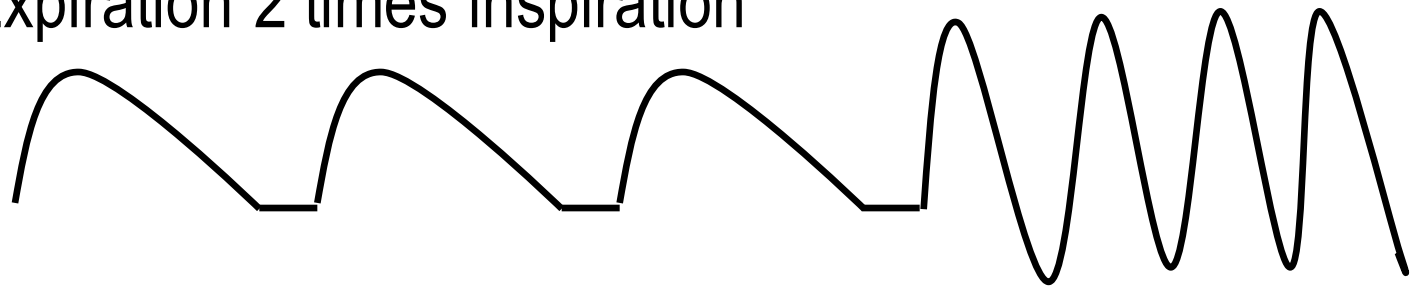
PULMONARY VENTILATION

Objectives

- The muscles used during ventilation
- The mechanism of ventilation of the lung
- The types of respiratory pressures
- The elastic recoil of the lung (surface tension)
- The chemical composition, functions and factors affecting surfactant production
- Types of respiratory dead space
- Significance of ADS

Mechanism of normal quite breathing (eupnoea)

- Respiratory cycle (inspiration, expiration, pause)
- Respiratory rate 12-16/min
- Expiration 2 times inspiration



Normal quite breathing

Exercise

- Pause disappear
- Expiration = inspiration
- ↑ Rate

- ↑RR→ tachypnea, e.g., exercise, fever.
- Arrest of respiration → apnea, e.g, deglutition apnea
- Difficulty in breathing → dyspnea, e.g, bronchial asthma.

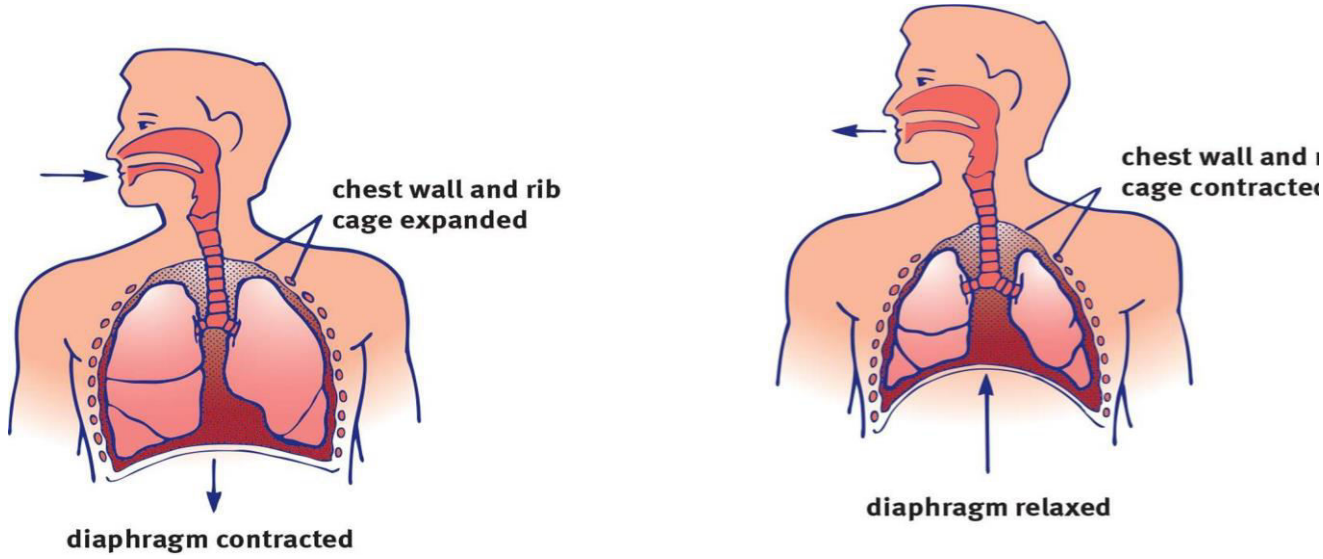
Muscles of respiration

Muscles of inspiration ➡ Inspiration is active

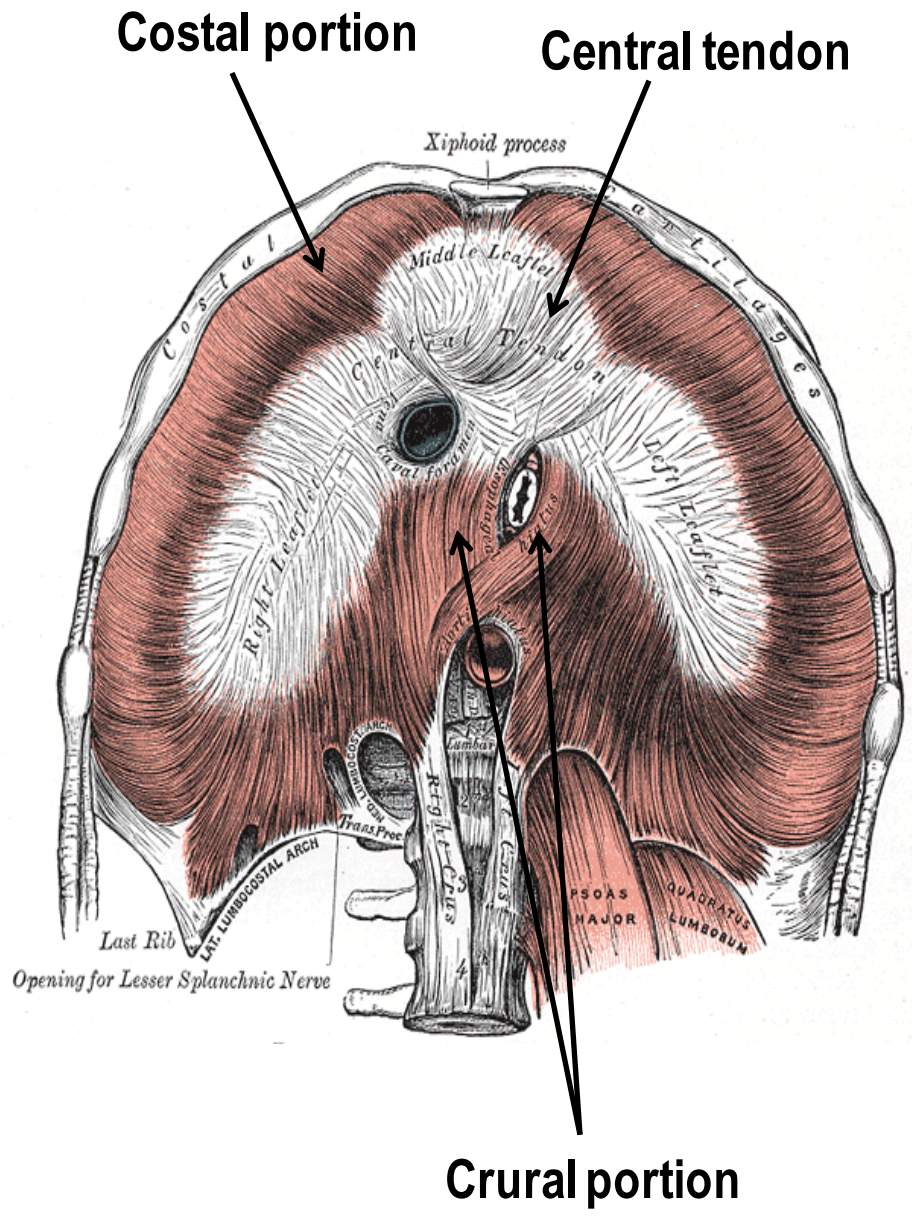
⊙ Normal inspiration

1) Diaphragm

- Descend (contraction) about 1.5 cm (quiet inspiration), 7cm(forced inspiration) →↑ vertical diameter
- 75% of air entry
- Diaphragmatic paralysis (C3,4&5) →respiration is seriously impaired.



- Diaphragm consists of costal portion, crural portion and central tendon
  - The costal and crural fibers are innervated by different parts of the phrenic nerves and can contract separately
  - Vomiting ⟶ ↑ intra-abdominal pressure by contraction of costal fibers but the crural fibers remain relaxed allowing materials to pass from the stomach into the esophagus.



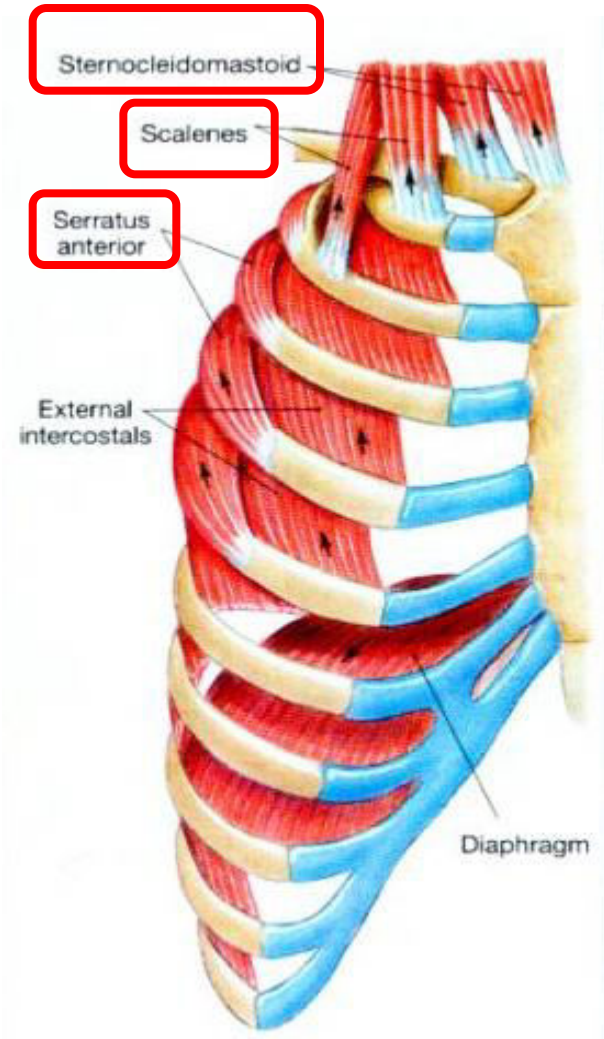
2) External intercostal muscles ➡ (run obliquely downward and forward from rib to rib)

- Eversion of ribs →↑ antero-posterior diameter
- Elevation of ribs →↑ transverse diameter

⊙ Forced inspiration

Accessory inspiratory muscles

- Sternocleidomastoid→ elevates sternum
- Scalene→ elevates 1ST 2 ribs
- Serratus anterior → elevates 1st 5 ribs



Muscles of expiration ➡ Expiration is passive

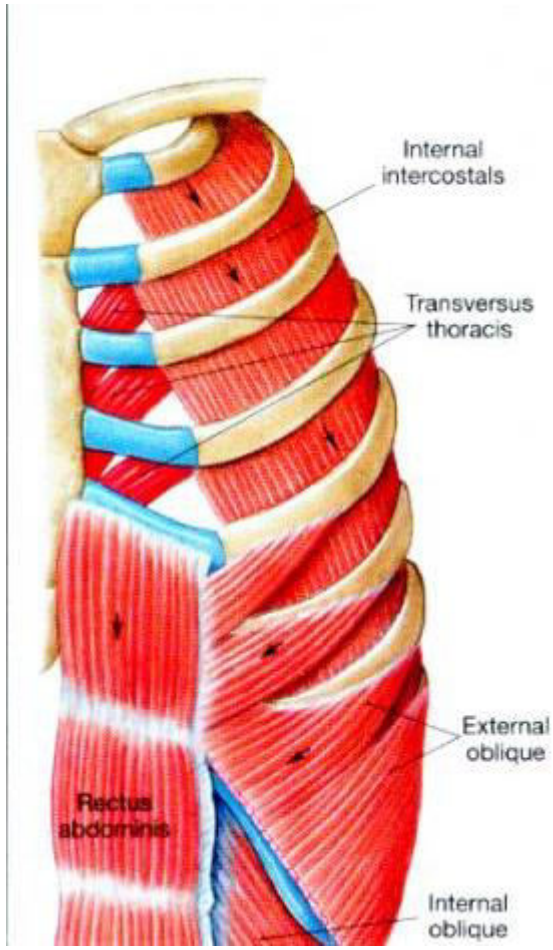
- Normal expiration (passive)

  No muscle contraction

- Expiratory muscles used only with
  - Forced expiration (exercise)
  - Diseases (obstructive lung diseases)

1) Internal intercostal muscles (pass obliquely downward and posteriorly from rib to rib)
   - Inversion and depression of ribs

2) Abdominal muscles
   - Pulling the rib cage downward and inward and increasing the intra-abdominal pressure



Mechanism of ventilation of lungs

Contraction of inspiratory muscles

↓

Thoracic cage moves out

↓

Parietal pleura moves out (adherent to the thoracic cage)

↓

Draws along with it visceral pleura (adherent to the lungs)

↓

The lungs expand (Due to dragging force exerted by the visceral pleura and also to elastic property of lung)

↓

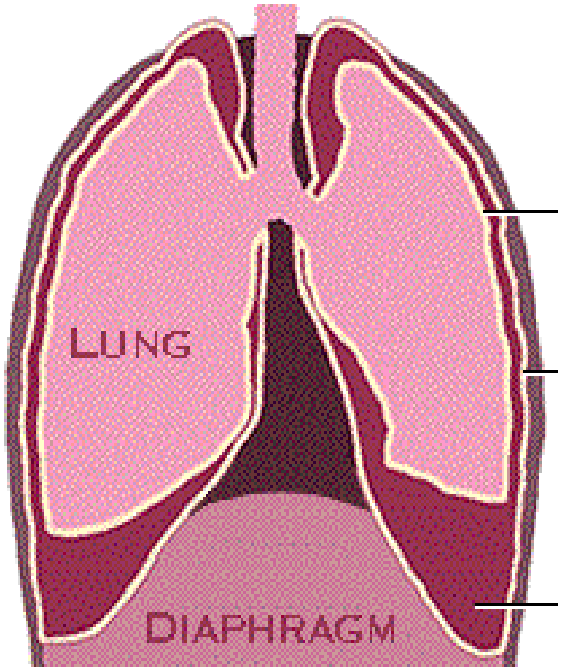
The inside volume is increased

↓

↓ Alveolar pressure (Boyle's Law)

↓

Air from outside is sucked into the lungs **(INSPIRATION)**



Relaxation of inspiratory muscles

↓

Lungs retract due to elastic recoil

↓

Inside volume decrease

↓

Alveolar pressure >atmospheric pressure

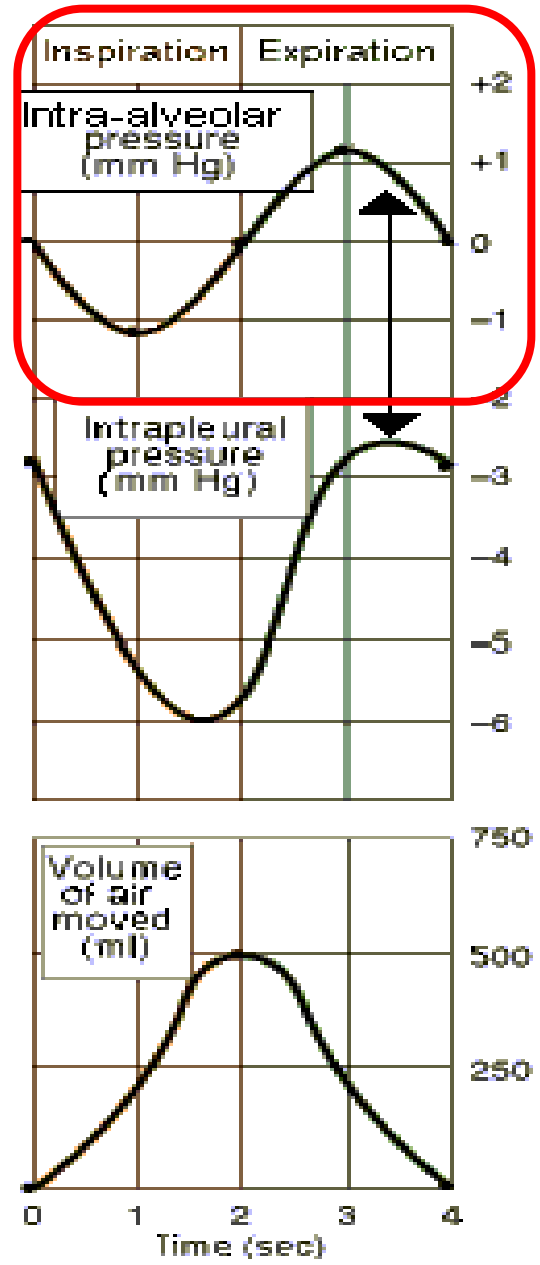
↓

Air driven out (**expiration**)

Pressure changes during respiratory cycle

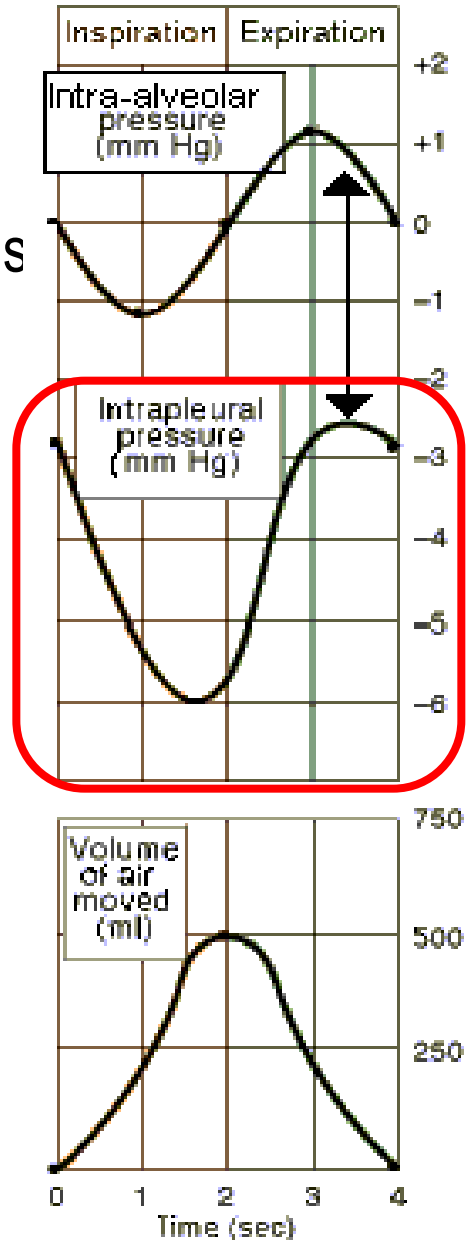
1) Intra alveolar (intrapulmonary) pressure

- Definition: pressure inside the alveoli
  - At the end of normal expiration the intrapul. pressure = atmospheric pressure = zero.
- Values:
  - Quite inspiration → negative
    - Mid inspiration = –1 mmHg
    - End of inspiration → zero
    - Forced inspiration (Muller's maneuver e.g sucking fluid with straw) → (–80 mmHg)
  - Quite expiration → positive
    - Mid expiration = +1 mmHg
    - End of expiration → zero
    - Forced expiration (Valsalva's maneuver e.g. straining) → (+100 mm Hg)



2) Intrapleural (intrathoracic) pressure

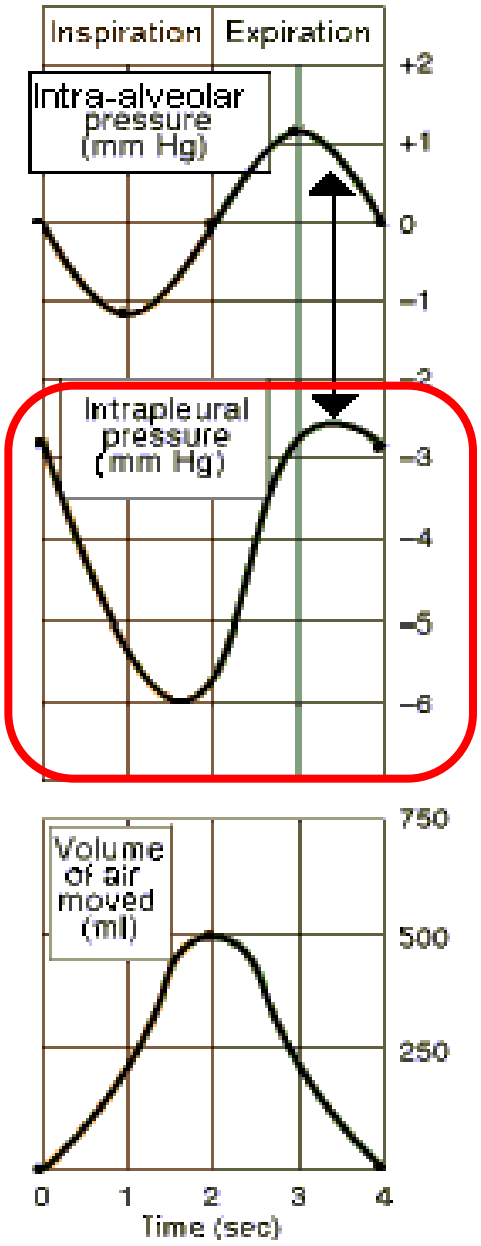
- Definition: pressure in pleural cavity
- Value: in normal breathing is always negative
  - Atmospheric pressure which is equal to 760 mmHg is taken as zero atmosphere
- Cause:
  - Continuous tendency of lung to recoil inwards (elasticity and surface tension) and chest wall to expand (elasticity) → These two forces are equal in intensity and act in opposite directions against a closed space→ negative pressure
  - Rapid absorption rate of pleural fluid by pulmonary capillaries and also by the lymphatics



⊙ Variation in intrapleural pressure (values)

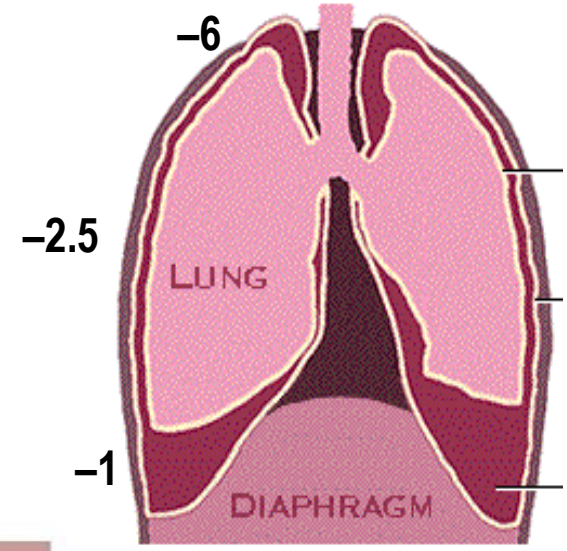
1) During different phases of respiration

- Inspiration (more negative)
  - ☞In quite inspiration (–6 mmHg)
  - ☞In forced inspiration(–12 to –18 mm Hg)
  - ☞In Muller's maneuver (– 40 mm Hg)
- During expiration (less negative)
  - ☞Towards the end of expiration (–2.5 mm Hg)
  - ☞Forced expiration ⟶ positive pressure
  - ☞In Valsalva's maneuver (+40 mm Hg)



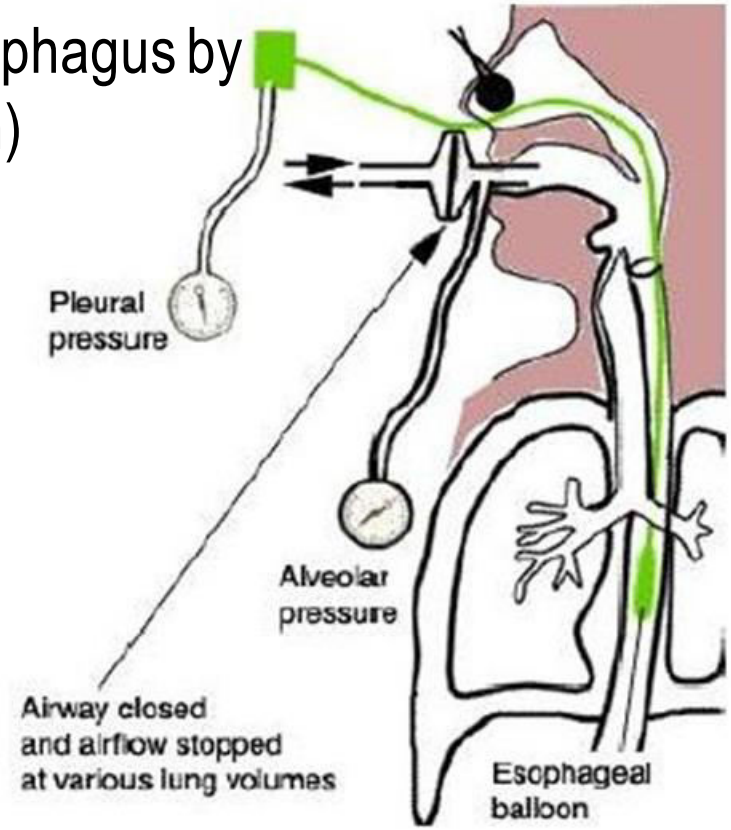
2) Regional variation (effect of gravity)

- Near the apex : (–6 mm Hg)
- In the middle part of the lung (-2.5mmHg)
- Near the base it is about (–1 mm Hg)



⊙ Measurement

- Indirect (measurement of pressure inside esophagus by esophageal balloon)

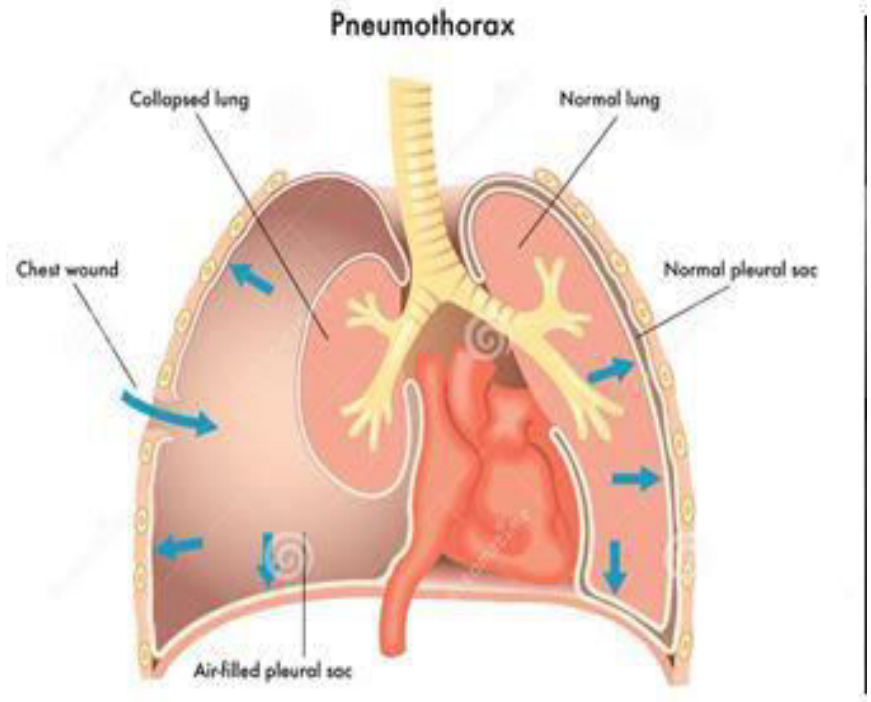


⊙ Importance of negative intrapleural pressure

- Prevent collapse of alveoli (lung)
- Aids venous and lymphatic return (against gravity)
- Clinically negativity is an index of lung elasticity

⊙ Effects of positive intrapleural pressure

- Normally (Valsalva's maneuver)
- Pathological (pneumothorax)
  - ☞ Lung recoils (collapse) and chest wall expands to their relaxed volumes.
  - ☞ Trachea, mediastinum shift toward healthy side.
  - ☞ Decreased venous and lymphatic return



Transpulmonary (transmural pressure)

- **Definition:** pressure difference across the lung
  - Intrapulmonary pressure - intrapleural pressure
  - ↑Transpulmonary pr → greater stretching of lung →↑ lung volume (↑during inspiration & ↓ during expiration)
- **Values:** (at the end of normal expiration)
  - At the apex of the lung: 0 - (-6) = 6 mmHg
  - In the middle of the lung: 0- (-2.5) = 2.5 mmHg
  - At the base of the lung: 0 - (-1) = 1 mmHg

  - Since the transmural pressure is less at the base of the lung:
    - ☞ The lung is less expanded at the base
    - ☞ This pressure further decreases at the end of forced expiration causing the airways to close at the base