Lecture 2
ELASTIC PROPERTIES OF THE LUNG

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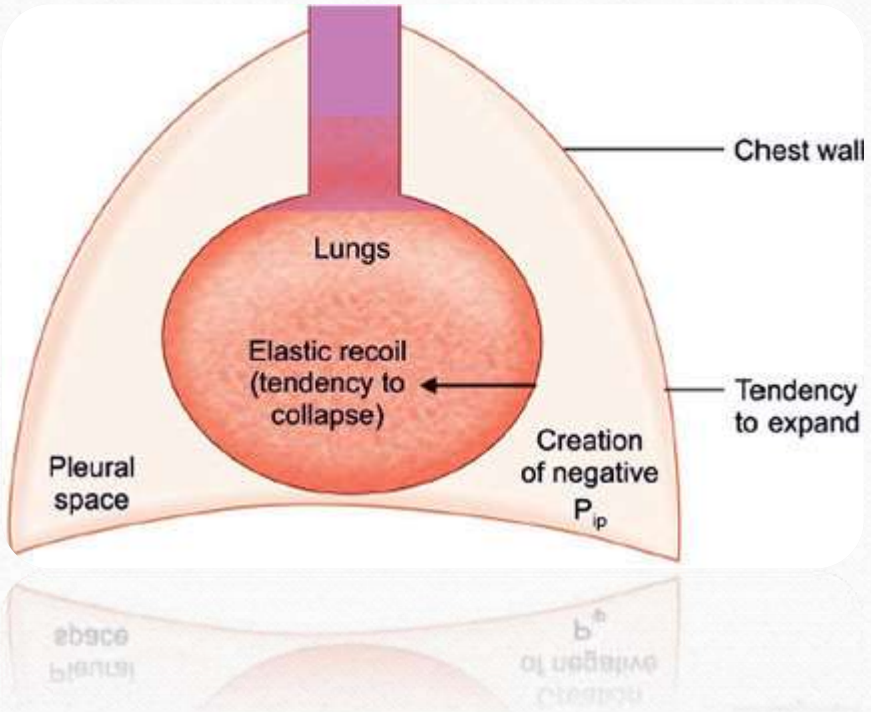
ILOs

- Elastic properties of normal lung.
- Lung surfactant; formation, functions, factors affecting and clinical disorders.
- Normal compliance of the lung and factors affecting it.
- Effect of decreased lung compliance.
- Work of breathing.

Introduction

• The lung is an elastic structure like a balloon that tends to collapse (recoil) when inflated.

• **Elasticity** helps the lungs return to their resting size after inspiration.



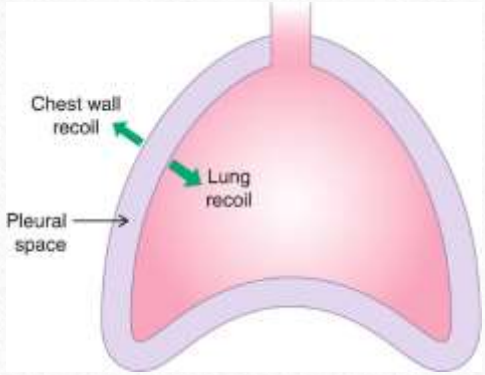
Factors Determining Elastic (Recoil) Power of the Lungs

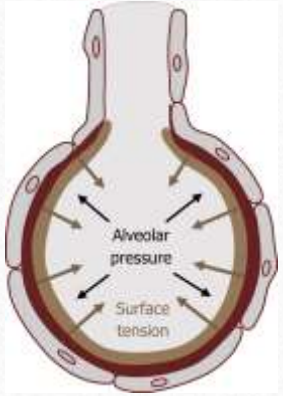
1. Elastic forces of lung tissue:

- Represent about 1/3 of the total recoil force.
- Depend on elastin and collagen fibers in the lung parenchyma.

2. Surface tension of alveolar fluid:

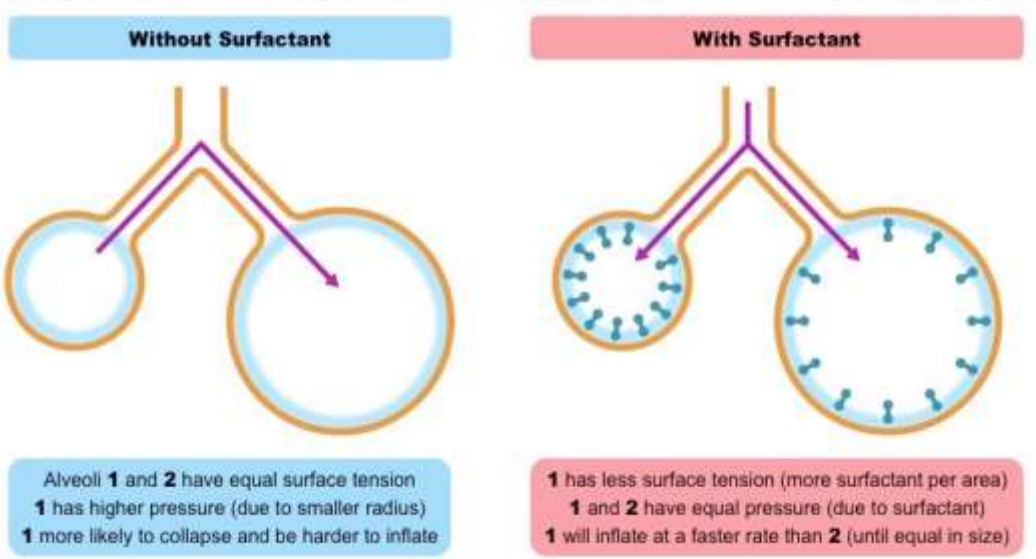
- Accounts for 2/3 of recoil tendency.
- Caused by intermolecular attraction that tends to collapse alveoli.





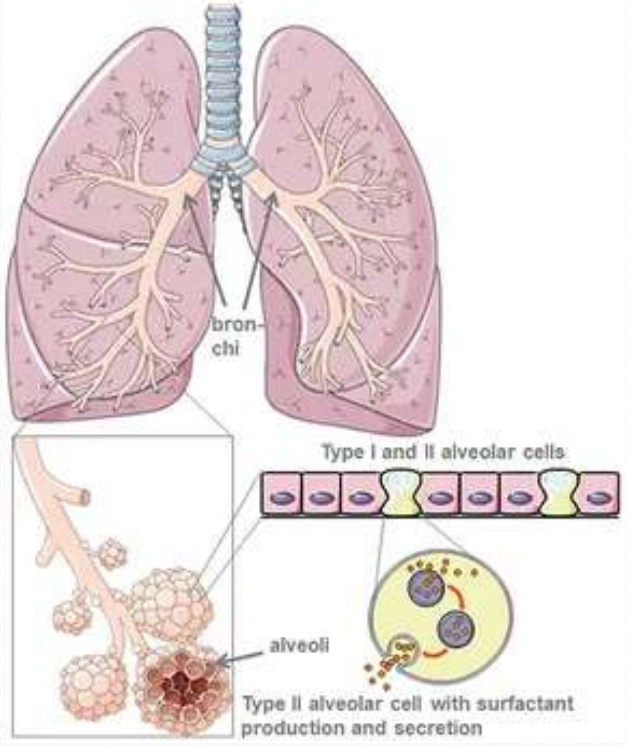
Notes on Surface Tension

- Surface tension is inversely proportional to alveolar diameter (higher in small alveoli).
- Acts as a collapsing force.
- Without surfactant, it may become too strong, making inspiration difficult.



Lung Surfactant – Definition

- Secreted by type II alveolar epithelial cells.
- Lowers surface tension of intra-alveolar fluid film.
- Facilitates lung expansion during inspiration.



Biochemical Structure of Surfactant

- Phospholipids: Mainly dipalmitoyl-phosphatidylcholine forming a monomolecular film lining the alveoli.
- Proteins:
  - SP-A: Regulates phospholipid recycling.
  - SP-B & SP-C: Facilitate monomolecular layer formation.

❖ Phospholipids alone cannot lower surface tension effectively without these proteins.

Clinical Significance of Surfactant

1. **Decreased secretion** → ↑ surface tension → alveolar collapse → Respiratory Distress Syndrome (RDS).
   a) Premature babies: immature type II cells.
   b) After open-heart surgery: interrupted pulmonary circulation.
2. **Increased surface tension** (~20 mmHg) draws fluid from capillaries → pulmonary edema.
3. **Prevents atelectasis & alveolar instability.**

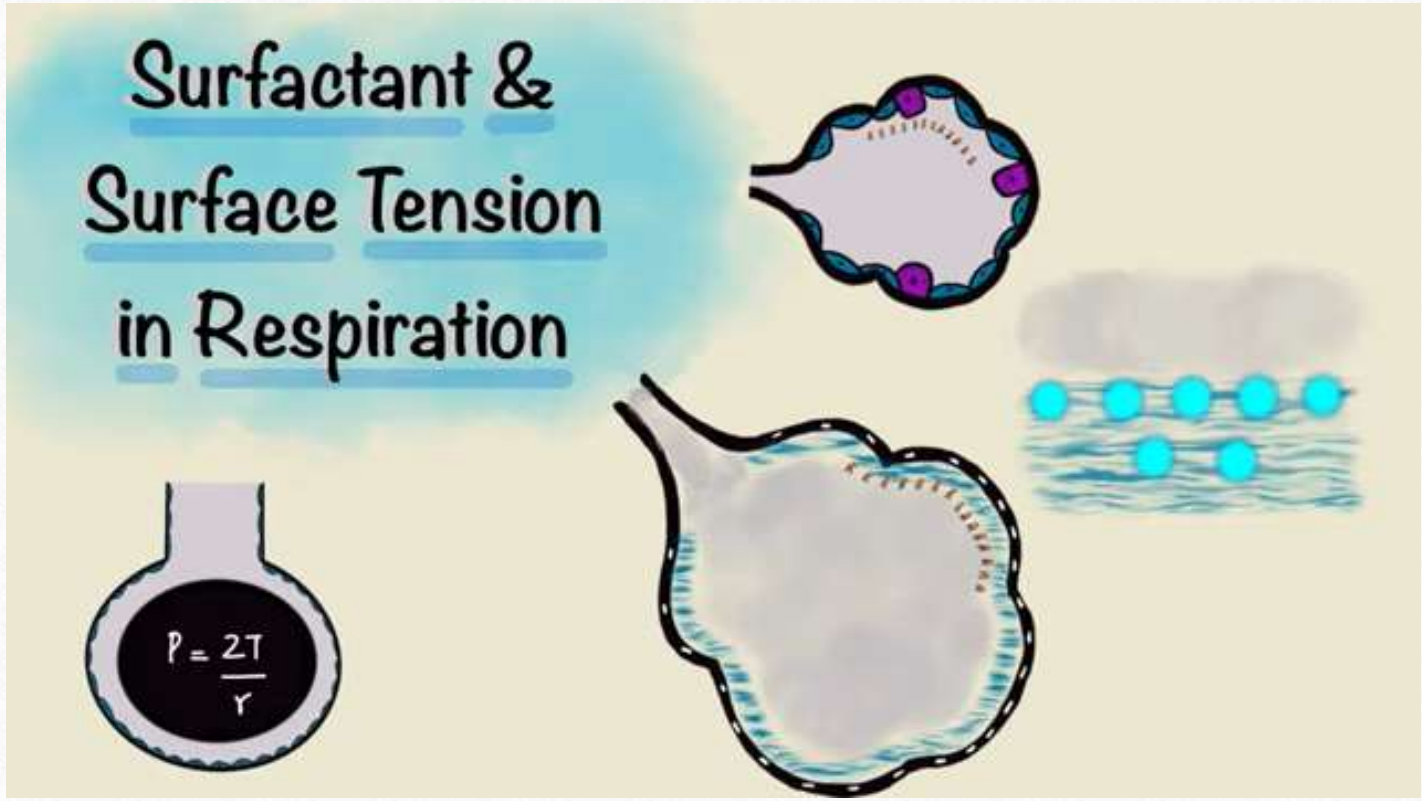
Laplace's Law and Alveolar Stability

P = 2T / r

- P: Pressure inside alveolus
- T: Surface tension
- r: Radius of alveolus

- Smaller alveoli need greater pressure to stay open.
- Surfactant reduces T, preventing collapse and stabilizing alveoli of different sizes.
- Alveolar interdependence also prevents collapse.

Laplace's Law and Alveolar Stability



Diagnosis of Surfactant Secretion

- Fetal surfactant secretion indicated by Lecithin/Sphingomyelin (L/S) ratio > 2:1.
- If L/S < 2:1 → deficient surfactant → risk of RDS (Hyaline Membrane Disease).

Factors Affecting Lung Surfactant

1. **Thyroid hormones** (T3, T4): stimulate synthesis.
2. **Glucocorticoids** (cortisol): essential for maturation.
3. **Cigarette smoking** during pregnancy: decreases surfactant.↓
4. **Hyperinsulinemia** (infants of diabetic mothers): decreases surfactant.↓

Compliance (C) of the Lungs – Definition

Lung compliance (C) refers to the **distensibility of the lung** — how easily the lungs expand when pressure changes.

It is defined as the **change in lung volume per unit change in distending pressure.**

Formula:

$C = \Delta V / \Delta P$

Compliance (C) of the Lungs – Definition

- Compliance **(C) = ΔV / ΔP**
- Measures distensibility of lungs.
- More compliant lungs are easier to inflate.
- Compliance is inversely related to elastance (tendency to recoil).

Types of Respiratory Compliance

Type	Distending transmural pressure	Normal values
Lung (C)	**Trans-pulmonary (P_L) =** **P_{in}** Alveolar pressure (P_A). **P_{out}** = Intrapleural pressure (P_{PL}). So, $P_L = P_A - P_{PL}$	200 ml/Cm H_2O
Lung & chest wall (C)	**Trans-respiratory (P_{RS})** **P_{in}** = Alveolar pressure (P_A). **P_{out}** = Pressure at body surface (P_{BS}). So, $P_{RS} = P_A - P_{BS}$	120 ml/Cm H_2O

N.B. **Transmural pressure**; is the pressure **across** any structure and it equals the **difference** between the pressure in and pressure out across any structure.

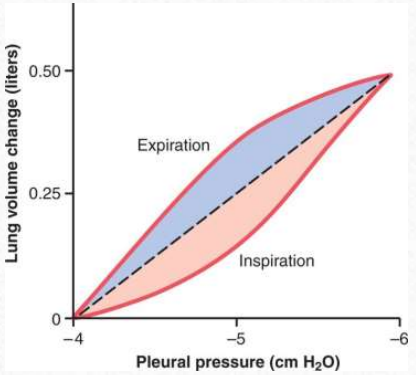
Measurement of Lung Compliance

- In animals: inflate isolated lungs, measure V at each P.
- In humans:
  - Intrapleural pressure via esophageal balloon.
  - Alveolar pressure via mouth (equal when glottis open).
- Plot volume vs. pressure → compliance curve.

Measurement of Lung Compliance

Measurement in Animals or Cadavers

- A lung can be taken and **subjected to inflation** at different pressures (P).
- At each pressure level, the **corresponding volume (V)** is measured.
- This produces a **pressure–volume relationship curve** for the lung.

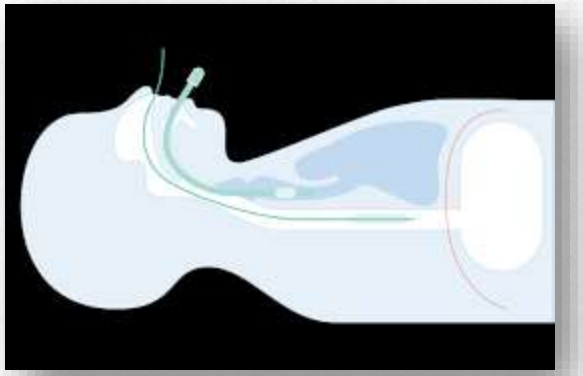


Measurement of Lung Compliance

Measurement in Living Humans

- Measured using a **spirometer and connected accessories:**
- **Intrapleural pressure**: measured by an *oesophageal catheter balloon* connected to a pressure transducer.
- **Alveolar pressure**: measured by a *manometer* connected to the mouthpiece of the spirometer.

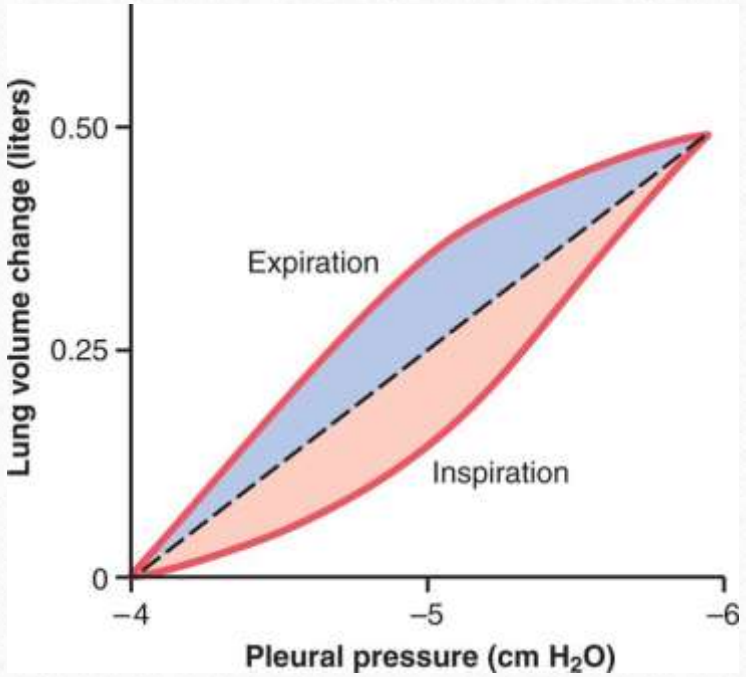
❖ Alveolar pressure equals mouth pressure when the glottis is open, and no airflow is present.



Measurement of Lung Compliance

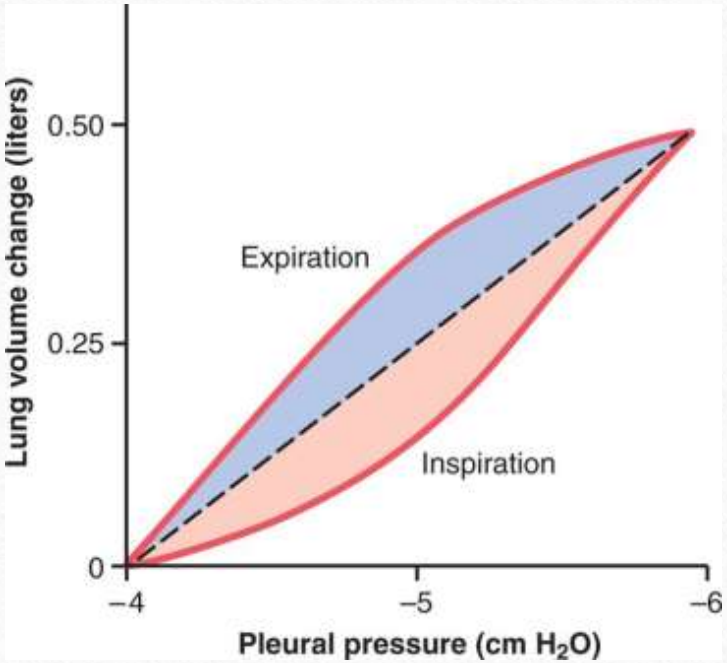
Method of Measurement

1. Start from the **mid-thoracic position (FRC)** where pleural pressure ≈ -3 mmHg (-5 cm H_2O).
2. The subject inhales **measured volumes of air** from the spirometer in steps up to tidal volume (0.5 L).
3. After each inhalation, the mouth shutter is closed, and pressures (P) are recorded.
4. An **inspiratory compliance curve** (Volume vs Pressure) is drawn.
5. Repeat during expiration to draw the **expiratory compliance curve**.
6. The **average line** between both curves gives the compliance curve; its **slope = compliance.**



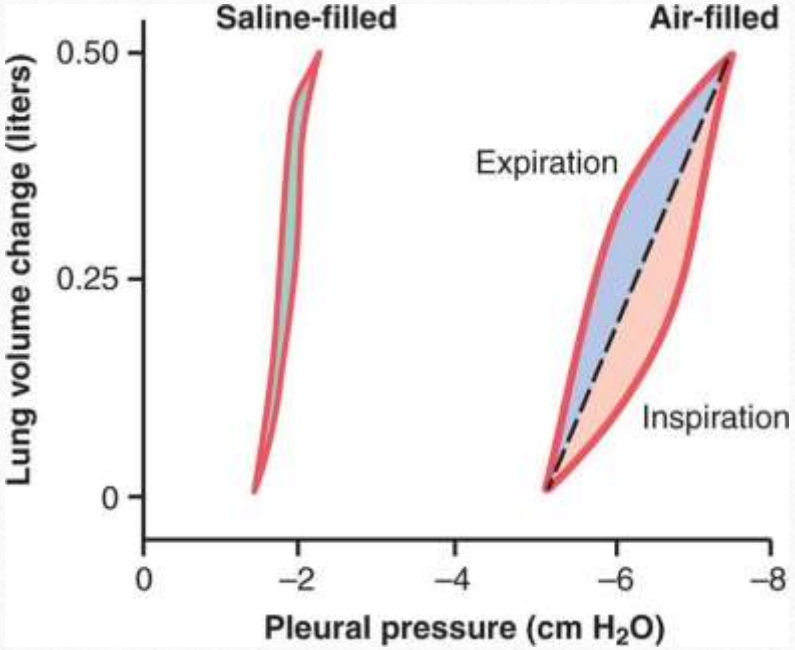
Hysteresis Phenomenon

- For any given lung volume, the **distending pressure during inspiration** is higher than during expiration.
- This difference is called **Hysteresis**.
- **Explanation:**
- During inspiration → alveoli are smaller → surface tension is higher → more pressure is needed.
- During expiration → surface tension decreases → less pressure is needed.



Measurement of Lung Compliance

- When lungs are filled with **saline instead of air:**
- **Surface tension forces disappear.**
- Only **elastic tissue** contributes to recoil.
- A **single compliance curve** is obtained, showing **increased compliance** at any pressure.



Factors Affecting Lung Compliance

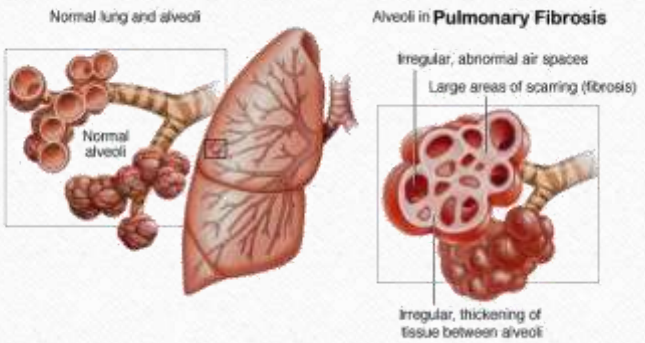
1. **Lung volume**: compliance decreases if lung volume reduced (e.g., pneumonectomy).

   - Specific compliance adjusts for volume differences.

2. **Lung elasticity**:

   - Emphysema → elastic tissue destroyed → C ↑.

   - Fibrosis → lungs stiffer → C ↓.



Work of Breathing

Work = ΔV × ΔP.

- Inspiration: active (muscular effort).
- Expiration: passive (elastic recoil).

➢ **Components of inspiratory work:**

a) Compliance/elastic work: expand lungs & chest.

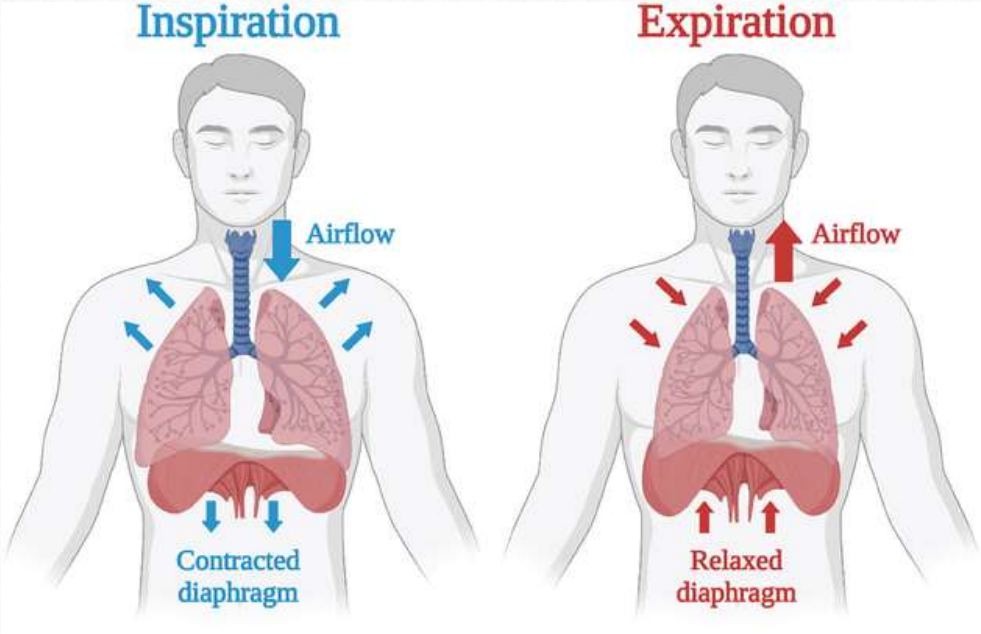
b) Tissue resistance work: overcome viscosity.

c) Airway resistance work: overcome air friction.

Work increases in:

✓ Obstructive diseases (e.g., asthma).

✓ Forced breathing or exercise.

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