

Diffusion: Allowing Earthworms to Breathe

The segmented, wriggly worms we know as earthworms are part of the phylum Annelida. More than 5,500 named species can be found all over the world, with the exception of polar and arid climates. While earthworms vary greatly from other living organisms, certain shared characteristics give them the ability to perform necessary functions of life, such as breathing. All living organisms – from earthworms to humans – are made up of cells. We can look at the make-up of a cell and the scientific process of diffusion to better understand how an earthworm is able to breathe.

While specialized organisms have a variety of cells with differing functions, one structure common among all cells is the cell membrane. This plasma membrane forms a boundary around most cells and acts as a regulator of what enters and exits the cell. The structure of the cell membrane is extremely important. Composed primarily of phospholipid and protein molecules, the membrane is able to control what can pass through it. A phospholipid is a charged molecule made up of two fatty acids, glycerol and a phosphate group. This composition makes a unique molecule; the phosphate group “head” is polar (hydrophilic), while the two fatty acids make up the non-polar (hydrophobic) tails. The molecules arrange themselves with the hydrophilic heads facing outward and the hydrophobic tails creating the inner portion of the membrane. Proteins are often found inside the membrane itself or on the membrane’s surface. Like all molecules, the molecules that make up the plasma membrane are in constant, random motion.

Why is the make-up of the membrane important? The membrane is semi-permeable, which means certain small, non-polar molecules can pass through it. Because the membrane’s molecules are in constant motion, temporary openings are formed that allow small molecules to cross from one side of the membrane to the other. The constant motion of molecules and the unequal concentration of molecules inside and outside of a cell contribute to the movement of molecules across the membrane. The materials inside of the cell also contribute to a concentration gradient between the cell and its environment. Inside the cell is cytosol (composed of mostly water), cell organelles and a number of compounds such as carbohydrates, proteins and salts, as well as other

molecules. Molecules naturally move “down the concentration gradient” – in other words, they will move from an area with a higher concentration to an area with a lower concentration. This process is known as diffusion.

Oxygen is an example of a small, non-polar and lipid soluble molecule that can pass through the cell’s plasma membrane. Oxygen is small enough to pass through the membrane without any facilitation by proteins, it is non-polar and it is able to dissolve in the inner lipid layer. Earthworms – as well as most living things – are constantly using oxygen for chemical reactions within their cells. These chemical processes include cellular respiration and energy production. Therefore, the concentration of oxygen within the cell stays low compared to the concentration of oxygen outside of the cell. The oxygen molecules diffuse from the outside environment into the cell. Once inside, they diffuse into red blood cells, and then diffuse out from the red blood cells into the areas where the concentration of oxygen is lowest.

In contrast, cells create more carbon dioxide than is in the environment, so there is a higher concentration of carbon dioxide inside the cell as compared to the outside environment. The carbon dioxide molecules diffuse from inside the cell to the outside environment.

This gas exchange is vital to an earthworm’s ability to live. Earthworms do not have specialized respiratory organs like we do; instead, they take in oxygen and expel carbon dioxide directly through their skin. Oxygen diffuses through the earthworm’s body surface and diffuses inward to the network of capillaries lying just under the body surface. The oxygen is consumed by body cells as the blood – specifically, the hemoglobin within red blood cells – circulates. In contrast, carbon dioxide is picked up by the blood and diffuses out into the air through the body surface.

In order for this simple diffusion of gases to sustain an earthworm, several things are required. First, the effective region must be moist, thin and large in relation to the size of the body. An earthworm’s tubular shape satisfies this requirement; it provides the necessary large surface area-to-volume ratio. Earthworms must keep their skin moist to absorb oxygen and give off carbon dioxide; they satisfy this requirement in two ways. The earthworm’s skin is kept moist by a slimy mucus produced by epithelial cells. This mucus also helps to trap and dissolve oxygen from the air. The skin is also kept wet by

body fluid that is excreted through pores between the body segments. Earthworms also keep their skin moist through their behavior. While the air provides a rich source of oxygen for the earthworm, it also can dry out the respiratory surface (skin). If this happens, the worm will die because the exchange of gases cannot take place. Earthworms are behaviorally adapted to stay in moist soil during the day. In dry weather, the earthworm will burrow deeper into the soil to avoid desiccation.

Yet too much moisture is also dangerous to the earthworm. Earthworms get oxygen from the oxygen in the soil; a heavy rainfall can lead to water taking the place of the valuable oxygen in the soil. If the soil is saturated, the earthworm cannot expel carbon dioxide, nor can it take in oxygen. This is one reason why earthworms often crawl to the soil surface after a heavy storm. Some scientists suggest earthworms might use the moist surface to travel more quickly than they can underground, reaching new areas to colonize. Also, if an earthworm is kept in water for too long, the concentration of ammonia discharged in its waste might make the water too toxic for it to survive. Though the earthworms cannot control the amount of water in the environment, they are able to adapt behaviorally to adjust for times of too little or too much moisture.

It is important to recognize that the process of diffusion that allows earthworms to breathe in oxygen and dispel carbon dioxide directly through its skin is a passive process; the earthworm cannot control the rate of diffusion nor can it control its environment. Organisms that use diffusion for the necessary exchange of gases are often limited to a certain surface area-to-volume ratio; earthworms have a closed circulatory system made of a network of blood vessels that aid them in transporting oxygen to various parts of their bodies. Also, respiration by diffusion through the body surface requires a moist environment. An earthworm's habitat and behavior is influenced by its need for a moist skin. The simple process of diffusion brings an earthworm both the necessary ability to breathe and expel waste but also some accompanying limitations.

References

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