Objectives
To define the different types of pressure involved with ventilation.
To outline the steps of inhalation and exhalation.
To define lung compliance and explain its significance.
Overview of the Gas laws.
Introduction to External Respiration.

Respiration
Exchange of gases between the air and the cells of the body.
- Pulmonary Ventilation
- External Respiration
- Internal respiration

Pulmonary Ventilation

Breathing

Two phases:
- Inspiration – air flows into the lungs
- Expiration – air gases exit the lungs
  - Movement of air occurs due to pressure gradient.
  - Depends upon volume changes in the thoracic cavity.

Types of Pressure
I. \( P_{\text{atm}} \) – respiratory pressures described relative to atmospheric pressure (air pressure exerted by gases around the body).
  \( P_{\text{atm}} = 760 \text{ mm Hg or 1 atm} \)
II. \( P_{\text{pul}} \) – intrapulmonary pressure = pressure in the alveoli. Always eventually equals with the atmospheric pressure.
III. \( P_{\text{pip}} \) – intrapleural pressure = pressure in the pleural cavity. Always about 4 mm Hg less than \( P_{\text{pul}} \). \( P_{\text{pip}} \) is negative to both \( P_{\text{pip}} \) and \( P_{\text{atm}} \)

Air Flow

Occurs due to changes of pressure in the lungs that alternate between higher and lower pressure – compared to \( P_{\text{atm}} \).

Inspiration – Lower pressure in lungs
Exhalation – Higher pressure in lungs
What keeps the lungs from collapsing?

Answer: The difference between \( \text{Pip} \) and \( \text{Ppul} \) (which keeps the air spaces of the lungs open).

Remember: The **pleural membranes** create a pressure gradient because the intra pleural cavity has a lower pressure than \( \text{Patm} \).

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**Inspiration**

Thoracic cavity expands, pressure decreases, Gases flow into the chamber.

Actions of normal inspiration:
1. Diaphragm contracts
2. External Intercostal muscles contract - lifts ribs
4. Lungs stretch
5. Intrapulmonary volume increases.
6. Ppul drops.
7. Air rushes in to fill the vacuum

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**Expiration**

*Passive process*
1. Inspiratory muscles relax and resume their resting position.
2. Thoracic volume decrease
3. When \( \text{Ppul} > \text{Patm} \) then gases flow out of the lungs.
4. Also aided by recoil of alveoli.

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**Lung Compliance**

The distensibility of healthy, stretchy lungs.

\[
\text{CL} = \frac{\text{change in lung volume}}{\text{change in transpulmonary* pressure}}
\]

Transpulmonary: \( \text{(Ppul - Pip)} \)

Significance:
The higher the compliance (CL) the *easier it is to expand the lungs* at any given transpulmonary pressure.

Two factors of lung compliance.
- Distensibility of the lung tissue and the surrounding thoracic cage.
- Alveolar surface tension

Healthy people have **high lung compliance** → which favors efficient ventilation.

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**Factors that reduce compliance**

- Fibrosis (scar tissue)
- Blockage of smaller respiratory passages.
- Reduce the production of surfactant
- Decrease the flexibility of the thoracic cage.

The lower the compliance the more energy it takes to breath and the harder it is to breath.
**Surfactant**

A fluid secreted by Type II cells (surfactant-secreting cells) that contains phospholipids and lipoproteins.

Fcn: Reduce surface tension in alveoli to prevent them from collapsing after exhalation. (maintains inflation of alveoli)

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**Gas Laws**

**Boyle's Law** - Volume changes are correlated to pressure changes i.e. the Flow of gases.

**Dalton's Law** – gas pressures in a mixture.

**Fick's Law** – Diffusion of gas across a membrane.

**Henry's Law** - Gases will dissolve in a liquid in proportion to their partial pressure.

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**External Respiration**

Movement of respiratory gases from the lung into the blood.

Involves diffusion across a respiratory membrane.

Lung tissue/capillary membrane

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**Partial Pressure Gradient**

<table>
<thead>
<tr>
<th>GAS</th>
<th>ATMOSPHERE (SEA LEVEL)</th>
<th>ALVEOLI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>APPROXIMATE PERCENTAGE</td>
<td>PARTIAL PRESSURE (mm Hg)</td>
</tr>
<tr>
<td>N₂</td>
<td>78.6</td>
<td>597</td>
</tr>
<tr>
<td>O₂</td>
<td>20.9</td>
<td>159</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.04</td>
<td>0.3</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.46</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>760</td>
</tr>
</tbody>
</table>

Oxygenation of blood is very fast (less than 0.25 sec).

However the solubility of CO₂ is 20 times more soluble into plasma and alveolar fluids compared to oxygen.

Net effect is equal amounts of the respective gases are exchanged.

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**Respiratory Volumes**

**I. Tidal** – normal resting breath.

**II. Inspiratory Reserve** – amt of air inspired forcibly.

**III. Expiratory reserve** – amt of air that can be expelled from lungs.

**IV. Residual** – amt of air that remains in lungs to keep alveoli open.
**Respiratory Capacities**

I. Inspiratory capacity (IC)

II. Functional residual capacity (FRC)

III. Vital capacity (VC): Maximum amount of air that can be expired after a maximum inspiratory effort.

IV. Total lung capacity (TLC): Maximum amount of air after max inspiratory effort.

**Spirometry**

A testing method that measures lung volumes and capacities. Used to test for obstructive pulmonary disease (such as chronic bronchitis) & restrictive disorders (e.g. fibrosis due to exposure to hazardous environmental agents like asbestos).

**Summary of respiratory volumes and capacities for males and females**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Adult male average value</th>
<th>Adult female average value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total volume (TV)</td>
<td>500 ml</td>
<td>500 ml</td>
<td>Amount of air inhaled or exhaled with each breath under resting conditions</td>
</tr>
<tr>
<td>Inspiratory reserve volume (IRV)</td>
<td>3100 ml</td>
<td>1900 ml</td>
<td>Amount of air that can be forcibly inhaled after a normal tidal volume inhalation</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>1200 ml</td>
<td>700 ml</td>
<td>Amount of air that can be forcibly exhaled after a normal tidal volume exhalation</td>
</tr>
<tr>
<td>Residual volume (RV)</td>
<td>1200 ml</td>
<td>1100 ml</td>
<td>Amount of air remaining in the lungs after a forced exhalation</td>
</tr>
</tbody>
</table>

**Dead Space**

> Some inspired air never contributes to gas exchange

> Anatomical dead space: volume of the conducting zone conduits (~150 ml)

> Alveolar dead space: alveoli that cease to act in gas exchange due to collapse or obstruction

> Total dead space: sum of above nonuseful volumes
Alveolar Ventilation

- Alveolar ventilation rate (AVR): flow of gases into and out of the alveoli during a particular time

<table>
<thead>
<tr>
<th>AVR (ml/min)</th>
<th>frequency (breaths/min)</th>
<th>(TV – dead space) (ml/breath)</th>
</tr>
</thead>
</table>

- Dead space is normally constant
- Rapid, shallow breathing decreases AVR

Basic Properties of Gases: Dalton’s Law of Partial Pressures

- Total pressure exerted by a mixture of gases is the sum of the pressures exerted by each gas
- The partial pressure of each gas is directly proportional to its percentage in the mixture

Basic Properties of Gases: Henry’s Law

- When a mixture of gases is in contact with a liquid, each gas will dissolve in the liquid in proportion to its partial pressure
- At equilibrium, the partial pressures in the two phases will be equal
- The amount of gas that will dissolve in a liquid also depends upon its solubility
  - CO₂ is 20 times more soluble in water than O₂
  - Very little N₂ dissolves in water