MYCOLOGY ANSWERS

HOW DO LICHENS SURVIVE SEVERE DROUGHT CONDITIONS?

Lichens flourish in a wide range of habitats, many of which are regarded as severe environments. There are over 13,500 species of lichenized fungi and they are usually long-lived organisms, growing very slowly (a few mm a year). They occur world-wide, doing best under conditions where little physical disturbance occurs, and are able to tolerate high levels of physiological stress such as low humidity, temperature extremes and low light conditions, in extremely exposed habitats. Most species are highly drought tolerant and only a very few can withstand submersion in water for any length of time. In general, lichens are unusual organisms in that their development, and the maintenance of healthy active thalli, is favoured by alternating periods of wetting and drying.

Lichenized fungi are much more tolerant to drying than are non-lichenised species and most are able to survive in very dry conditions for weeks or even months. However, lichens do not conserve water and have very little control over water loss. In times of drought water is lost by evaporation but thalli can endure remarkably low water contents, down to as little as 2-5% dry weight. As drying out occurs levels of metabolic activity decline and the thallus becomes physiologically inactive. In some environments lichens spend much of the year in a dry state and the lack of physiological activity may explain, at least in part, the slow proliferation of thalli.

The vegetative part of a lichen, known as the thallus, is usually composed of two partners in close contact, a fungal component (mycobiont) and either a green alga or a cyanobacterium (photobiont). The associates are self-supporting; the fungus (mainly species of ascomycetes and a few basidiomycetes) provides an anchor and protection from environmental influences whilst obtaining its entire supply of carbohydrate from the photosynthetic activities of the partner (green algae e.g. *Trebouxia*, and *Pseudotrebouxia* or cyanobacteria e.g. *Nostoc*, *Scytonema* and *Trentepohlia*). The structure of thalli is very varied ranging in complexity from fairly loose aggregations of cells of the partners (*Lepraria* spp.) to simple layered structures (species of *Lecanora, Parmelia, Peltigera, Xanthoria*), through to multilayered and more elaborate arrangements (*Usnea* spp., *Ramelina* spp.). The fungal partner often forms an upper layer (cortex) covering the thallus and thus provides some protection from the prevailing environment. The photobiont usually comprises only a small proportion of the total thallus and is restricted to a shallow layer just below the upper surface. Central portions (medulla) of the thallus may be more or less densely filled with fungal hyphae. In some lichens the arrangement of algal cells and fungal hyphae in the inner layers of the thallus are quite loose and the structure therefore dries out quickly. Others have denser cellular arrangements and dry out more slowly. Some component hyphae, especially those in more structured thalli, are embedded in matrix materials (probably polysaccharides) which bind the structure together and enhance the mechanical strength.

The water content of the thallus reflects that of the surrounding environment (lichens are poikilohydrous) and much is lost by evaporation although some water is bound into molecules within the body of the thallus and into the matrix materials. However, lichens are able to absorb water from the environment remarkably quickly. Water vapour from the air is utilised extremely efficiently. Indeed, this is often enough to maintain metabolic activity even in the absence of liquid water supplies. Additionally, when supplies of liquid water become available (rain, dew, run-off) absorption into the thallus is very rapid (5-30 min to become fully saturated) and physiological processes are re-initiated very quickly. Many lichens take up water through both the upper and lower surfaces. Much of the water absorbed is taken into the central medulla and into the gelatinous matrix of the cortex. Some water may be retained in intercellular spaces (hydrophobic compounds are sometimes found in the medulla) and also, in

more saturated thalli, within the cell walls of component hyphae. It is interesting that, for many lichens, a prolonged state of full water saturation (100 - 300% dry biomass) can cause metabolic damage. Healthy activity is maintained best in thalli subjected to alternating periods of wetting and drying.

Under conducive conditions, in the presence of the fungal partner, the photobiont cells are stimulated to release large amounts of photosynthates. Cyanobacterial symbionts liberate products which are converted to glucose and then released to the fungal cells. Green algal photobionts liberate carbohydrate products which are converted to polyols (sugar alcohols such as ribitol, erythritol and sorbitol) and then released for use by the fungus. These are rapidly converted to fungal carbohydrates (mannitol and arabitol) which cannot be used by the photobionts. This sets up a one-way flow of carbohydrates to the fungal partner and the fungal polyols act as storage compounds which are slowly depleted in times of nutrient stress. High concentrations of mannitol also act to lower the osmotic potential in the thallus, thus assisting with water accumulation. Additionally, under conditions of water stress polyols can replace water in molecules in lichen thalli, acting to protect proteins in membranes and thereby maintaining membrane integrity.

In dry thalli physiological activity is very low. On rewetting there is a rapid rise in respiration rate (and a concomitant loss of CO_2, which is a physical reaction) followed by a subsequent decline to the normal rate for the conditions. Some solutes, such as polyols and phosphates, can be lost from the component cells at this time, as a result of changes in membrane permeability, and there may also be an accompanying loss of carbon although some of that may be reabsorbed as the water balance is restored.

In exposed situations the surface of a lichen thallus can quickly become very hot during periods of sunshine, particularly since there is little cooling by water evaporation. Many lichens are relatively tolerant to high temperatures and are quite resistant to thermal damage but withstand such elevated temperatures only when the thallus is dry. High light levels are also very damaging. In some species the thick walls of the cortical cells, which are often pigmented, protect the underlying photobiont as the thallus dries out. Some further protection is also given where thalli roll up when dry (e.g. *Chrondropsis semiviridis*). On rehydration the cells expand and the available radiant energy reaches the photobiont. Photosynthesis can resume at about 65-95% water saturation although the actual levels vary with species.

Although some lichens are composed of only a relatively few cells a fine balance is maintained between the activities of the component organisms and the environment, making them remarkably tolerant and extremely responsive to changes in the prevailing conditions.

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