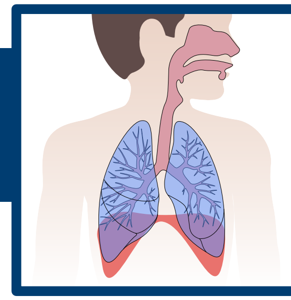
Teacher Background

PULMO PARK

Lesson 2: *Respiratory Exploratory*



Objectives:

The Student Will Be Able To:

1. Explain the basic mechanics of the respiratory system.
2. Describe the benefits of a passive respiratory system.
3. Demonstrate a variety of data collection methods.
4. Generate hypotheses from observations.
5. Create models from which to draw inferences about the respiratory system.
6. Discuss the inter-related nature of body systems.

Lesson Support Information

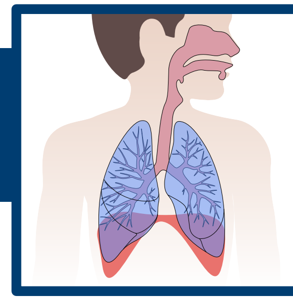
Using the respiratory system, this lesson engages students with hands-on activities to discover basic principles of science, including observations, hypotheses based on observations, data collection and analysis, and model creation. These Nature of Science (NOS) principles are important skills students can apply to this and future lessons.

This lesson is designed to explore the mechanics of the respiratory system with short, engaging labs which can be done individually or in groups. These labs can be completed at desks or in the lab and are designed to spark discussions about the respiratory system. The "Processing Out" for each lab engages students in critical thinking as they make connections between the lab and the mechanics of breathing.

Expansion, Pressure, and Tension – Oh! My!

Breathing is a passive process resulting from a pressure difference between the lungs and the atmosphere. Inhaling (inspiration) expands the thoracic cavity which creates a negative pressure (a decrease in pressure) within the lungs. In other words, the pressure inside the lungs is less than the pressure outside of the body. Air naturally moves from an area of higher pressure into an area of lower pressure until the pressures are equalized. When the air pressure inside the lungs is equal to the air pressure outside the body, inspiration stops.

Because lungs have elastic properties, they expand during inspiration. But just like a stretched rubber band, there is a limit to how far the lungs can expand. When a stretched rubber band is released, it returns to the original size and shape. Just like the rubber band, when the lungs approach their expansion limit, their elastic properties pull them back. As the lungs contract, the air inside has less room, forcing the air molecules together. When gases are forced together, the pressure increases, resulting a higher pressure inside the lungs.



The air inside the lungs moves out of the body into the now lower external pressure. As the air flows out of the body, this is called exhaling or exhalation.

Keep in mind the air pressure outside the body has not changed. Only the air pressure inside the lungs changes. The changes in air pressure within the thoracic cavity is largely due to the movement of the diaphragm. This large, flat muscle separates the thoracic cavity from the abdominal cavity. As the diaphragm contracts and moves downward toward the abdomen. This expands the thoracic cavity and air flows into the lungs through the nose and/or mouth. When the diaphragm relaxes, it moves upward, forcing the thoracic cavity to get smaller which works with the contracting lungs to force lung gases closer together which increases the pressure in the lungs. The body takes advantage of pressure changes to passively move air in and out of the body. This greatly reduces the amount of energy the body uses to breathe.

The Mechanics of Breathing

With every breath, we take in oxygen-rich air through our nose and mouth. Air is a mixture of different gases. Approximately 20% of this mixture of gases is O_2. When we inhale, air enters the lungs. Once in the lungs, the air moves through a series of smaller and smaller passages until the air enters the alveoli. The alveoli are surrounded by tiny, tubular blood vessels called capillaries. Oxygen diffuses (passes through from an area of high concentration to low concentration) from the alveoli and enters the circulatory system (bloodstream) where oxygen levels are low. Once in the circulatory system, O_2 binds to proteins of the red blood cells and moves through the pulmonary veins which lead to the heart. The heart pumps the oxygenated blood to the body through a series of blood vessels, starting with large arteries which branch into smaller arterioles.

The arterioles branch into even small capillaries. Capillaries are very thin – the wall of this smallest of blood vessels is only one cell thick. Once in the capillaries, the oxygenated red blood cells come in close contact with the body's cells. Cellular respiration (a metabolic process that takes place inside cells; a chemical reaction between oxygen and nutrients to generate energy) depletes oxygen and releases carbon dioxide (CO_2). Oxygen diffuses out of the capillaries and through the body cell membranes. At the same time, CO_2, which has a high concentration inside the cells diffuses into the capillaries where CO_2 levels are low. The blood is now oxygen-poor. The capillaries transport the oxygen-poor blood into larger venules. Venules connect to even larger veins which connect to the heart. The heart pumps the oxygen-poor blood into the pulmonary arteries which carry the blood to the lungs. Again, the blood passes through arterioles into capillaries which form a net around the alveoli. Differences in concentration levels of CO_2 in the blood and O_2 in the alveoli, called a "concentration gradient" results in diffusion, with CO_2 and O_2 moving across cell membranes. The CO_2 is expelled from the body through exhalation and the O_2 moves into the bloodstream and the process repeats.

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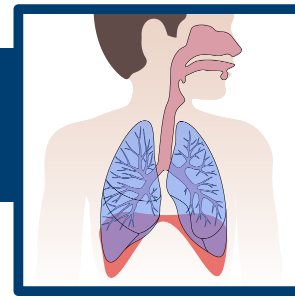
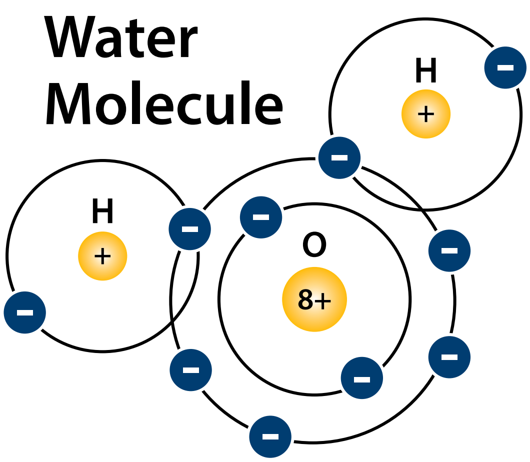
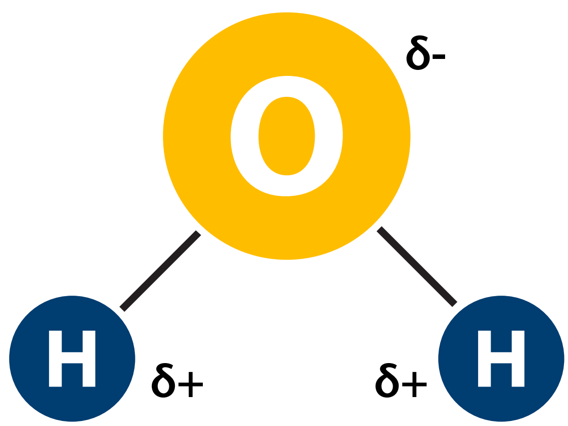


Surface Tension

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 (-2) because of the missing 2 electrons. Hydrogen, the smallest of atoms has 1 outer electron, making it have a slightly positive charge (+1). The slightly negative charge of an oxygen atom attracts the slightly positively charged hydrogen atoms. Since oxygen needs 2 electrons, it can attract 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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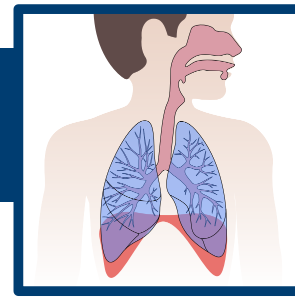
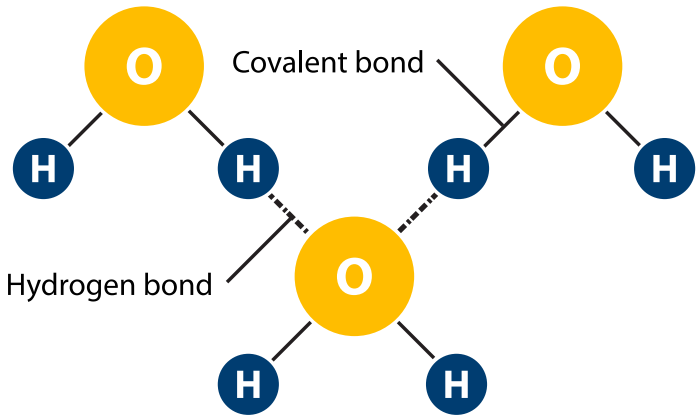
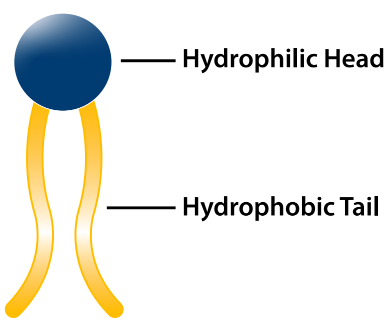




As already discussed, opposites attract. When multiple water molecules are together, individual molecules attract other water molecules. The partial positive charge on each hydrogen is weaking attracted to the positive oxygen of neighboring water molecules. This weak bond is called "hydrogen bonding". 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. It is hydrogen bonding that helps the liquid move up the straw. Each hydrogen bond pulls the adjacent water molecules up, too. Another example is creating a water droplet. When a drop of water falls, it forms a rounded structure. This is caused by hydrogen bonds pulling water molecules together, creating surface tension.



Surface tension is great for drinking from a straw, but can cause issues inside the body. The hydrogen bonds could cause the alveoli to collapse in on themselves, like a deflated balloon. When alveoli collapse, gas exchange does not happen. The body cells keep producing the waste product CO_2 but do not receive the necessary O_2. In other words, the cells "suffocate". To prevent alveolar collapse, the lungs have specialized cells which produce a "surfactant". The surfactant is a specialized phospholipid which has a hydrophilic end (loves water) and a hydrophobic end (repels water). The hydrophobic end disrupts hydrogen bonds which reduces the surface tension and keeps the alveoli inflated.