Plants Must Carry On Gas Exchange

We have seen that in green plants the intake of carbon dioxide for photosynthesis and the release of oxygen occurs across the membranes of the cells of the mesophyll. It is a common misconception that gas exchange in green plants consists exclusively in this exchange of gases. Carbon dioxide is not, however, the only gas needed by plant cells—oxygen is necessary as well. Recall that when nutrient compounds are broken down during respiration, over 90 percent of the energy yield depends on the presence of oxygen, which makes possible the complete oxidation of the compounds to carbon dioxide and water and the production of large amounts of ATP. Thus, all living cells in plants are constantly taking in oxygen and releasing carbon dioxide as cellular respiration occurs. When a green plant is exposed to bright light, both photosynthetic and respiratory gas exchange are usually taking place in the leaves. However, since the rate of photosynthesis exceeds the rate of respiration during the day, there is a net uptake of carbon dioxide and release of oxygen. The reverse is true, of course, in the nonphotosynthetic parts of the plant or when the green plant is in the dark. ***Respiratory gas exchange is a requirement for plants as much as it is for animals.***

Gas Exchange Occurs by Diffusion Across a Moist Cell Membrane

Gas exchange between a living cell and its environment always takes place by diffusion across a cell membrane. No active transport or facilitated diffusion is involved. Furthermore, the gases must first dissolve in the film of water that coats the cells if they are to diffuse through the membrane. In photosynthetic protists and many small nonvascular plants, particularly those that are aquatic, this requirement poses no serious problem. Each cell in these organisms is either in direct contact with the surrounding water or only a few cells away. These organisms have usually not evolved special respiratory surfaces but simply use their body surface for gas exchange. Many of these organisms are very small, so they have an adequate surface area to support their small volume. Others are large only in one or two dimensions, such as many of the algae. Some of the brown algae, the kelps, may grow to lengths of 60 to 70 meters, but the blades of even the longest kelps remain very thin. As a result, no cell is far from the surface, and the total gas-exchange area is fairly large in relation to the volume of the alga. Because these organisms live in water, their surface is kept moist.

In Terrestrial Plants the Requirements of Water Conservation Conflict With Those of Gas Exchange

The terrestrial environment is in many ways hostile to life. When fluids do not bathe the plant's entire surface, one of its most serious problems is obtaining enough water. The plant must maintain an extensive moist surface for gas exchange, but, at the same time, it must prevent excessive loss of water by evaporation. The large terrestrial plants have a real challenge when it comes to gas exchange. They must balance protection from water loss caused by sun and wind with their need to take in carbon dioxide and oxygen for photosynthesis and respiration, respectively. Simultaneously, they must support the fragile, thin tissues that do the gas exchange, and protect them from tearing. To solve these problems, most terrestrial plants have evolved "compromise" mechanisms that address three basic needs:

(1) **a respiratory surface area of adequate dimensions.** The problem of maintaining adequate surface area as volume increases applies to all parts of the plants, particularly the roots and leaves. While the absorbing surface of the root is increased by branching, root hairs, and mycorrhizae, the leaf gas-exchange surface is increased by the many intercellular spaces in the mesophyll.

(2) **a means of protecting the fragile gas-exchange surface from mechanical injury.** Because a thin, moist surface is fragile and can easily suffer mechanical damage, the tendency has been toward the evolution of protective devices. Many plants have evolved outer body coverings that are relatively impermeable. Coverings such as the waxy cuticle on leaf epidermis or the bark of tree stems are protective barriers between the fragile internal tissues and the often hostile outer environment. The presence of these coverings, however, makes the maintenance of an adequate exchange area even more difficult.

(3) **a means of keeping the tissues moist, that is, preventing desiccation.**
The cells must be directly exposed to the environment for gas exchange to occur, but they must be exposed in such a way as to minimize the tendency to dry out. Xylem delivers water to the cells, keeping cells moist, and protective devices such as bark, epidermis, and cuticle, help retard water loss.

It is important to remember that in plants, all gas exchange is done "locally", i.e., each living cell exchanges gases directly with the environment. There is no special system specialized for gas exchange as there often is in animals, nor do the vascular tissues in plants transport gases from one part of the plant to another.

The Living Cells of Stems and Roots Must Exchange Gases

Gas exchange is not confined to the leaves, though these organs are beautifully adapted for this process. Young stems also have ***stomata*** through which gases are exchanged, but older stems have impermeable bark on their surface, so gas exchange generally takes place through numerous ***lenticels.*** Lenticels are groups of loosely arranged cells with many spaces between them through which gases move to reach the interior tissues. Since most of the cells in the inner layers of large stems are dead, there is little need for oxygen in the intercellular spaces to penetrate deep into the stem.

Root cells also carry out gas exchange. In young roots, gases can diffuse readily across the membranes of root hairs and other epidermal cells, which present an enormous surface area for gas exchange as well as for nutrient procurement. In older roots, the epidermis and cortex is often replaced by bark; lenticels are present in such roots to allow the exchange of gases in the interior tissues. For all roots, however, the soil in which they grow must be well aerated to provide sufficient oxygen for the cells of the root. One of the benefits of hoeing, raking, plowing, or otherwise cultivating the

Plants, unlike animals, do not seem to need any special gas-transporting mechanisms. Most of the intercellular spaces in the tissues of land plants are filled with air, in contrast with those in animal tissues, which are filled with fluid. These air-filled spaces are interconnected to form the intercellular apoplast system that opens to the outside through stomata and lenticels and penetrates to the innermost cells of the plant body. Thus, incoming gases can move through the apoplast directly to the internal parts of the plant without having to cross membranous barriers. They do not have to diffuse long distances through water or cellular fluids, because they do not go into solution until they reach the film of water on the surfaces of the individual cells. Since oxygen can diffuse some 10,000 times faster through air than through liquids, the intercellular air-space system ensures that all cells, even the more internal ones, are adequately supplied. Gas exchange in roots and stems, then, is done "locally"; there is no long distance transport of respiratory gases by the xylem or phloem.