Respiratory System
Non-respiratory functions of the system:
1-water loss and heat elimination, also keeps alveoli wet
2-enhances venous return
3-acid-base balance
4-enables speech
5-defends against foreign inhaled matters.
6-removes, modifies, & activate or inactivate materials “prostglandins”
7-smelling
8-shape of the chest
9-protects heart & vessels
10-aireate the blood between respiratory phases
Respiratory Physiology

• **Structure:**
  - Air conducting channels
  - Respiratory spaces
  - Lungs float in the thoracic cavity + pleura
Respiratory passages comprises two portions

A- Conducting part
1- Nose and mouth
2- Nasal cavity
3- Pharynx
4- Larynx
5- Trachea
6- Bronchi and Bronchioles

Inside lungs

B- Respiratory part
1- Alveolar ducts, Alveolar Sacs and alveoli inside lungs
Respiratory Physiology

Steps:
1- pulmonary ventilation: air flow between the atmosphere and the lungs.
2- diffusion of gasses between the alveoli and the blood.
3- transport.
4- regulation.
Atmosphere

Alveoli of lungs

Pulmonary circulation

Systemic circulation

Tissue cell

Steps of external respiration

1. Ventilation or gas exchange between the atmosphere and air sacs (alveoli) in the lungs

2. Exchange of O₂ and CO₂ between air in the alveoli and the blood

3. Transport of O₂ and CO₂ between the lungs and the tissues

4. Exchange of O₂ and CO₂ between the blood and the tissues

Internal respiration

Food + O₂ → CO₂ + H₂O + HTP

Fig. 12-1, p. 366
Mechanics of ventilation

1. By down word and upward movement of the diaphragm → lengthen or shorten (Normal)

2. By elevation and depression of the ribs (anteropost) ribs and sternum moves away from the spine (20% more)
Mechanics of ventilation

• Muscles:
  1- Inspiratory:
    → Diaphragm
    → External intercostals
    → Sternoclidomastoid
    → Sternum - Scalini (2 ribs)
    → Anterior serrati
Mechanics of ventilation

2- Expiratory muscles:

- internal intercostals
- Abdominal recti
Accessory muscles of inspiration

- Sternocleidomastoid
- Scalenus

Sternum

Ribs

External intercostal muscles

Diaphragm

Major muscles of inspiration

Internal intercostal muscles

Muscles of active expiration

Abdominal muscles
Air movement

- Movement of air is determined by pressures.
- The lung is an elastic structure that resembles a balloon floating in the thoracic cavity.
- Both lungs are surrounded by plural fluid which has negative pressure between the parietal a visceral layers.
Lollipop

Water-filled balloon

Right lung

Left lung

Right pleural sac

Thoracic wall

Diaphragm

Left pleural sac

Parietal pleura

Visceral pleura

Pleural cavity filled with intrapleural fluid

Pleural cavity filled with intrapleural fluid

Fig. 12-4, p. 369
1- Pleural pressure:

- fluid pressure
- slight suction that helps the lungs to open at rest.
- (-5 to -7.5) cm H$_2$O, during normal inspiration.
Respiratory pressure

2- Alveolar pressure:
→ the pressure Inside the Alveoli:
A- Glottis open, no air flow → 0 cm H$_2$O
B- Inward flow → sub atmospheric (-1 cm H$_2$O) within 2s
C- Outward flow → positive (1 cm H$_2$O) within 2-3s.
Atmospheric pressure (the pressure exerted by the weight of the gas in the atmosphere on objects on the Earth’s surface—760 mm Hg at sea level)

Intra-alveolar pressure (the pressure within the alveoli—760 mm Hg when equilibrated with atmospheric pressure)

Intrapleural pressure (the pressure within the pleural sac—the pressure exerted outside the lungs within the thoracic cavity, usually less than 756 mm Hg)
3- Transpulmonary pressure:

Pressure difference between the alveolar pr. and pleural pr. [pr.differ. b/w alveoli and outer surfaces of the lungs]

it measures elastic forces that tend to collapse the lungs each point of expansion [recoil pressure].
Transmural pressure gradient across lung wall =
intra-alveolar pressure minus intrapleural pressure

Transmural pressure gradient across thoracic wall =
atmospheric pressure minus intrapleural pressure

Numbers are mm Hg pressure.
Inspiration

Expiration

Atmospheric pressure

Intra-alveolar pressure

Intraplural pressure

Transmural pressure gradient across the lung wall

Pressure (mm Hg)

© Brooks/Cole - Thomson Learning

Fig. 12-13, p. 375
Figure 37-2. Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing.
Fig. 12-8a, p. 371

Puncture wound in chest wall

Numbers are mm Hg pressure.
Spontaneous pneumothorax

Hole in lung

Numbers are mm Hg pressure.
Numbers are mm Hg pressure.
Compliance of the lungs

- Expandability of the lungs
- Stretch ability of the lungs.
- The extent to which the lungs will expand for each unit increase in transpulmonary pr.
- Total compliance of both lungs is around 200 ml/cm H2O transpulmonary pressure.
Compliance of the lungs
A. the curves in the figure above depend on the elastic forces of the lungs:

1) elastic forces of the lung tissue (elastin and collagen fibres) (1/3 of the total force)

2) Surface tension of the fluid (2/3 of the total force)

\[ \text{Surface tension is huge when surfactant is absent:} \]
\[ \text{H}_2\text{O molecules on the surface of the water have an extra strong attraction for one another} \]
\[ \text{attempts to contract and collapse the alveoli.} \]
B. Surfactant:

Surface-active agent in water secreted by type II alveolar epithelial cells (10% of surface area of alveoli).

Phospholipids, dipalmitoylphosphatidylcholine (DPPC), proteins (apoprotein), and ions (calcium) that help in spreading phospholipids.
## Compliance of the lungs

<table>
<thead>
<tr>
<th></th>
<th>Without surfactant</th>
<th>With surfactant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface tension</strong></td>
<td>50 dynes/cm</td>
<td>5-30 dynes/cm</td>
</tr>
<tr>
<td><strong>Collapsing pressure</strong></td>
<td>18 cm H2O</td>
<td>4 cm H2O</td>
</tr>
<tr>
<td>In one alveoli</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pressure generated by S.T = $2 \times \frac{S.T.}{\text{Radius}}$

Effect of size of the alveoli on collapsing pr.:
- The Radius is inversely proportional to coll. pr. So smaller alveoli have greater pr. than the larger ones.

- Premature babies have small alveolar radius and less surfactant → tendency for lung collapse is 6-8 times greater than in adults → Respiratory distress syndrome of the newborn
- Instability of the alveoli (rupture),
- Safety factors:
  1. Interdependence phenomenon (Sharing septal walls)
  2. 50,000 functional units w/ fibrous septa
  3. Surfactant effect:
     a) reduces S.T from 8 to 3 cm H$_2$O
     b) [surfactant] in smaller alveoli > than in large
Compliance of the lungs

- Compliance of thorax and lungs: 110 ml/cm H2O pr.

- At high volume or compressed to low volumes, the compliance can be as little as one-fifth that of lungs alone.
Work of breathing:

1. Work required to expand the lungs against the lung and chest elastic forces (compliance work)

2. Work required to overcome the viscosity of the lung and chest wall (tissue resistance work)

3. Work required to overcome airway resistance (airway resistance work)
Figure 37–5. Graphic representation of the three types of work accomplished during inspiration: (1) compliance work, (2) tissue resistance work, and (3) airway resistance work.
- Minute respiratory volume:
  - Total volume of new air moved into respiratory passages each minute
  - MRV = TV * freq.
  - Normal = 500 x 12 = 6L/min
  - (1.5 L/min fatal). (high value like 200 L/min is fatal).
Alveolar ventilation:
rate at which new air reaches these areas (respir. spaces).

\[(TV - D.S) \times \text{freq.} = 4.2\text{L/min}\]
### TABLE 12-2
Effect of Different Breathing Patterns on Alveolar Ventilation

<table>
<thead>
<tr>
<th>BREATHING PATTERN</th>
<th>TIDAL VOLUME (ml/breath)</th>
<th>RESPIRATORY RATE (breaths/min)</th>
<th>DEAD SPACE VOLUME (ml)</th>
<th>PULMONARY VENTILATION (ml/min)*</th>
<th>ALVEOLAR VENTILATION (ml/min)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet breathing at rest</td>
<td>500</td>
<td>12</td>
<td>150</td>
<td>6,000</td>
<td>4,200</td>
</tr>
<tr>
<td>Deep, slow breathing</td>
<td>1,200</td>
<td>5</td>
<td>150</td>
<td>6,000</td>
<td>5,250</td>
</tr>
<tr>
<td>Shallow, rapid breathing</td>
<td>150</td>
<td>40</td>
<td>150</td>
<td>6,000</td>
<td>0</td>
</tr>
</tbody>
</table>

*Equals tidal volume \( \times \) respiratory rate.

**Equals (tidal volume – dead space volume) \( \times \) respiratory rate.
• Respiratory passageway:
• 1-Main resistance to the airflow present in Large bronchioles and bronchi
• 2-Sympathetic system dilate bronchioles
• 3-Parasympathetic system constrict bronchioles
• 4-Irritation of membrane passageways cause constriction as (smoking, dust, Infection)
• 5- Histamine and slow reactive substance of anaphylaxis secrete locally by the lungs
• By mast cells during allergic reaction as in Asthma. These cause bronchiolar constriction
• 6- Atropine relax respiratory passageway.