Extended Abstract

What An Arborist Needs To Know About Lichens

Joseph Murray
Staunton, Virginia
murray@treebio.com

"When we try to pick out anything by itself, we find it hitched to everything else in the Universe." (John Muir, *My First Summer in the Sierra*, 1911)

Since, as arborists, we educate the public about all aspects of trees, it's only natural to extend that lesson to include one of the most common inhabitants on trees – lichens. Although they may appear to be insignificant (especially when growing on one of nature's largest organisms, trees), lichens play important roles in forest ecosystems across our planet.

It is estimated that there are between 13,500 to over 30,000 species of lichens in the world, with over 3,600 species residing in North America. Lichens will grow just about everywhere: from the north and south poles to the tropics, deserts, artic tundra; from intertidal zones of oceans to the tops of some of the tallest mountains on Earth (over 23,000 feet). Lichens grow on all soil surface types, rocks and tree bark, and even survived 15 days in the vacuum of space, unprotected.

One is tempted to describe lichens as epiphytes, non-parasitic plants growing upon other plants (e.g., mosses, ferns and flowering plants like bromeliads), but this term is not wholly accurate since lichens are not plants. Lichens have perplexed taxonomists since it was first revealed that a "lichen" is not an individual organism, but rather a composite between a fungus (mycobiont) and one or more species of algae or photosynthetic bacteria (photobionts). Lichens are named after the mycobiont since many of the photobionts appear in more than one mycobiont.

Like most fungi, mycobionts consist of elongated tubular cells linked together in long thread-like, branching filaments called hyphae. The hyphae of lichenized fungi make-up over 80% of the body, or thallus, of the lichen. The mycobiont's thallus provides the photobiont with a favorable microenvironment that includes protection from excessive sunlight, a supply of mineral nutrients and moisture. What appears to be a chaotic assemblage of long, branching, filamentous hyphal strands is a highly connected network capable of not only moving water and mineral nutrients to the entrapped photobionts but also efficiently distributing the photosynthates (sugar alcohols from green algae and glucose from cyanobacteria) throughout the thallus of the lichen.

The photosynthetic component, the photobiont, is either green algae, cyanobacteria, or both. The photobionts are diverse, coming from the Protist Kingdom (primarily green algae, with a few representatives from golden and brown algae) and the ancient group of bacteria, cyanobacteria. Surprisingly, only a dozen genera serve as photobionts in the majority of lichens. Identification of the photobionts is difficult not only because they are located in the body (thallus) of the lichen, but also because the mycobionts can significantly alter the appearance of the photobionts.

Although the association between the mycobiont and photobiont has been held up as a model example of mutualistic symbiosis, it is clear now that, for the most part, mycobionts help themselves to the majority of the phototsynthates (nearly 90% in some species) and that the photobionts are systematically weakened and killed by the mycobionts. Fortunately, photobionts reproduce faster than they are destroyed. This revelation in the relationship between mycobionts and photobionts has caused lichenologists to reconsider the blanket description of “mutualism” in favor of a new form of controlled parasitism that can occur. Yet, because the photobionts, when associated with their compatible mycobionts, are capable of living in new areas where they would be unable to survive on their own, there is reluctance to abandon the term mutualism.

Just as arborists start the tree identification process by first noting the characteristics and arrangement of the tree’s foliage (buds, in winter) along a twig, the initial steps for lichen identification start with the recognition of the lichen’s growth form. The growth form of a lichen is determined by the mycobiont’s genetic instructions, but the photobionts play some role because a lichenized fungi will develop a growth form different than the same form it would grow in its non-lichenized state. Although lichens present many different shapes and sizes, most lichen field identification keys initially divide lichens into one of three growth forms: crustose, foliose, and fruticose.

Before exploring the three major growth forms of lichens, it may be helpful to first understand the general anatomical features making up lichens. The surface of the lichen’s thallus, the upper cortex, consists of thick-walled fungal hyphal cells, closely packed together in a gelatinous matrix. The upper cortex may contain pigments to regulate the intensity of sunlight for the photobionts. Beneath the upper cortex is the photobiont layer enmeshed in the uppermost region of a loose network of fungal hyphae called the medulla. Comprising the base of the lichen’s thallus is the lower cortex, structurally similar to the upper cortex but usually darkly pigmented. The lower cortex may also contain specialized fungal structures for anchoring the lichen to the substrate.

The overall appearance of crustose lichen looks as if the lichen was painted (or spray painted) onto the surface of a tree’s bark. The outer cortex of crustose lichen often contains colorful pigments because crustose lichens can be found in exposed areas subjected to full sunlight. The photobiont and medulla layers are located beneath the upper cortex, but the lower cortex is absent, resulting in the lower medulla being tightly fixed to, and often interwoven, with the substrate. The absence of the lower cortex makes the collection of crustose lichen almost impossible to remove from the substrate unless one also removes the upper portion of the substrate (e.g., tree bark).

The foliose lichens are characterized by their flattened, leaf-like, thallus. Most foliose lichens have well-defined layers, including a lower cortex with specialized structures for attachment to the substrate. The structure of a foliose lichen is similar to a green leaf with an upper and lower cortex equivalent to the leaf's upper and lower epidermis. The photobionts in a lichen's medulla function like the photosynthetic palisade parenchyma cells beneath the upper epidermis. Both foliose lichens and plant leaves have a loosely packed region with air spaces to permit gas exchange through special pores with the external environment.

Fruticose lichens are similar to foliose lichens sharing well-defined layers, but differ in two ways: first, fruticose lichens have one outer cortex enveloping the thallus; and second, compared to foliose lichens' two dimensions, fruticose lichens exist in three dimensions. Fruticose lichen growth forms always stand out from the substrate, varying from erect, highly branched shrub-like structures to long, unbranched hanging filaments.

Lichens typically grow upon one of three substrates, or surfaces: rock, soil or tree bark, with the occasional odd lichen living on the hair of slow-moving sloths or lichen employed as camouflage on insect larval bodies or on birds' nests. Those that grow on tree bark are called corticolous lichens. The fact that lichens appear to be restricted to specific substrates aids in their identification. Unlike other fungi, the majority of lichenized fungi use their substrates, not as a surface to extract nutrients, but merely as a surface on which to live.

Lichens do not have any specialized absorptive structures, like plant roots, to absorb water and minerals. Instead, lichens absorb water and minerals (dissolved in water) directly across their thalli. Since lichens are such efficient bioaccumulators of minerals, they are used to monitor minerals that normally exist only in trace amounts in the substrate or atmosphere. In addition to monitoring for pollutants, lichens have been used in a prospecting role, providing useful information concerning the presence metal-bearing ores (like copper and iron) in a particular locality.

Yet for its success colonizing surfaces across the planet, many lichens do have one vulnerability - air pollution. Since the thalli of lichens lack a protective waxy cuticle, allows lichen to readily absorb water and dissolved minerals directly from the atmosphere, lichens are at risk of absorbing air pollutants, especially sulphuric and nitric acids (common components of acid rain), fluorides, ozone, hydrocarbons, and metals. Because lichens differ in their sensitivity to pollutants, pollution indices, scales and maps have been developed to provide a quick, efficient, and widely available system for monitoring air quality. Following exposure to air pollution population of lichen undergo a reduction from a diverse collection of lichen species to only the pollution-tolerant species, typically crustose species. The most pollution-sensitive lichens include the fruticose species and those lichens containing cyanobacteria.

Lichens are typically the first organisms to live on bare rock. Lichens living on rock release chemicals that contribute to the gradual dissolution of the rock into mineral components, an important process in soil formation, oftentimes at a faster rate than weathering processes. Lichen forms a "crust" on soil helping to stabilize the soil environment for other soil microorganisms, prevent soil erosion, and prevent soil compaction from rain striking exposed areas of soil. Also, the leaching of nutrients and addition of organic matter from soil-borne lichen and corticolous lichens improve the soil structure and nutrient content.

Like other photosynthesizing plants, lichens serve as carbon sinks. Given all of the diverse areas where lichens can live, it's imperative that they find adequate temperature, moisture and light so the photobiont's "balance sheet" of photosynthesis exceeds the respiration demands of the photobiont and mycobiont host. Long ago, when lichens comprised the dominant land vegetation on Earth, there is evidence that lichens had a profound influence on the Earth's climate and atmosphere. Researchers have proposed that the colonization of land by lichen in the Precambrian period was responsible for lowering carbon dioxide levels so low that it initiated a series of global glaciation events (750-580 million years ago). At the same time they contributed enough oxygen into the atmosphere to permit the "Cambrian" radiation of species around 540 million years ago.

Lichens containing cyanobacteria as their photobiont are capable of "fixing" nitrogen from the atmosphere and converting it into ammonia or nitrate, a usable form for the growth of lichens. Following leaching of the usable nitrogen from the body of the lichen, the nitrogen becomes available to plants and other organisms. The contribution of nitrogen into ecosystems is still being studied, it has been reported to be as high as 50% of the total nitrogen input in old growth conifer forests of the Pacific Northwest.

Lichens are an important food source for herbivorous organisms, especially in areas where other food sources are scarce due to harsh environmental conditions; for example, lichen serves as a critical food source to sustain large herds of caribou. Used by birds and mammals as nesting materials, lichens offer an added benefit of camouflaging the nest.

Because of poor air quality and other factors, arborists, living and working in urban areas, may not be aware of the diversity and importance of corticolous lichens in forest ecosystems. Too often when some tree owners become aware of lichens, they are apt to associate the presence of lichen with a tree disorder. This "guilt by association" is common when a tree's canopy is in decline and the increase in light stimulates the growth of lichen. Yet, it wasn't that long ago that we became aware of the importance of mycorrhizal fungi. As we continue to learn more about the importance of corticolous lichens we may have another, this time lichen-related, “awakening” of a mutualistic symbiotic relationship that functions even in urban landscapes.

As with new awareness, we can adjust our practices to help promote lichen density and diversity in urban landscapes. There really is no need to remove corticolous lichens. because it is highly unlikely that they cause damage to trees. Pruning practices such as crown thinning, crown raising, and crown reduction can significantly alter the air humidity and light levels within the crown of a tree. Likewise, which discourages the growth of some lichen species while favoring the growth of others. Likewise, the use of nitrogen fertilizers and fungicide applications will also selectively inhibit some species of lichens while favoring others.

If corticolous lichens are beneficial to trees in forest ecosystems, perhaps they may be beneficial to trees in the urban forests as well. We know that lichens serve as; effective bioindicators for air quality, perhaps corticolous lichens may serve as an indicator for arborists as well. If an arborist has familiarity with common lichens in an area, the arborist may be better able to judge the secondary growth rate of branches and the trunk, as well as response growth around defects based upon the growth pattern of foliose lichen, if present. The density and diversity of lichens may serve as an indicator of repeated instances of past experiences of defoliation or periods when the tree’s crown was sparse based upon the type of lichens present. Furthermore, it is been shown that numerous insectivorous birds are attracted to trees with abundant corticolous lichens because of the presence of invertebrates associated with lichens.

Returning to the opening quote from John Muir, in urban landscapes devoid of lichens on trees, we are the poorer for it. More sterile perhaps, but poorer in that we have less diversity and the absence of all the other organisms “hitched” to the lowly lichens.

References

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. *Lichens of North America*. New Haven: Yale University Press. 795 p.

Hinds, J.W. & P.L. Hinds. 2007. *The Microlichens of New England*. Bronx, New York: The New York Botanical Garden Press. 584p.

Nash, T.H. (Editor) 2008. *Lichen Biology*. 2nd Edition. Cambridge University Press. 489 p

Pallardy,S.G. 2008. *Physiology of Woody Plants*. Third Edition. New York: Elsevier. 454 p.

Purvis, O.W. 2000. *Lichens*. London: Natural History Museum and Washington DC: Smithsonian Institution. 112p.

Seaward, M.R.D. 2008. Environmental Role of Lichens. pp. 276-300. In, *Lichen Biology*. 2nd Edition. Cambridge University Press.

Walewski, J. 2007. *Lichens of the North Woods.* Duluth, MN: Kollath and Stensaas Publishing. 152p.