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 “prostaglandins”
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**

**Steps of external respiration**

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

2. Exchange of $O_2$ and $CO_2$ between air in the alveoli and the blood

3. Transport of $O_2$ and $CO_2$ between the lungs and the tissues

4. Exchange of $O_2$ and $CO_2$ between the blood and the tissues

**Internal respiration**

Food + $O_2$ → $CO_2$ + HO₂ + HTP

**Alveoli of lungs**

**Pulmonary circulation**

**Systemic circulation**

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

Muscles of active expiration

- Sternum
- Ribs
- External intercostal muscles
- Diaphragm
- Abdominal muscles

Major muscles of inspiration
Respiratory muscles

Expiration:
- Increased vertical diameter
- Increased A-P diameter
- External intercostals contracted
- Internal intercostals relaxed
- Abdominals contracted

Inspiration:
- Elevated rib cage
- Diaphragmatic contraction

Airway resistance..

- Due to friction when air moves through airways.
- Medium-sized bronchi contribute most of the resistance.
- Small airways contribute 20%.
Factors responsible for elastic recoil of lungs

- Elastic fibers in the lungs & chest wall.
- The surface tension in the fluid lining the alveoli.
Cont...

- At end of quiet exp → -5 cm H2o.
- At end of quiet insp → -8 cm H2o.
- More (-) during maximal inspiration.
- Becomes (+) during maximal expiration.
Lollipop

Water-filled balloon

Right lung

Left lung

Right pleural sac

Left pleural sac

Thoracic wall

Pleural cavity filled with intrapleural fluid

Diaphragm

Pleural cavity filled with intrapleural fluid

Parietal pleura

Visceral pleura

"Lung"

"Pleural sac"
1- Pleural pressure:
→ fluid pressure
→ slight suction that helps the lungs to open at rest.
→ (-5 to -7.5) cm H₂O, during normal inspiration.
Cont...

- At end of quiet expiration → -5 cm H₂O.
- At end of quiet inspiration → -8 cm H₂O.
- More (-) during maximal inspiration.
- Becomes (+) during maximal expiration.
Respiratory pressure

2- Alveolar pressure :
→the pressure Inside the Alveoli:
A- Glottis open, no air flow → 0 cm H₂O
B- Inward flow → sub atmospheric (-1 cm H₂O) within 2s
C- Outward flow → positive (1 cm H₂O) 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
Figure 37-2. Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing.
Numbers are mm Hg pressure.
Spontaneous pneumothorax

Hole in lung

Numbers are mm Hg pressure.
Numbers are mm Hg pressure.
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

- The extent to which the lungs expand for each unit increase in transpulmonary pressure.

- Compliance = \[
\frac{\Delta V}{\Delta P}
\]

- Normal value = 200 ml/cm H₂O
Chest wall compliance

- Chest wall is an elastic structure.
- Compliance of the respiratory system is a combination of both, lung & chest wall compliance.
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)

Surface tension is huge when surfactant is absent: H₂O molecules on the surface of the water have an extra strong attraction for one another attempting 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 = \(2\times S.T\)  

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
The Relationship Between Pressure & Surface Tension in Alveolus

Laplace’s law
elastic fibers
reseting
stretch

P

surface
tension of
fluid lining
the alveoli

T
Rule of surfactant...

- The tension is decreased with decrement of radius therefore the pressure kept constant.
- Causes surface tension to vary with surface area of the alveolus.
Physiological advantage of surfactant

- Increase lung compliance.
- Prevents collapsing tendency of the alveoli.
- Decrease surface tension.
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.
Energy required for respiration: 3-5% of total body energy and can increase to 50 fold during heavy exercise and some obstructive diseases.