Gas Exchange in the Respiratory System
Breathing is made possible because in our respiratory system by two mechanisms:

1. Pressure Differences
2. Anatomical Structures
Pressure Differences

Pressure Differences between the atmosphere and the thoracic cavity determine the movement of air into and out of the lungs.

Air pressure remains relatively constant but the pressure within the chest cavity may vary.

*Gases always move from an area of high concentration to an area of low concentration*
The main structures that accommodate air flow within the thoracic cavity are the intercostal muscles, the rib cage and the diaphragm.

During Inspiration, the diaphragm muscle contracts, pulling downward.

This causes the chest volume to increase and the pressure in the lungs to decrease. Atmospheric pressure is now greater than the pressure in the lungs, and air moves into the lungs.
During Inspiration:

- Rib cage moves up and out.
- Diaphragm contracts and moves down.
- Pressure in lungs decreases, and air comes rushing in.
During expiration, the diaphragm relaxes and returns to its dome shape.

This causes the volume in the chest to decrease and the pressure inside the lung to increase.

Pressure inside the chest cavity is greater than the atmospheric pressure, and air moves out of the lungs.
During Expiration:

- Rib cage moves down and in.
- Diaphragm relaxes and moves up.
- Pressure in lungs increases, and air is pushed out.
Gas exchange within the lungs occurs by diffusion.

CO₂ will follow its concentration gradient into the alveolus and O₂ will follow its concentration gradient into the capillary.
Changes in chest volume during inspiration

**Expiration**
- trachea
- chest cavity
- diaphragm relaxes, muscle is dome shaped

**Inspiration**
- lungs
- diaphragm contracts, muscle flattens
The diaphragm, a dome-shaped sheet of muscle that separates the chest cavity from the abdominal cavity, regulates the pressure in the chest cavity. During inspiration, the diaphragm muscle contracts, or shortens, pulling downward. The chest volume increases and pressure in the lungs decreases. The atmospheric pressure is now greater than the pressure in the chest cavity, and air moves into the lungs. During expiration, the diaphragm relaxes and returns to its dome shape due to the force exerted by the organs in the abdomen. The chest volume decreases and pressure increases. The pressure in the chest cavity is now greater than the atmospheric pressure, and air moves out of the lungs. Have you ever found yourself gasping for air after receiving a blow to the solar plexus (the bottom of the rib cage)? The blow drives abdominal organs upward, causing the dome shape of the diaphragm to be exaggerated. Volume in the chest cavity is reduced, causing a large quantity of air to be expelled.

Think of the diaphragm as a piston. As the piston moves down, the volume in the chest cavity increases and pressure begins to fall—air is drawn into the lungs. As the piston moves up, the volume in the chest cavity decreases and pressure begins to increase—air is forced out of the lungs.

The diaphragm is assisted through the action of the intercostal muscles, which cause the ribs to move. Have you ever noticed how your ribs rise when you inhale? The ribs are hinged to the vertebral column, allowing them to move up and down. Bands of muscle, the external intercostal muscles, are found between the ribs. A nerve stimulus causes the external intercostal muscles to contract, pulling the ribs upward and outward. This increases the volume of the chest, lowers the pressure in the chest cavity, and air moves into the lungs. If the intercostals are not stimulated, the muscle relaxes and the rib cage falls. The fluids inside the pleural membrane push against the lungs with greater pressure, and air is forced out of the lungs. A second set of intercostals, the internal intercostal muscles, pulls the rib cage downward during times of extreme exercise or forced exhalation, such as blowing out a candle. The internal intercostal muscles are not employed during normal breathing.
Movement of Gases

Transportation of O₂ and CO₂ in the blood
How do GASES move through the blood???

GASES DIFFUSE FROM AN AREA OF HIGHER PRESSURE TO AN AREA OF LOWER PRESSURE!!
Therefore each gas in a mixture has its own pressure or partial pressure.

The partial pressure of oxygen is **highest** in the atmospheric air and **lowest** in the veins and tissues.

This allows for oxygen to move from the atmosphere, the area of highest partial pressure to the alveoli and into the blood.
Oxygen Transport

1. Dissolved in the Plasma

- This method is not very effective because oxygen is not very soluble in blood and is not enough for our body’s demands.
2. Attached to the protein HEMOGLOBIN

This is the main why oxygen travels in body!

- Hemoglobin is a protein found within red blood cell that contains 4 iron atoms per molecule. Hemoglobin greatly increases the oxygen-carrying capacity.

- Once oxygen dissolves in the plasma, hemoglobin forms a weak bond with the oxygen molecule to form OXYHEMOGLOBIN

\[
\text{O}_2 + \text{Hb} \rightarrow \text{HbO}_2
\]

\[
\text{Oxygen} + \text{Hemoglobin} \Rightarrow \text{Oxyhemoglobin}
\]
Blood now carries 20 mL of oxygen per 100 mL of blood as compared to 0.3 mL. The amount of oxygen that combines with hemoglobin is dependent on the partial pressure. The partial pressure in the lungs is 13.3 kPa, therefore blood leaving the lungs is saturated with oxygen. As blood enters the capillaries (at the tissue), the partial pressure drops to 5.3 kPa causing the dissociation or split of oxygen from the hemoglobin and oxygen then diffuses into the tissues.
Carbon Dioxide Transport

There are 3 ways in which carbon dioxide is transported in the blood:
1. Dissolved in Plasma

Carbon dioxide is much more soluble in blood than oxygen.

About 9% of carbon dioxide is transported unchanged, simply dissolved in the plasma.
2. Bound to Hemoglobin

Carbon dioxide attaches to hemoglobin to form carbaminohemoglobin.

Carbon dioxide does not bind to iron, as oxygen does, but to amino groups on the polypeptide chains of hemoglobin.

About 27% of carbon dioxide is transported bound to hemoglobin and plasma proteins

\[ CO_2 + Hb \Rightarrow HbCO_2 \ (carbaminohemoglobin) \]
3. Bicarbonate Ions (HCO$_3^-$)

The majority of carbon dioxide is transported in this way.

Carbon dioxide enters red blood cells in the tissue capillaries where it combines with water to form carbonic acid (H$_2$CO$_3$).
The rapid conversion of free carbon dioxide into carbonic acid causes a decrease in the concentration of CO2 in the plasma, therefore CO2 continues to diffuse from the tissue into the blood. (keeps the appropriate concentration gradient)
Blood capillary → Lung

- $\text{HCO}_3^-$ → $\text{H}^+$ + $\text{CO}_2$ + $\text{H}_2\text{O}$
- $\text{HCO}_3^-$ + $\text{H}^+$ → $\text{H}_2\text{CO}_3$
- $\text{H}_2\text{CO}_3$ → Carbonic anhydrase
- $\text{Cl}^-$
- $\text{CO}_2$
Respiratory Disorders

~ Section 8.4 ~
1. Asthma

Contraction of the smooth muscle of the bronchial that surrounds the airways

Makes breathing more difficult

Thought to be partly an allergic reaction

Treated with bronchodilators (medication usually taken with a puffer to target constricted airways)
2. Bronchitis

Inflammation of the bronchial lining causing patient to cough frequently

Overproduction of mucous in bronchial tubes.

This increased production of mucous blocks smaller airways, reduces respiratory efficiency and causes discomfort when breathing.

Treated with bronchodilators
associated with long term bronchitis.

decreased diameter in the bronchioles creates resistance to the movement of air out of the lungs and thus air pressure builds up in the lungs.

the alveoli are unable to support this high pressure and then stretch and eventually rupture.

fewer alveoli means there is less surface area for gas exchange.

causes increased breathing rate and heart rate.
Homework

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Take Notes on Tonsillitis, Laryngitis, & Pneumonia (page 455-459)