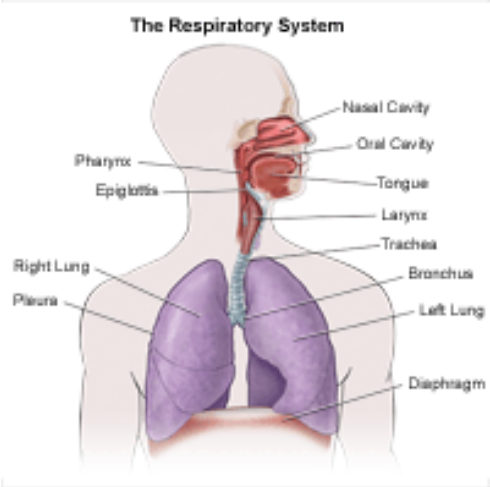
The Respiratory System

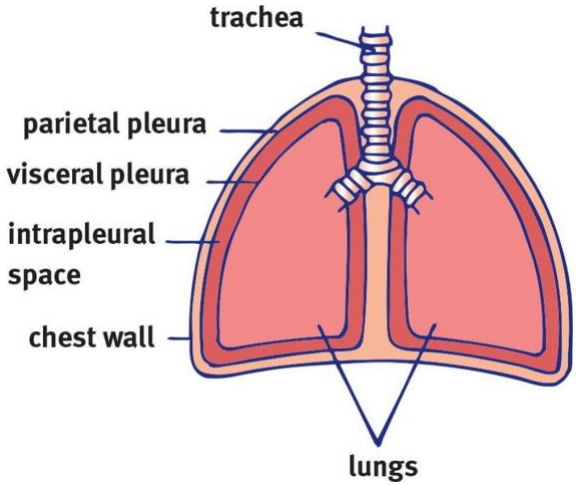
Anatomy and Mechanism of Breathing

Lungs are located in the **thoracic cavity**.

Anatomy

- Gas exchange occurs in the lungs. This gas (Air) is brought in through the external **nares** (nostrils) and then pass through the nasal cavity in which they are filtered by a mucous membrane and nasal hairs (**vibrissae**)
- Air then passes through the **pharynx**. This structure lies near the nasal cavity at the back of the mouth. It is a common location for both food and air.
- **Larynx** lies below the pharynx and is only for air. Has an opening called the **glottis** that is covered by an **epiglottis** during swallowing in order to prevent food from entering.
    - Contains two **vocal cords**
- Air then passes to the **trachea** and then into one of the two **bronchi**.
    - These contain ciliated epithelial cells to catch materials that made it past the membrane.
- The lungs are now reached, and the bronchi differentiate into smaller **bronchioles**, which divide further into tiny balloon like structures called **alveoli**. This is the location of gas exchange
    - Each Alveoli is coated with **surfactant** which is a detergent that lowers surface tensions and prevents them from collapsing.
    - Each Alveolus is surrounded by a network of capillaries to carry O_2 & CO_2.
    - Branching and small size allow for a large surface area ~100 m^2.
- Each lung is surrounded by a membrane known as **pleurae**. This forms a closed sac which the lung expands against
    - Parietal pleura is the outer part and the visceral pleura is the surface next to the lung
- **Diaphragm** is a thin muscle between the thoracic cavity and the abdominal cavity, and it is the main muscle responsible for producing the negative pressures within the lung.
    - Additional muscles in the chest wall, back and neck may also help
    - Under somatic control, but breathing itself is under autonomic control





Breathing

The **intrapleural space** is the space between the visceral pleura and the parietal pleura. This space contains a thin layer of fluid and helps to lubricate the two surfaces. The pressure difference that drives breathing is created across this space.

Inhalation

- Diaphragm + **external intercostal muscles** are used to expand the thoracic cavity. This increases the **intrathoracic volume** (volume of chest cavity) increases.
- Intrapleural space has its volume increase first since it is closest to the chest cavity. This causes a decrease in pressure.
- The lungs then expand into the intrapleural space and air will then be sucked in from the higher atmospheric pressure environment. This is called **negative pressure breathing**.

Exhalation

- Does not have to be an active process such as inhalation. Just needs the simple relaxation of the external intercostal muscles and diaphragm.
- Pressure will increase in intrapleural space and this will cause the air in the lungs to be pushed out by the higher pressures.
- **Internal Intercostal Muscles** and abdominal muscles can be used to make exhalation an active process.
- Surfactant prevents the complete collapse of alveoli during exhalation by lowering the surface tension.
- Lungs connection to the chest wall prevents the lungs from collapsing on recoil.

Lung Capacity and Volumes

A spirometer is a measurement tool used to test the capacities of the lung.

- Total Lung Capacity (TLC): Max volume of air in the lungs when one inhales completely
- Residual Volume (RV): Min volume of air in the lung when one exhales completely
- Vital Capacity (VC): Diff between the min and max volume of air in the lungs (TLC – RV)
- Tidal Volume: volume of air inhaled or exhaled in a normal breath
- Expiratory Reserve Volume (ERV): volume of additional air that can be forcibly exhaled after a normal exhalation
- Inspiratory Reserve Volume (IRV): Volume of additional air that can be forcibly inhaled after a normal inhalation.

Regulation of Breathing

- Ventilation is regulated by a collection of neurons in the medulla oblongata called the **ventilation center**.
    - These neurons fire rhythmically to cause regular contraction of resp muscles.
    - Neurons contain **chemoreceptors** that are sensitive to CO_2.
        - As CO_2 increases, respiratory rate increases to expel more gas.
        - Sometimes respond to changes in oxygen concentration, but only during periods of significant **hypoxemia**.
    - Have some voluntary control over breathing with our cerebrum, but overall the medulla oblongata can override it.

Functions of the Respiratory System

Gas Exchange

- Primary function of the lungs. Capillaries bring deoxygenated blood from the **pulmonary arteries** (from right ventricle of heart) to the alveoli.
- Alveoli have very thin walls which help in the facilitation of diffusion. Oxygen goes into the capillaries while carbon dioxide goes into the lungs. The oxygenated blood is then carried back to the heart through the **pulmonary veins**
- Driving force of this gas exchange is the pressure differential between the gases.

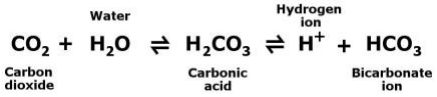
Thermoregulation

- Since the respiratory tract is highly vascularized and has a large surface area, it can be used in thermoregulation.
- The capillaries within the nasal and tracheal capillary beds are frequently **vasodilated** (allows larger amount of heat to escape through large blood flow rate) or **vasoconstricted** (conserves thermal energy).
- Can also transfer heat to the environment by evaporating water in mucous secretions. This mechanism is taken advantage of by dogs through panting.

Immune Function

- Large area provides ample room for pathogens such as bacteria, viruses, and fungi to infect the lungs. Additionally, can gain easy access to rest of the body due to high vascularity of the lungs.
- First line of defense is within the nasal cavity: small hairs (vibrissae) help trap particulate matter and potentially infectious matter. Also contains the enzyme ***lysozyme***, which is able to attack the peptidoglycan walls of gram-positive bacteria.
- Mucociliary Escalator: Internal airways are lined with mucus, which can further trap foreign invaders. Cilia lining the walls then propels the particulate matter up into the oral cavity for expulsion.
- Also contain many immune cells. Especially in the alveoli
    - **Macrophages** engulf bacteria and digest pathogens and signal the rest of the immune system on a potential invasion.
    - **IgA antibodies** are also found on mucosal surfaces to protect against pathogens
    - **Mast Cells** have preformed anti-bodies on their surfaces. If cell attaches to the antibody, the mast cell releases inflammatory chemicals in order to promote an immune response. Also the cause of a lot of allergies since they are sensitive to molds and pollen

Control of pH



- Body always attempts to maintain a pH between 7.35-7.45. A lower pH indicates higher H+ concentration (academia). Acid-sensing chemoreceptors (just outside the blood-brain barrier) send signals to the brain to increase the respiratory rate. Additionally, the buffer system will shift to create more carbon dioxide which will also promote an increase in respiratory rate.

- Increased respiration rate causes the buffer system to shift even more to the left through expulsion of carbon dioxide.
- If blood is too basic (**alkalemia**), respiration rate is slowed which results in higher concentration of carbon dioxide in the blood, which will shift the buffer system to the right.