NOTES: Respiratory System (CH 13) – Breathing Mechanism

Mechanism of Breathing

- **Inhalation**: Diaphragm contracts (moves down)
- **Exhalation**: Diaphragm relaxes (moves up)

- **Rib cage** expands as rib muscles contract
- **Air inhaled**
- **Lung**
- **Diaphragm**

- **Rib cage** gets smaller as rib muscles relax
- **Air exhaled**

Dr. Aarif
*Changes in the size of the thoracic cavity accompany **INSPIRATION** and **EXPIRATION**.*

⇒ **INSPIRATION** = inhalation

⇒ **EXPIRATION** = exhalation
Pressure...

* **ATMOSPHERIC PRESSURE** (the “weight” of the air) is the force that moves air into the lungs.

* Air (gases) move from regions of **HIGH PRESSURE** to regions of **LOW PRESSURE**
INSPIRATION:

• Air pressure is exerted on all surfaces in contact with air
  – Lungs are also subjected to pressure
• When respiratory muscles are at rest, pressure inside the lungs and alveoli and on the outside of the thoracic wall are the same
INSPIRATION:

• Pressure and volume are related in an **opposite or inverse** way (Boyle’s Law)

• Syringe example:
  – Pull plunger
    • **increase** volume inside, **decrease** pressure inside…air goes into syringe
  – Push plunger
    • **decrease** volume inside, **increase** pressure inside…air goes out of syringe
INSPIRATION:

- If the pressure inside the lungs/alveoli decreases, atmospheric pressure will force air into the lungs
INSPIRATION:

*How does the pressure inside the lungs decrease???*

> Impulses from **phrenic nerve** contract diaphragm

> Diaphragm contracts (**moves downward**)

> Thoracic cage moves upward and outward (**external intercostal muscles contract**)
The diaphragm is shaped like a parachute.
INSPIRATION:

→ the **INCREASE IN VOLUME** of the thoracic cavity causes a **DECREASE IN PRESSURE**
INSPIRATION:

• as the walls of the thoracic cavity expand, they pull on the parietal pleura
• the serous fluid in the pleural cavity holds the pleural membranes tightly together (much like a wet microscope slide will stick to another microscope slide)
• as the parietal pleura is pulled outward, the visceral pleura follows…
The Mechanics of Breathing

- Inhalation:
  - Oxygen enters the lungs
  - Diaphragm rises

- Exhalation:
  - Carbon dioxide exits the lungs
  - Diaphragm returns
  - Space inside chest decreases
INSPIRATION:

- the lungs expand in all directions and air is pulled inward!!

**for a deeper breath, the diaphragm and intercostals muscles contract with more force**
INSPIRATION:

• Moist pleural membranes help expand lungs but moist inner surfaces in alveoli have the opposite effect.

• Attraction water molecules creates a force (surface tension) that make inflation of alveoli difficult and may even collapse them.
INSPIRATION:

• How do we prevent alveoli from collapsing?
  – Certain alveolar cells continuously secrete a lipoprotein called a surfactant.
  – Surfactants reduce the tendency for alveoli from collapsing especially when lung volume is low.
<table>
<thead>
<tr>
<th>Surfactant:</th>
<th>absent</th>
<th>present</th>
</tr>
</thead>
<tbody>
<tr>
<td>radius ( r ):</td>
<td>0.1 mm, 0.05 mm</td>
<td>0.1 mm, 0.05 mm</td>
</tr>
<tr>
<td>surface tension ( T ):</td>
<td>0.072 N/m, 0.072 N/m</td>
<td>0.02 N/m, 0.01 N/m</td>
</tr>
<tr>
<td>recoil pressure ( 2T/r ):</td>
<td>( \frac{N}{m^2} ): 1440, 2880</td>
<td>( \frac{N}{m^2} ): 400, 400</td>
</tr>
<tr>
<td>( cm , H_2O ):</td>
<td>14.4, 28.8</td>
<td>4, 4</td>
</tr>
</tbody>
</table>
INSPIRATION:

• Surfactant is very important especially when inflating a newborn’s lungs for the first time
  – Premature babies tend to suffer from respiratory distress syndrome
  – Inject with synthetic surfactant or use ventilator to help with breathing
EXPIRATION:

• the forces for normal exhalation come from **ELASTIC RECOIL** of tissues

• the opposite pressure and volume changes occur...pressure inside the lungs increases and forces air out
EXPIRATION:

How does the pressure inside the lungs increase???

> Diaphragm relaxes (moves upward)

> External intercostals muscles relax; thoracic cage moves downward and inward
EXPIRATION:

→ Lungs and thoracic cage recoil and return to their original shape

→ the **DECREASE IN VOLUME** of the thoracic cavity causes an **INCREASE IN PRESSURE**

→ *air is forced out!!*
EXPIRATION:

• Visceral and parietal pleural membranes are held closely together due to low intrapleural pressure
  – Also, no significant space that separates them in pleural cavity
• What happens if thoracic wall is punctured?
  – Atmospheric air can enter cavity and intrapleural pressure becomes equal to atmospheric pressure thus collapsing lung
  – This is called pneumothorax
RESPIRATORY AIR VOLUMES AND CAPACITIES:

• one **RESPIRATORY CYCLE** = one inspiration followed by one expiration

• the amt. of air that moves in (or out) during a single respiratory cycle is the **TIDAL VOLUME**
RESPIRATORY AIR VOLUMES AND CAPACITIES:

- even after forceful expiration, some air remains in the lungs (RESIDUAL VOLUME) ...why?
- so that lungs don’t collapse! (alveoli always stay partially inflated)
- prevents the $O_2$ and $CO_2$ levels from fluctuating greatly (“new” air always mixes with “old” air)
RESPIRATORY AIR VOLUMES AND CAPACITIES:

- the maximum amount of air a person can exhale after taking the deepest possible breath is the **VITAL CAPACITY**
TOTAL LUNG CAPACITY =

VITAL + RESIDUAL CAPACITY VOLUME

**all of these volumes/capacities vary with age, sex, and body size**
RESPIRATORY AIR VOLUMES AND CAPACITIES:

- **Inspiratory reserve volume**: amount of air that can be inhaled in addition to the resting tidal volume

- **Expiratory reserve volume**: amount of air that can be exhaled in addition to the resting tidal volume
Lung volume in milliliters (mL)

- Inspiratory reserve volume
- Tidal volume
- Residual volume
- Expiratory reserve volume
- Vital capacity
- Inspiratory capacity
- Total lung capacity
- Functional residual capacity

Adapted from: Shier D, Butler J. Lewis R. Hole’s human anatomy and physiology • 2004 • McGraw Hill : Boston, New York
NONRESPIRATORY MOVEMENTS: used to clear passageways, or to express emotion

• COUGH -
  -may be produced through conscious effort
  -may be triggered by the presence of a foreign object
  -clears the object from the lower respiratory tract
• SNEEZE -
  - clears the upper respiratory tract
  - a reflex triggered by a mild irritation in the lining of the nasal cavity
  - can propel a particle at 200 miles per hour!
• **LAUGHING** - involves taking a breath and releasing it in a series of short expirations

• **CRYING** - similar to laughing

• **HICCUP** - a sudden inspiration to a spasmodic contraction of the diaphragm

• **YAWN** - may aid respiration by providing an occasional deep breath