Respiratory Systems
In Lower Animals and Plants

All living things obtain the energy they need by metabolizing energy-rich compounds, such as carbohydrates and fats. In the majority of organisms, this metabolism takes place by respiration, a process that requires oxygen. In the process, carbon dioxide gas is produced and must be removed from the body.

In plant cells, carbon dioxide may appear to be a waste product of respiration too, but because it is used in photosynthesis, carbon dioxide may be considered a byproduct. Carbon dioxide must be available to plant cells, and oxygen gas must be removed. Gas exchange is thus an essential process in energy metabolism, and gas exchange is an essential prerequisite to life, because where energy is lacking, life cannot continue.

The basic mechanism of gas exchange is diffusion across a moist membrane. Diffusion is the movement of molecules from a region of greater concentration to a region of lesser concentration, in the direction following the concentration gradient. In living systems, the molecules move across cell membranes, which are continuously moistened by fluid.

Simple organisms

Single-celled organisms, such as bacteria and protozoa, are in constant contact with their external environment. Gas exchange occurs by diffusion across their membranes. Even in simple multicellular organisms, such as green algae, their cells may be close to the environment, and gas exchange can occur easily.

In larger organisms, adaptations bring the environment closer to the cells. Liverworts, for instance, have numerous air chambers in the internal environment. The sponge and hydra have water-filled central cavities, and planaria have branches of their gastrovascular cavity that connect with all parts of the body.

Plants

Although plants are complex organisms, they exchange their gases with the environment in a rather straightforward way. In aquatic plants, water passes among the tissues and provides the medium for gas exchange. In terrestrial plants, air enters the tissues, and the gases diffuse into the moisture bathing the internal cells.

In the leaf of the plant, an abundant supply of carbon dioxide must be present, and oxygen from photosynthesis must be removed. Gases do not pass through the cuticle of the leaf; they pass through pores called **stomata** in the cuticle and epidermis. Stomata are abundant on the lower surface of the leaf, and they normally open during the day when the rate of photosynthesis is highest. Physiological changes in the surrounding guard cells account for the opening and closing of the stomata.

Animals

In animals, gas exchange follows the same general pattern as in plants. Oxygen and carbon dioxide move by diffusion across moist membranes. In simple animals, the exchange occurs directly with the environment. But with complex animals, such a mammals, the exchange occurs between the environment and the blood. The blood then carries oxygen to deeply embedded cells and transports carbon dioxide out to where it can be removed from the body.

Earthworms exchange oxygen and carbon dioxide directly through their skin. The oxygen diffuses into tiny blood vessels in the skin surface, where it combines with the red pigment hemoglobin**.** Hemoglobin binds loosely to oxygen and carries it through the animal's bloodstream. Carbon dioxide is transported back to the skin by the hemoglobin.

Terrestrial arthropods have a series of openings called spiracles at the body surface. Spiracles open into tiny air tubes called tracheae, which expand into fine branches that extend into all parts of the arthropod body.

Fishes use outward extensions of their body surface called gills for gas exchange. Gills are flaps of tissue richly supplied with blood vessels. As a fish swims, it draws water into its mouth and across the gills. Oxygen diffuses out of the water into the blood vessels of the gill, while carbon dioxide leaves the blood vessels and enters the water passing by the gills.

Terrestrial vertebrates such as amphibians, reptiles, birds, and mammals have well-developed respiratory systems with lungs. Frogs swallow air into their lungs, where oxygen diffuses into the blood to join with hemoglobin in the red blood cells. Amphibians can also exchange gases through their skin. Reptiles have folded lungs to provide increased surface area for gas exchange. Rib muscles assist lung expansion and protect the lungs from injury.

Birds have large air spaces called *air sacs* in their lungs. When a bird inhales, its rib cage spreads apart and a partial vacuum is created in the lungs. Air rushes into the lungs and then into the air sacs where most of the gas exchange occurs. This system is the birds' adaptation to the rigors of flight and their extensive metabolic demands.

The lungs of mammals are divided into millions of microscopic air sacs called alveoli**.** Each alveolus is surrounded by a rich network of blood vessels for transporting gases. In addition, mammals have a dome-shaped diaphragm that separates the thorax from the abdomen, providing a separate chest cavity for breathing and pumping blood. During inhalation, the diaphragm contracts and flattens to create a partial vacuum in the lungs. The lungs fill with air, and gas exchange follows.