

LICHENS

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Summary

Lichens are nutritionally specialized fungi that live in symbiosis with photosynthetic organisms (algae or cyanobacteria). The latter acquire an additional source of nutrients, as well as a stable habitat, while the fungus acquires a food source via the photobiont. Lichens occur on rock, soil, wood, bark, and living leaves, as well as on a range of man-made substrates, from the arctic to the equatorial zones. Almost half of all ascomycetes are lichenized (ca. 13-14.000 species). The evolution of lichenization may be very old, possibly pre-Cambrian. From its occurrence in distantly related groups of fungi, lichenization apparently occurred several times. Lichens have no means of controlling their water relations, which makes them strong competitors in extreme environments. Generally, only the mycobiont retains the capacity of sexual reproduction. Lichens are one of the most important sources of biologically active compounds other than plants; most of these are produced by the lichen "in toto", and are not known from each isolated symbiont alone. Lichens are very sensitive to air pollution, and are currently used to monitor the effects of gaseous and metal pollution in many countries. They are also important in the biodeterioration of monuments.

1. Introduction

Lichens are symbiotic phenotypes of nutritionally specialized fungi that live in symbiosis with algae and/or cyanobacteria as ecologically obligate biotrophs. They can be considered as small ecosystems, with a primary producer (the photosynthetically active partner, or "photobiont") and a consumer (the fungus). The former is also called "phycobiont" (if an alga) or "cyanobiont" (if a cyanobacterium), the latter is called "mycobiont", and is generally an ascomycete, more rarely a basidiomycete. The photobiont cells live within the body ("thallus") formed by the hyphae of the mycobiont. The great majority of phycobionts are green algae (Chlorophyta); only two genera have been reported from other groups of algae (*Petroderma*, a brown alga, and *Heterococcus*, a golden alga), whereas the cyanobionts belong to quite diverse groups (Chroococcales, Nostocales and Stigonematales).

The relationship between myco- and photobionts is said to be mutually beneficial, i.e. the biological fitness of both partners is increased in the symbiotic state: the algae (or the cyanobacteria) acquire an additional source of nutrients, as well as a stable habitat within the lichen thallus, where they are sheltered from the external environment. On the other hand, the fungus acquires a food source via the photobiont, that produces carbohydrates by photosynthesis. Lichen mycobionts are therefore obliged to secure adequate illumination, to facilitate the gas exchange of their photobiont cell population, and to compete for space. Cyanobacteria also represent a source of organic nitrogen for the mycobiont, gaseous N₂ being fixed in the heterocysts of cyanobacterial colonies. When the two bionts grow together in the lichen symbiosis, the lichen phenotype differs substantially from those of the two bionts grown separately in culture. In agar culture the mycobiont forms undifferentiated colonies of cartilaginous consistency, whereas the photobionts produces jelly colonies, often formed by filaments instead of single coccoid cells. The formation of a typical symbiotic phenotype, similar to that from which the two organisms were isolated, can only occur when the two partners are in contact.

The morphology of the lichenized thallus is strongly dependent on the photobiont. In nature there are several cases where the same mycobiont forms two thalli ("morphotype pairs") with, respectively, a cyanobacterium and a green alga. These thalli can be similar ("isomorphic", as in several *Peltigera* species) or different ("heteromorphic", as in the *Sticta/Dendriscoocaulon* couple). Intermediates between these morphologically distinct thalline phenotypes have been described as "lichen *chimerae*". The lichen thallus, especially the foliose or fruticose thalli of the so-called macrolichens, is probably the morphologically and anatomically most complex vegetative structure in the fungal kingdom, and illustrates well the innovative force of the fungus-alga symbiosis.

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Biographical Sketches

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