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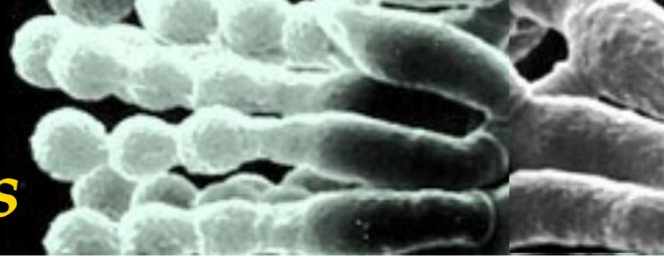

Lichens, key environmental bioindicators

David L. Hawksworth

Lichens may look like independent organisms, but they are not. They are an ecosystem in which a fungus forms an outside structure which has other organisms living inside. The most important of these are photosynthetic algae or cyanobacteria, but numerous specialized bacteria and other fungi can also be living there or on the outside surface. It was especially for lichen associations that the term "symbiosis" was coined by the German mycologist Albert B. Frank in 1877. The various organisms involved each have their own scientific names, but the association itself has no name at all! For instance, *Xanthoria parietina* (**Figure 1**) is strictly only the name of the lichen-forming fungus that provides the overall structure to a lichen, but is used as a sort of shorthand to refer to the whole ecosystem. The fungi involved are mostly only known as a part of a lichen association.

Figure 1. *Xanthoria parietina*, forming a foliose (leaf-like) lichen in nitrogen-enriched habitats.

The associations are self-sufficient, obtaining their carbohydrate (and sometimes nitrogen) needs from the included photosynthetic partners, and water and minerals from rain and dust in the atmosphere. This makes them especially valuable as bioindicators of air quality, as they respond directly to the ambient conditions regardless of whether they are growing on rock, wood, glass, iron, or even rubber. In addition, they are slow growing, often just a few millimetres each year, extraordinarily long-lived and can be monitored at any time of the year.

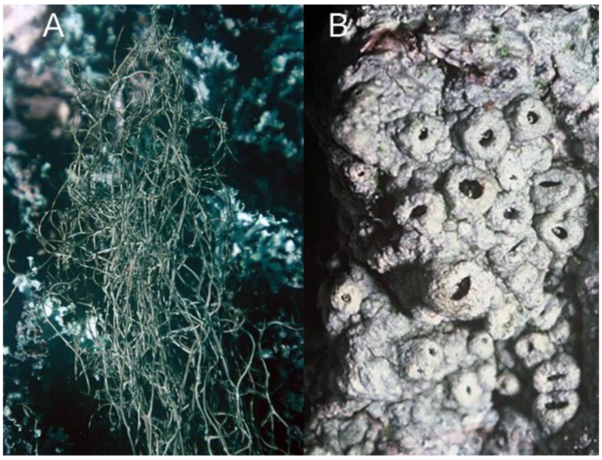

Figure 2. **(A)** *Bryoria fuscescens*, forming a hair-like lichen indicative of acid bark (pH 3.5–5.5). **(B)** *Thelotrema lepadinum*, a large-spored species forming a crusty lichen which is an old-forest indicator.

They are particularly sensitive to sulphur dioxide air pollution. Species vary in sensitivity, some preferring more acid barks (**Figure 2A**) and this made it possible to relate lichen communities to the mean levels of this pollutant in the air – and to estimate mean concentrations. This is not just of academic interest as it is the membranes of the chloroplasts in the algae that are damaged by sulphite and bisulphite ions, as are those in chloroplasts in plants. The presence of particular lichens was used to indicate where commercial forestry could be practised, as well as mapping air pollution patterns. When the European Union came to define critical levels of air pollutants that should not be exceeded, the commended annual mean level of 20 μm/m^3 was partly based on lichen sensitivity.

Many lichens were eliminated from large areas of the UK and continental Europe by sulphur dioxide air pollution until legislation started to reverse the trend in the late 1970s. There was a dramatic and rapid expansion of lichens into central London following the closure of the last Thames-side power station in 1983. London had just nine species on the bark of trees in 1970, but in 1988 there were 49 species recorded on trees in north-west London, and the number has continued to grow.

Today, nitrogenous compounds, especially nitrogen oxides, have replaced sulphur dioxide as the main air pollutants of concern, and lichens that thrive in nitrogen-rich environments have expanded exponentially over the last 25 years. The yellow-orange *Xanthoria parietina* (**Figure 1**) is now commonplace on twigs and branches in cities, along busy roadsides, and in agricultural areas (where nutrient-enriched dust blows around and crops are fertilized). This expansion is exemplified by the behaviour of this species in Albury Park, Surrey where it was only found on gravestones in 1991, but was ubiquitous on trees by 2016. If you see abundant yellow-orange lichen growths, you can be sure there is a nitrogen pollution problem.

Heavy metals, apart from copper, however, are just mopped-up by lichens which can accumulate them internally to high concentrations, often as complexes on the surfaces of the hyphae and cells and so outside the living protoplasts. Studying the iron or lead content can be used to map contaminated areas. This ability came to the fore in 1986 as caesium-136 accumulation enabled the deposition of radioactivity from the Chernobyl nuclear disaster to be traced across Europe.

Their value as bioindicators is not confined to air pollution. Some have large spores that do not travel far, and have difficulties of re-establishment once eliminated from woodlands. This enables them to be used as indicators of the ecological community of ancient trees in woodlands, especially as they are always there to be surveyed (**Figure 2B**). The range of old-forest indicator lichens in a site can be used to calculate an Index of Ecological Continuity, and is now one of the criteria used in determining woodland Sites of Special Scientific Interest in the UK. If they have many of these special lichens those sites are also likely to be important for, example, certain rare plants, mushrooms, bracket fungi, beetles, or spiders.

Sources of further information

Dobson FS (2018) *Lichens: an illustrated guide to the British and Irish species.* 7th edition. 520 pp. Slough: Richmond Publishing. ISBN 978-0-9565291-0-7.

AUTHOR PROFILE

David Hawksworth CBE is an Honorary Research Associate at the Royal Botanic Gardens Kew and a Scientific Associate of the Natural History Museum, London. A past president of the British Mycological Society, he is an Honorary President of the International Mycological Association and was recipient of the Acharius Medal of the International Association of Lichenology. Now 'retired' David was the last Director of the International Mycological Institute at Kew and Egham. Here he provides a glimpse of one of his passions, a sometimes unappreciated value of lichens.