Lichens: Nature’s pioneers

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Lichens are among the most fascinating organisms on this planet and are nature’s pioneers. They find their homes in some of the most barren and inhospitable parts of the world. From there they slowly begin the process of creating a foundation for habitation by others.

What are lichens?
Their very structure is unique: a symbiosis of two organisms—a fungus and alga(e)—so complete that they behave and look like an entirely new being.

Lichens grow in spots that are too harsh or limited for most other organisms. They are pioneers on bare rock, desert sand, cleared soil, dead wood, animal bones, rusty metal, and living bark. Able to shut down metabolically during periods of unfavorable conditions, they can survive extremes of heat, cold, and drought, with each partner (symbiont) doing what it does best, and thriving as a result of a natural cooperation. They live as one organism, both inhabiting the same body. The complexity of lichen partnerships has caused lichens to be described as “small ecosystems.”

They are classified as members of the Fungus Kingdom by systematists because the fungus partner is always the major partner. After a lichen symbiosis is established, the fungus has the greatest influence on the final form of the lichen body’s shape, i.e., whether it is tough or flexible. The algal or cyanobacterial partner(s) each have their own scientific names, but the lichen symbiosis is known only by the name of its fungus. The great majority of the nearly 19,000 species of lichenized fungi are Ascomycetes, the “Cup Fungi.” About 20 species, found in tropical and temperate rain forests, are Basidiomycetes, the “mushrooms.” About 40 genera of algae and cyanobacteria are found in lichen partnerships.

Lichens first appeared about 400 million years ago. Some individual species, such as Hypogymnia physodes, have been around for at least 25 million years and maybe for as long as 70 million years. Obviously, the lichen symbiosis is a successful strategy. They are colorful—greens, grays, blacks, browns, oranges, and yellows are common.

Lichens as food
Arctic and subarctic lichens are food for many mammals, including caribou and moose. Some lichens are used as a supplemental food for sheep, cattle, and humans. To make this possible, the lichen must be soaked in a soda solution (which converts the acids to their salts), then dried and powdered. The result is then mixed with regular food, such as potatoes or yams. In the Middle East, certain lichens were used to make a type of nutritious bread.

One explorer, Gabriel Franchere, tasted pit-cooked Bryoria fremontii in 1814 and recorded, “I thought I had put a piece of soap in my mouth.” Some of the many Native American groups in the Northwest who ate this lichen savored it as a delicacy, though; others used it only as a famine food. “Wolf lichen,” or Letharia vulpina, was the most widely used dye lichen for native peoples in North America, from what is now the Yukon down the west coast, and through the mountain states into Arizona. The Apache painted wolf lichen crosses on their feet so they could pass their enemies unseen. In another example of ritualistic use of lichens, the Gitksan in British Columbia associated the lichen Lobaria pulmonaria with frogs and used it in a spring bathing ritual to bring health and long life.

In Japan Umbilicaria esculenta is considered a delicacy, where it is eaten in soup or in salads. Other Umbilicaria species are or have been eaten in other countries. Some people believe that Lecanora esculenta was the original Biblical manna, as it easily comes loose from its substrate (what it was growing on) and is blown around by the wind. In the northern tundra, reindeer and caribou eat large quantities of lichens, mostly species of Cladonia and Cetraria. During the winter, lichens can make up half the food of these animals, who dig them up from under the snow. Eskimos and Lapps both harvest and store these lichens as part of the winter feed for their animals.

Lichens as health remedies
In medieval times and earlier, lichens were used medicinally based on their appearance or where they were found. For example, lungwort was used to treat tuberculosis, pneumonia, and other lung ailments. Yellow lichens were used to treat jaundice. Dog lichen, the fruits of which look like teeth, was supposedly used to treat rabies. The skull lichen (usually found on rocks but sometimes on skulls) is said to have been eaten in other countries. Some people believe that Lecanora esculenta was the original Biblical manna, as it easily comes loose from its substrate (what it was growing on) and is blown around by the wind. In the northern tundra, reindeer and caribou eat large quantities of lichens, mostly species of Cladonia and Cetraria. During the winter, lichens can make up half the food of these animals, who dig them up from under the snow. Eskimos and Lapps both harvest and store these lichens as part of the winter feed for their animals.

Pharmacological activity of lichen compounds was summarized for the first time by Dr. W. Zopf in 1907 in his well-known book Die Flechtenstoffe in Chemischer, Botanischer, Pharmakologischer und Technischer Beziehung. In Europe, records from around the 15th century suggest that by then several lichens were in regular medicinal usage. For example, Usnea florida was used for hair
problems, *X. parietina* for jaundice, and *Pettigera canina* as a cure for rabies. Well known is the application of *Cetraria islandica* against coughing and *Lobaria pulmonaria* against lung diseases. Depsides, depsidones, and usnic acid are active against gram-positive microorganisms. The sodium salt of usnic acid was used as a drug in Russia for its antibiotic, antitumor, and antimitagomic activity. Partially acetylated β-glucan from the lichen *U. esculenta* inhibits the cytopathic effect of human immunodeficiency virus (HIV) in vitro. Extracts from different lichen species have demonstrated allergenic, anti-inflammatory, and antifungal activities.

**Sweet smell of lichens**

Lichens are still used in the perfume industry. It is estimated that around 9,000 tons of lichens are used this way each year at Grasse, the center of the perfume industry in France. The bulk of this consists of *Evernia prunastri* (oak moss or “mousse de chêne”) and *Pseudevernia furfuracea* (tree moss). The ethanol extract of both lichens has a typical “mossy” scent and is used not only as a component in certain perfumes but also as a fixative that keeps the scent for a long time. Usnic acid is used as a preservative in cosmetic creams.

In Mediterranean countries, red and purple dyes were long made from species of *Roccella*. Other purple dyes used in the 18th century were made from *Pertusaria coralina* in France and *Ochrolechia tartarea* in Scotland. A brown dye has also been manufactured from *Parmelia ophalodes*. Other lichens have been used for wool and silk dyes, making browns, yellows, and reds.

**Lichen lipids**

Lipids detected in lichens are of great interest, but their analysis is much less extensive than that of many other organic compounds. Total lipid content has been studied in some lichens collected from various regions of the world having climatic peculiarities. As a rule, total lipids have been determined in the majority of lichens during summer or early autumn periods. Total lipids in such lichens show variations from 6 to 84 mg/g dry wt, and from 107 to 588 mg/g fresh wt. Neutral lipids contain mainly mono- and triglycerides as well as free fatty acids (FA), hydrocarbons, fatty alcohols, sterols, sterol esters, and carotenoids. Lipids characteristically contain classical glycolipids found almost exclusively in the Plant Kingdom, i.e., monoglycosyl- and diglycosylglycerol. Polar fractions also contain classical phospholipids: phosphatidylcholine, phosphatidylglycerol, phosphatidyserine, and phosphatidylethanolamine, as well as two unusual nonphosphorus-containing betaine ether-linked glycerolipids, diacglycerol-4′-(N,N,N-trimethyl)homoserine and diacyl-glycerylhydroxymethyltrimethyl-β-alanine. Glyco-, phospho-, and betaine lipids have been found in lichen symbionts.

**Lichen FA**

FA compositions of lichen species have been examined by many authors, who generally have used packed gas chromatography (GC) columns. The packed-column-analysis of FA indicated six major acids: 16:0, 18:0, 18:1n-9, 18:1n-11, 18:2n-6, and 18:3n-3. The capillary-column mass spectrometric
analysis of FA in more than 120 lichen species showed the presence of many additional FA: very long chain (C_{24}–C_{30}), branched (iso-, anteiso-, pristanic and phytanic), hydroxy-, keto, dicarboxylic, polyunsaturated: 18:4n-3, 20:4n-3, 20:5n-3, 22:4n-3, 22:5n-3, and 22:6n-3, and also derivatives of FA, such as γ-lactones and macrolides described by Siegfried Huneck and colleagues in Germany and Japan.

Lichens are unique symbiotic organisms that produce many different chloro-containing metabolites as reported by Huneck and Isao Yoshimura. Tomas Rezanka and I have found a series of novel brominated FA in some lichen species. Two new C_{18} acetylenic acid methyl esters of (5E,17E)-18-bromo-octadeca-5,17-diene-15-ynoic acid 1 (13.1%) and 18-bromo-octadeca-5,17-triynoic acid 3 (8.8%) have been isolated from the lichen Acorospora gobiensis collected in the Asian Tian Shan mountains near Lake Issyk-Kul. These two brominated FA, 1 and 3, and eight other new brominated acids 2,4–10 were found in lichens, Cladonia furcata, Lecanora fructulosa, Leptogium sarcina, and Xanthoria sp. The methyl ester of 18-bromo-(5E,17Z)-octadeca-5,17-diene-15-ynoic acid 2 was isolated from C. furcata (0.4% of dry wt), P. linctina (2.8%), and Xanthoria sp. (5.7%). The methyl ester of 16,18-dibromo-(15E,17Z)-octadeca-15,17-diene-5,7-diynoic acid 4 was found in L. fructulosa (3.2%), P. linctina (6.3%), P. comtseliadalis (0.5%), and Xanthoria sp. (2.4%). The methyl ester of 18,18-dibromo-17-octadecene-5,7-diyonic acid 5 is present in C. furcata (3.3%), L. saturnium (1.9%), P. comtseliadalis (0.8%) and Peltigera canina (0.5%). The methyl ester of 6-bromo-(5E,15Z)-octadeca-5,15-diene-11,13,17-triynoic acid 6 has been found in lichens P. linctina (9.4%), P. comtseliadalis (3.0%). The unusual epoxy brominated FA 7, 18-bromo-9-hydroxy-12,13-trans-epoxy-(10E,15Z)-octadeca-10,15-diene-17-ynoic acid, methyl ester has also been found in P. canina and L. saturnium. The methyl ester of 18-bromo-5,6-trans-endomethylene-7,11,15-trimethyl-(8E,10Z)-octadeca-8,10-diene-17-ynoic acid 8 was found in less than 0.1 mg/50 g of dry wt.

Two new bromoallenic FA have been found in some lichens: (12E,15S,18S)-15-hydroxy-18-bromo-12,16,17-octadecatrienoic acid 9 and (13Z,15R,18R)-15-hydroxy-18-bromo-13,16,17-octadecatrienoic acid 10. Even though FA with an allenic moiety have been known in nature for a long time, the first bromoallenic acids from natural sources have only recently been described.

Resource Readings
