Microscopic Examination of a Leaf & a Lichen To Show Convergent Evolution

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Before 1859, the year Charles Darwin published his book *On the Origin of Species,* it was generally believed that the biological world was unchanging. All of the many species of organisms were believed to have been created at the same time and had remained unchanged since their creation. According to the Darwinian theory of evolution, species change over long periods of time, and this leads to the creation of new species. As explained by Darwin, changes are due to natural selection of variant individuals of a species. Those variants with characteristics that allow them to better cope with natural phenomena in their environment will have a greater chance of surviving, reproducing, and passing on their characteristics to their offspring. Consequently, beneficial characteristics will accumulate over many generations, whereas there will be a tendency for characteristics that are either harmful or of no benefit to be lost. Thus, the characteristics of a species change as time goes by, and such changes can eventually give rise to new species.

Natural selection often leads to species that are markedly different from each other and from their ancestors; this process is called divergent evolution. For example, modern horses and zebras are different species of the genus *Equus.* They not only differ from each other in several ways, but also from their common ancestor, a member of the extinct genus *Pliohippus.* It is generally divergent evolution that comes to mind in students, and the population at large, when giving their attention to evolutionary change.

In contrast to divergent evolution, organisms with dissimilar ancestors sometimes come to resemble each other—a process called convergent evolution. For example, cetaceans (whales, dolphins and porpoises), like fishes, have a streamlined body to reduce resistance to movement through water, stabilizing fins, and a powerful muscular tail to bring about movement. Be that as it may, the ancestors of cetaceans were land-dwelling mammals that moved on four legs.

A convenient way of observing convergent evolution in the classroom can be achieved by microscopic study of a leaf and a lichen.

The primary function of leaves is photosynthesis: a series of actions by which light energy is converted to chemical energy, which is then used to synthesize organic molecules from inorganic molecules taken in by the plant from its environment. Thus, plants can make their own food from simple chemicals. The leaf has evolved into a remarkably well-constructed structure, with its different constituent cells positioned in a way that allows for efficient photosynthesis.

In addition to its necessity for plants, photosynthesis is basic for the existence of virtually all other forms of life; exceptions being photosynthetic and chemosynthetic bacteria, and animals living in the vicinity of deep ocean vents that are the beneficiaries of chemosynthetic bacteria inhabiting the same environment. The products of photosynthesis are used directly or indirectly by animals, fungi, and most species of bacteria as a source of energy, without which they could not exist.

Lichens are composite organisms consisting of a fungus and certain species of unicellular plants belonging to either the cyanophyta or chlorophyta groups of algae. This relationship allows the two organisms to live in places where neither of them could exist alone; for example, on bare rock. The fungus obtains organic nutrients from the photosynthesizing algal partner. It is not a one-sided relationship, since the fungus supplies water and provides a habitat for the algae. The fungus forms the bulk of a lichen, and protects the algae from wind, excessive light, and desiccation—conditions the algae would be vulnerable to as free-living organisms in the kinds of harsh environments where lichens are usually found.

Although a leaf is an organ of a higher plant and a lichen is an association of a fungus and algae, both the leaf and lichen have a similar arrangement of cells (Figures 1 and 2). This reflects the photosynthesizing activity of leaves and lichens, and the requirement for photosynthetic cells to be in a position that allows them to receive optimal light for photosynthesis. The photosynthetic cells, in turn, need to be protected and supported by other cells.

The upper surface of a leaf is a protective layer of epidermal cells, with cuticle covering its outer

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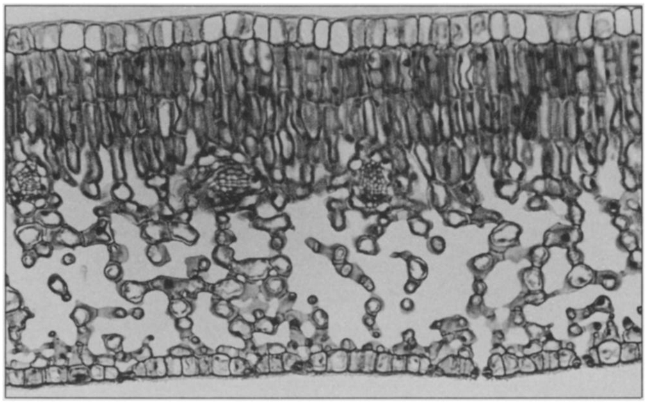

Figure 1. The microscopic appearance of a cross section of a privat leaf. The main photosynthetic cells are the elongated cells below the upper surface. See the text for a full description.

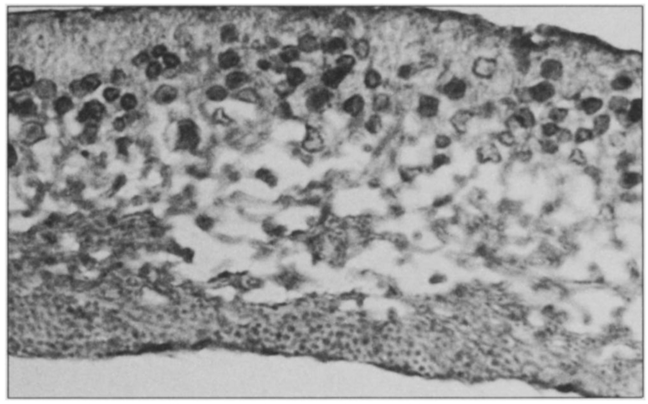

Figure 2. The microscopic appearance of a cross section of a member of the lichen genus *Physcia*. The photosynthetic algal cells are the dark-staining roundish cells below the upper surface. See the text for a full description.

surface. The waxy cuticle provides additional protection, and also prevents loss of water from the leaf. Immediately below the epidermis are palisade cells, the main photosynthesizing cells of the leaf. The epidermis and cuticle are transparent, thus these protective structures allow light to reach the palisade cells. Below the palisade cells are the spongy mesophyll cells, photosynthetic cells, but more loosely arranged than the palisade cells. The loose arrangement of cells, giving a sponge-like appearance to this part of the leaf, allows for high uptake of carbon dioxide across the exposed surface of spongy mesophyll and palisade cells, and the release of oxygen from the cells.

Carbon dioxide is essential for photosynthesis. Oxygen is a waste product of the process and must be eliminated from the cells. Movement of materials into and out of the photosynthetic cells would be less efficient if, instead of being loosely arranged, the cells in this part of the leaf were closely packed. The lower surface of the leaf, like the upper surface, is a protective layer of epidermal cells. Carbon dioxide and oxygen move into and out of the leaf through the stomata, microscopic openings that are usually more abundant in the lower epidermis than in the upper epidermis.

Most kinds of lichens have a similar organization of their cells. There is an upper cortex of fungal cells, beneath which the algal cells are located. Below the algal cells is an area of loosely organized fungal cells called the medulla. Beneath the medulla is a lower cortex of fungal cells. Cortices are often covered with cuticle or some other protective material.

The above descriptions reveal striking similarities between a leaf and lichen. The epidermal layers of the leaf and the cortices of the lichen provide protection. The photosynthesizing cells are just below the upper surface in both leaf and lichen. Furthermore, the spongy mesophyll of the leaf and the medulla of the lichen consist of loosely arranged cells, which allow for a ready exchange of carbon dioxide and oxygen between the photosynthesizing cells and the atmosphere.

Microscopic slides showing cross sections of leaves and lichens are available from biological supply companies. Thus, good and long-lasting materials can easily be obtained that show convergent evolution. The leaf described herein was that of *Ligustrum vulgare*, commonly called privet. The lichen was of the genus *Physcia*. Since lichens are made up of organisms from two different kingdoms, they are a problem with respect to classification and are named after the fungal component.