Mechanics of Ventilation

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Part 1 – Lung Volumes and Capacities

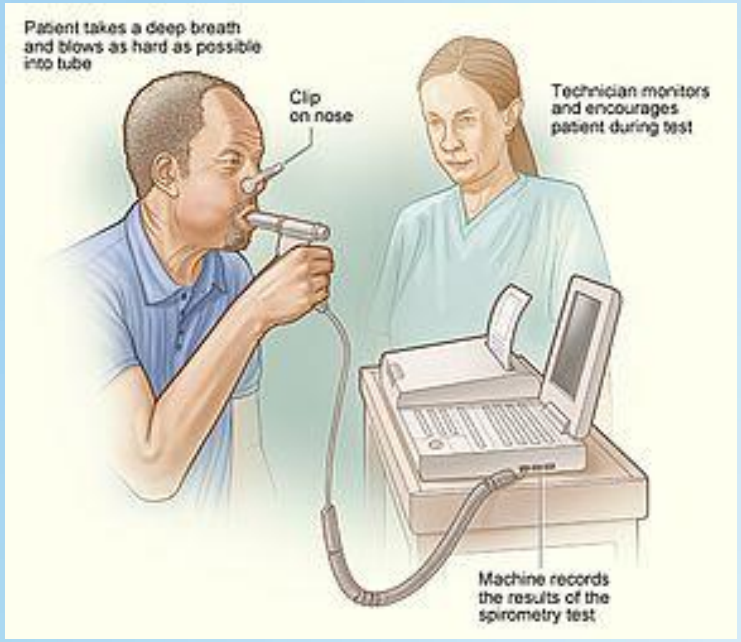
Overview

Lung Volumes

- Measured by spirometry (*exception*: RV)
- 4 types
- V_T, IRV, ERV and RV

Lung Capacities

- Calculated from the lung volumes (≥ 2 lung volumes)
- 4 types
- IC, VC, FRC and TLC



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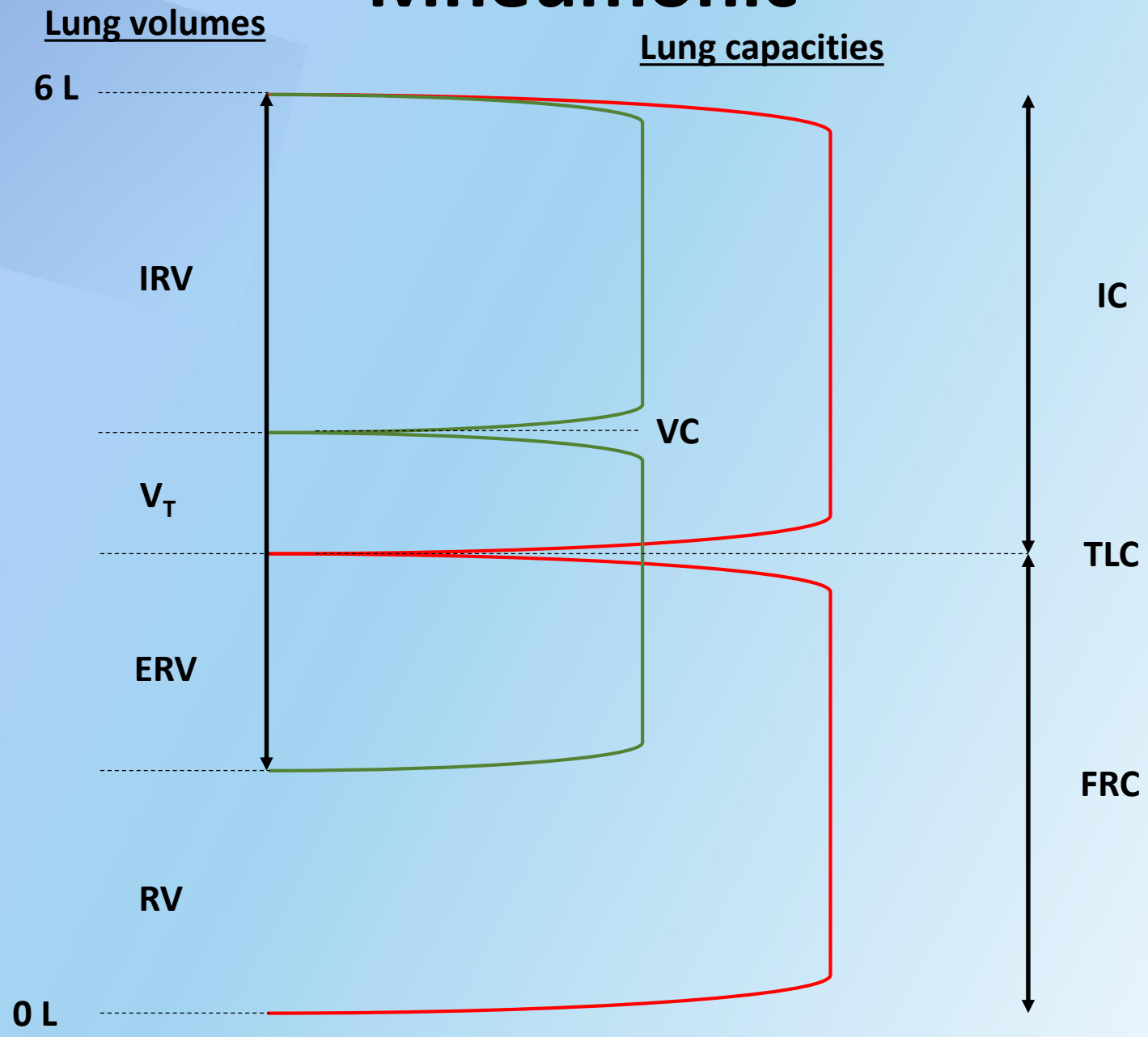
Mneumonic



Questions

- **«Which of the following represents total lung capacity (TLC)?»**

a) TLC = V_T + IRV + ERV

b) TLC = RV + ERV + V_T

c) TLC = IC + ERV

d) TLC = VC + RV

e) TLC = FRC + IRV

- **Which are the only lung volumes and capacities NOT measurable with spirometry?»**

a) RV, FRC and VC

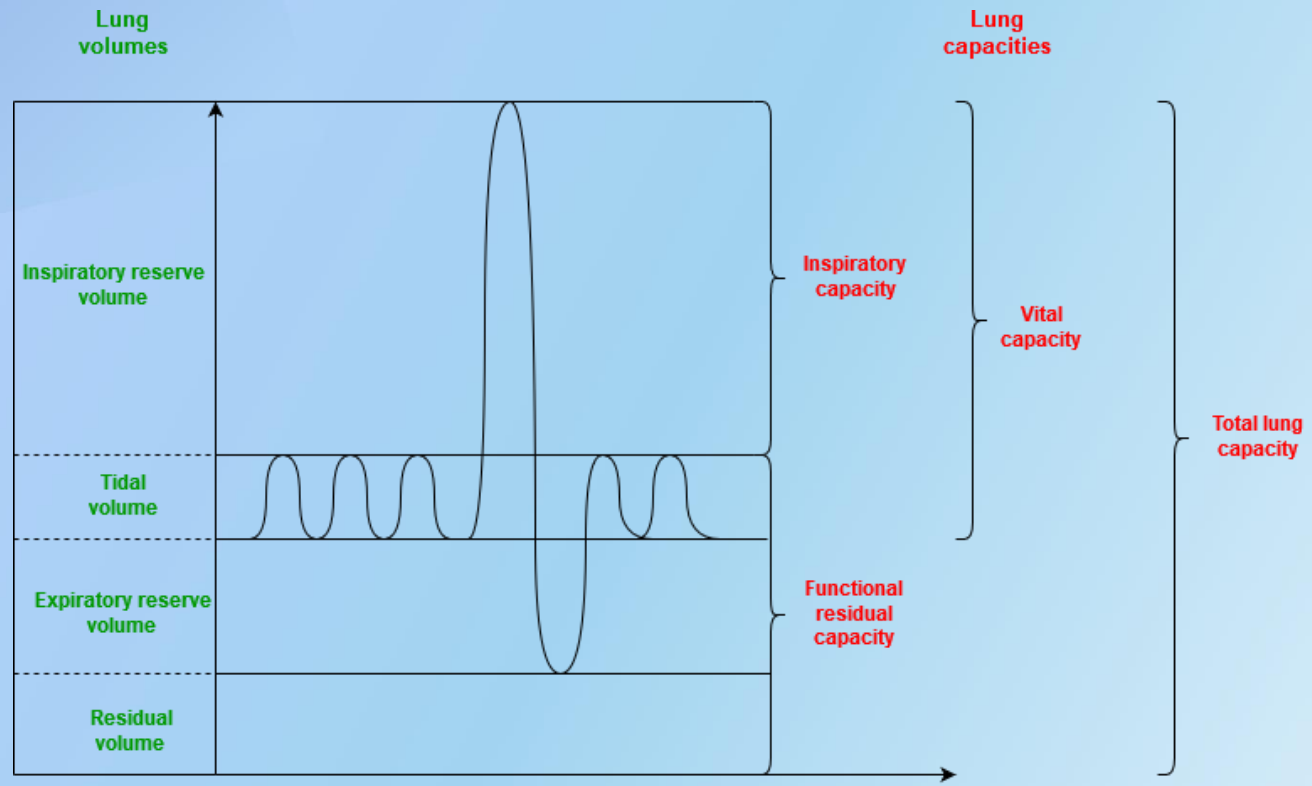
b) RV, VC and TLC

c) RV, FRC and TLC

d) All of the lung volumes and capacities are technically measurable with spirometry

e) It depends on the patient

Term	Definition	Value
Tidal volume (V_T)	Amount of air inspired or expired during *quiet* ventilation	0,5 L
Inspiratory reserve volume (IRV)	The maximal amount of air that can be inspired with effort at the end of a normal inspiration	3 L
Expiratory reserve volume (ERV)	The maximal amount of air that can be expired with effort at the end of a normal expiration	1,2 L
Inspiratory capacity (IC)	Maximal inhalation after normal expiration	3,5 L



- **Vital capacity (VC)**
- **Residual volume (RV)**
- **Functional residual capacity (FRC)**

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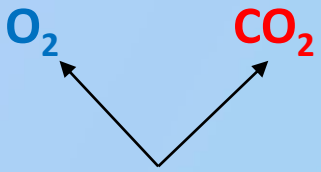
Part 2 - Ventilation

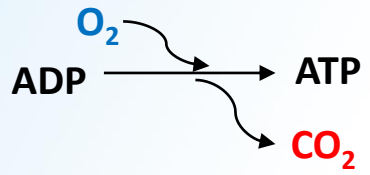
Definition

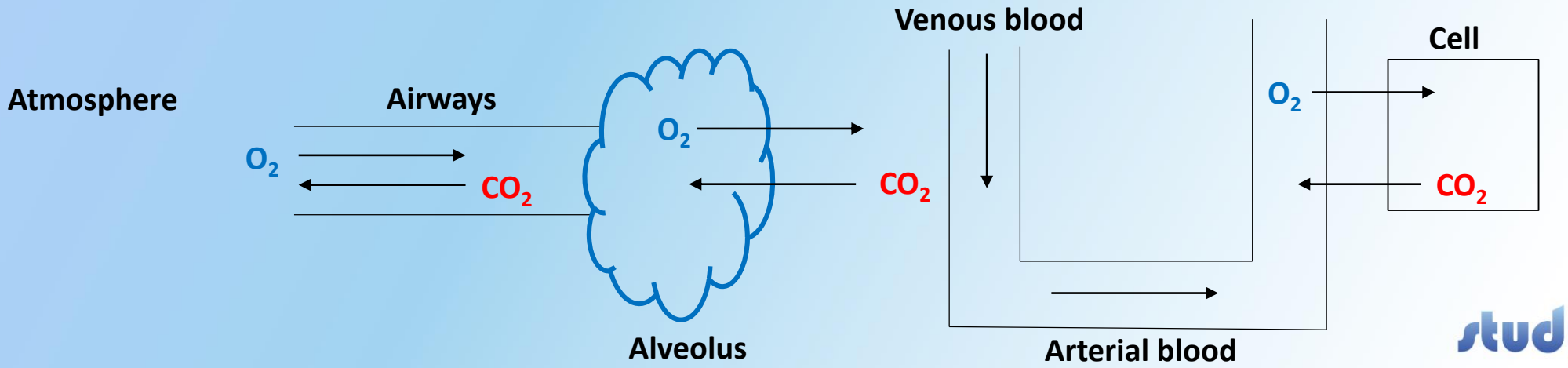


- «*The movement of air between the atmosphere and the lungs through the process of inspiration and expiration*»

- It must be distinguished from *respiration*

Ventilation	Respiration
Mechanical	Ventilation + diffusion + perfusion





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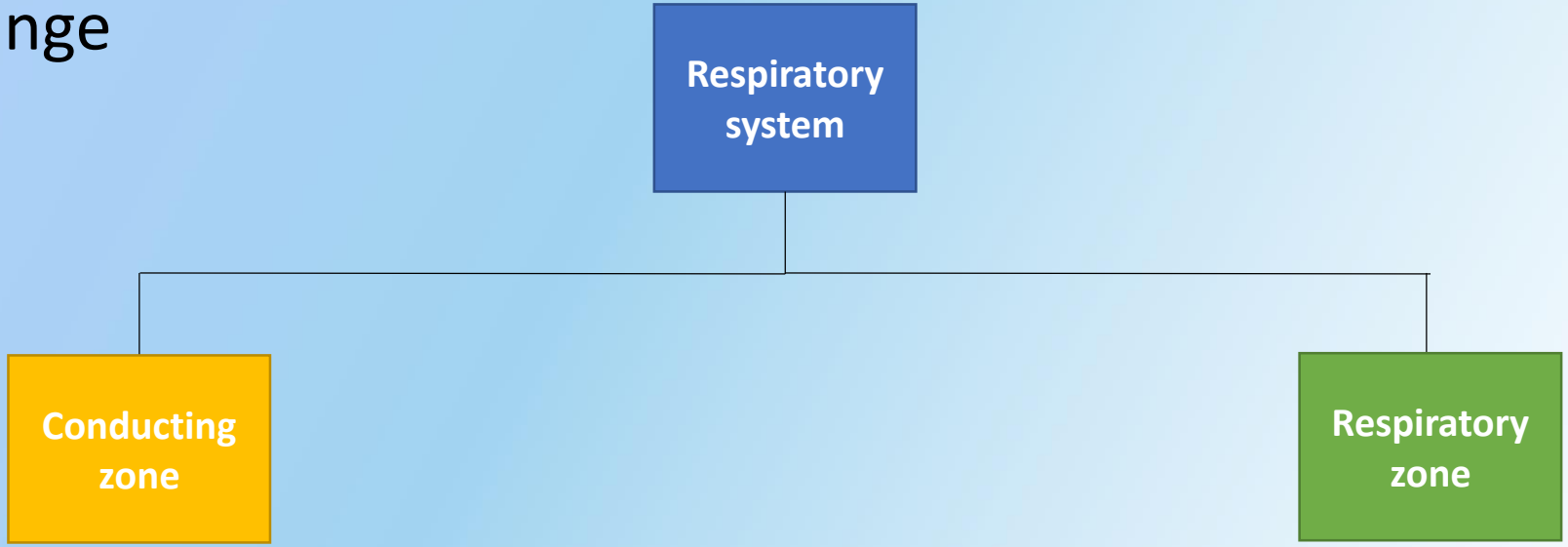
Conducting zone and respiratory zone

Conducting zone

- Composed of the airways (*trachea*, *bronchus*, *bronchioles* and *terminal bronchioles*)
- Does not participate in gas exchange

Respiratory zone

- Composed of the lung (*respiratory bronchioles*, *alveolar ducts* and *alveolar sacs*)
- Participates in gas exchange



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Minute ventilation and alveolar ventilation

Minute ventilation (V_M)

- **Definition**
  - Refers to the total volume of gas that enters the respiratory system per minute
- **Equation**

$$V_M = (CZ + RZ) \times RR$$

- **Calculation**

$$V_M = (CZ + RZ) \times RR$$
$$V_M = V_T \times RR$$
$$V_M = 500\ mL \times 15/min$$
$$= 7{,}500\ mL/min$$

Alveolar ventilation (V_A)

- **Definition**
  - Refers to the volume of gas that reaches the alveoli per minute
- **Equation**

$$V_A = (V_T - V_D) \times RR$$

- **Calculation**

$$V_A = (V_T - V_D) \times RR$$
$$V_A = (500\ mL - 150\ mL) \times 15/min$$
$$V_A = 350\ mL \times 15/min$$
$$= 5{,}250\ mL/min$$

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Dead space

Dead space

- Volume of gas that does not participate in gas exchange («*wasted ventilation*»)

Physiological

Anatomical

- Volume of gas within the conducting zone

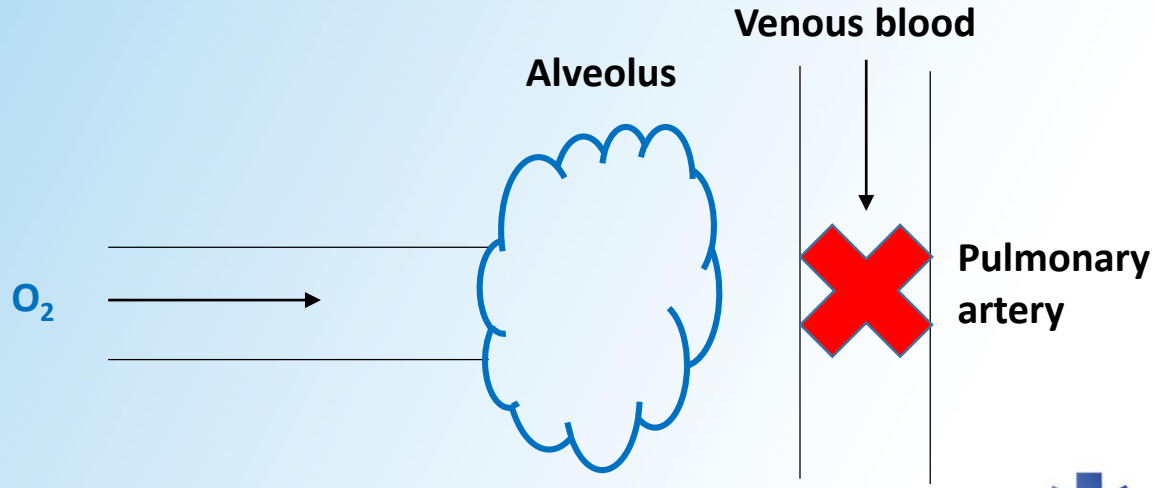
Functional

Alveolar

- Volume of gas within unperfused alveoli

Pathological

- COPD
- PE



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Part 3 – Mechanics of Ventilation

Overview

Ventilation

- Mechanical

Inspiration

Muscles

- **Quiet**
  - Diaphragm
  - *External* intercostal muscles
- **Forced**
  - Accessory muscles
    - **Sternocleidomastoid**
    - **Scalene muscles**

Forces

- Intrapleural pressure

Expiration

Muscles

- **Quiet**
  - Nothing
- **Forced**
  - Accessory muscles
    - **Abdominal muscles**
    - ***Internal* intercostal muscles**

Forces

- Elastic recoil of the lung

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Ventilation

- Mechanical

Inspiration

Muscles

- **Quiet**
  - Diaphragm
  - *External* intercostal muscles
- **Forced**
  - Accessory muscles

Forces

- Intrapleural pressure

Expiration

Muscles

- **Quiet**
  - Nothing
- **Forced**
  - Accessory muscles

Forces

- Elastic recoil of the lung

Muscles of inspiration

1 cm H_20 = 0,74 mmHg

Muscles

- *Quiet* inspiration

I. **Diaphragm**
- Major muscle
- Contraction of the diaphragm → downward displacement
- Increases the vertical diameter of the thoracic cavity

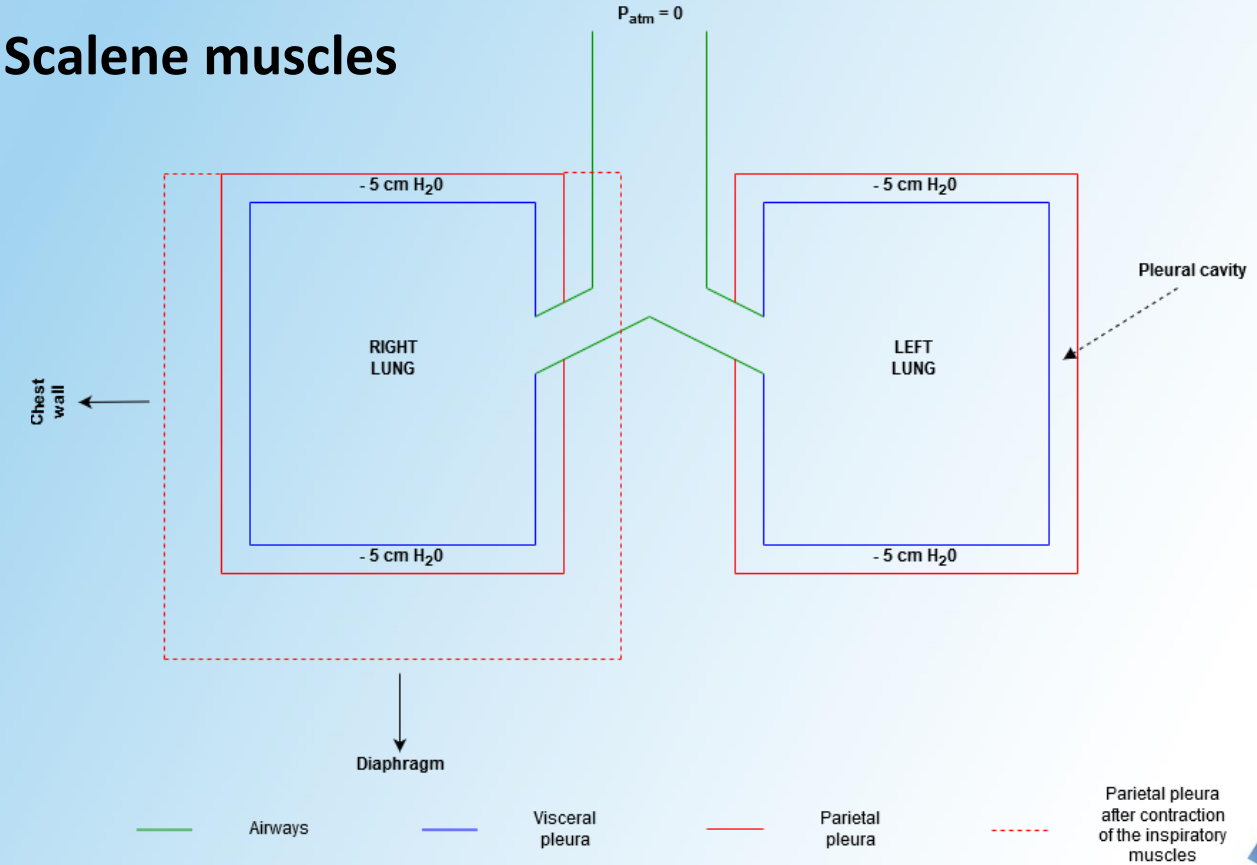
II. ***External* intercostal muscles**
- Minor muscle
- Contraction of the *external* intercostal muscles → ribs are lifted up and out
- Increases the anteroposterior – and horizontal diameter of the thoracic cavity

Muscles

- *Forced* inspiration

I. **Sternocleidomastoid**

II. **Scalene muscles**



Ventilation

- Mechanical

Inspiration

Muscles

- **Quiet**
  - Diaphragm
  - *External* intercostal muscles
- **Forced**
  - Accessory muscles

Forces

- Intrapleural pressure

Expiration

Muscles

- **Quiet**
  - Nothing
- **Forced**
  - Accessory muscles

Forces

- Elastic recoil of the lung

Forces of inspiration

- **Forces**

I. Intrapleural pressure

1. Represents the pressure in the pleural cavity
2. Subatmospheric (*negative*)
3. Expanding force

Boyles law

$P \frac{1}{\propto} V$

Intrapleural pressure

- Negative

?

Elasticity

- Ability to recoil when stretched

Chest wall

- Tendency to spring out

Lung

- Tendency to collapse

$P_L = (P_A) - (P_{pl})$

Expanding pressure

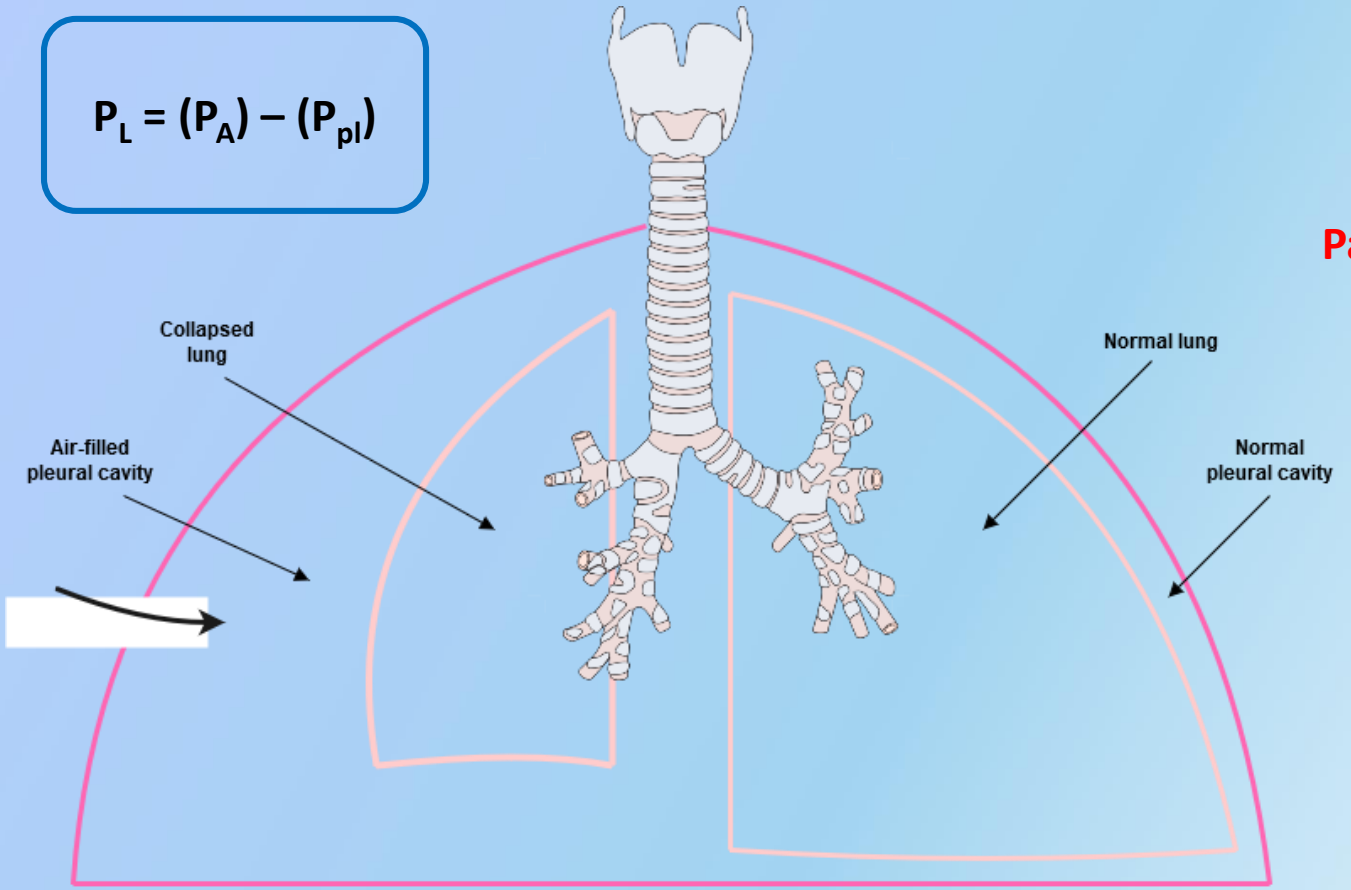
Collapsing pressure

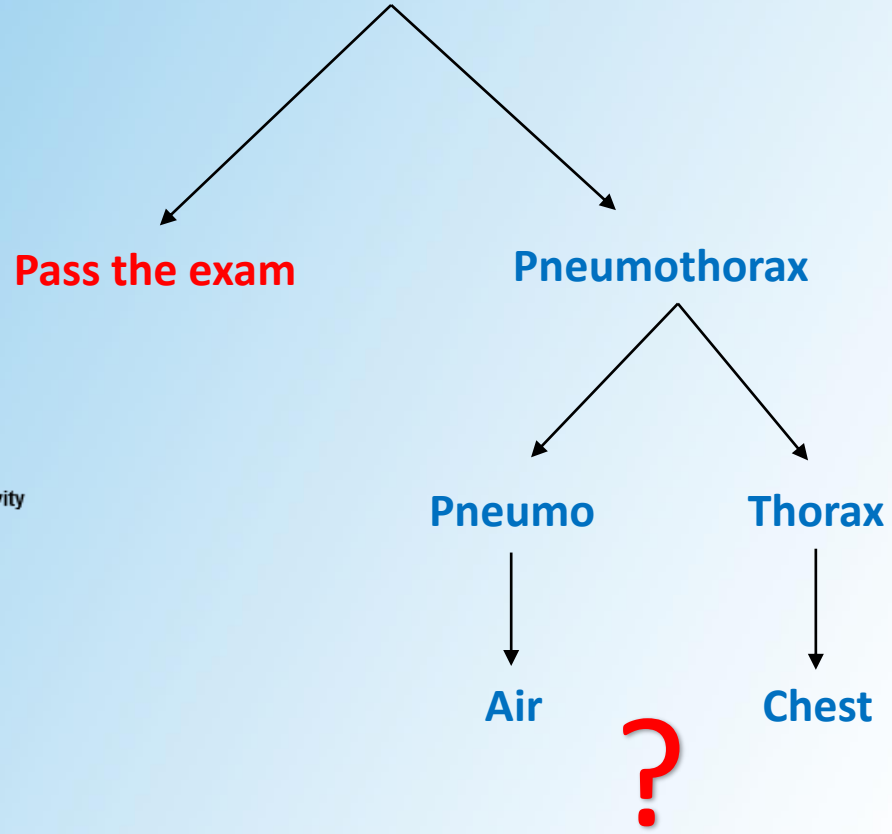
- P_L = Transpulmonary pressure
- P_A = Alveolar pressure
- P_{pl} = Intrapleural pressure

Clinical correlation

- **Why do we need to know something about intrapleural pressure?**

$$P_L = (P_A) - (P_{pl})$$





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Ventilation

- Mechanical

Inspiration

Muscles

- **Quiet**
  - Diaphragm
  - *External* intercostal muscles
- **Forced**
  - Accessory muscles

Forces

- Intrapleural pressure

Expiration

Muscles

- **Quiet**
  - Nothing
- **Forced**
  - Accessory muscles

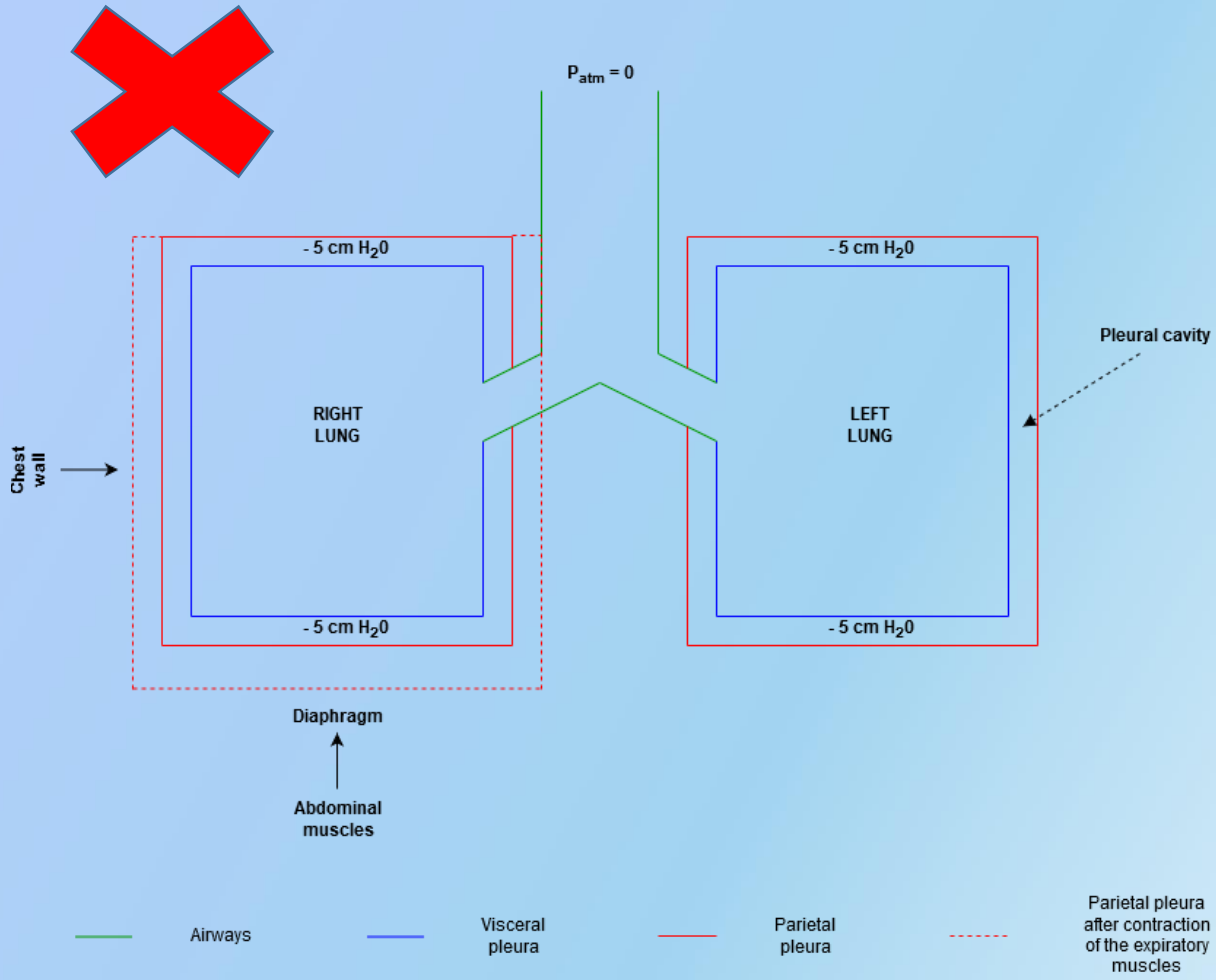
Forces

- Elastic recoil of the lung

Muscles of expiration

Muscles

- *Quiet* expiration



Muscles

- *Forced* expiration

I. **Abdominal muscles**
- Contraction of the abdominal muscles → upward displacement of the diaphragm
- Decreases the vertical diameter of the thoracic cavity

II. ***Internal* intercostal muscles**
- Contraction of the *internal* intercostal muscles → ribs are pulled down and in
- Decreases the anteroposterior – and horizontal diameter of the thoracic cavity

Ventilation

- Mechanical

Inspiration

Muscles

- **Quiet**
  - Diaphragm
  - *External* intercostal muscles
- **Forced**
  - Accessory muscles

Forces

- Intrapleural pressure

Expiration

Muscles

- **Quiet**
  - Nothing
- **Forced**
  - Accessory muscles

Forces

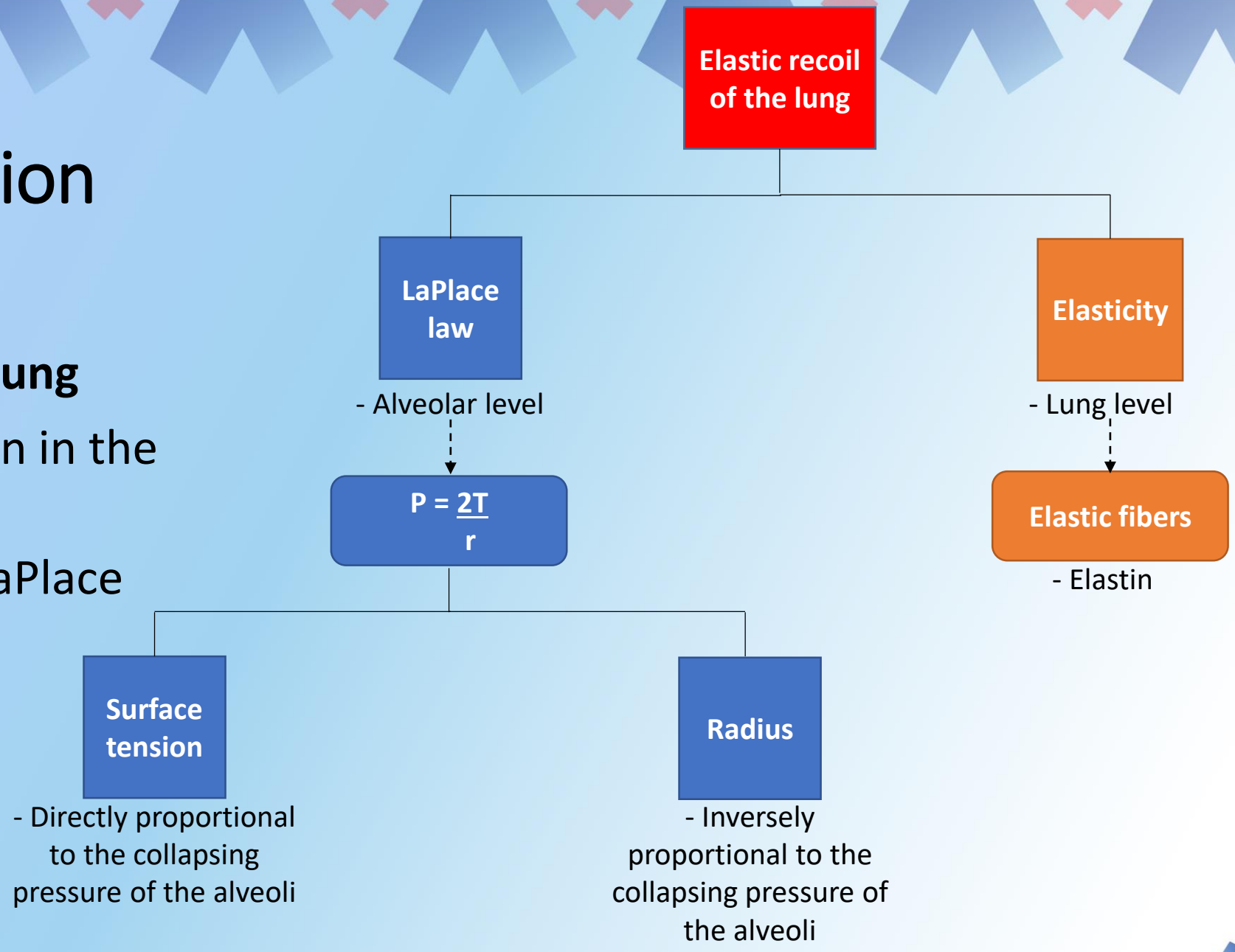
- Elastic recoil of the lung

Forces of expiration

- **Forces**

I. Elastic recoil of the lung

1. Represens the tension in the wall of the lung
2. It is determined by LaPlace law and the inherent elasticity of the lung
3. Collapsing force



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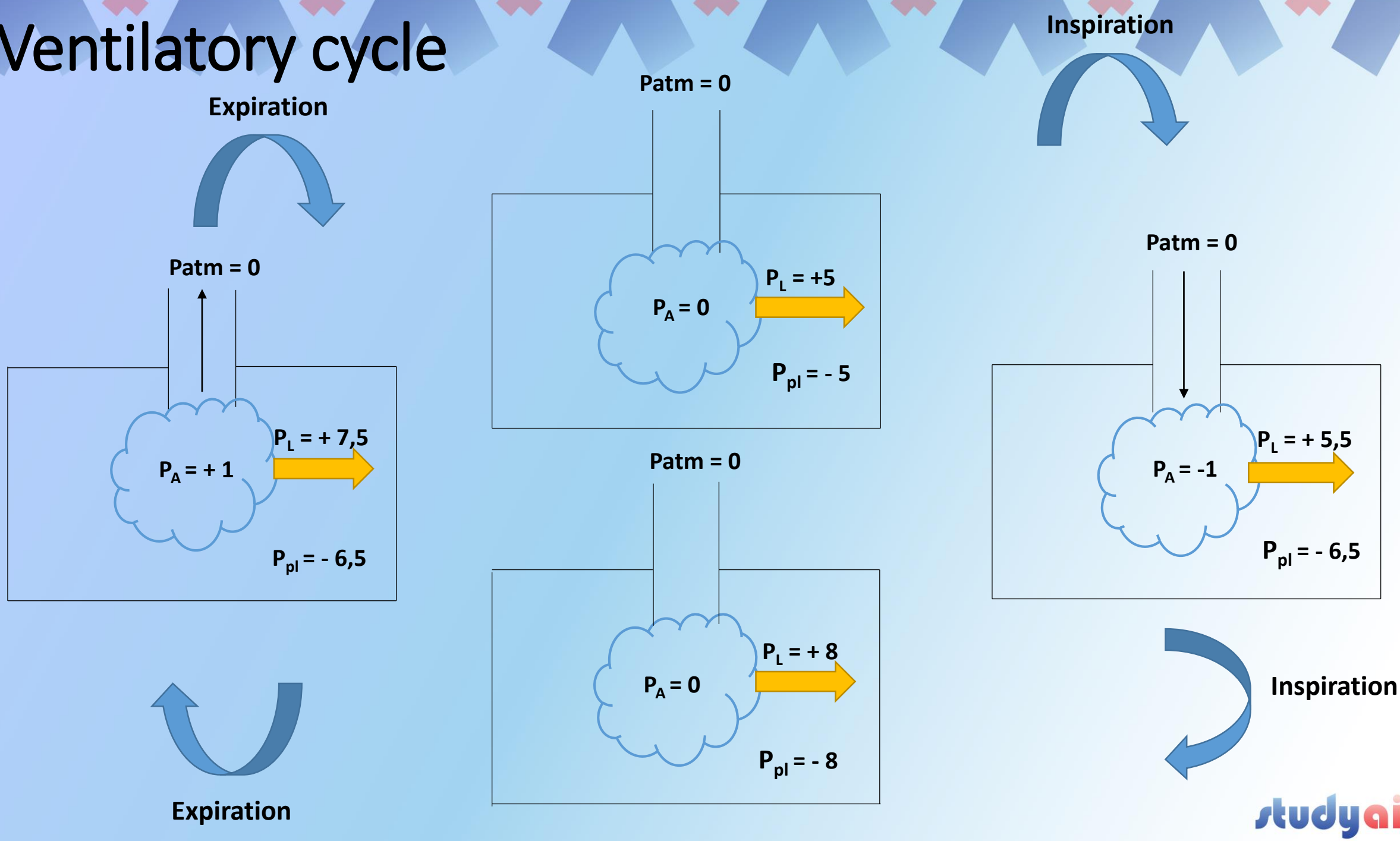
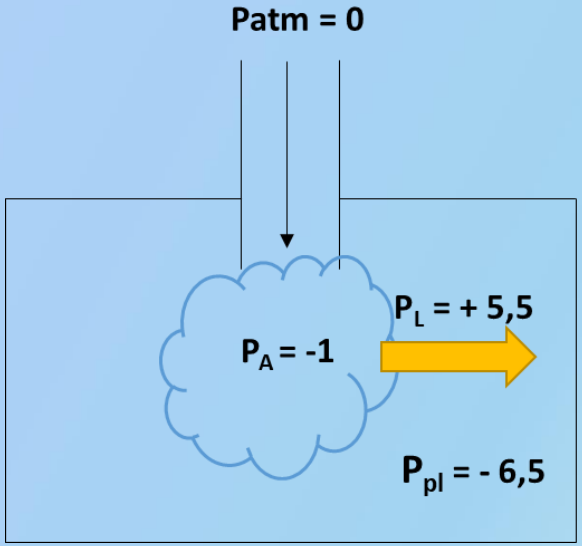
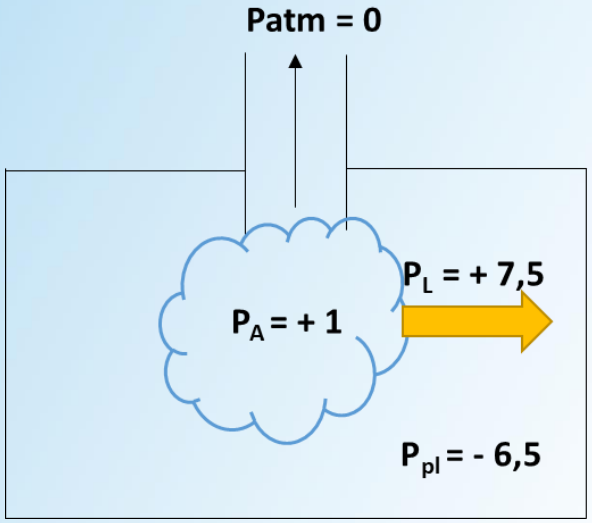
Ventilatory cycle



Clinical correlations

	Restrictive lung disease	Obstructive lung disease
Pathophysiology	Fibrosis of the lung tissue → ↓compliance	Destruction of elastic fibers → ↓elasticity → ↑compliance
Definition	Any pathology that interferes with the ability to develop negative P_A	Any pathology that interferes with the ability to develop positive P_A
Main problem	Inspiration	Expiration
Examples	Pulmonary fibrosis (IPF)	Chronic obstructive pulmonary disease (COPD) Asthma





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Thank you ☺