

Physiology of Respiration: Lung Mechanics and Gas Exchange

Presented By

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- Respiration involves a coordinated set of processes to **deliver** oxygen (**O₂**) to tissues and **remove** carbon dioxide (**CO₂**).
- Understanding the physiology of respiration requires a grasp of lung mechanics (how air moves in and out of the lungs) and gas exchange (the transfer of gases between the alveoli and the blood).

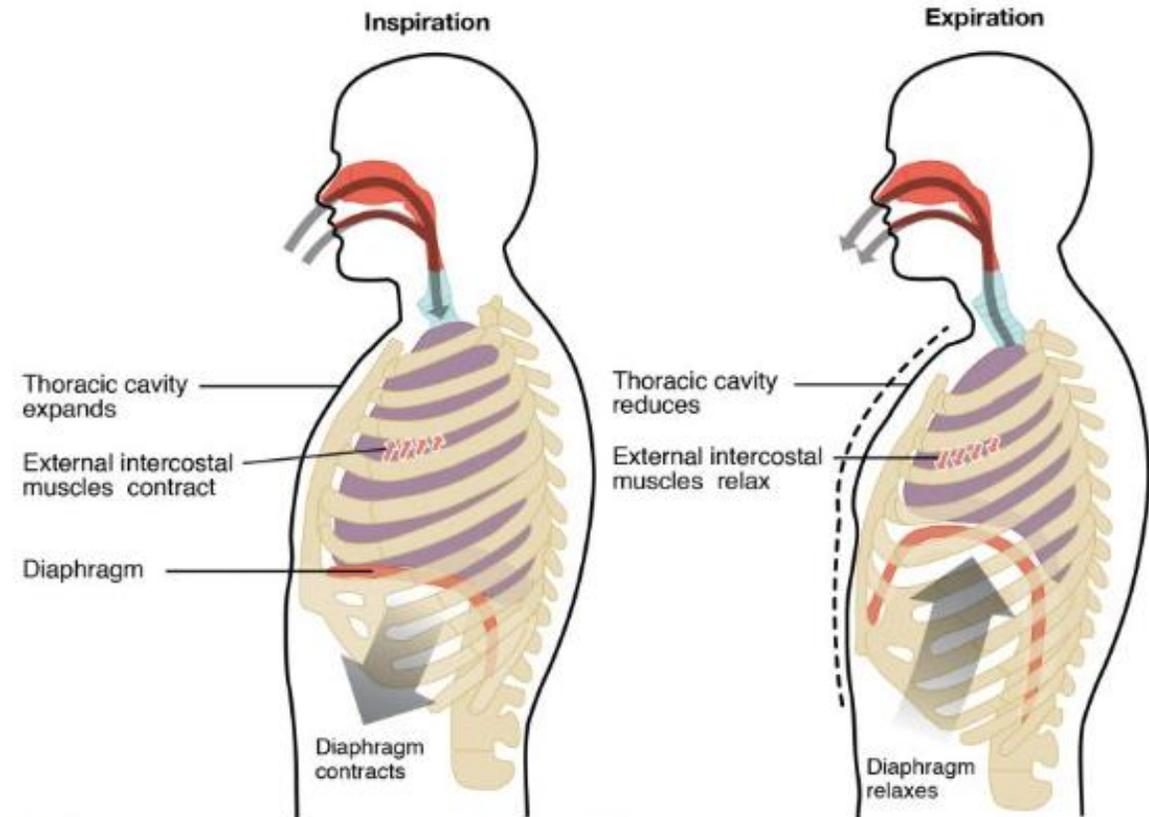
1. Lung Mechanics

- Lung mechanics involve the principles that regulate airflow, lung expansion, and ventilation. Key concepts include:

1.1. Ventilation: Inspiration and Expiration

Inspiration (active):

- Diaphragm **contracts**, pulling downward, and external intercostal muscles lift the ribcage. Thoracic cavity volume increases, decreasing intrapleural pressure (**from $-5 \text{ cmH}_2\text{O}$ to $-8 \text{ cmH}_2\text{O}$**). Air flows into the lungs as alveolar pressure drops below atmospheric pressure.



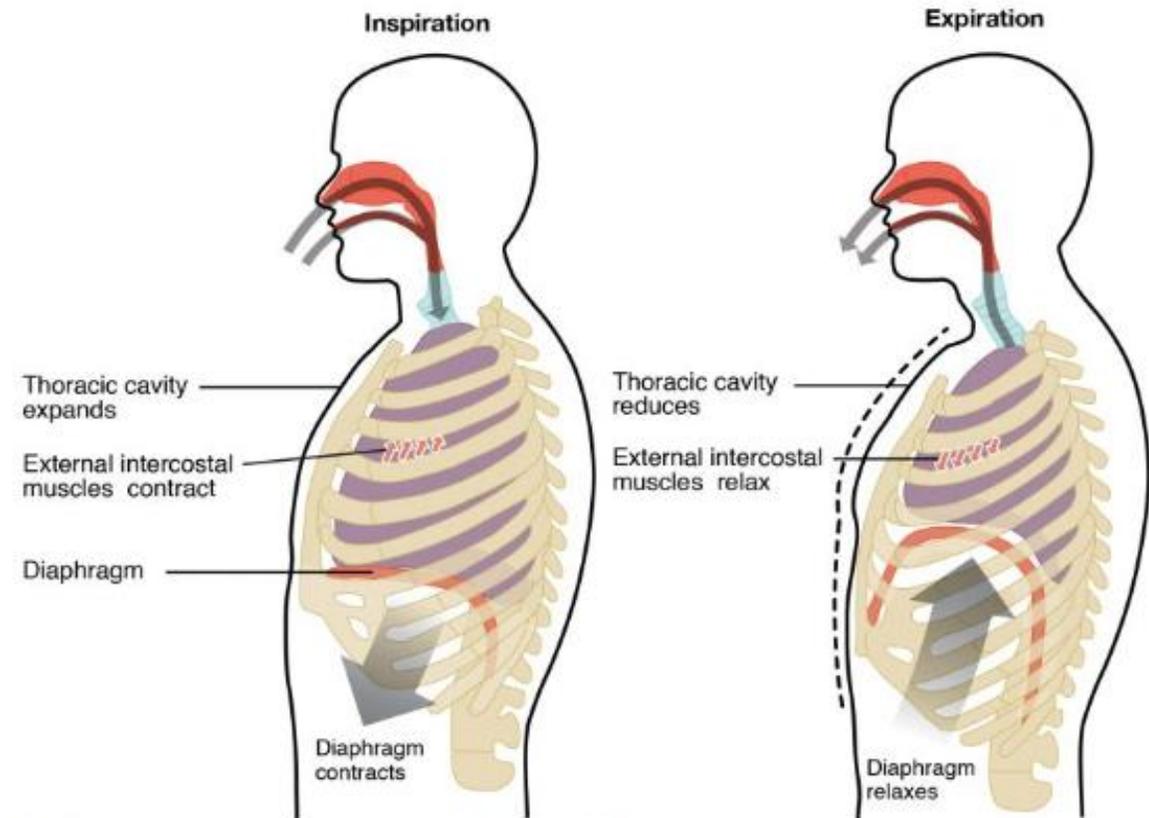
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Expiration (passive at rest):

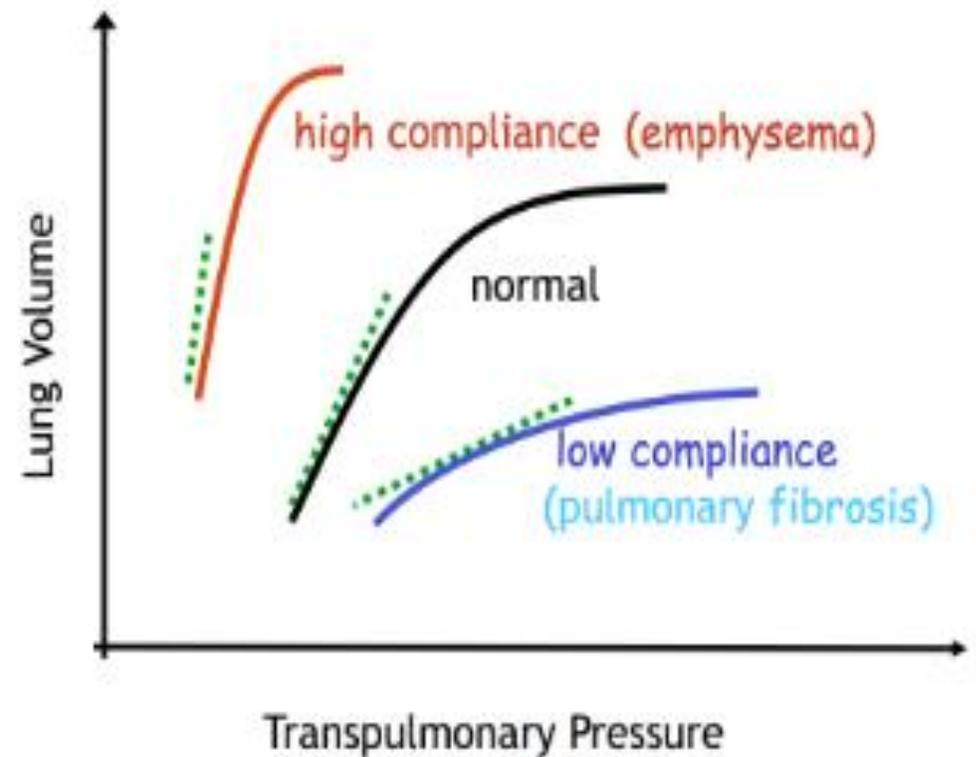
- Diaphragm and intercostal muscles **relax**, allowing elastic recoil of the lungs and chest wall. Intrapulmonary pressure increases, pushing air out of the lungs. During forced expiration, accessory muscles (e.g., abdominal muscles) are involved.



1. Lung Mechanics

1.2. Compliance of the Lungs

- Compliance is the ease with which the lungs expand during inspiration:
 - * **High compliance**: Lungs expand easily (e.g., emphysema).
 - * **Low compliance**: Stiff lungs resist expansion (e.g., pulmonary fibrosis).
- **Determined by**:
 - **Lung elasticity** (collagen and elastin fibers).
 - **Alveolar surface tension**, counteracted by surfactant (produced by type II alveolar cells).



1. Lung Mechanics

1.3. Airway Resistance

- Airflow follows **Poiseuille's law**: resistance is **inversely proportional** to the 4th power of the airway radius. Increased resistance (e.g., asthma, COPD) decreases airflow.
- **Regulated by** bronchoconstriction (parasympathetic) and bronchodilation (sympathetic).

1.4. Intrapleural and Alveolar Pressures

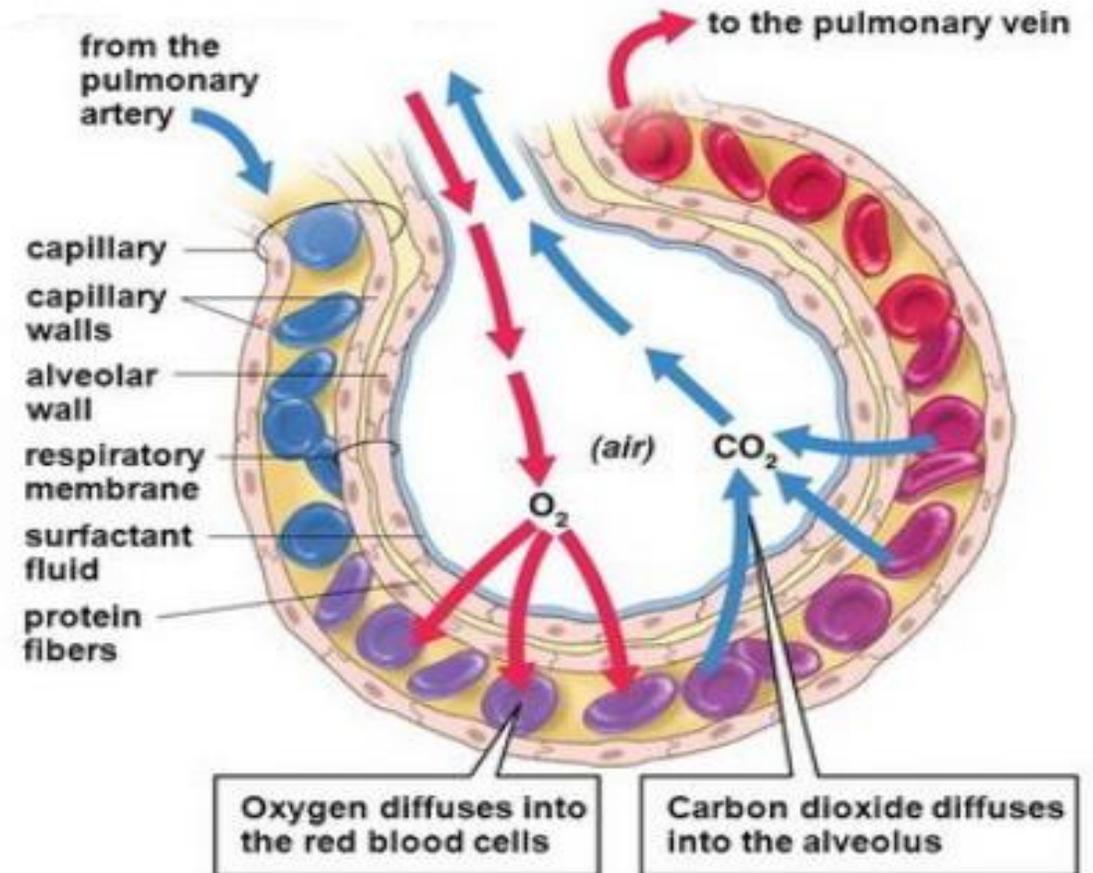
- **Intrapleural pressure**: Negative pressure between the pleural layers prevents lung collapse.
- **Transpulmonary pressure** (alveolar pressure - intrapleural pressure) keeps the alveoli open.

2. Gas Exchange

- Gas exchange occurs via diffusion across the alveolar-capillary membrane, driven by partial pressure gradients.

2.1. Alveolar-Capillary Interface

- The alveoli, surrounded by capillaries, form the site for O_2 and CO_2 exchange.
- The alveolar membrane is thin (~ 0.5 microns), facilitating rapid gas diffusion.



2. Gas Exchange

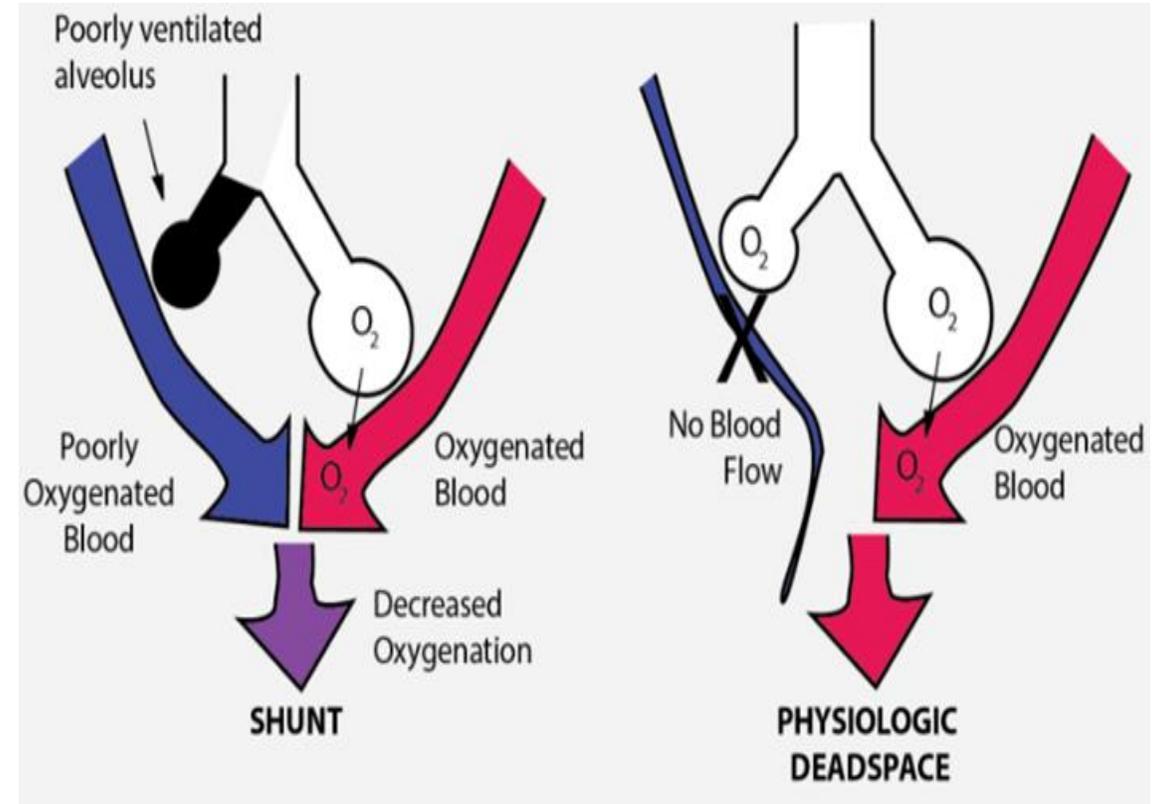
2.2. Partial Pressures and Gas Diffusion

- Partial pressure gradients govern gas movement:
 - **O₂** moves **from alveoli** ($PAO_2 \approx 100$ mmHg) **to capillaries** ($PaO_2 \approx 75 - 100$ mmHg).
 - **CO₂** moves **from capillaries** ($PvCO_2 \approx 35 - 45$ mmHg) **to alveoli** ($PACO_2 \approx 38 - 42$ mmHg).
- The rate of diffusion depends on:
 - Surface area of alveoli (↓ in emphysema).
 - Thickness of the alveolar membrane (↑ in pulmonary fibrosis).
 - Solubility and molecular weight of gases (CO₂ diffuses ~20x faster than O₂).

2. Gas Exchange

2.3. Ventilation-Perfusion (V/Q) Matching

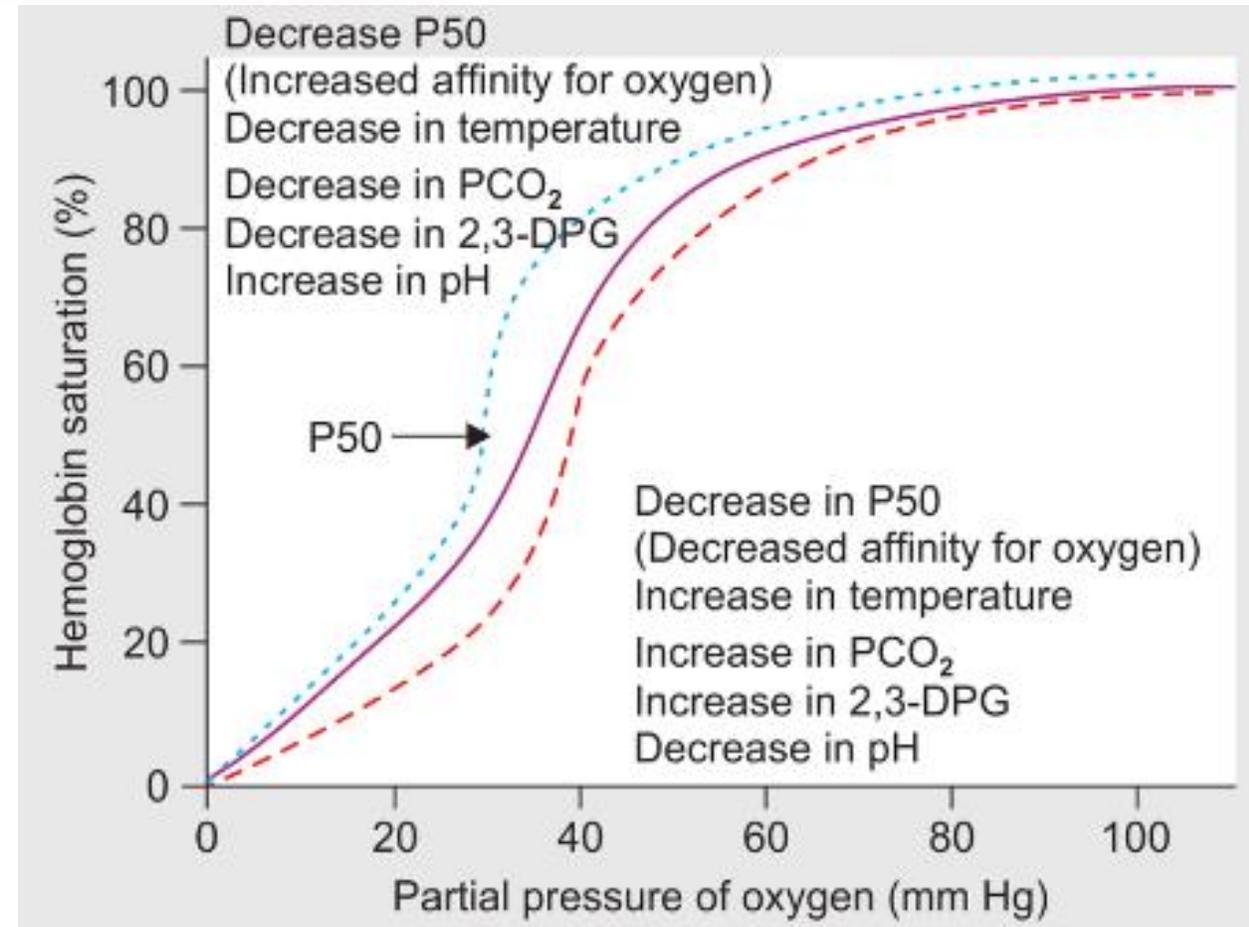
- V/Q ratio ensures efficient gas exchange.
- **Normal V/Q = 0.8** (ventilation slightly less than perfusion).
- **Shunt:** Perfusion without ventilation (e.g., pneumonia).
- **Dead space:** Ventilation without perfusion (e.g., pulmonary embolism).



3. Oxygen and Carbon Dioxide Transport

3.1. Oxygen Transport

- **98% of O₂** binds to hemoglobin (Hb) to form oxyhemoglobin.
- **Oxygen dissociation curve:** Relationship between PaO₂ and hemoglobin saturation (SaO₂).
 - **Shift to the right: ↓ Hb affinity** for O₂ (e.g., acidosis, hypercapnia).
 - **Shift to the left: ↑ Hb affinity** for O₂ (e.g., alkalosis, hypothermia).



3. Oxygen and Carbon Dioxide Transport

3.2. Carbon Dioxide Transport

- CO₂ is transported in three forms:
 - Bicarbonate (HCO₃⁻) (~70%).
 - Carbaminohemoglobin (bound to Hb) (~20-30%).
 - Dissolved CO₂ (~7-10%) in plasma.

4. Control of Respiration

- Respiration is regulated by **neural** and **chemical** feedback mechanisms.

4.1. Neural Control

- Medullary respiratory centers:
 - * Dorsal respiratory group (DRG): Controls basic rhythmic breathing.
 - * Ventral respiratory group (VRG): Active during forced breathing.

4.2. Chemical Control

- Central and peripheral chemoreceptors detect changes in:
 - * CO₂: Primary driver of respiration ($\uparrow \text{PaCO}_2 \rightarrow \uparrow \text{ventilation}$).
 - * O₂: Hypoxia stimulates peripheral chemoreceptors (in carotid and aortic bodies).

Thank
You!