

TWELVE READINGS ON THE LICHEN THALLUS

V. Conversational

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Figure 1. *Teloschistes arcticus* deep in conversation. Photo by Tim Wheeler.

*We commonly think of animals and plants as matter,
but they are really systems through which matter is
continually passing.*

William Bateson

REGULAR READERS OF THESE ESSAYS (hi mom!) will by now be resigned to my insistence that macrolichens, no less than their constituent parts – fungi, algae, bacteria – qualify as fully integrated organisms, composite organisms say (Essays III, IV). In a sense this much is already stale news: an opinion ventured 140 years ago by the great lichen deconstructionist himself, Simon Schwendener (Essay II). Yet the human mind, it seems, isn't very good at attending to dual perspectives simultaneously (Essay I). What really counts here is not so much the terms – composite + organism – as where we place the

emphasis. Thus, are lichens to be seen primarily as *composite organisms* or as *composite organisms*? And furthermore, does any of this really matter?

Consider the following three propositions:

- 1 Understanding the organismic nature of the lichen thallus requires that we learn as much as we can about the fungi, algae and bacteria that constitute it.
- 2 Understanding the fungi, algae and bacteria that constitute the lichen thallus requires that we learn as much as we can about the systems that tie them to the lichen enterprise.

- 3 Understanding the systems that tie the constituent parts to the lichen requires that we learn as much as we can about the context within which those systems have evolved – by which I mean the organismic nature of the lichen thallus.

Taken together, these propositions operate within the reinforcing structure of a feedback loop – a fact hardly worth noting except insofar as this particular feedback loop seems to want to tell us something. My own interpretation – one can never be too sure about these things – is that some of lichenology's most basic questions are likely to remain unanswered, perhaps even unasked, until such time as lichenologists learn to accord equal status – and research time – to lichens both as **composite** entities *and* as **organisms**. Of course most contemporary lichen taxonomists are already pretty good at this, though I dare say we need to know much more about whole lichens than how consistently to apply names to them.

Let me stand back a bit and remind myself what these essays are supposed to be about. The series title says it pretty handily, if a bit obscurely. *Readings on the Lichen Thallus* is actually the zipped version of a much longer train of thought beginning with the intuition that lichens, especially macrolichens, have quite a lot to teach us about *place*. In a sense I would argue that macrolichens *are* place. Or rather they are as close to place as the study of macroscopic organisms is likely to carry us. As the self-sufficient byproduct of feedback relationships among phylogenetically unrelated entities, macrolichens by their very ability to establish and grow have more to tell us about a particular habitat, its changing moods, than we're likely any time soon to fully absorb.

Learning to "read" the environment through the lens of macrolichens requires, of course, that we first learn to "read" macrolichens themselves. This is no small task, though I do think it can be managed, even if only with a certain necessary waving of the arms aloft. Key to the whole exercise is finding some means of articulating the linkage between lichen form and lichen function: some way of relating how lichens "look" – morphology, anatomy, chemistry, physiology – to how and where lichens grow. Thinking of lichens in terms of their constituent parts won't do, since this leads us inexorably back to thinking of lichens as composite. What we really need is an approach that emphasizes the processes at work within the lichen or – more attainably – the *systems* that underlie those processes.

SYSTEMS

By definition a system is simply a set of interacting or interdependent entities that form an integrated whole. The study of systems is called *systems theory*, while that of structure in self-regulating systems is termed *cybernetics* (from Greek, helmsman). Both disciplines operate on the not unhelpful principle that systems are pretty much where you find them: that any given class of systems viewed from a sufficiently high level of abstraction will be found to operate in roughly similar ways. Could be it's DNA we have in mind, or an ecosystem, or an organ, or a cell, or Gaia. Or for that matter a lichen. Lichens of course are systems from the ground up.

To a student of systems theory, lichens would have to be classified as *complex adaptive systems*. Not only do lichens have multiple parts – making them complex – they also learn from experience and modify themselves accordingly – making them adaptive (Figure 1). One key characteristic of such systems is that they are non-linear, meaning, in this context, that not all of the properties of the entities they form can be predicted from the properties of the parts that form them (Figure 2).

The cybernetician, for her part, would urge us to think of lichens in terms of an ongoing internal exchange of information. Lichens, she would insist, operate by way of interconnected feedback circuits, all linked together, all hierarchically arranged, and all firing off and receiving messages that, taken together, enable the system to self-correct as necessary (more of this in Essay VI). Rounded out, this is much like saying that the inner workings of the lichen have the form of a conversation between the constituent parts.

Now we're getting somewhere. In effect cybernetics invites us to visualize the lichen as an infinitely detailed transcription of a very long "meeting" for which the thallus has not only acted as stenographer but also now provides the filing cabinet. On the agenda, and hence duly recorded in the thallus, are certain actions taken in response to an ongoing, but ever varied, interplay of environmental variables – rain, dry, damp, warmth, chill, chemistry, and so on. Hence we have the lichen thallus seen as document: the ways and moods of the weather through the seasons and, indeed, across the years.

When we apply systems thinking to the lichen enterprise, results soon follow. For one thing we can finally dispense with those nagging questions regarding the constituent parts: the nature of their

Emergent property. *n.* Any outcome the properties of which cannot be predicted from the properties of its constituent parts.

Lichen. *n.* In the abstract, the enduring physical byproduct of lichenization. More concretely, a lichen thallus.

Lichen fungus. *n.* Any fungal taxon actively involved in the process of lichenization, and hence contributing to the formation of a *thallus*. Similarly, “lichen alga” and “lichen bacterium.”

Lichenization. *n.* Any biological process whereby a *nonlinear system* comprising an unspecified number of fungal, algal and bacterial taxa give rise to a *thallus* viewed as an emergent property of its constituent parts.

Lichen-forming fungus, lichenized fungus. *n.* In current usage, both terms are synonymous with *lichen fungus*; see above. Strictly speaking, however, fungi cannot form lichens - only lichen-forming systems can do this; nor can fungi be lichenized, this again being an attribute of lichen-forming systems, not of their constituent parts. See also *lichenologist*.

Lichenologist. *n.* Broadly defined, a person who specializes in the study of *lichens* or any of their constituent parts. Narrowly defined, one who studies *whole lichens*, it being within the whole lichen that *lichenization* takes place. Lichenologists specializing in *lichen fungi* might more appropriately be regarded as “lichen mycologists.” Hence also “lichen algologist,” “lichen bacteriologist.” See also *lichenized fungus*.

Nonlinear system. *n.* Any set of interacting or interdependent entities that form an integrated whole having properties not deducible from the properties of the individual parts. Nonlinear systems are hence *emergent*.

Thallus. *n.* In lichenology, the outward manifestation of *lichenization*, i.e., physical “body” of a lichen, composed of an unspecified number of fungal, algal and bacterial taxa, and comprising a wide array of growth forms.

Figure 2. The lichen enterprise defined from the perspective of systems theory.

relationships and so forth (Essay iv). Such questions no longer signify simply because the lichen is no longer *about* its parts, rather it’s about the conversation the parts are engaged in. Untold million of years after it began, the conversation has taken on a life of its own. What’s running the show nowadays is the lichen-forming system, more obliquely referred to as lichenization.

Nor need we any longer feel intimidated by the breathtaking range of variation with which the whole great lichen enterprise confronts us. No two biological systems can ever be identical, evolution loves to fool around, so why *shouldn’t* lichen-forming systems come in a wide and varied assortment of configurations strung out along on every feasible sort of outcome? Mycophycobiosis, biotrophic parasitism, parasymbiosis, photosymbiodemes, two-, three- and four-membered symbioses, lichenicolous fungi, lichenicolous lichens: these are all simply waypoints along a kaleidoscopic continuum of possibility made much more accessible when we learn to think of lichens as systems.

Unless I’m mistaken, this newfound application of systems thinking confers at least one more advantage to lichenology. It enables us, finally, to concoct what seems to me a workable definition for the word *lichen*,

as well as for all of its satellite terms (Figure 2). But also this: that just as lichenologists (and others) have lately reclaimed *symbiosis* to its original 19th century definition (a living together of differently named organisms *without regard* to relationship), so I think the time has come to do the same for the word *lichen*. With all due respect, I think the essence of lichens ought explicitly to be permitted once again to reside in the organism, rather than in the composite; more in Figure 2.

DIFFICULTIES

Yet lichens are by no means made easier by being made cybernetic. It simply becomes a little easier to understand how conceptually problematic lichens really are. New problems and challenges arise to take the place of the old. Here, for example, are four points in immediate need of attention:

- 1 **Features.** It now becomes of fundamental importance to recall that the so-called “parts” of the lichen – lobes, rhizines, cyphellae, soralia – are not to be compared with the “parts,” say, of the human body, with its ears, arms, and left big toe. In fact the only “parts” the lichen can rightly be said to possess are its constituent parts, the fungus, the alga, the

bacterium. As for its lobes, lobules, etc., these might better be described as thallus “features” – much as high cheekbones or drooping eyelids are said to be features of the face. That is, they must be understood in context to be understood at all.

2 **Cause and Effect.** Here’s something. Most if not all of the features characteristic of a given lichen are apt to make their first appearance in more or less predictable order. The hair lichen *Bryoria fremontii*, for example, has at least nine discernible features, which arise approximately as follows: (1) biosynthetic pathway, (2) branch elongation, (3) lateral branching, (4) terminal branching, (5) hierarchic branching, (6) cortical vents, (7) medullary cavity, (8) soralia, and (9) a tangled, fallen-locks habit. The quasi-successional status of these features is interesting, and must surely betoken some sort of interlinking chain of cause and effect. Perhaps each successive feature arises in response to physiologic stress or “tension” within the thallus, which its elaboration thus somehow “corrects.” If so, then it seems reasonable to suppose that these tensions must originate either in some adverse environmental input, or in the simple elaboration of one or more of the antecedent features – or possibly both. I’ll have more to say on this in future essays, but for now I can only offer Table 1 and move hurriedly on.

3 **Cues.** The ability of *B. fremontii* to elaborate a wide array of features (Table 1) seems to me to imply a corresponding ability to discern at least an equivalent number of physiologic states, each read as a physiologically mediated “cue.” I’ve suggested that each cue must somehow take the form of a specific “species” – or perhaps degree – of internal tension. From this it follows, or seems to, that *B. fremontii* must be capable of recognizing at least six such cues, i.e., those that stimulate production of lateral branches, terminal branches, hierarchic branching, cortical vents, medullary cavities and, in some thalli, soralia (Table 1). Of course these things will need much more careful thinking about, not least by me.

4 **Decisions.** Enduring biological systems self-correct, this much is certain. The problem of unselfconscious self-correction is already tricky enough when we have in mind, say, an Arctic Tern winging southward to some Antarctic heath: the unspoken inner tensions that hold it fast to the old ancestral flyway. Obviously something similar is going on in *B. fremontii*, as when it sends out a lateral branch or cleaves a cortical vent. The tern, of course, is in possession of a mind, so we’re reasonably comfortable with its ability to stay its course. But with the lichen things are different, no such

FEATURE INITIATED:	RESPONSE TO:	OBSERVATIONS:	INTERPRETATION:	IMPLICATIONS:
1 Biosynthetic pathway	Environment?	Numerous chemical variants.	Chemical variants environmentally induced?	Biosynthesis somewhat flexible at resynthesis?
2 Branch elongation	Positive carbon balance?	Markedly rapid.	Transfer of carbon toward growing tips?	“Upstream” carbon transfer?
3 Lateral branching	Negative carbon balance?	“Accessory” branches stay short.	Carbon boost to parent branch?	“Downstream” carbon transfer?
4 Terminal branching	Positive carbon balance?	Furcations more or less symmetric.	Expanding surface area.	“Upstream” carbon transfer?
5 Hierarchic branching	Negative carbon balance: primary branches?	One of the terminal furcations eventually dominates.	Tensile strength conferred as required.	System-wide “self-awareness”?
6 Cortical vents	Unrealized growth potential?	Vents are “randomly” distributed	Gas exchange and growth enhanced near vents?	Vents partly determine thallus form?
7 Medullary cavity, also cortical “dimples”	Negative carbon balance?	Not present in all thalli.	Auto-absorption by the fungus.	Medullary hyphae “sacrificed” for alga partner?
8 Soralia	Negative carbon balance?	Soralia rather infrequent in <i>B. fremontii</i> .	Soralia bias set low?	A response to highly specific physiologic need?
9 Tangled tresses	Time.	Optimally developed in localities prone to fog or mist.	Improved microclimatic conditions; increased fragmentation?	Branching confers fitness in most hair lichens?

Table 1. Readings in *Bryoria fremontii*: nine characteristic “features” arranged roughly in order of first appearance, with notes on their interpretation. For additional details, see Essays VI, VII, and VIII in this series.

mind exists, and yet there it is, a lateral branch, a decision taken, the conversation within the thallus. I doubt very much that the decision taken by *B. fremontii* is of the scheduled, preordained kind mediated in our own bodies by the hox genes. Thallus development in the macrolichen is surely much less determinate than this implies, much more necessarily responsive, for example, to the vagaries of rain and wind. Perhaps it's not for nothing, then, that systems theory places within the class of complex adaptive systems not only the lichen – and hence lichenization – but also the brain – and hence the human mind.

But though we will never know how it *feels* to be a lichen in physiologic need of specific readjustment – time for a lateral branch say – we can at least infer, broadly, what sorts of stimuli must be responsible for the tensions responsible for the kinds of “decisions” it ultimately takes. Our inferences, moreover, can be carefully tested against scientific protocol, and hence confirmed or refuted. This, I submit, is already something, and for now it will have to be enough.

What I call *Reading the Lichen Thallus* thus necessarily resolves to an exercise in hypothesis generation: hypotheses based first on patterns seen, and then on interpretations brought to bear through the elucidating (if admittedly metaphoric) lens of systems theory in general and cybernetics in particular.

PROSPECTS

So where does this leave us? For my money – and this is the penny that sooner or later needs to drop – it leaves us with the strong to overwhelming likelihood that the lichen is not what it has for so long seemed. Lichens in the popular mind will doubtless always be identified with the forms, hues and textures of the lichen thallus. That said, lichenologists themselves would do better, I think, to learn to focus their attention on the systems behind the thallus. For the lichen truly *is* the conversation of which the constituent parts are the participants and thallus the outward physical manifestation. The name we give to the lichen conversation is lichenization, and it is here, come down to it, that the lichen truly resides.