S7-4

Lichen Substances and Their Use

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A Lichen is an association of a fungus and a photosynthetic symbiont (or simply a fungus and an alga), resulting in a stable body called a thallus. Lichens exist only in symbiosis in nature, but both symbiont can be cultured separately in laboratory works. The morphological and physiological features of a thallus are genetically very stable. The number of lichens is about 13,500 (Hawksworth and Hill 1984) species, which covers about 20 % of all fungi. More than 98 % of lichens belong to the Ascomycotina and about 46 % of the Ascomycotina is lichenized (Fig. 1).

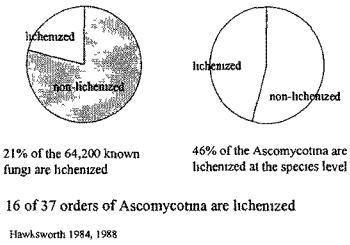


Fig. 1. Constitution of lichenized fungi

Lichens grow on various kinds of substrata such as rocks, tree barks or soil. Most of them prefer to live in sunny and airy habitats and are widely distributed in the world. The lichen rich habitats in Eastern Asia include coniferous forest, alpine and subalpine slopes or deciduous broad-leaved forests.

Lichens are traditionally divided into three main morphological groups: the crustose, foliose and fruticose types. The crustose lichens are tightly attached to the substrate with their medullary hyphae and may not be removed from it without destruction. The foliose lichens are leaf-like, flat and only partially attached to the substrate by rhizines. In cross section, upper and lower cortices, algal layer and medullary layer are recognized. The fruticose lichens always stand out from surface of the substrate. The thallus lobes of fruticose lichens are hair-like, strap-shaped or shrubby and the lobes may be flat or cylindrical.

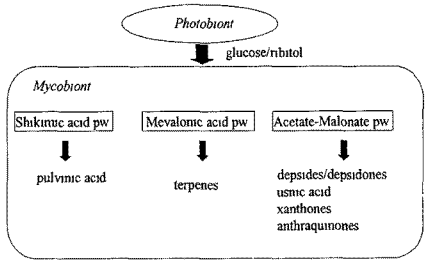
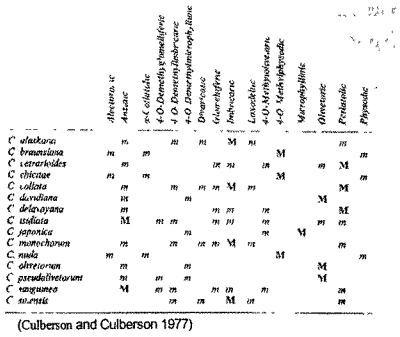


Fig.2. Biosynthetic pathways to lichen secondary metabolites

Reproduction of lichens is made both by sexual or asexual ways. The sexual reproduction is just for mycobionts, which produce ascospores in ascomata such as apothecia and perithecia. The principal problem for spores is the necessity of making re-synthetic connections with appropriate photosynthetic partner to

establish a new thallus. Many lichens also produce asexual propagules called isidia, soredia or lobules. These propagules contain both fungus and photobiont cells and are easily removed from the thallus, thereby forming new thalli without re-synthesis. The presence or absence of asexual propagules is the one of the most important characteristics to recognize the species of lichen.



(Culberson and Culberson 1977)

Fig. 3. Chemosyndorome found in *Cetrelia*

Many lichens produce characteristic secondary substances called lichen substances. The majorities of them are produced by mycobionts and are deposited on the surface of the hyphae using organic compounds derived from photobionts. Every substance is produced through one of the three pathways, the shikimic acid, the mevalonic acid and the acetate-malonate pathways (Fig. 2). At present more than 650 lichen substances have been found and chemical characteristics are regarded of importance for lichen taxonomy in species or higher ranks. Determination of lichen substances is made by the color tests, the micro-crystallization technique (Asahina and Shibata 1954), the TLC methods (Culberson and Johnson 1976), HPLC and UV irradiation.

In lichens, three main chemical variations are observed such as the additional type, the replacement type and the chemosyndrom type. The former two are commonly found within species or in higher ranks. In contrast, chemosyndrom type variation is characteristically found in the genus *Cetrelia*; each species of this genus produces chemically closely related substances as shown in figure 3 (Culberson and Culberson 1977).

Lichens have been used for medicines and perfumes (*Evernia prunastri, Pseudevernia furfuracea*), dyes (*Candelaria candelarius, Roccella tinctoria, Ochrolechia tartarea*), indicator of air pollutions (*Parmelia, Usnea,* etc.), food (*Umbilicaria esculenta*), feed for farm animals (*Cetraria islandica, Cladonia rangiferina*), Christmas wreath, model building (*Cladonia*) and biocides. Lichens are very sensitive to air pollution and useful for an indicator species. However, all lichens are not equally sensitive to all air pollutants but different lichen species exhibit differential sensitivity to specific air pollutants. In general, foliose and fruticose lichens such as species of *Parmelia* (s. lat.), *Ramalina* and *Usnea* are more sensitive than crustose ones. The use of lichens in folk medicines persists to the present day. Both the Seminole Indians in Florida and the Chinese herbal doctors employ various lichens in medicines, especially as expectorants. The antibiotic effect of a number of lichen

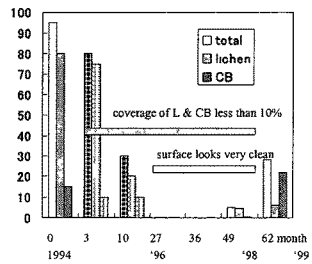


Fig. 4. Effect of Koretrel on concrete covered with lichens

metabolites was found to be significant for Gram-positive bacteria, but ineffective against Gram-negative bacteria. The most active antitumor lichen substances are water-soluble polysaccharides (Nishikawa 1970).

Lichens play an important role in breaking down rocks physically and chemically. Physical weathering occurs mechanically through hyphae and rhizines growing into the rocks. Lichen substances such as oxalic acid, acidic polysaccharides and depsides may assist altering rocks chemically. These actions partly contribute to soil formation but prove harmful for the substratum. Some people do not like to keep lichens on stained glass of churches or on gravestones mainly because of its unglamorous appearance. A biocide, 'Koretrel', is very effective in removing lichens and blue-green algae from the surface of concrete. After spraying 'Koretrel' in the open air, lichens (*Caloplaca* sp., *Endocarpon petrolepideum, Physciella melanchra, Phaeophyscia hispidula*, etc.) growing on buildings died within three months and peeled off from the substratum. One year after treatment, concrete surfaces were almost lichen free for three or four years (Fig. 4). The biocide makes use of a kind of lichen substance and harmless both for substances and environment. Our recent experiments show that it is also useful for water grasses growing on the surface of an aqueduct of a hydroelectric power station.

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