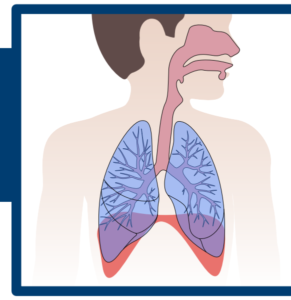
PULMO PARK
Lesson 3: *Respiratory Exploratory – Diving Deeper*



TEXAS BIOMEDICAL RESEARCH INSTITUTE
HEALTH STARTS WITH SCIENCE

Objectives:

The Student Will Be Able To:

1. Analyze how particulates affect the respiratory and ultimately, other body systems.
2. Apply the nature of science principles to experimental procedures.
3. Generate hypotheses from observations.
4. Design experiments guided by hypotheses.
5. Create models from which to draw inferences.
6. Describe general chemical processes which impact the respiratory system.
7. Compare diffusion and osmosis as related to the respiratory system.
8. Discuss the inter-related nature of body systems.

Lesson Support Information

This lesson engages students with hands-on activities to discover basic principles of science, including observations, hypotheses based on observations, data collection and analysis, and model creation. These important Nature of Science (NOS) process skills are important for students to apply to all science lessons. Respiratory Exploratory – Diving Deeper is designed to explore the mechanics of the respiratory system with engaging labs which provide the flexibility to be completed individually or in groups. The "Processing Out" for each lab engages students in critical thinking as they make connections between the lab activity and the optimal functioning of the respiratory system through the application of NOS skills. Vocabulary terms are italicized in all Student Background information.

Dust & Us: Particulates in the Air

The health of our lungs is impacted by particulates suspended in the air. These particulates include pollutants, pollen, dirt/dust, and pathogens such as bacteria and viruses. Our respiratory system has developed protective mechanisms against particulates, such as fine hair within the nasal passage. These hairs trap particulates which cause an increase in mucus production. Particulates and pathogens cling to the mucus and are expelled through sneezes. Particulates and pathogens which pass through the nasal passage are generally trapped by mucus. In the upper portion of the throat are specialized lymph node cells commonly called adenoids and tonsils. These specialized cells are part of the immune system and absorb particulates and pathogens to be destroyed by specialized immune cells. Despite the body's defenses, particulates and pathogens can make their way deeper into the throat. When we swallow, the epiglottis closes and the mucus carrying particulates and pathogens are swallowed and transported to the stomach. The stomach produces hydrochloric acid (HCl). The HCl acid has a pH between 1.5 and 3, which makes it a strong acid. Particulates and pathogens are destroyed by HCl and any remnants pass through the body. However, sometimes particulates and pathogens make their way into the lungs.

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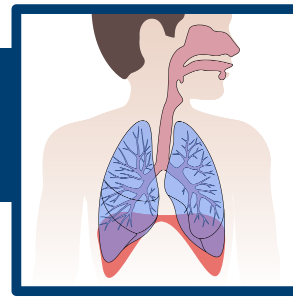


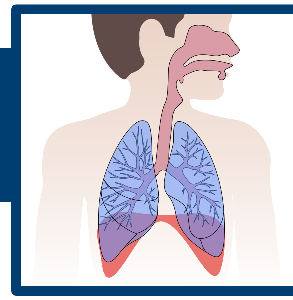
The lungs have additional defense mechanisms. The bronchi and smaller branches of the bronchioles are lined with cilia. Cilia are finger-like projections of tissue coated in mucus. Cilia are coated in mucus which traps particulates and pathogens. To rid the body of these intruders, we cough. A "productive cough" is the body's mechanism to eliminate particulates and pathogens from the lung. Particulates and pathogens can irritate the tissue which lines the bronchi and bronchioles. This further activates the body's immune system. Fluid containing specialized immune cells [*lymphocytes* (B and T), *macrophages*, *neutrophils*, *eosinophils*, *basophilic*, and *mast cells*], each with a specialized function and response. These cells are released into the *interstitial fluid* and blood stream to surround particulates and to neutralize pathogens. When the immune system is overwhelmed by particulates or pathogens in the lungs ability to take in sufficient oxygen is decreased resulting in a build-up of carbon dioxide throughout the body. With high levels of carbon dioxide and low levels of oxygen, body cells build up toxic levels of CO_2. Metabolic processes stop and the cells begin to die.

Branching Out

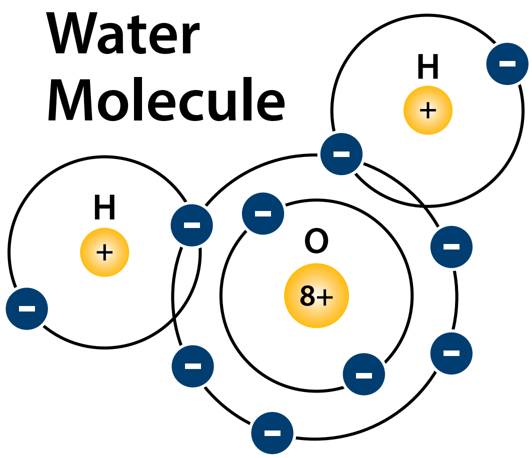
As air moves into and through the lungs, it travels through increasingly smaller tubes (bronchi ⟶ bronchiole) until the air makes it way to the sac-like alveoli. Frequently referred to as the pulmonary tree, the branching structure within the lungs actually increases the efficiency of the lungs by increasing the surface area available for gas exchange. Although increased surface area within the lung benefits gas exchange, it also increases the areas to which pollutants and pathogens can attach. In other words, the structure which optimizes our ability to breath also increases risk of exposure to pollutants and disease. Just as tree branches sway and move when the wind blows, the branches within the lungs also exhibit a type of movement. The spongy lung tissue which surrounds the bronchi and bronchioles is called the ***parenchyma*** (pa-RENK-ah-ma). The parenchyma holds the bronchi and bronchioles in place which limits movement of the bronchi and bronchioles. Rather than swaying, the parenchyma limits movement of the pulmonary tree, allowing only expansion and contraction of the tubes. Diseases, such as asthma cause the bronchi and bronchioles to contract too much which distorts the parenchyma. During an asthma attack, teh constricting tubes pull the parenchyma inward which increases the pressure insde the bronchi and bronchioles. It is this distortion which contributes to feeling a tightness in the chest and difficulty breathing. Similar tightness can be felt when the lungs are exposed to pollutants like smog (surface ozone, O_3) or if pathogens have made their way past the lungs' defenses.

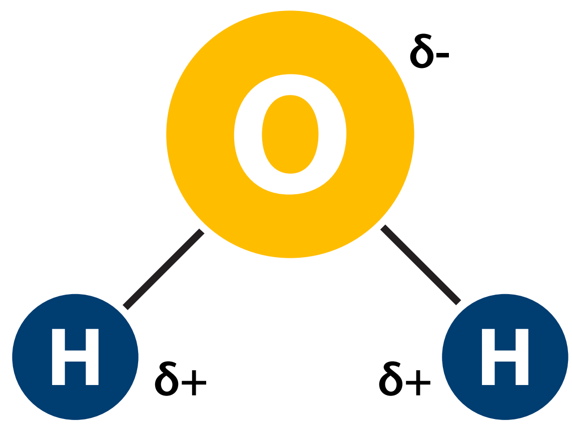
Exchange It!

The circulatory system is a transport system, carrying O_2 and nutrients to body organs and cells while transporting metabolic waste products, like CO_2, to the lungs. Blood is a complex solution. In addition to O_2, CO_2, and nutrients, blood also contains red blood cells, white blood cells (part of the immune system), and plasma. Plasma is the liquid component of the blood which allows it to flow through the body. Plasma is 90% water with the other 10% being made of electrolytes to maintain pH levels, hormones, vitamins, enzymes, and coagulates (platelets) for blood clotting.

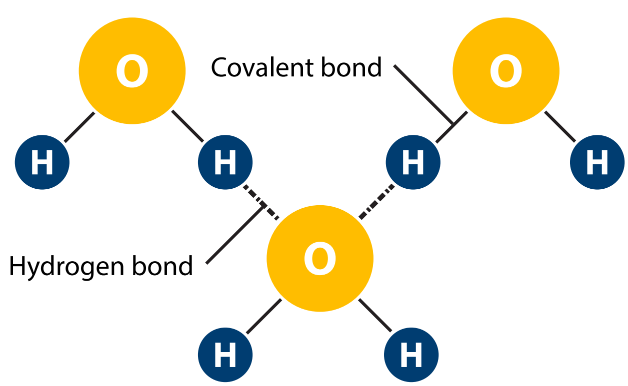


In other words, our blood is about 90% water, which is important for processes like diffusion. But water has unique properties. The water molecule consists of 2 hydrogen atoms bonded to 1 oxygen atom (H_2O). The oxygen atom contains 6 outer electrons, but atoms are only stable when there are 8 outer electrons. As a result, oxygen atoms seek out other atoms that can share electrons. This imbalance of outer electrons means an oxygen atom has a slight negative charge (O^{-2}) because of the missing 2 electrons. Hydrogen, the smallest of atoms has 1 outer electron, making it have a slightly positive charge (H^{+1}). The slightly negative charge of an oxygen atom attracts the slightly positively charged hydrogen atoms. Since oxygen needs 2 electrons, it attracts 2 hydrogen atoms.





The oxygen and hydrogen share electrons, called a covalent bond. But it is not an equal sharing. Oxygen atoms are bigger than hydrogen atoms. Very simply, think of oxygen as a "bully" who keeps hydrogen's single electron. As a result, the water molecule is "polar", meaning the molecule has an unequal distribution of charge. The oxygen atom pulls the electrons away from the hydrogen atoms resulting in the oxygen atom having a partial negative charge (-δ) and each hydrogen atom has a partial positive charge (+δ).



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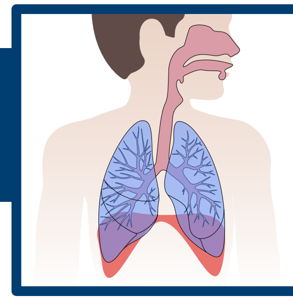


As already discussed, opposites attract. When multiple water molecules are together, individual molecules attract other water molecules. The partial positive charge on each hydrogen is weakly attracted to the positive oxygen of neighboring water molecules. This weak bond is called "hydrogen bonding". Think about when drinking a soda through a straw. Soda is mostly water. When drinking through a straw, the pressure inside your mouth is lower than the atmospheric pressure. The liquid travels up the straw to equalize the pressure. It is hydrogen bonding that helps the liquid move up the straw. Each hydrogen bond pulls the adjacent water molecules, moving the liquid up the straw. Another example is a water droplet. When a drop of water falls, it forms a rounded structure. This is caused by hydrogen bonds pulling adjacent water molecules together, creating surface tension.

Confusion About Diffusion

Two terms which are frequently used interchangeably are osmosis and diffusion. Although both terms related to equalizing concentration, they are not the same. When conducting this experiment, consider the following definitions for each term:

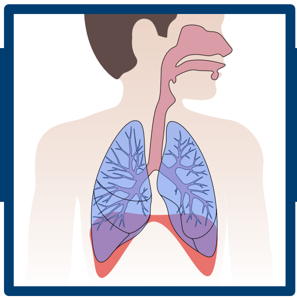
Osmosis: the movement of ***solvent*** particles across a semipermeable membrane from a dilute solution into a concentrated solution. The solvent moves to dilute the concentrated solution and equalize concentration on both sides of the membrane.

Diffusion: the ***movement of particles*** from an area of higher concentration to lower concentration. The overall effect is to equalize concentration throughout the medium.

Think about how these terms are similar and different. Both processes take place within the body. When discussing osmosis, it involves the movement of solvent particles. Water is commonly referred to as the "universal solvent" as it breaks apart many materials. Water even breaks apart or erodes rock! The majestic Grand Canyon in Arizona was formed by river water eroding the rocks in the river bed and the rocks along the shore. At one mile deep, the Grand Canyon continues to get deeper as the river continues to erode the river bed and canyon walls.

Internally, our bodies are designed to function best under specific conditions referred to as ***homeostasis*** (ho-me-oh-STAY-sus). Homeostasis is a relatively stable type of equilibrium which is attained through osmosis and diffusion. However, equilibrium can be disrupted by many factors including environmental conditions or illness. As a result, solvents (osmosis) and molecules (diffusion) continually move to counter-act conditions which upset equilibrium. In order to maintain optimal conditions inside our body, osmotic and diffusion processes are nearly continuous, resulting in ***dynamic equilibrium***.

Osmosis involves a solution which consists of a solvent and solute(s): the solvent dissolves the solute(s). In a glass of sugar water, the solvent is water and the solute would be the sugar (what is dissolved). Other terms



often associated with osmosis are semi-permeable membrane and isotonic, hypotonic, and hypertonic solutions. A semi-permeable membrane acts as a filter, allowing some molecules, ions, and particulates to pass through while others are too big to pass through the membrane.

The terms hypertonic, hypotonic and isotonic compare concentrations of solute on either side of a semi-permeable membrane. Hypertonic solutions have a higher concentration of solute while a hypotonic solution has a lower concentration of solute. An isotonic solution has equal concentrations of the solute on either side of the semi-permeable membrane.