Lichens: A Partnership for Life (A Van Andel Creation Research Center Report)

George F. Howe and Mark H. Armitage*

Abstract

This is the first in a series of papers in which we discuss lichens growing on rocks at the Van Andel Creation Research Center, (VACRC), Chino Valley, Arizona. We introduce lichens in general, dealing with their nature, size, growth rate, morphology, distribution, physiology, taxonomy, reproduction, and laboratory growth in this paper. We also analyze aspects of the origin of lichens from both the creationist and macroevolutionary perspectives.

Characteristics of Lichens

Lichens are plants that consist of a particular fungus growing in close contact with an alga (plural algae). The lichen is a third entity, which results from this partnership:

> Lichens are an association of specific fungi and algae so intimate in terms of functional interdependence and so integrated morphologically that a sort of third kind of organism resembling neither of its components is formed. Odum (1983, p. 400). An association between a fungus and an alga that develops into a unique morphological form that is distinct from either partner is termed a lichen. Moore-Landecker (1972, p. 380). When we consider one lichen, we seem to be dealing with three plants: a fungus, an alga, and the composite form… Amadjian (1967, p. 1).

It has been generally assumed that the alga of a lichen supplies food to its fungus while the fungus in turn provides such benefits as water, shade, minerals, and protection for its algal partner (Fuller et al., 1972, p. 380). The alga and fungus supposedly form a mutualistic symbiotic union in which they both benefit. Concerning the algae, however, Bessey (1971, p. 216) wrote that the "…constant tribute levied in the form of food substances diffusing out from the cells must reduce their vigor somewhat."

Using radioactive tracer nuclides, workers have demonstrated that photosynthetic products of the alga do indeed enter the cells of the fungus partner, where they are readily stored (Moore-Landecker, 1971, p. 385). Carbon-14 experiments demonstrated that about 70% of the carbon-14 fixed by *Nostoc* in the *Peltigra* lichen quickly showed up as carbon in mannitol molecules within the nearby fungus cells (Smith, 1973, pp. 11–12).

The fungal strands called hyphae predominate when it comes to the biomass of a lichen (Hale, 1961, p. 3). D.C. Smith (1973, p. 16) indicated that although the alga makes up only about 10–20% or less of the dry weight of a lichen, it supplies all the food. Webster (1980, p. 368) found no evidence that minerals, water, or other substances move from the fungus to the alga, although many authors like Haupt (1956, p. 311) have assumed that the fungus does supply such items to its algal partner. "The benefit gained by the alga from the association is not at all clear," according to D.C. Smith (1973, p. 7).

Stern (1997, p. 338) called the lichen relationship a "controlled parasitism" on the part of the fungus. Daubenmire (1959, p. 313) wrote that the many lichen fungi manifest varying degrees of symbiosis, all the way from a balanced mutualism to a parasitism in which the fungus actually sends hyphae called haustoria into the algal host cells. Delevoryas (1966, p. 34) agreed that the fungus/alga relationship in the lichen is probably parasitic to some extent but "…not severe enough to harm the algal host".

Most Lichens are Epiphytes

Like mosses, many lichens grow upon trees where they are simply epiphytes which means they are plants that live upon other plants but do not parasitize them (Stern, 1997, p. 339). A few lichens, however, are known to attack nearby moss plants which may be destroyed as a result (Bessey, 1971, pp. 217–218). Some tropical lichens have likewise been observed to invade leaves of plants by entering the leaf pores (stomates) and then parasitizing the leaf tissues (Bessey, 1971, p. 217).

*George F. Howe, 24635 Apple Street, Newhall, CA 91321-2614
Mark H. Armitage, Azusa Pacific University, P.O. Box 7000 Mary Hill Center, 101, Azusa, CA 91702-7000
Received 15 July 2001; Revised 17 August 2001

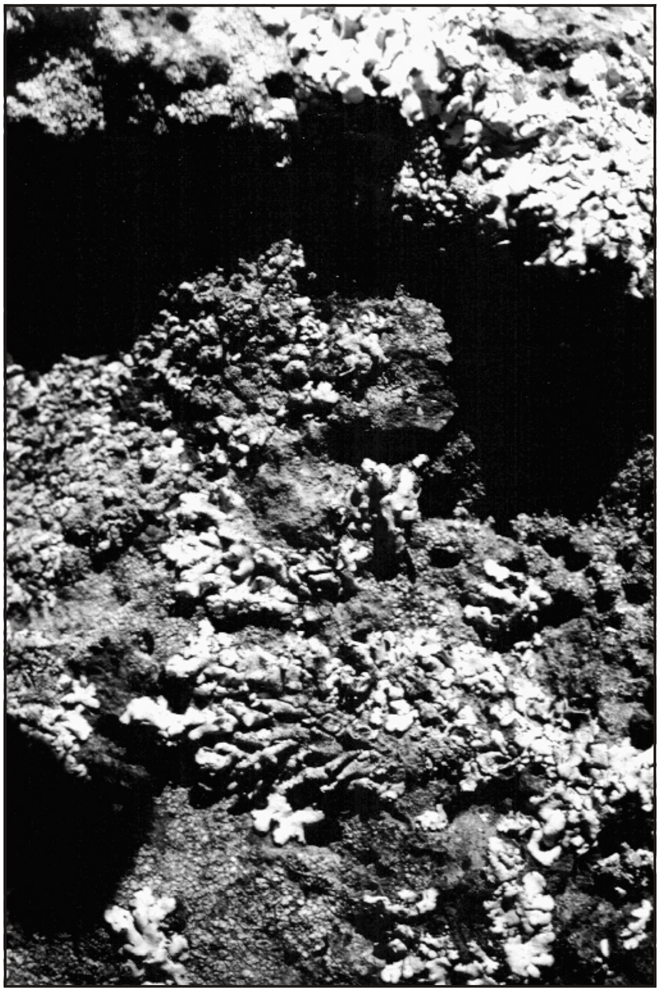

Figure 1. Foliose lichens. The large colonies of foliose lichen seen at the top right and in the lower third of this photograph are *Xanthoparmelia* (States, 1990, pp.208-209; Hale, 1979, p. 159). Although attached to rocks at various points, sections of a foliose lichen curve up from the rock, like miniature leaf-like lobes.

Lichen Growth Rates

Lichens grow very slowly and this is thought to be attributable largely to the slow growth of the algal partner. It has been shown in culture experiments, however, that the lichen fungi also grow quite slowly. The growth rates of three lichens and a moss have been observed at VACRC over a period of 14 years and will be reported in a later paper.

How Big Is a Lichen?

Lichen colonies range widely in size from those which are barely visible (one millimeter in diameter) to some which are up to two meters across (Stern, 1997, p.338). The very large lichen colonies are thought to be quite old.

Figure 2. Crustose lichens. *Acarospora* (visible on the lower rock from center to left) is a lemon-yellow colored lichen classed as being crustose because it adheres closely to the rock surface throughout its thallus (States, 1990, pp.208-209; Hale, 1979, pp.32 and frontice picture). Note the small sections (areoles) separated from each other by cracks. There are no fruticose lichens at VACRC.

The Form of Lichens

The lichen plant body is called a thallus (thalli plural) because it does not have organs like leaves or stems. Morphologically lichen thalli fall into three overall growth forms: crustose, foliose, and fruticose:

> If the lichen forms a crustlike growth closely appressed to the substratum, it is termed a crustose lichen … if a leafy growth projecting from the substratum, a foliose lichen… and if a branching bushy growth mostly free from the substratum, a fruticose…(Fuller *et al* ., 1972, pp. 380–381)

Bessey (1971, p. 217) reported that the term "fruticose" comes from *frutex* which means shrub in Latin. Bessey also indicated that some lichens can change from one type to another as they grow and that in some lichens the distinction between these three morphological phases (crustose, foliose, fruticose) is not clear. We have not found fruticose lichens at VACRC.

In describing the types of lichen plant bodies, Doyle (l965, p. 29) put things quite succinctly: "Thalli are commonly leafy (foliose), encrusting, or shrubby." Fink (1935, p. 3) reported that crustose lichens often have a "chinky" surface pattern, being divided into small sections known as "areoles" (see Figures 2 and 4a). Both crustose and foliose forms may have rootlike rhizoids on their lower surfaces where they touch the rock or other substrate. We will discuss the internal and cellular anatomy of the lichens at VACRC in a later paper. For illustrations of a foliose lichen, see Figures 1, 4a, and 4b.

Figure 3a. *Grimmea*, a moss. Both lichens and mosses grow on bare rocks throughout the southwestern United States (Marshall, 1910, pp. 178-179). Three or four species of lichens are growing on this exposed rock surface while mats of the moss (*Grimmea apocarpa*) are seen in the shaded crevice below. We will discuss the identifying colors of these lichens in another paper.

Figure 3b. *Grimmea*, a moss, is growing adjacent to a lichen-covered rock surface. While a large share of "soil-building" on bare rocks can be attributed to lichens, Daubenmire (1968, p. 118) has argued that mosses like, *Grimmea*, growing outward from crevices, may "overgrow" lichens that are present and may make an even bigger contribution than lichens to forming soil on a rock substrate.

Figure 4a. Ascocarps. In the lower left and center of this photograph is a large colony of the foliose lichen *Xanthoparmelia* in which cup-like objects with black centers are barely visible, the ascocarp reproductive structures of the lichen fungus. These range from less than one-half inch up to one inch in diameter.

Where Do Lichens Live?

It might be easier to answer the question "where are lichens unable to grow?" because they are known for their very widespread geographic distribution and their ability to survive extremes of climate. Taylor et al. (2000, p. 244) summed it up this way: "…lichens can be found in a wide range of habitats, extending from close to the poles to deserts and rainforests." They are able to live in deserts and other warm, dry climates because they have an amazing endurance for drought and high temperatures. Although

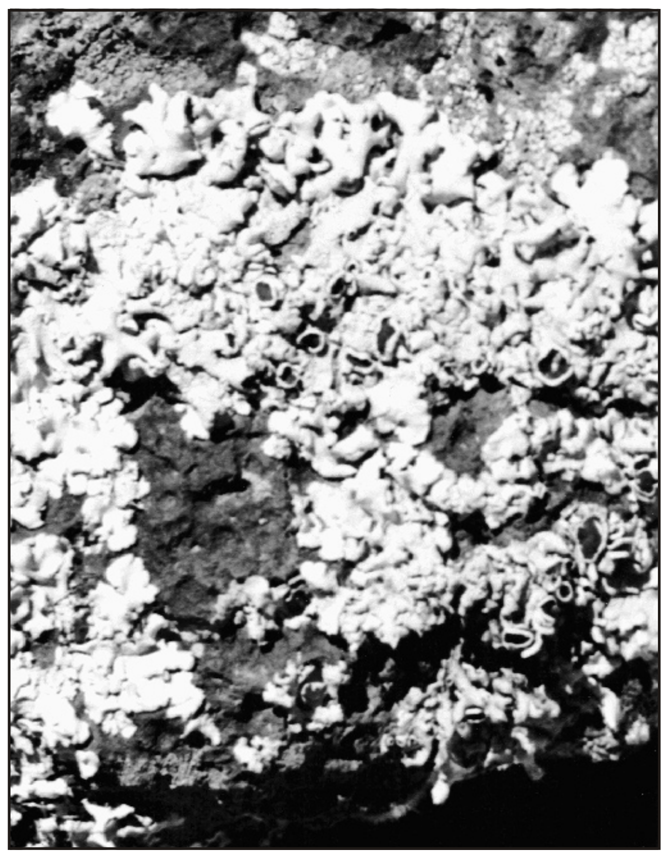

Figure 4b. *Xanthoparmelia* ascocarps enlarged. This is a portion of Figure 4a enlarged. Some cuplike ascocarps are nearly circular while others have variously curved borders. The center of each is black because it is there that the pigmented ascospores are produced inside miniature sacs called asci, visible only with a microscope.

they become dry enough to be brittle, lichens can yet survive. If the water content in the tissues of most other plants goes down to 50% dry weight or lower, they die (Daubenmire, 1968, p. 117). By way of contrast, lichens can survive with a water content as low as 2% during drought (Moore-Landecker 1972, p. 382; Stern 1997, p. 338). Dry lichens, on the other hand, can absorb water up to 300% of their dry weight when water becomes available. Their cellular osmotic pressures can go as high as 1000 atmospheres which enables them to extract water directly from moist air (Daubenmire 1968, p. 117). Stern reported that lichens produce a gelatinous substance which helps them resist desiccation.

It has been found that certain dry lichens can absorb up to 50% of their maximum possible water content during the first 5 seconds after water is added to them and they become almost completely saturated in just 30 seconds. After exposure to solar radiation for as little as one hour, a thallus that was previously fully saturated with water can become fully dry again (Amadjian, 1967, p. 103). Isaac noted that some danger to lichens results if the wetting and drying cycles are too rapid and too frequent:

> The loss of carbon on rewetting, together with the rapid rise in temperature (resaturation respiration) are the most potentially damaging effects of dry conditions and extremes of temperature. Lichens recover well from these conditions unless the wetting and drying cycles are very rapid and repeated (Isaac, 1992, p.315).

On the opposite extreme from these lichens that can easily absorb water are certain crustose lichens that are almost unwettable such that they are "… not able to take up liquid water even if they are kept submerged for hours" (Amadjian, 1967, p. 104).

Lichens in The Ocean

While lichens grow in such varying terrestrial regions from dense tropical forests to deserts and even into the arctic tundra, they also thrive on rocks at the shoreline of the ocean where they are often completely submerged (Stern 1997, p. 338). Bands and tar-like patches of blackish crustose lichens are to be found on rocks of the intertidal zone (Sumich, 1976, p. 156; Fox, 1983, p. 233).

Lichens at High Temperatures

The temperature of lichens growing on rocks exposed to the sun's radiation has been recorded to be as high as 50° C (D.C. Smith, 1973, p.4). Amadjian (1967, p. 111) reported that the temperature of exposed lichen thalli on a hot day may reach 50–70° C and possibly even higher. Bessey (l971, p. 216) attributed this resistance of lichens to high temperatures and drought to the fungus member.

Lichens at Low Temperatures

Daubenmire (1968, p. 117) reported that lichens have been found to carry out photosynthesis during winter. They thrive around icecaps (The World Book, 1986, p. 85) and above the "treeline" in Greenland, Iceland, and Alaska (Moore-Landecker, 1972, p. 380). Isaac (l992, p. 315) reported that, "Low temperatures are tolerated by lichens providing that the thalli are dry when the temperature is low." The ability of lichen thalli to survive experimentally induced low temperatures is phenomenal.

Lichens that were:

> … frozen in liquid oxygen at –183C [sic] for eighteen hours still respired when thawed and kept at a warmer temperature… A specimen of *Xanthoria parietina* has been reported to have withstood a temperature close to absolute zero…—a characteristic which it shares with some mosses, algae, and insects…—and moreover to have retained vitality after six years in a vacuum (Amadjian, 1967, p. 111).

Lichens, Ecological Succession, and Soil Formation

It has long been assumed that lichens enhance the weathering of rocks and thus contribute to soil formation. They are also thought to be the first step in an ecological succession or series of changes leading from bare rock to a full grown forest (Fuller et at., 1972, p. 382). Daubenmire (1968, p. 118) cogently argued, however, that soil building on bare rock in certain habitats may actually proceed outward from crevices where mosses like *Grimmea* thrive (see Figures 3a and 3b). Soil develops most rapidly in these moss colonies, according to Daubenmire, while the nearby lichen patches simply prepare the way for secondary lichen communities. The clumps of mosses and of flowering plants grow outward from the crevices, in many cases directly "overriding" the patches of lichens. The importance of mosses to the entire ecosystem in general and to the study of intelligent design in origins has been reviewed by Bergman (1998).

Wilson *et al*. (1962, p. 413) and Lee (1999) maintained that lichens contribute to rock weathering largely by way of the back and forth mechanical action which occurs when the lichen undergoes cyclic wetting and drying. The hyphae of lichens can penetrate considerable distance into rocks (Bessey 1978, p. 218). Lee concluded that it is the mechanical effect of hyphae of a particular lichen that caused rocks to weather:

> This preliminary work shows that the main weathering effect of *Rhizocarpon geographicum* on granite is by mechanical rather than chemical processes. (Lee, 1999, p. 20).

But lichens may weaken rocks chemically too because they secrete carbonic acid and other acids (Daubenmire, 1968, p. 117). Marshall summarized the role of mosses and lichens as soil-builders:

> They work by two methods. The one chemical, the other mechanical. By chemical, action they either construct plant tissue of gases taken in directly from the air or they first free from the rock or wood or earth-mould, the minerals needed and then construct them into plant tissue. By mechanical action they pry off bits of soil from hard rock, arrest dust and debris brought to them by the wind, and constantly add to the mass, such plant tissue as they themselves are continually shedding. (Marshall, 1910, p.12)

The famous writer John Ruskin penned this stirring little note about lichens and their action on rocks:

> Meek creatures; the first mercy of the earth, veiling with hushed softness its dustless rocks; creatures full of pity, covering with strange and tender honour the scarred disgrace of time. Marshall (1910, p.4).

Lichen Taxonomy

Most lichen fungi are not extensively free-living but are usually found growing in their lichen partnership. About one-fourth of all the different species of fungi are the fungi found in lichens (D.C. Smith, 1973, p. 3). Each lichen species is given a latin binomial and is classified on the basis of its fungus partner (Amadjian, 1967, p. 3). Commenting on lichen taxonomy, Odum (1983, p. 400) wrote that "Lichens are usually classified as single 'species' even though they are composed of two unrelated species." Each lichen species is thought to have its own unique species of fungus (Stern,1997, p. 338) except for about 20 tropical lichen species which all have the same fungus. But Doyle (1965, p. 29) maintained that this idea of each lichen species having its own unique fungus "needs verification."

The various lichen fungi fall into three major fungus divisions which are called the Ascomycota, (those fungi that produce sexual spores in little sacs called asci; ascus singular), Basidiomycota (those fungi that produce sexual spores on small club-like projections called basidia; basidium singular), and Deuteromycota (those fungi which have no known sexual reproduction). In some older works the Ascomycota taxon is called the "Discomycetes" (Moore-Landecker, 1972, p. 383) or the Ascomycetes. Most of the lichen fungi are Ascomycota members while some are in the Basidiomycota division and a few in the Deuteromycota. Stern (1997, p. 338) reported that one exceptional lichen had a bacterium growing with its alga rather than a fungus.

The Ascomycota-containing lichens produce spores called ascospores within sac-like cavities called asci. The asci are in turn produced in cup-like or vase-shaped fruiting structures known as ascocarps (see Figure 4a and 4b). The order within the Ascomycota to which most lichen fungi belong is the Lecanorales (Bessey, 1971, p. 215; Webster, 1980, p. 367). Concerning families and genera, Bessey (1971, p. 223) noted that there are 37 families of lichen fungi containing about 275 genera.

The number of lichen species ranges variously depending on the source consulted: 7,400 (Bessey 1971, p. 223), 15,000 (Fuller *et al*., 1972, p. 380; Haupt, 1956, p. 309), 16,000 (Sumich, 1976, Table 4.1; Moore-Landecker, 1972, p. 380), 18,000 (D.C. Smith 1973, p. 3) and 25,000 (Stern, 1997). Perhaps the true number of lichen species lies somewhere within this amazing spread of estimates!

Lichen Algae

One lichen species generally consists of one particular fungus associated with one specific alga (Hale 1967, p. 9). A few lichen species, however, are able to use two or more different algae (Bessey, 1971, p. 217). Since there are far more species of lichen fungi than of lichen algae, many lichen species possess the same alga, although they have their own specific type of fungus. Amadjian (1967, p. 79) wrote about one species of lichens that was found to have different algal species when it was collected from different localities. He also indicated that some lichens have different algae in the same plant: in one case both blue-green and green algae. He summed up the pairing as follows:

> The lichenization of a single alga by different fungi…or, conversely, the lichenization of different algae by one fungus… is probably very common. (Amadjian, 1967, p. 79)

The unicellular green alga *Trebouxia cladoniae* (G.M. Smith, 1950, p. 224) is the alga most commonly found in lichen species (Hale, 1967, p.31). Another name for *Trebouxia* in certain older books (e.g. Fink, 1935, p. 318) is *Cystococcus*. *Trebouxia* algae are found in over 70% of all lichen species (D.C. Smith, 1973, p. 3). It is found in 83% of the lichen species in Scandinavia (Hale, 1967, p. 8)

The alga found in second highest percentages among lichen species is *Trentepohlia*, another green alga. The third most common autotrophic partner in lichens is *Nostoc*, a nitrogen-fixing blue-green bacterium (a group formerly called "blue-green algae"). Nitrogen fixing is the ability to take molecular nitrogen (N_2) from the atmosphere and to convert it to ammonia (NH_3) or to the nitrogen of amino acid molecules in the cell. Lichens, which contain Nostoc (or certain other nitrogen-fixing blue-green bacteria), are themselves able to fix atmospheric nitrogen.

Probably 90% of all lichen species contain one of these "top three" algal partners: *Trebouxia*, *Trentepohlia*, or *Nostoc* (D.C. Smith, 1973, p.3; Stern, 1997, p. 338). The various algae found in lichens belong in a total of 26 genera. Eight of these genera are actually "blue-green algae", now classified as bacteria. One genus of lichen algae is a yellow-green alga and the remaining 17 genera of lichen algae are in the green algae division (Moore-Landecker, 1972, p. 383; Amadjian, 1967, p. 12). The anatomy of *Trebouxia* and *Protococcus* cells (two algae present in the lichens at VACRC) will be examined with electron photomicrography in a later paper.

Lichen Reproduction

Many lichens produce asexual reproductive bodies called soredia, which are small dust-like clusters, each of which contains some algal cells together with attached fungus hyphae. These soredia, dispersed by wind or water, are believed to routinely initiate lichen growth on new rocks or trees. Many species of lichens do reproduce asexually by soredia (G.M. Smith, 1950, p. 224).

The fungi in many different lichens are members of the Ascomycota division and, as such, produce ascospores inside the asci of their cup-like ascocarps, as part of their sexual life history (see Figures 4a and 4b). It is believed that new lichens can arise:

> … after ascospores carried by the wind come into contact with independently living algae, germinate, and parasitize them (Stern, 1997, p. 340).

Some lichen algae like *Protococcus* and *Trentepohlia* have a widespread distribution independently of their lichen fungus in various natural habitats, e.g. on tree trunks or rock surfaces. It is conceivable in the case of these two and certain other algae that their lichen fungi, growing nearby from germinating ascospores, could routinely make contact with them and grow together to produce a lichen *de novo*, as Stern suggested. But Stern added the curious fact that "No one has yet observed the initiation of an new thallus in nature…" (Stern, 1997, p. 340). Lichen dispersal and establishment has been extensively reviewed by Bailey (1976, p. 215).

In those lichens in which the algal partner is *Trebouxia* (which is most of the lichens), one might imagine that new thalli would also arise when germinating ascospores hook up with the free living alga. *Trebouxia* cells do not grow as widely as *Protococcus* and *Trentepohlia* by themselves, however, which may suggest that lichens which contain *Trebouxia* reproduce mostly by asexual means rather than by ascospores.

Some of the algae in lichens have the genetic capability of forming asexual reproductive cells of their own called zoospores. But this ability to produce self-propelled (motile) algal spores is ordinarily suppressed when the algae are living in the lichen relationship (Bessey, 1971, p. 216). Amadjian (1967, pp. 25–26) noted that *Trebouxia* in culture by itself can produce such motile spores, but it does not do so when growing in a lichen thallus.

Synthesis of Lichens in the Laboratory

> It is possible to grow the algal and fungal partners of many lichens separately in pure culture, and physiological studies of the separate components and intact lichen thalli have been made… Attempts have also been made to synthesize algal thalli *in vitro* from cultures of the two components, but typical lichen thalli have rarely been formed… (Webster, 1980, p. 367).

Here Webster was summarizing the extensive researches on laboratory growth of lichens carried out by Amadjian (1967) and others. Amadjian himself, however, took a much more positive view of lichen synthesis experiments and concluded that:

> "Reestablishment of a lichen association can be accomplished under laboratory conditions" (Amadjian, 1967, p. 80).

Amadjian supplied the following valuable summary about culturing lichens in the laboratory:

> 1. The most important conditions for the establishment of lichen associations are nutrient poor substrates and slow drying…; 2. Spores of a lichen fungus are capable of reestablishing lichen unions in culture; 3. The fungal symbiont can fruit in the absence of its algal partner; 4. A mycobiont in culture loses its ability to fruit but can still form the lichenized state with algae (Amadjian, 1967, p. 87). [Note, the isolated fungus is here called a "symbiont" which means that it ordinarily grows in symbiolic union with an alga. Amadjian also refers to the fungus of the lichen growing by itself as a "mycobiont".]

The Origin of Lichens

In each of the articles on lichens we will examine certain aspects of their origins. Convincing links and mechanisms showing that one lichen species had a common ancestry with another do not exist. In defense of evolution theories, however, it has been asserted that the lichen fungi evidently differentiated from one another long before each subsequently underwent lichenization separately:

> Since there are many varied types of algae and fungi in lichens, it is possible that the symbiosis has arisen on a number of separate occasions in the course of evolution. (Smith, 1973, p.6)

But no one has ever observed a non-lichenized fungus undergoing the changes required to convert it to a fungus equipped to collaborate with a particular alga. In other words, the origin of a new lichen species has never been observed in nature or the laboratory. Presumably a suite of very selective changes would be needed to convert a free-living saprophytic (feeding on dead or decaying materials) or parasitic fungus into a suitable lichen partner. If lichens themselves do not give rise to new lichens, many (if not all) of them must have arisen by repeated parallel evolution in which numerous unrelated lines of fungi each underwent the prerequisite steps enabling them to become suitable stable partners for the algae. Purvis (2000, p. 46) admits that lichenization had to occur independently at least seven times. He wrote that since the lichen association involves very different fungal groups (Ascomycota versus Basidiomycota or even Deuteromycota members):

> It has clearly evolved independently numerous times (polyphyletic)…" (Purvis, 2000, p.46).

No evidence exists, however, to support such wholesale convergent evolution (polyphyletic evolution) in the origins of lichens.

In this evolutionary scenario one would predict that for many of the lichenized fungi there would exist the "ancestral", non-lichenized counterpart of each, living in various saprophytic or parasitic niches. But such is not the case as, Amadjian (1967, p.33) noted: "… lichen fungi must have originated from free-living forms, but there is little evidence to support this view." Attempts to demonstrate that various lichen fungi are the equivalent of various non-lichenized saprophytic or parasitic fungi have been unsuccessful according to Amadjian (1967, pp. 33–34). It appeared that Amadjian was still hopeful in this regard, however, even though there had been no success in attempts to relate several lichen fungi to free-living molds:

> Further isolations of mycobionts from the fifteen to twenty thousand species of lichens undoubtedly will reveal additional relationships between lichen fungi and free-living fungi. (Amadjian, 1967, p. 35)

As an alternative to the evolutionary view of lichen origins, there is the concept that the Creator produced many separate kinds of fungi that were preadapted to unite with various algae, to yield the many kinds of lichens. Although this view carries with it the necessary task of trying to find the limits of various lichen "kinds", it is more in keeping with scientific evidence than is the macroevolutionary scenario.

A Lesson from Lichens?

We suggest finally that lichens figure effectively in a field called "natural theology." This is the practice of finding spiritual lessons in nature itself, a discipline which was popular in the eighteenth and nineteenth centuries. Natural theology has been revived recently by Gothard and his associates (Character Studies, 1985, pp. 360–361) who have discussed moral and spiritual lessons which can be deduced by the study of plants and animals. On pp. 360–361 they actually derive such lessons from lichens and lemmings.

To our surprise it was Odum (1983, p. 401), evolutionist and GAIA advocate, who also drew an important moral lesson from lichens. He noted in lichens a kind of symbolism directing human beings away from wholesale destruction of their habitat back to "… a mutualistic stage in their relationship with nature." We agree with Odum that wherever possible people ought to live in harmony with the rest of the ecosystem, like a lichen fungus "gently parasitizing" its algae host cells! Hoffberg (1998) has endeavored to show that a balanced ecological ethic is found in Biblical theology.

We further suggest to the "Odum's" of evolutionary science that moral lessons like these can be found in little plants called lichens and elsewhere in nature because nature itself is the product of a moral and loving Creator. The existence of moral lessons in biology is incomprehensible otherwise.

Acknowledgments

Although we alone take responsibility for the content of this article, we thank the following individuals for valuable suggestions: Eugene Chaffin, Emmett Williams, and John Meyer. We thank John Meyer for help in identifying the VACRC lichens. We gratefully acknowledge the help of Bobbi Blade in manuscript preparation. We thank an anonymous lichenologist who helped us identify these lichens from our photographs. We are thankful likewise to those who have donated to the C.R.S. research fund and to the VanAndel Creation Research Center Fund, interest from which has helped to support various aspects of this study. Finally, we appreciate and gratefully acknowledge the many thousands of hours of intense study on lichens that have been spent by hundreds of workers worldwide, some of whose research we cite here.

References

CRSQ: *Creation Research Society Quarterly*

Amadjian, Vernon. 1967. *The lichen symbiosis*. Blaisdell. Waltham, MA.

Bailey, R.H. 1976. Ecological aspects of dispersal and establishment in lichens. In: D.H. Brown, D.L. Hawksworth, and R.H. Bailey. 1976. *Lichenology*: *progress and problems*, pp.215–249. Academic Press, London.

Bergman, Jerry. 1998. The critically important plants called mosses. *CRSQ* 35:27–30.

Bessey, Ernest A. 1971. *Morphology and taxonomy of fungi*. Hafner, New York.

Character Studies, Vol. III. 1985. Institute of Basic Life Principles. Oak Park, IL
Daubenmire, Rexford F. 1959. *Plants and the environment*. John Wiley and Sons, New York.
———. 1968. *Plant communities*. Harper and Row, New York
Delevoryas, Theodore. 1966. *Plant diversification*. Holt, Rinehart, and Winston. New York
Doyle, William T. 1965. *Nonvascular plants: form and function*. Wadsworth, Belmont, CA.
Fink, Bruce. 1935. *The lichen flora of the United States*. The University of Michigan Press, Ann Arbor, MI.
Fox, William T. 1983. *At the sea's edge*. Prentice-Hall. Englewood Cliffs, NJ.
Fuller, Harry J., Zane B. Carothers, Willard W. Payne, and Margaret K. Balbach. 1972. *The plant world*, fifth edition. Holt, Rinehart, and Winston, New York.
Hale, Mason E. 1961. *Lichen handbook*. Smithsonian Institution Press, Washington, D.C.
———. 1967. *The biology of lichens*. Edward Arnold, London.
———. 1979. *How to know the lichens*. William C. Brown, Dubuque, IA.
Haupt, Arthur W. 1956. *An introduction to botany*. third edition. McGraw-Hill, New York.
Hoffberg, Greg. 1998. A theology of ecological ethics. Privately published: 29021 Bouquet Canyon Road, Saugus, CA. 91350
Isaac, Susan. 1992. *Fungal-plant interactions*. Chapman and Hall, London.
Lee, Martin R. 1999. Organic-mineral interactions studied by controlled pressure SEM. *The Americas Microscopy and Analysis*, March.
Marshall, Nina L. 1910. *Mosses and lichens*. Doubleday, Page, Garden City, New York.
Moore-Landecker, Elizabeth. 1972. *The fungi*. Prentice-Hall, Englewood Cliffs, New York.
Odum, Eugene P. 1983. *Basic ecology*. Saunders, Philadelphia.
Purvis, William. 2000. *Lichens*. The Smithsonian Institution Press, Washington. D.C.
Smith, David C. 1973. *The lichen symbiosis*. Oxford University Press, Oxford.
Smith, Gilbert M. 1950. *The freshwater algae of the United States*. McGraw Hill, New York.
States, Jack. 1990. *Mushrooms and truffles of the southwest*. The University of Arizona Press, Tucson, AZ.
Stern, Kingsley R. 1997. *Introductory plant biology*, seventh edition. William C. Brown, Dubuque, IA.
Sumich, James L. 1976. *An introduction to the biology of marine life*. William C. Brown, Dubuque, IA.
Taylor, T.N., H. Hass, W. Renny, and H. Kerp. 2000. The oldest fossil lichen. *Nature* 378:244.
The World Book Encyclopedia of Science. 1986. *The plant world*. World Book, Chicago.
Webster, John. 1980. *Introduction to Fungi*, second edition. Cambridge University Press. London.
Wilson, Carl L., Walter E. Loomis, and Hannah T. Croastsdale. 1962. *Botany*, third edition. Holt, Rinehart and Winston, New York.

Note from the Panorama of Science

Rate of Speleothem Formation: Observations in Country Limestone

Jerry Akridge*

Speleothems are dripstone features found in subterranean voids resulting from the deposition of calcite into various shapes seen as stalactites, stalagmites, flowstone, rimstone dams, drapery, and curtains (Davies and Morgan, 1984). Uniformitarian doctrine usually indicates that speleothems took great amounts of time to form. However, uniformitarian scientists should rethink the supposed rates of speleothem formation in view of known facts.

This study involves fieldwork on recently formed and ongoing formation of speleothems in country limestone in Huntsville, Alabama. While the determination of exact rates of formation is possible and being studied, the age of the speleothems has been ascertained within a definite time frame. Because the rate of speleothem formation is of interest to researchers regarding Earth's history, this study not only documents information countering erroneous claims of long ages needed for speleothem growth, but also provides evidence in support of the young-Earth Flood model.

*2626 Pine View Drive, Arab, Alabama 35016

Site Location and Description

This research was done in Three Caves, a feature located at the base of the western slope of Monte Sano Mountain and within the eastern boundary of Huntsville, in Madison County, Alabama (Figure 1). Three Caves is not a natural cave, but a rock quarry that was excavated from 1945 through 1952. The feature has the appearance of a large cave with three entrances in close proximity and a fourth entrance further removed (Figure 2).