PY6.3.1
Describe the alveolar surface tension, compliance, airway resistance

Compliance of the lungs

- A measure of distensibility of lungs.

- Defined as change in lung volume per unit change in pressure. $\Delta V / \Delta P$

Compliance of the Lungs

- The extent to which the lungs will expand for each unit increase in transpulmonary pressure (if enough time is allowed to reach equilibrium) is called the lung compliance.

- The total compliance of both lungs together in the normal adult averages about **200 ml /cm H2O transpulmonary pressure.**
- every time the transpulmonary pressure increases by 1 cm H2O, the lung volume, after 10 to 20 seconds, will expand 200 ml.

Static compliance

- Normal value is 200ml/cm H20
- The pressure change during inspiration is 2 cmH2O
- Volume distension during quiet inspiration is 200ml x 2.5 = 500ml

- **Compliance of lungs plus thorax is 110 ml/cmH20**

Specific Compliance

- **Compliance expressed as a fraction of FRC**
- Compliance/FRC

Dynamic Lung Compliance

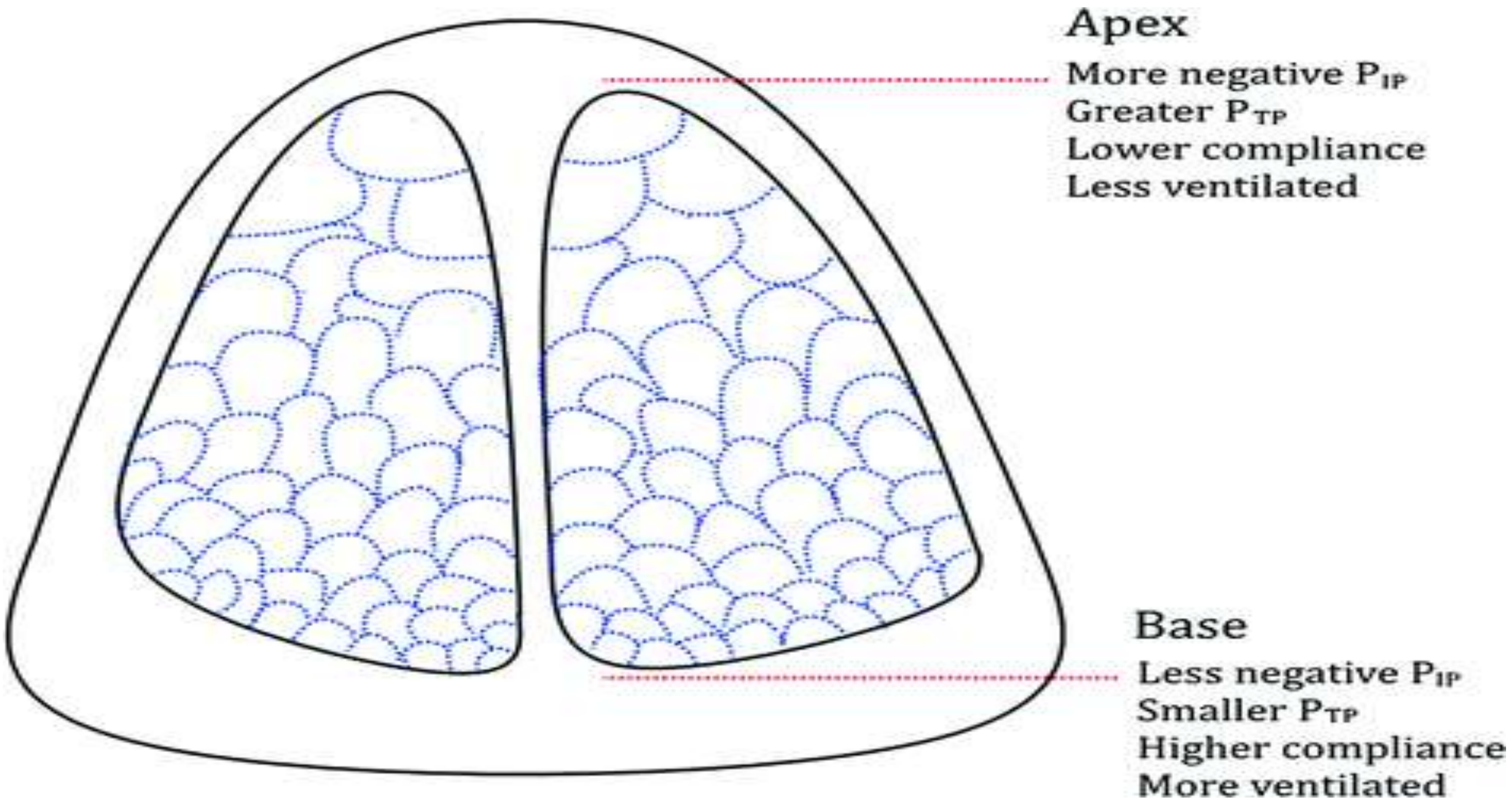
- $\Delta V/\Delta P$ changes with respiration
- **Changing compliance with the phase of respiration**
- Small pressure change good volume change-----compliance is high
- With more pressure change volume change is not much----compliance is low

- **Compliance is inversely related to the surface tension**
- **At the start of inspiration-----surfactant is efficient--------surface tension decreases-----compliance is high**

- By the end of inspiration----surfactant is less efficient--------surface tension increases ----compliance is low

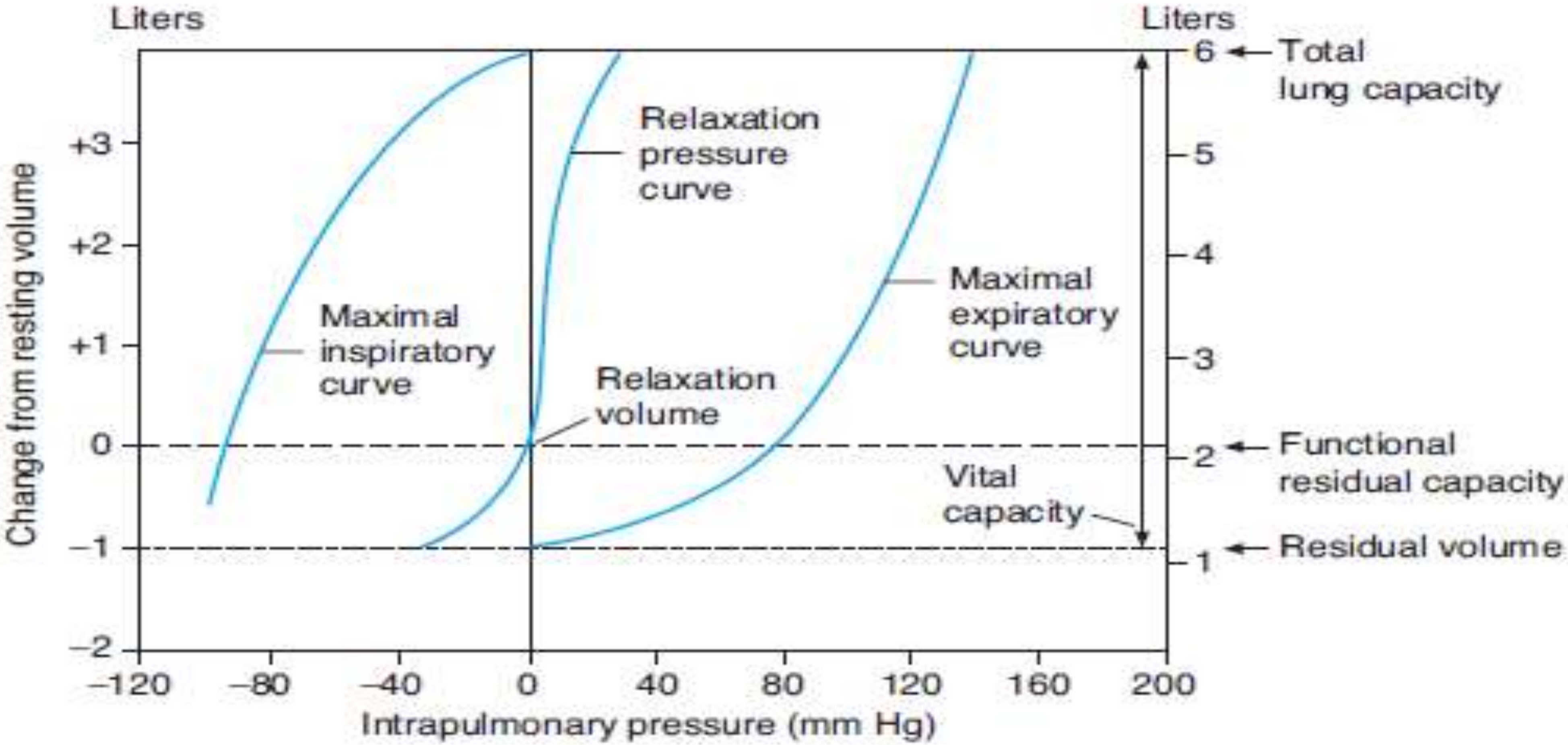
- At the beginning of respiration at lower lung volumes------**compliance is high.**
- At the end of inspiration, when alveoli are filled with air, at higher lung volumes-----**compliance is low.**

- **Compliance is greater at the base of the lungs, compared to apex.**



Measurement of compliance of lung and thoracic wall

Relaxation Pressure curve



1. Relaxation Pressure Curve

- Represents the **passive recoil** of the lungs and chest wall when no muscular effort is applied.
- At **0 mm Hg**, the lung is at **Functional Residual Capacity (FRC)** (2 L).

2. Maximal Inspiratory Curve

- Shows the **maximum negative pressure** a person can generate to inhale.
- Reflects **muscle strength and compliance**.

3. Maximal Expiratory Curve

- Shows the **maximum positive pressure** a person can generate to exhale.
- Reflects **expiratory muscle effort and airway resistance**.

Compliance Diagram

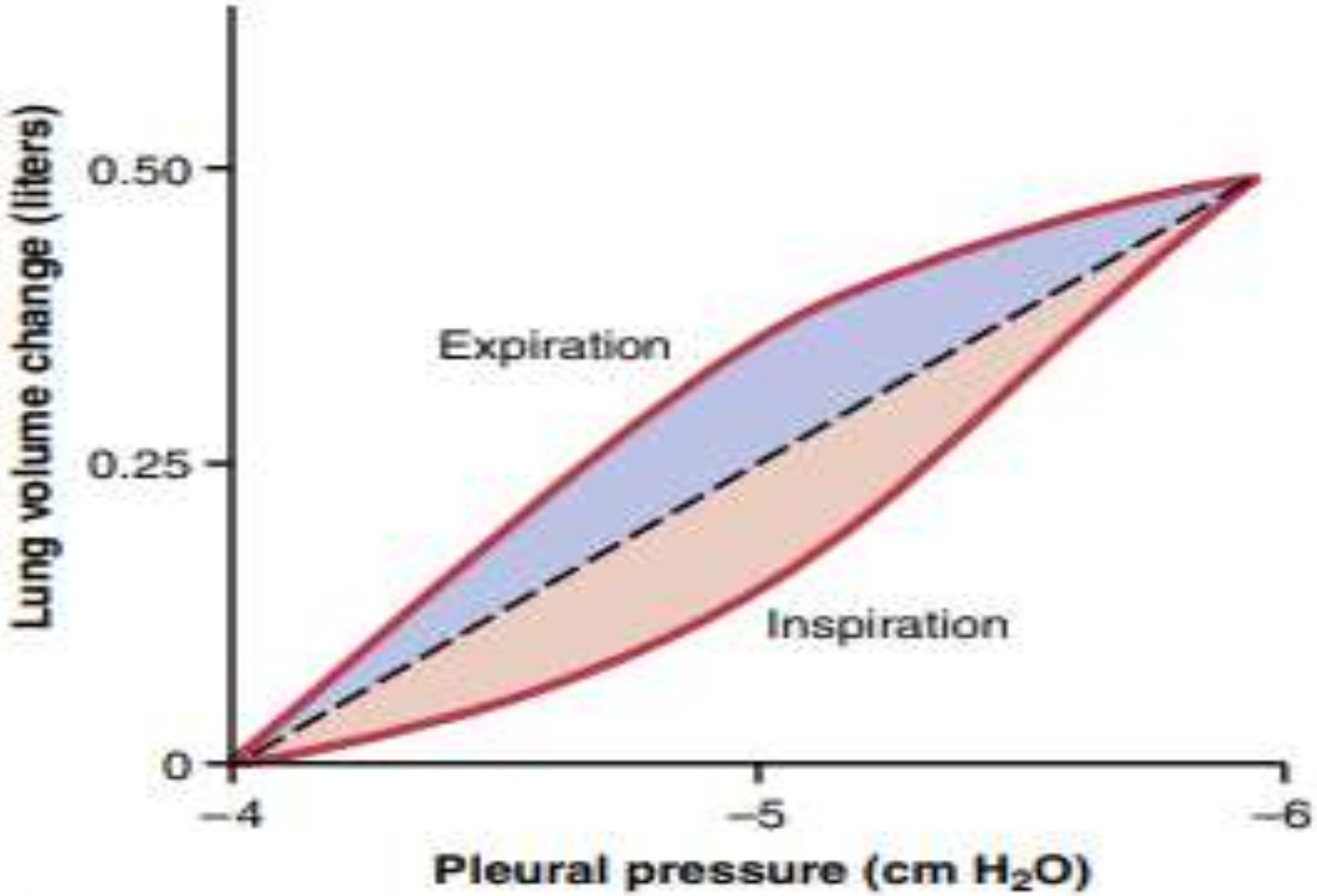


Figure 38-3 Compliance diagram in a healthy person. This diagram shows changes in lung volume during changes in transpulmonary pressure (alveolar pressure minus pleural pressure).

Compliance diagram are determined by ELASTIC FORCES-

(1) elastic forces of the lung tissue

(2) *elastic forces caused by surface tension of the fluid that lines the inside walls of the alveoli* and other lung air spaces.

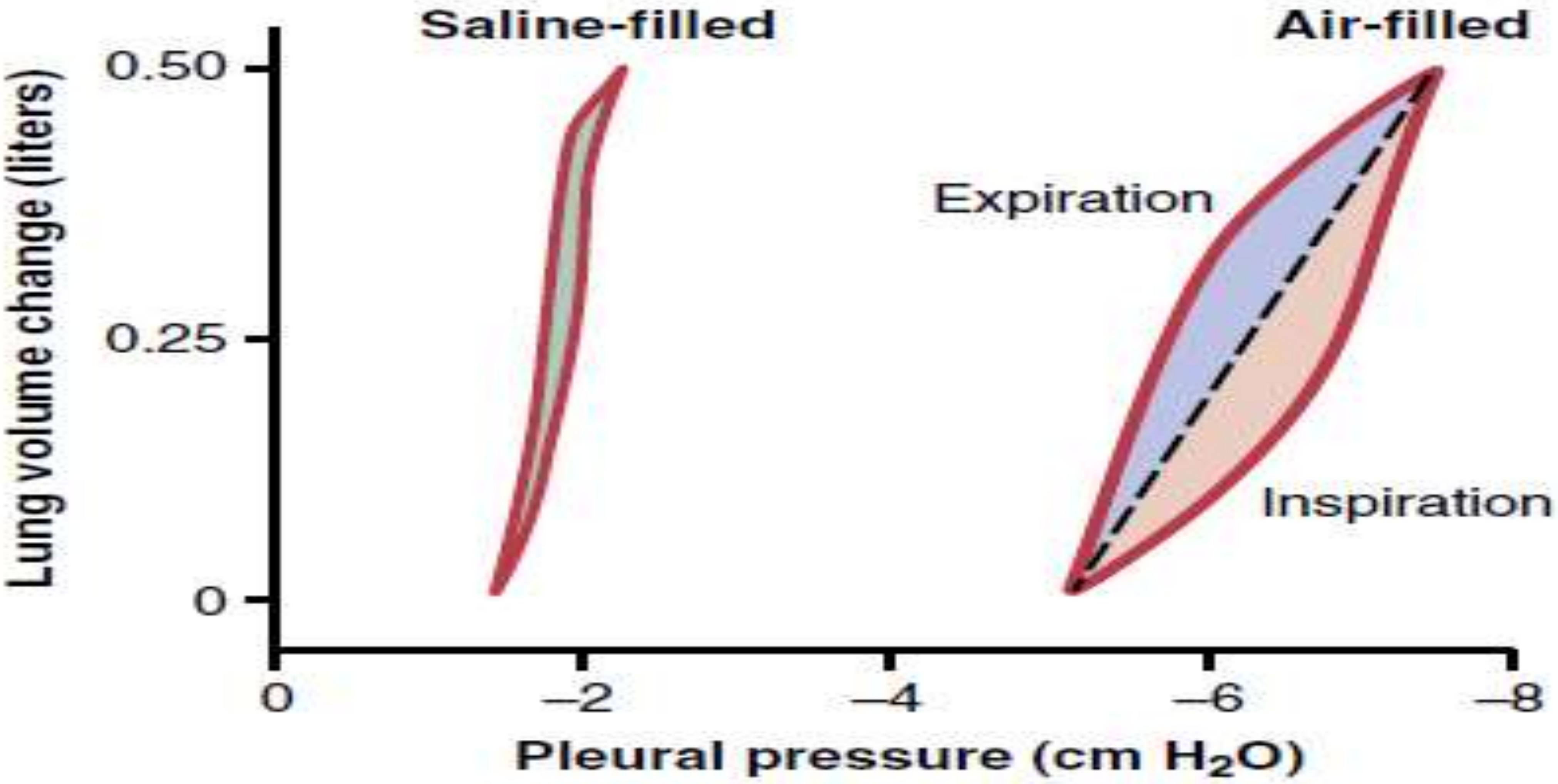


Figure 38-4 Comparison of the compliance diagrams of saline-filled and air-filled lungs when the alveolar pressure is maintained at atmospheric pressure (0 cm H_2O) and pleural pressure is changed to change the transpulmonary pressure.

Factors affecting Compliance

1. **Lung volume: (Compliance is volume dependent)**

   at high(TLC) and very low lung(RV) volumes, compliance

   becomes very low.

2. Phase of respiration:

- compliance is greater in the mid inspiration phase of respiration.

- End inspiration and end expiration compliance is low.

3. Gravity:

Compliance is less in apex of the lungs in standing position as alveoli are more distended

4. Surfactant:

Surface tension is high with deficiency of surfactant----more pressure is required to distend the lungs.

- With high surface tension, a large pressure change produces only a small volume change-----lung compliance decreases.

5. Old age:

- **Lung compliance increases**

- loss of functionality of elastic fibers in the lung parenchyma --- decreased recoil pressure of the lungs-----lungs become more distensible

- loss of recoil----deflate poorly

-The chest wall, however, stiffens with age → compliance decreases.

6. Compliance is reduced in restrictive lung disease: Lungs become stiff

A given pressure produces only a **small change in volume → low compliance**.

e.g. pulmonary fibrosis, paralysis of respiratory muscles, deformity of thoracic cage.

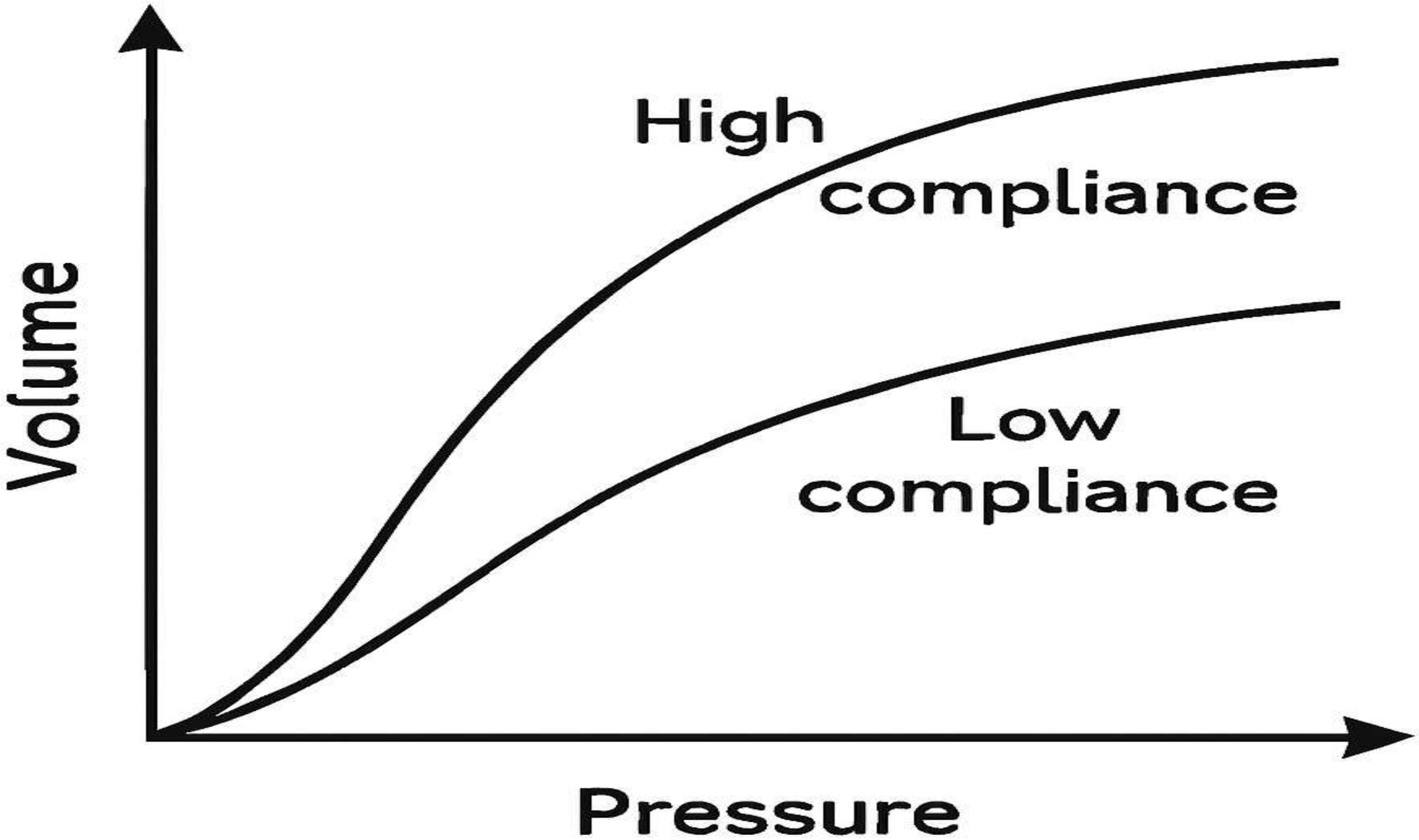
7. Compliance is increased in obstructive lung disease e.g. emphysema

- elastic fibers are destroyed------- reduced elastic recoil pressure.
- The lungs become over-distensible.
- Patients can inflate lungs easily, but deflation is impaired → air trapping and hyperinflation.

- When lungs become over-distensible (loss of elastic fibers, reduced recoil)
- They inflate very easily with small pressure changes.
- This means compliance increases.

- **Asthma & Chronic Bronchitis**
- narrowing and mucus plugging, not parenchymal stiffness.
- **Compliance of lung tissue itself is often normal or increased**, but airflow limitation makes breathing inefficient.

COMPLIANCE DIAGRAM



Surfactant and surface tension

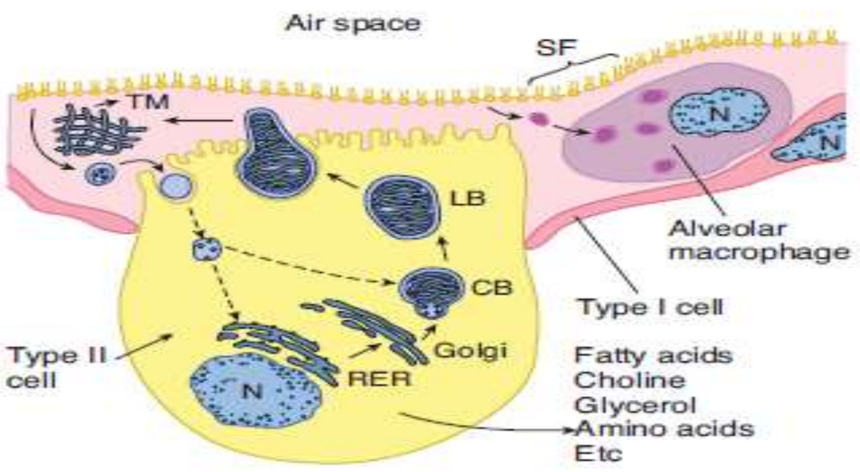
- Surface tension is present at fluid air interface.
- **Surfactant:**

- Surface active material that **reduces the surface tension** within the alveoli

- By reducing the surface tension--**decreases the collapsibility and increases the expandability of the lungs**

Synthesis of surfactant

- Type II alveolar epithelial cells(type II pneumocytes)
- Constitute about 10% of the surface area of the alveoli



- Synthesis begins at 17-20 weeks of gestation, begins to appear by 28 weeks of gestation.
- **tubular myelin within type II pneumocytes is the precursor.**

Composition of Surfactant

- 90% lipids and 10% Carbohydrates
- Main constituent: DPPC—Di-Palmitoyl-Phosphatidyl choline
- Phosphatidylglycerol surfactant apoproteins(SP)
- Calcium: required to spread the surfactant

- SP-A: regulation of surfactant turn over, immune regulation within the lungs, formation of tubular myelin
- SP-B&C: spreading ability of surfactant

Functions of Surfactant

1. Reduces the collapsing tendency, increases the lung compliance:

Compliance is inversely related to surface tension

Surfactant reduces the surface tension and increases the distensibility-----compliance increases

2. Helps keep the alveoli dry

In the absence of surfactant

the inward recoil of the alveolus tends to pull the plasma fluid into the alveolus-----alveoli are filled with fluid.

3. Surfactant stabilizes the alveolar system of “interdependence”

- **Laplace’s Law:**
- **P= 2T/R**
- **Pressure in the wall of hollow viscus is directly proportional to the tension(T) in the wall and inversely proportional to the radius.**

In the presence of surfactant:

- In the presence of surfactant air will flow form large to small alveolus(by interdependence) both alveoli will be stabilized.

In the absence of surfactant:

- Small alveolus(with lesser radius)------will have relatively more pressure in its wall compared to neighbouring large alveolus -----small alveoli will go on collapsing
- Situation of instability in the lung

- Inflammation of lung parenchyma-------destruction of type II pneumocytes-------surfactant synthesis stops

- Surfactant deficiency is an important cause of **infant respiratory distress syndrome** (IRDS, also known as **hyaline membrane disease**).

WORK OF BREATHING

- During normal quiet breathing,
- all respiratory muscle contraction occurs during inspiration
- expiration is almost entirely a passive process caused by elastic recoil of the lungs and chest cage.

WORK OF BREATHING

The work of inspiration can be divided into three fractions:

(1) that required to expand the lungs against the lung and chest elastic forces, called ***compliance work* or *elastic work***

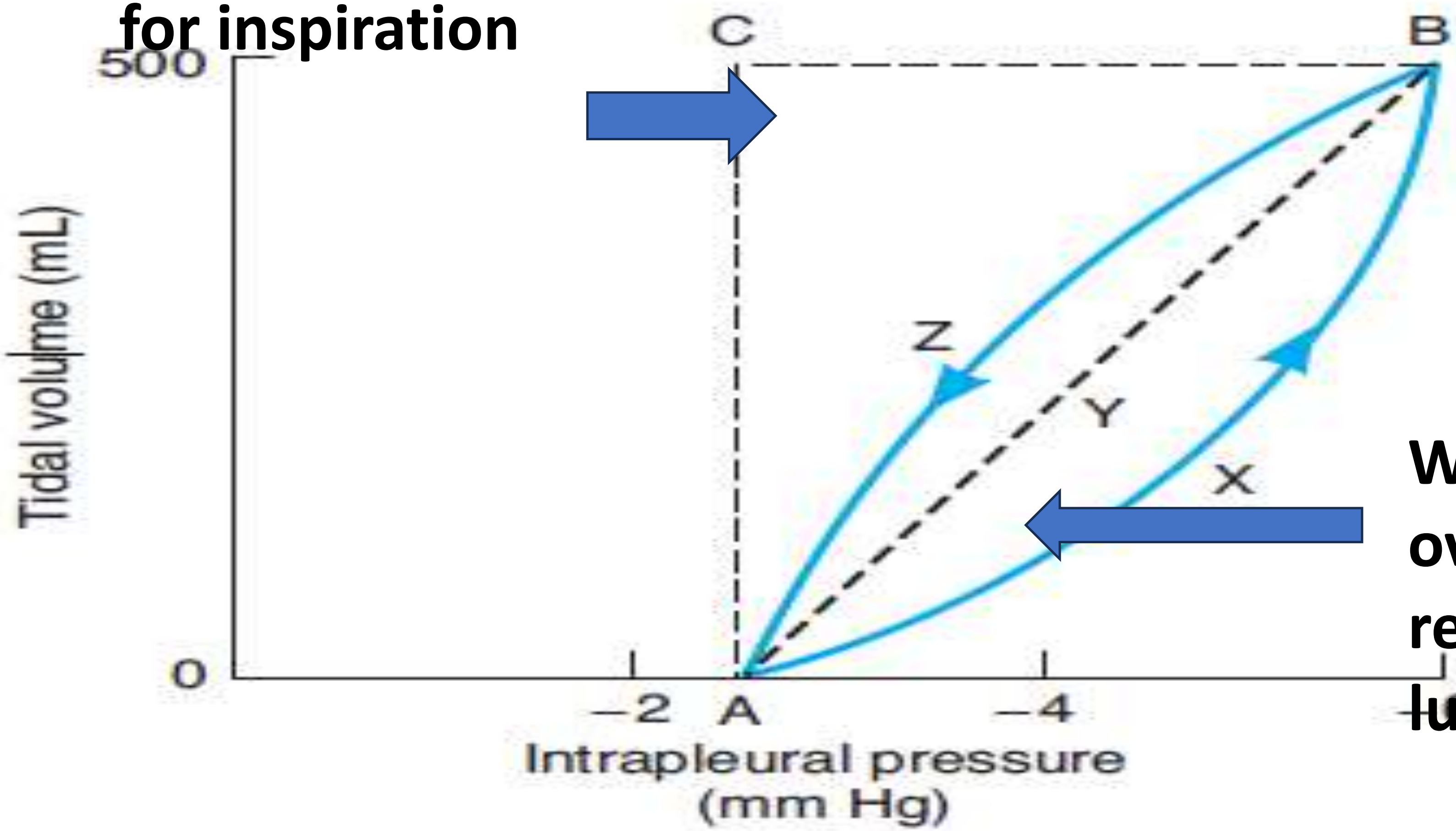
(2) that required to overcome the viscosity of the lung and chest wall structures, called ***tissue resistance Work***

(3) that required to overcome airway resistance to movement of air into the lungs, called ***airway resistance work*.**

WORK OF BREATHING

- ***65% : compliance work*** **or** ***elastic work***
- ***7%: tissue resistance Work***
- ***28%: airway resistance work.***

Total elastic work for inspiration



Work done to overcome airway resistance and lung viscosity

FIGURE 35–15 Pressure volume relationships in breathing. Diagrammatic representation of pressure and volume changes during quiet inspiration (line AXB) and expiration (line BZA). Line AYB is the compliance line.

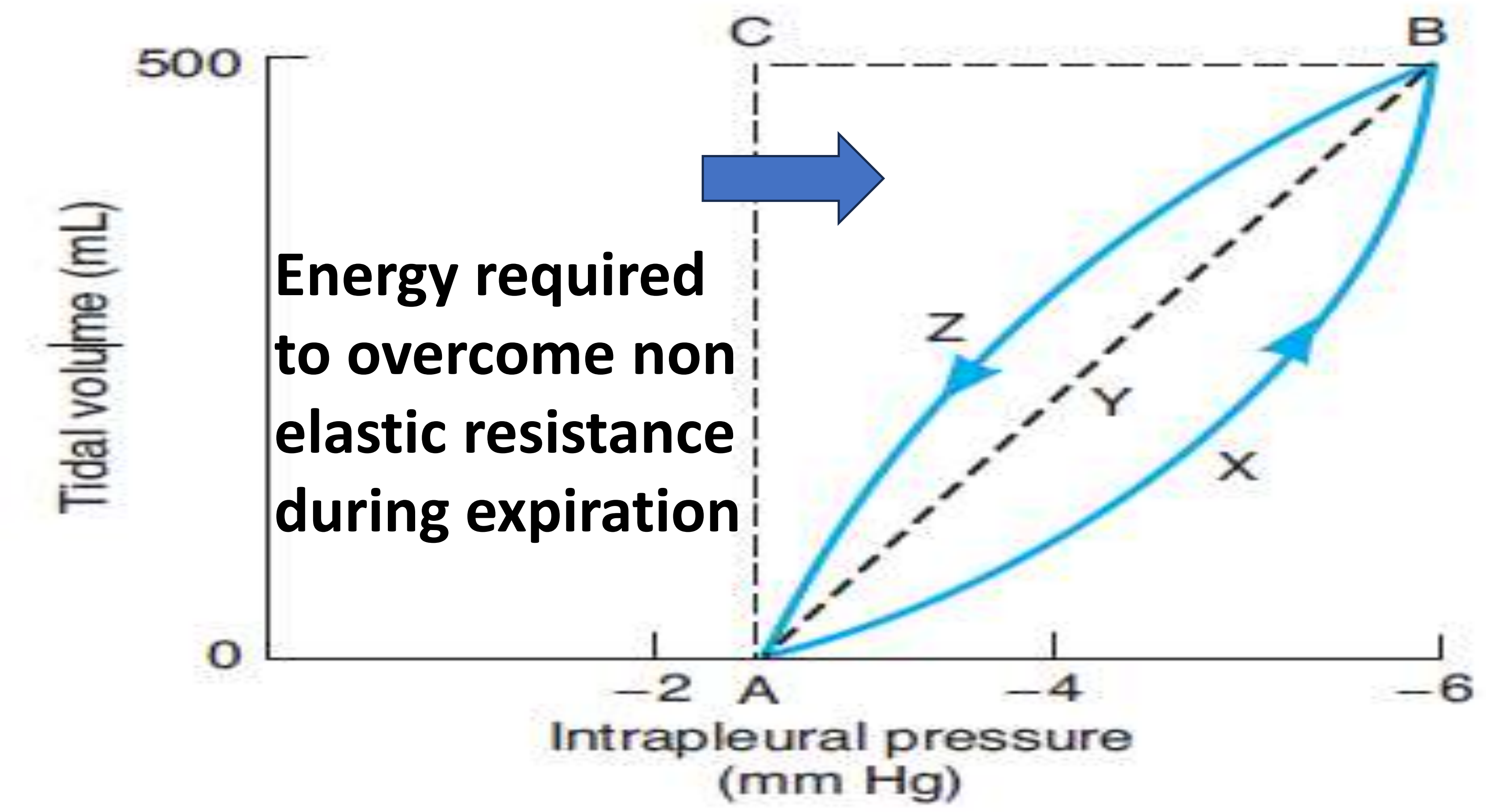
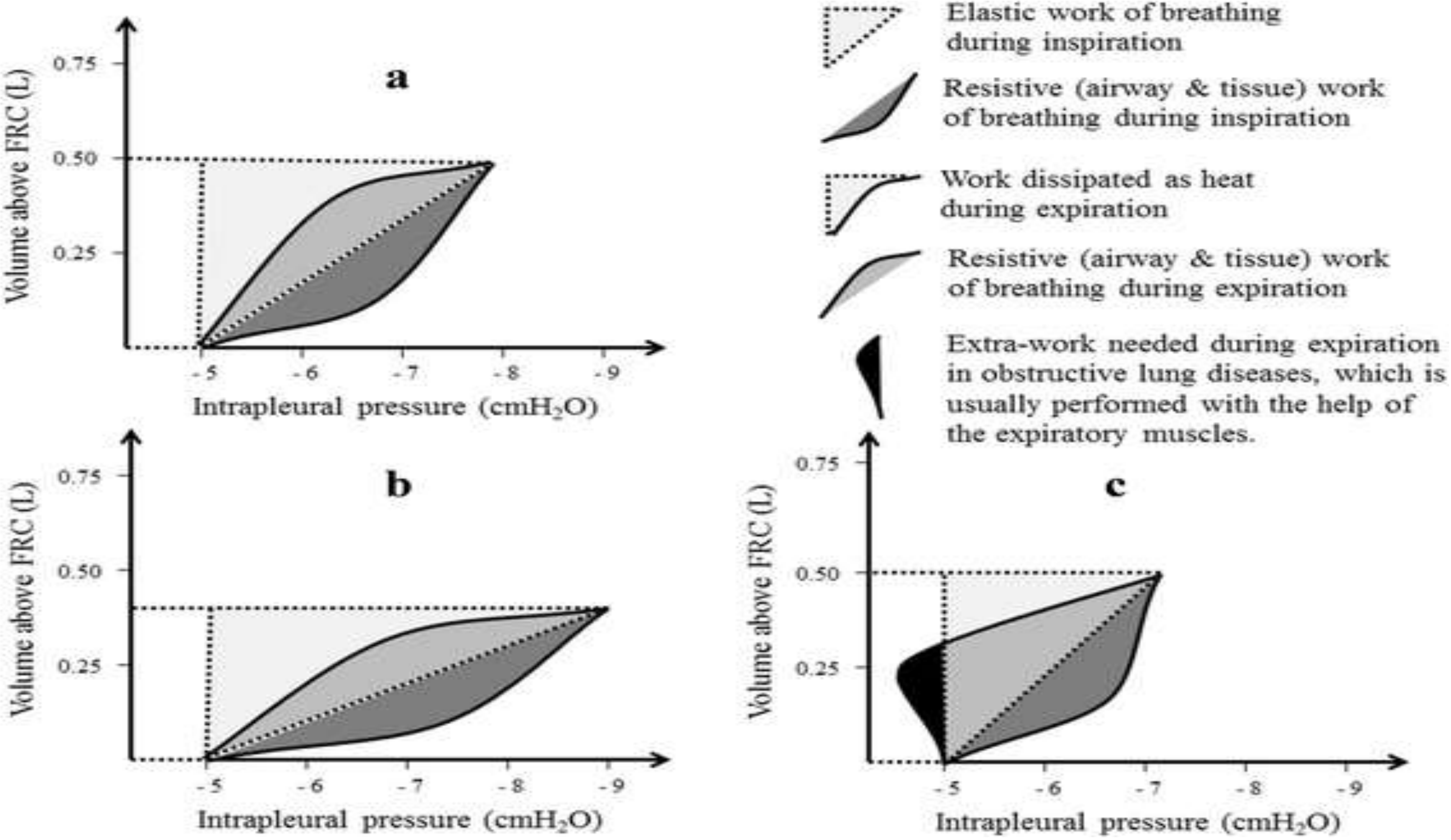


FIGURE 35–15 **Pressure volume relationships in breathing.** Diagrammatic representation of pressure and volume changes during quiet inspiration (line AXB) and expiration (line BZA). Line AYB is the compliance line.



a
b
c
Volume above FRC (L)
0.75
0.50
0.25
-5
-6
-7
-8
-9
Intrapleural pressure (cmH_2O)
Elastic work of breathing during inspiration
Resistive (airway & tissue) work of breathing during inspiration
Work dissipated as heat during expiration
Resistive (airway & tissue) work of breathing during expiration
Extra-work needed during expiration in obstructive lung diseases, which is usually performed with the help of the expiratory muscles.

- **Interstitial lung diseases:** tissue resistance work is increased

  - patient economize ventilation by rapid and shallow breaths

- **Obstructive diseases :** airway resistance work is increased

  - patient economize ventilation by deep and slow breaths

Airway Resistance

- Airway resistance is the opposition to airflow within the respiratory tract.
- It reflects how much pressure is needed to generate a given flow of air.
- Mathematically:
- R= $\triangle$ P/ F
- Delta P = pressure difference between alveoli and mouth
  Flow = rate of airflow.

Airway Resistance

1. Size of the airway

- Large airways have greater diameter and small airways have more cross-sectional area.
- Greatest resistance(80%)to airway occurs in the medium sized bronchi

- Resistance is inversely proportional to the fourth power of radius (Poiseuille’s law).
- Even small narrowing (bronchospasm, mucus, edema) causes a large increase in resistance.

- **Airway length:** Longer tubes increase resistance, but this is **relatively constant in humans.**
- Airflow pattern:
- Laminar flow → lower resistance.
- Turbulent flow (at high rates, e.g., exercise, or in narrowed airways) → much higher resistance.

- Most resistance is in the medium-sized bronchi (not the smallest airways).
- Small peripheral bronchioles contribute little because they are numerous and arranged in parallel, reducing overall resistance.
- In healthy adults, total airway resistance is about 0.5–2.5 cm H_2O/L/sec.

Changes in Exercise

- Ventilation increases, but airway resistance doesn’t rise proportionally because:
- Airways dilate due to sympathetic stimulation (β_2-adrenergic effect).
- High lung volumes during exercise keep airways open.

2. Tone of the bronchial smooth muscle

3. Lung Volume:

- At higher lung volumes:

More negative intrapleural pressure and transpulmonary pressure-------airways are pulled open----airway resistance is less

- At lower lung volumes:

more recoil pressure of the lungs-----airways are narrowed------airway resistance is more