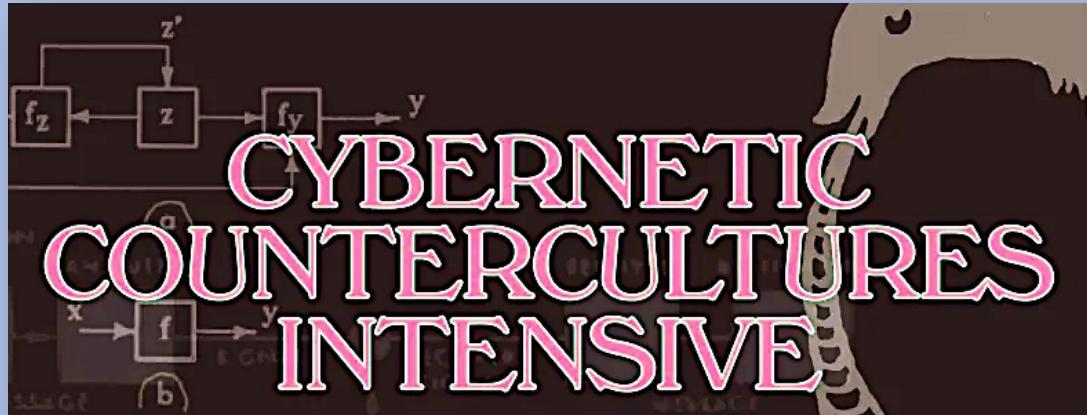


# Week 10: Whole Earth Redux



Part Three: Doing the Metabiotic

# Doing the Metabiotic: or, Natural Technicity: Autopoiesis, Sympoiesis, and the Allegory of the Lichen



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The strength of symbiosis as an evolutionary force undermines the prevalent notion of individuality as something fixed, something secure and sacred.

—Lynn Margulis and Dorion Sagan, *What is Life?*

If it is true that neither biology nor philosophy any longer supports the notion of independent organisms in environments, that is, interacting units plus contexts/rules, then sympoiesis is the name of the game in spades.

—Donna J. Haraway, *Staying with the Trouble*

Symbiosis is a kind of prosthesis or technological process.  
Lichens are nonhuman technologies.

—Derek Woods, “Prosthetic Symbiosis”

In this talk I will discuss the American evolutionary theorist Lynn Margulis's signature themes of *symbiosis* and *symbiogenesis* as fundamental ecological and evolutionary dynamics binding communities, producing new species and generating Gaian biodiversity. Largely due to the feminist theorist Donna Haraway's own popularizations of Margulis's work, these concepts are now regularly invoked as precursors to the concept of *sympoiesis*, the bundle of processes enabling the mutual and relational becomings and assemblages out of which distinct beings appear to emerge.\* I will take up this cluster of concepts here, as fundamental dynamics within interspecies communities, but also as primary processes for what I will be calling *natural technicity*. In this regard, I will interrogate the environmental scholar Derek Woods' recent demonstration that symbiosis in operation may also include a *metabiotic* sense as a "a kind of prosthesis or technological process."

\* Discussions of sympoiesis figure prominently in Donna J. Haraway, *Staying with the Trouble: Making Kin in the Cthulucene* (Durham: Duke University Press, 2016), and in her ongoing writing. Scott F. Gilbert and I trace the history of the concept of sympoiesis in "Margulis, Autopoiesis, and Sympoiesis," in Caroline A. Jones, Natalie Bell, and Selby Nimrod, eds., *Symbionts: Contemporary Artists and the Biosphere* (Boston: MIT Press, 2022), 63-77.

To bring these matters into focus, we can start with an interview Lynn Margulis recorded in Barcelona around 2000 for NHK TV. In these remarks, Margulis links together a series of concepts basic to our discussion today:

- autopoiesis and growth (*biotic potential*)
- symbiosis, as embodied by the lichen
- symbiogenesis as evolutionary bricolage, or natural technicity

Lynn Margulis interviewed in Barcelona, @ 2000



Life. What is life? Life is not a thing. Life is a process. It's a process that makes itself, and as far as we know, it is always based on cells. Cells may be as small as a millionth of a meter, which is a micron. These things wrap themselves into structures of their own making. And intrinsic to life is the propensity to grow—to grow, to excrete, to exchange material, and to grow and to grow and to grow, and this is life. Life is a way of behaving. Yes, it's material. Yes, there is DNA, RNA, and many other chemicals. Yes, it's carbon-based. But dead life has got the same material as live life. What do I mean? If you have a bull and he's fighting the bullfighter, this is life. Five minutes later the bull is dead, there's no life there. The DNA is there, the carbon is there, the water is there, but the bull is dead. What has been lost? What has been lost is the process. And what is the process?

It is the self-making process, where components from the environment are taken in and moved around and changed chemically, to do what? To make more. Why? To make more. Why? To make more. Life is always expanding, always making more of itself. Now, some people use a fancy word for this, and they call it *autopoiesis*, that is, the self-making. And this is a good word, because this word tells us that the components are taken from the environment, the energy is taken from the environment, but by what? By the live thing. The live thing keeps moving, keeps making more, keeps making more, keeps growing, to make more, to grow, to reproduce. So life is not the thing or the matter, because the matter is the same right after death. Life is the property of growing, of making oneself, making more of oneself, and so on.

So, what is the smallest, simplest unit of material that can do this? This is a cell. We know of nothing less complicated than a cell that has this property of making more, of growing, of making more, of growing, and eventually reproducing. But it's the self-making property of the materials, the chemicals, interacting. Now, what is a cell? We have at least 3000 proteins, maybe more, we always have those proteins wrapped up in a membrane. Who makes the proteins and the membrane? The system itself. No one makes it from the outside. The system itself makes itself. Why? To make more, to grow, to make more. Now, this property of to grow-to make more-to wrap oneself-and to make more-and eventually-to reproduce, this property is present in all life.

Symbiosis is a very simple word and a very simple idea. It's simply the living-together of unlike organisms. In fact, in the early definition, it was the living together of differently named organisms. For example, all over northern Siberia and northern Canada, one has the tundra, and the tundra is the food for the reindeer, and the people eat the reindeer. What is that food? That food is lichen. And as the early Russian botanists studied, what is this lichen? It's a product of symbiosis. What does that mean? It means in the lichen, you have the alga, which is the green part, which is making the food, and it's teamed up with the fungi, which is the white part. And the fungi is very boring-looking fuzz, and the alga is very boring-looking green material, and together, when they grow together, they form by symbiosis the lichen. The lichen looks like a plant. It's very similar to a plant. It used to be called a plant, but we know it's not a plant, it's the product of symbiosis.

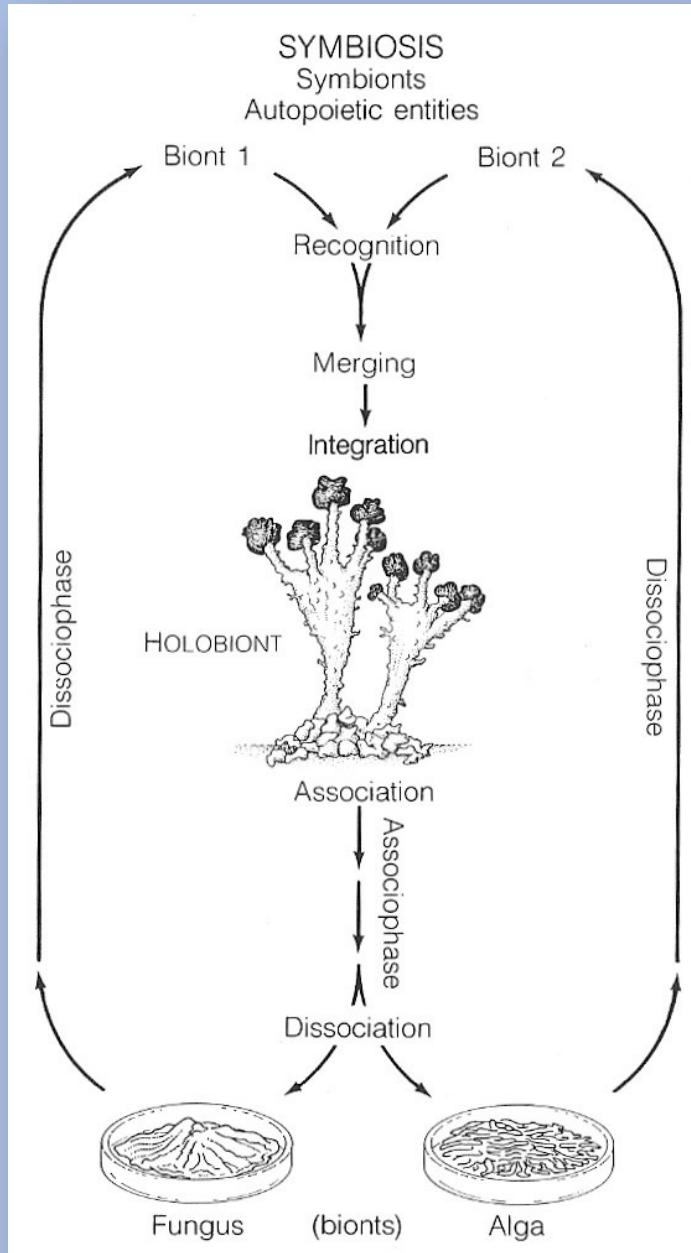
Now, all biologists agree that the lichen is formed by symbiogenesis. What is symbiogenesis? It is simply symbiosis leading to new kinds of evolution. What we now know, which is so different, in fact, it's different from what many people are taught today, is that it's not just the lichen that is the product of symbiogenesis, it is all animal cells, all plant cells, all fungal cells, and all protocell cells. That is, all life on earth that is not bacteria is the product of symbiogenesis. What does that mean? It means that very different sorts of organisms came together to make a new kind of being. Now, people who work with computers know this very well. You don't start all over making the modem, you don't start all over making the hard disk, you recombine already refined parts that were already developed by others, and then you get something genuinely new.

So then, to begin with, in their literal sense as biological concepts:

- *Symbiosis* names the intimate bodily cohabitation, whether mutualistic or parasitic, of different *biotic* forms.
- *Symbiogenesis* names processes of speciation arising from the permanent coupling of previously distinct kinds of organisms, whether by lateral gene transfer or wholesale endosymbiotic incorporation.

As a scientific term, the concept of *symbiosis* was invented in the late nineteenth century to describe the formation of the lichen—a mutualistic, enduring but non-obligatory alliance between a fungus and a photosynthetic partner, a bacterium or an alga.

-diagram from Lynn Margulis, *Symbiosis in Cell Evolution: Life and its Environment on the Early Earth*, 2nd ed. (W. H. Freeman, 1993).





And in our own time, in his essay “Prosthetic Symbiosis,” Derek Woods speaks of lichens “as more than one life form among others. They are special because of their status as symbiotic organisms. They are symbols of future coexistence. Indeed, lichens have an ecotopian meaning that has attracted some cultural attention in recent years . . . lifting them from obscurity and the injustice of being mistaken for moss.”\*

\* Derek Woods,  
“Prosthetic Symbiosis,”  
*New Centennial Review*  
22:1 (Spring 2022): 162.

—Treating all organisms as isolated and strictly self-involved individuals is a damaging Western bias. Woods’ “ecotopian meaning” celebrates the lichen’s emblematic status as a liberator from traditional notions of what is “natural.”

Here is one *allegory* of the lichen. We will need to ask later, under what terms can living systems effectively combine their various operations and become *metabiotic*—life to the second power?



Margulis's career-defining discourse of symbiosis as an essential condition of participation in the biosphere was a key driver in this larger reorientation of biological doctrine, a shift in biological thinking beyond the ideal of the individual. Gilbert, Sapp, and Tauber's anthemic "A Symbiotic View of Life: We Have Never Been Individuals" offers a memorable summary:

"For animals, as well as plants, there have never been individuals. This new paradigm for biology asks new questions and seeks new relationships among the different living entities on Earth. We are all lichens."\*

\* *The Quarterly Review of Biology* 87:4 (December 2012): 336.

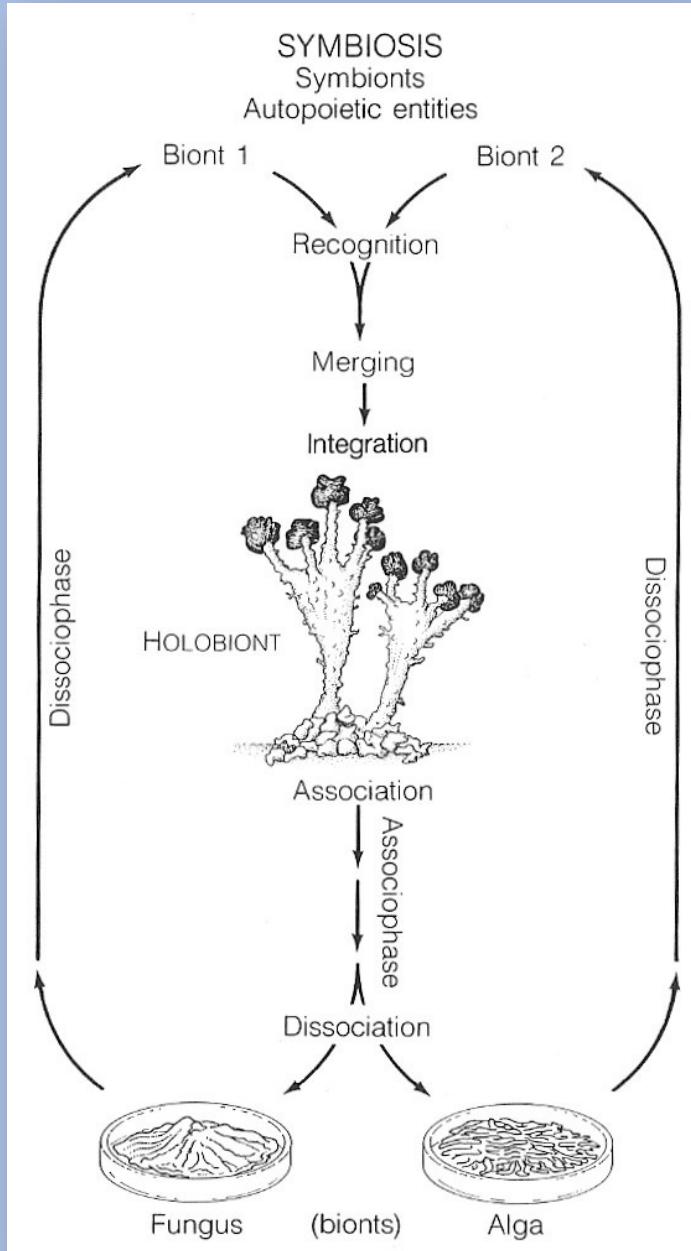
—We could say that the contemporary allegory of the lichen—its extended significance, its charismatic resonance as the poster-organism for sympoiesis—arises from its demonstration of sympoiesis in action.

The compressed equation *we are all lichens* underwrites the conceptual trope of sympoiesis as an appealing posthumanist figure of thought. The lichen-likeness of the human holobiont joins us to the more-than-human living world. We are all lichens insofar as we are also sympoietic beings, that is, evolutionarily speaking, symbiogenetic consortia of distinct biological entities. The cultural allegory of the lichen symbiosis universalizes and socializes a humbly appealing vista of the good-natured interrelatedness that sustains and nurtures the Gaian system.

—Before unfolding the concept of sympoiesis further, however, let us step back for a moment and review the basic biology of the lichen. It may be noted that the lichen association is not a universal but a highly specific arrangement. And yet the formal arrangement or basic organic template of the lichen allows for a vast radiation of types and species. Margulis' major study *Symbiosis in Cell Evolution* provides a diagram of lichenization that stresses its status as a symbiogenetic holobiont coordinating distinct processes of symbiosis and autopoiesis.\*

\* Margulis, *Symbiosis in Cell Evolution: Life and its Environment on the Early Earth*, 2nd ed. (W. H. Freeman, 1993).

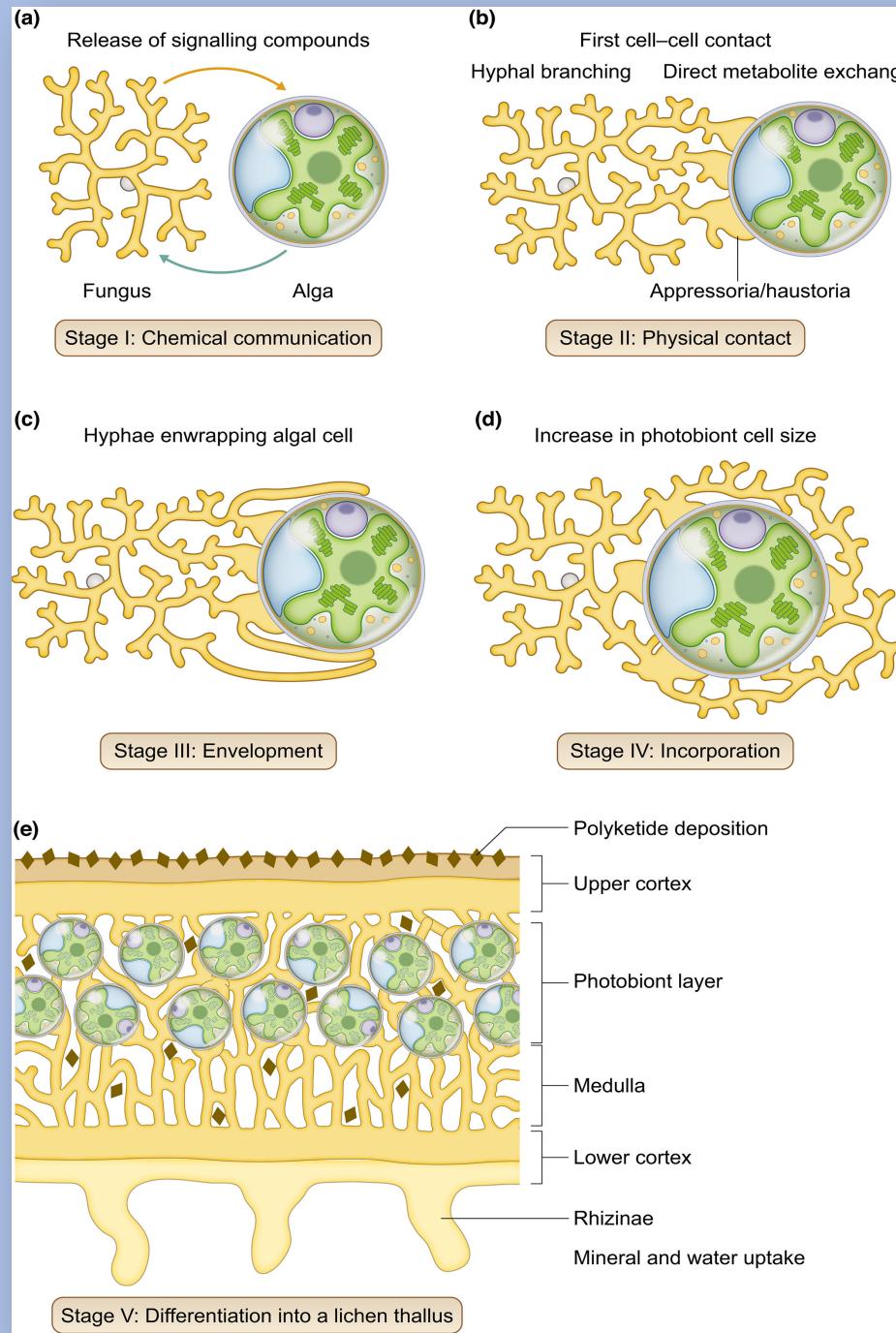
-diagram from Lynn Margulis,  
*Symbiosis in Cell Evolution: Life and its Environment on the Early Earth*, 2nd ed.  
(W. H. Freeman, 1993).



In Margulis' description, the lichen consists of:

- Two bionts from separate biological kingdoms— always a fungus allied with a photosynthetic partner, which can be either an alga or a bacterium.
- Two distinct autopoietic entities achieving integration and association in a composite body unlike the body of either symbiont on its own.

—The contemporary scientific article “How to Build a Lichen” provides additional details summarizing the current understanding of lichen formation. Upon sensing the other’s proximity, distinct cross-kingdom biota enter into productive relations by initiating chemical communications that release signaling compounds leading to metabolite exchange, the envelopment and incorporation of the photosynthetic partner by the fungal partner, and the differentiation of the lichen thallus as a new organic formation.



The basic template of sympoiesis is symbiosis + autopoiesis = incorporation + differentiation.

“How to build a lichen: from metabolite release to symbiotic interplay”

*New Phytologist*  
238:4 (29 January 2023): 1362-1378.

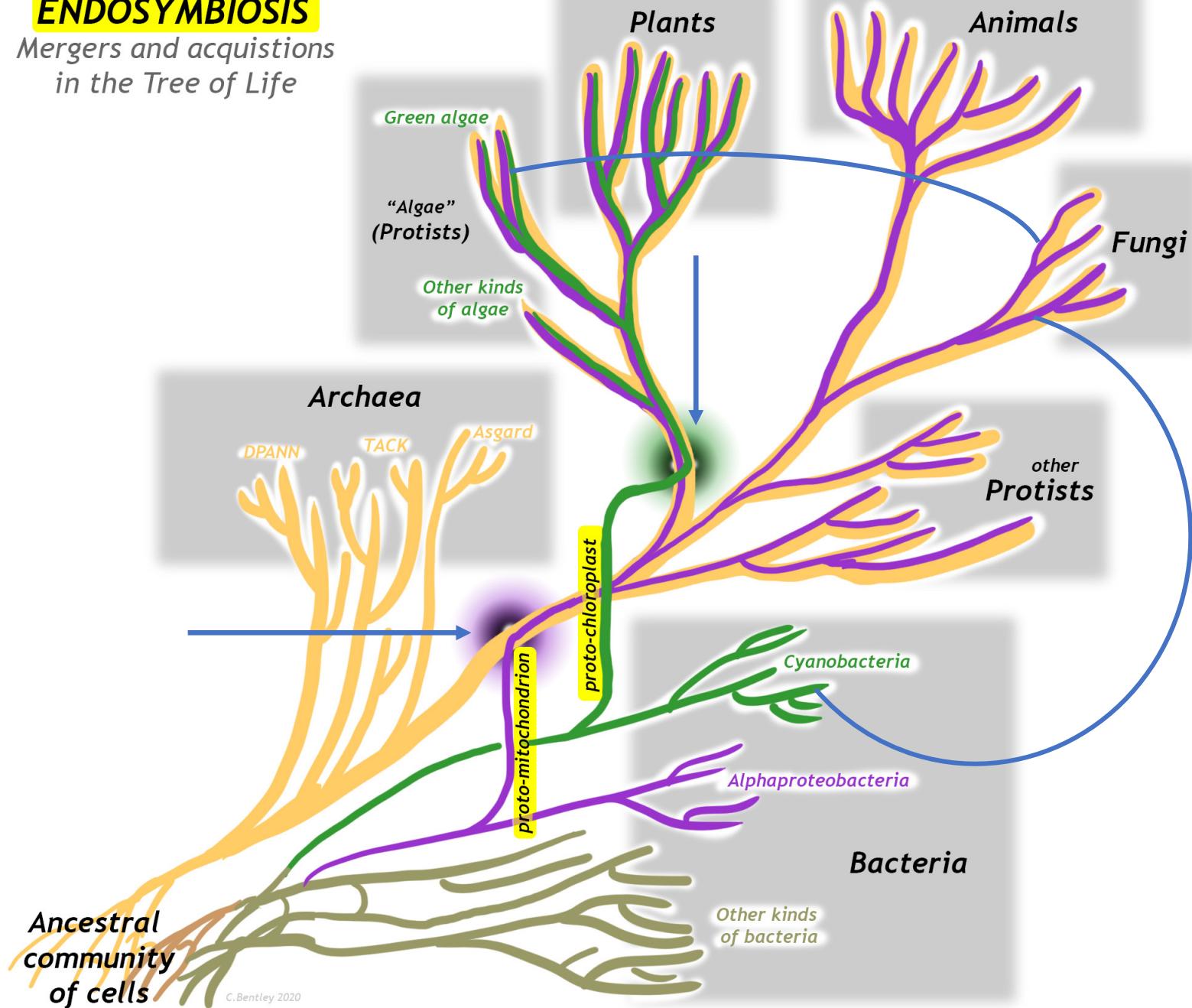
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—In Margulis's own idiom, the processes of mutual recognition and nutrient sharing in the lichen may also be said to be mediated by the cellular cognition that emerges from and so accompanies active autopoietic organizations. The key thing to note in the lichen symbiosis, as specified in her own account, is the maintenance of autopoietic distinction between the bionts even as the effective operation of their symbiotic association produces a third thing that is neither fungus nor photosynthesizer alone—the lichen thallus.

So we have the following formula: the sympoietic process that “builds a lichen” emerges from the combination of symbiosis *and* autopoiesis, from the maintenance of differentiation in the midst of incorporation.

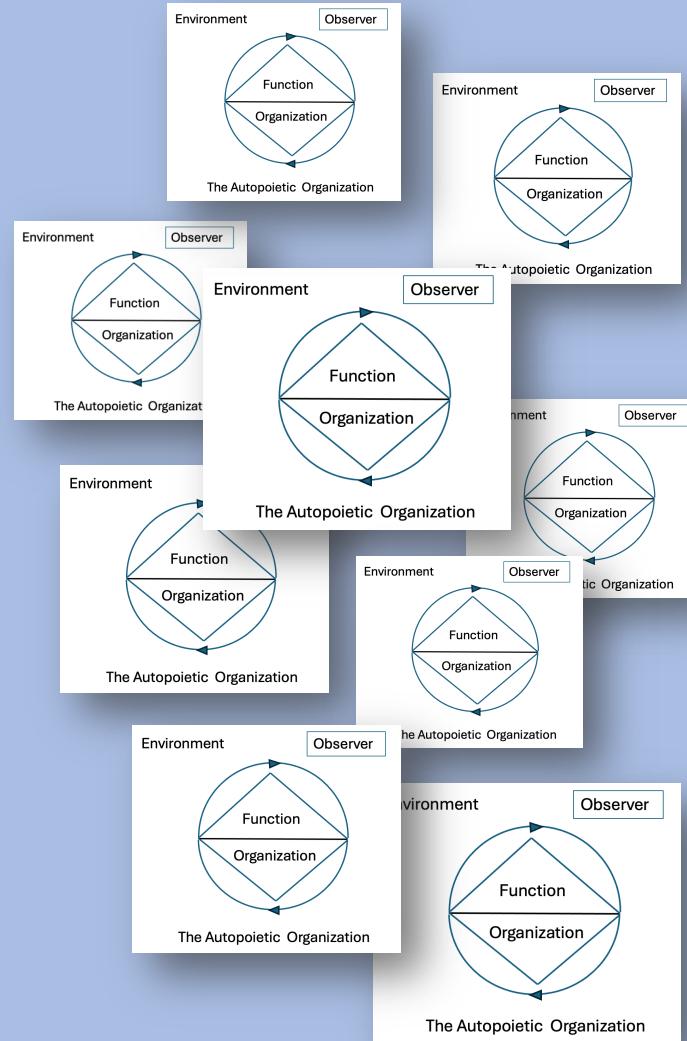
# ENDOSYMBIOSIS

Mergers and acquisitions  
in the Tree of Life



The lichen symbiosis is not obligatory on the part of its symbionts. When environmental conditions change, lichen symbionts may dissociate and go their separate ways. The survival of the symbionts beyond lichen dissociation is possible only because they retain autopoietic differentiation throughout their sympoietic interlude within the lichen symbiosis.

Sympoiesis is a general description of mutual becoming-with that renders its participants more than individuals. Some have sought on occasion to subtract autopoesis from symbiosis on the consideration that the “self-production” of the former is transcended by the collectivity of the latter. However, the life-cycle of the lichen teaches us that there are good reasons to hold on to the autopoietic description of distinct living beings. Autopoietic processes drive the dynamics of symbiotic consortia themselves and as well as their necessary commerce with allopoietic, that is, externally produced technical structures. As signified all along by the additive portmanteau neologism, the concept of sympoiesis is most productively treated as a *metabiotic* production of consensual complexity through the differential aggregation of symbiotic and autopoietic processes.



—Moreover, the autopoietic perspective underlines the cellular basis of viable metabolisms, despite diverse chemical signaling on the part of adjacent cells that can induce tissue and organ differentiations within, say, the developing cells of animal fetuses. Scott F. Gilbert neatly delineates these dynamics as “developmental symbiosis—symbiopoiesis,” a body of processes within the embryonic elaboration in plants and animals that conclusively belies any absolutist formulation of the autonomy of autopoietic operations. Or again, the lichen comes together when the proximity of its discrete symbionts triggers the release of signaling compounds that initiate phenotypic changes. Nevertheless, whenever such external factors lead to such cellular modulations, the actual molecular and metabolic processes arising from the *operational* closure of the cell’s membrane-bounded organization have not been outsourced: minimal but definitive individual specificity persists at the autopoietic level of any biological cell’s recursive integrity.

—for instance, chemical signals, as in the formation of the lichen

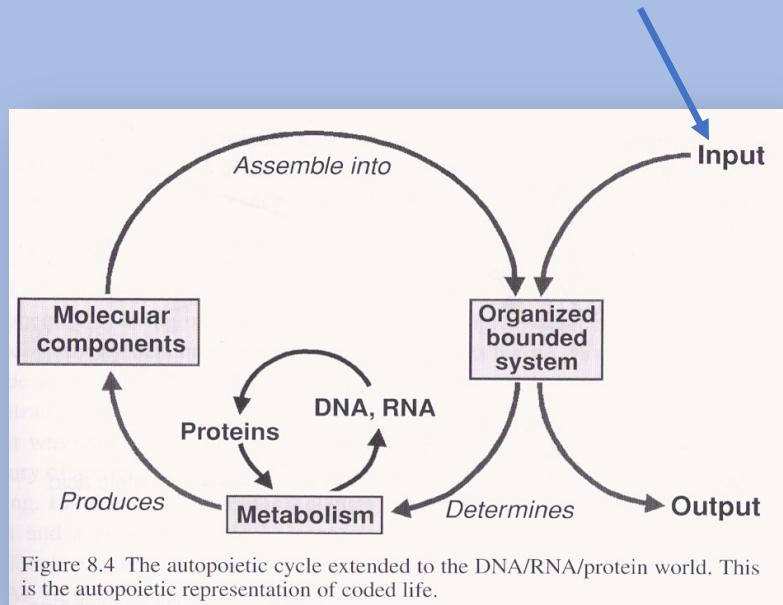


Figure 8.4 The autopoietic cycle extended to the DNA/RNA/protein world. This is the autopoietic representation of coded life.

from Pier Luigi Luisi, “Autopoiesis: The Logic of Cellular Life,” in *The Emergence of Life* (Cambridge, 2006).

This is to say that, in fact, we are *all* individuals, once you go to the ultimate cellular level. Derek Woods notes the biological bottom line in this matter: “even if it is difficult to demarcate the boundaries of individuals, they remain individuals to the extent that they can die” (166). In other words, whereas the loss of symiotic interrelation may well not be terminal for its components, as in the lichen, the autopoietic process is biologically primary in that, if *it* is lost, life ends for that organism. No matter how complex any holobiont may be, its symbionts—including the ostensible plant or animal host of that symiotic consortium—can perish one by one and on their own time. For all this concept’s utility at other levels of biospheric organization, exclusivist notions of sympoiesis risk sidelining the datum of mortality and covering over the supplemental and accidental contingencies of abiotic elements and environmental structures.

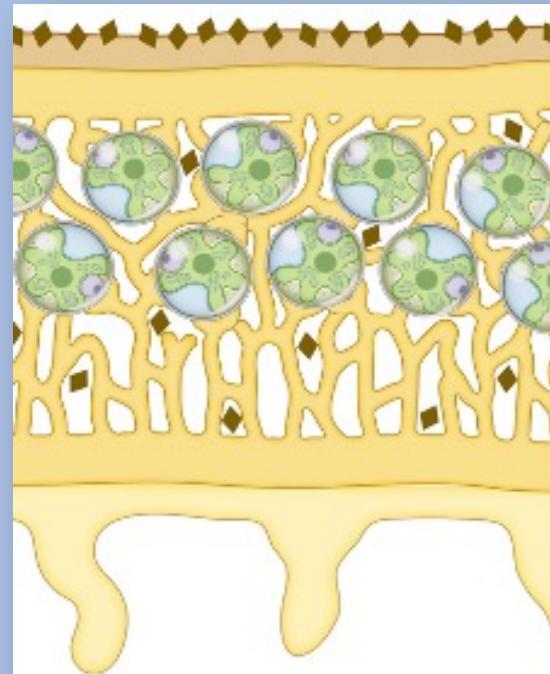
—Now, where does the idea of *natural technicity* fit into these concepts of symbiosis and sympoiesis? Well, if we press on the architectural or technical metaphor in the phrase “building a lichen,” we’re reminded how Margulis construed the sense of symbiogenesis itself as a kind of evolutionary *bricolage*.



—Lynn Margulis:

“All life on earth that is not bacteria is a product of symbiogenesis. What does that mean? It means that very different sorts of organisms came together to make a new kind of being. Now people who work with computers know this very well. You don't start all over making the modem, you don't start all over making the hard disk. You recombine already refined parts that were already developed by others, and then you get something genuinely new.”

In “Prosthetic Symbiosis,” Woods argues persuasively that symbiotic relations among diverse organisms operationalize a technical dynamic that is no longer exclusively organic *per se*, but also *metabiotic*, a mutual coupling of prosthetic supplementation, a reciprocal co-environmental externalization. He writes: “Symbiosis is a kind of prosthesis or technological process” (160). Lest this statement be misconstrued as a kind of simplistic mechanistic schema, Woods clarifies that “Symbiogenesis is not a matter of organisms using one another like nonliving tools or machines, but a fundamental technical process in which one autopoietic life form externalizes functions into another. Life forms in mutualism supplement one another to open new functions and relations to their environments” (160). It is in this light, then, that “Lichens are nonhuman technologies.” As this figure from “How to Build a Lichen” perfectly illustrates, “The fungus is a greenhouse for the alga and the alga is a solar panel for the fungus” (160).

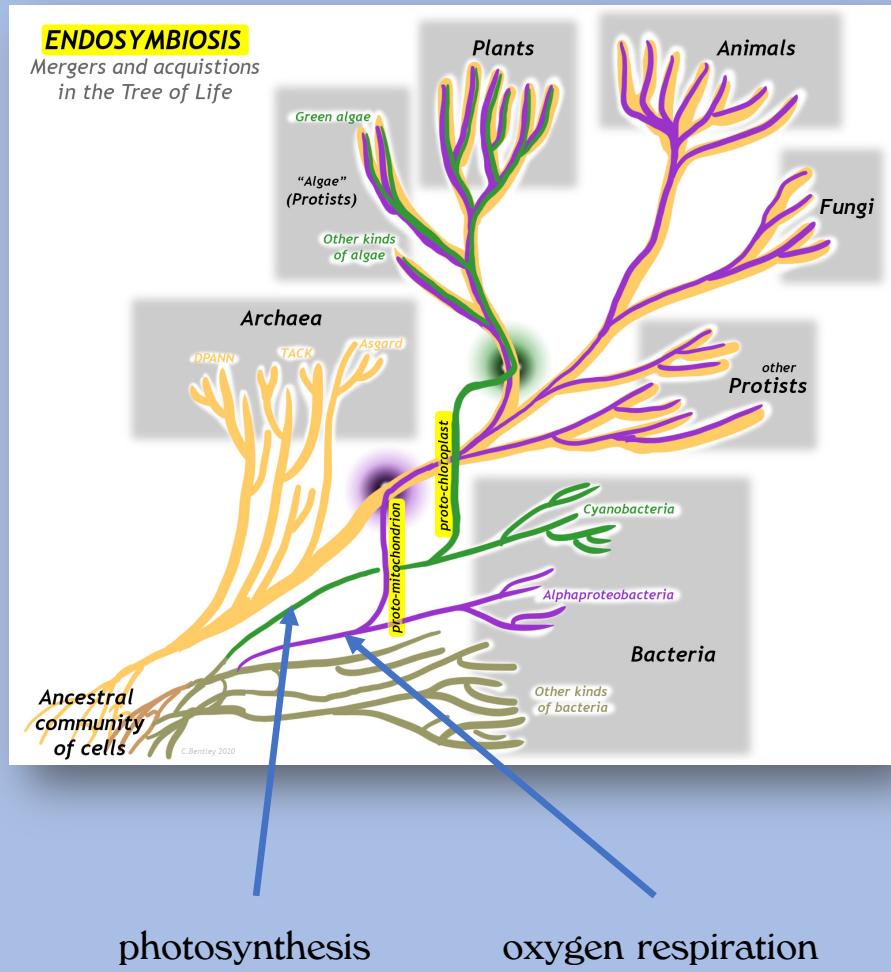


—This metabiotic technology is possible precisely because, in their autopoietic specificity, the symbionts remain formally bounded, mutually external to each other, and thus suitable for discrete reorganization within an encompassing superstructure. For even as the symbionts will be “functionalized by the new lichen-like symbiotic unit,” lichenization is fundamentally a technical process “in which one autopoietic life form externalizes functions into another” (160).

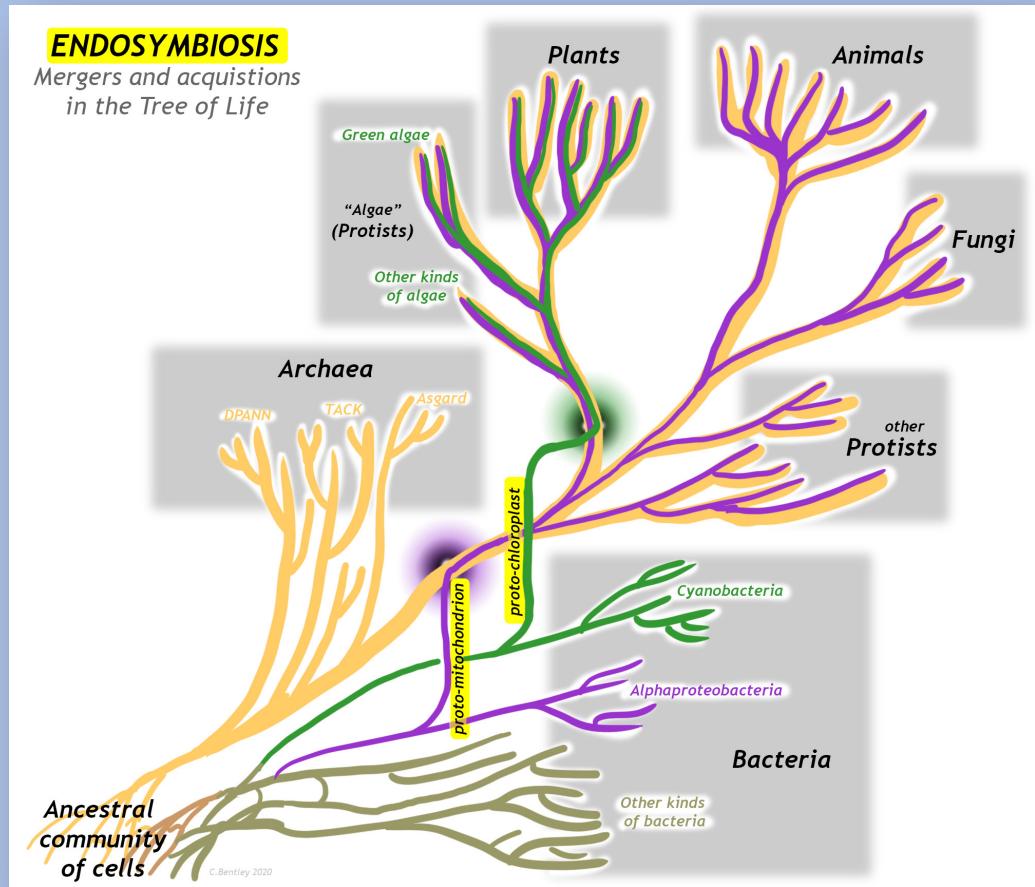
And this view is strengthened when considering that there are no lichen cells as such: there are only algal or bacterial and fungal cells that, for the duration of their symbiotic consortium, mutually induce each other to form a thallus and dwell within the differentiated body of a lichen. Thus, the symbiotic lichen is also a metabiotic entity: it is as much a technical mediation as it is a biological organism.



It turns out that biological evolution has always surpassed itself through a metabiotic recursion of affordances. In the earliest life forms—archaea and bacteria, evolution proceeded symbiotically by lateral gene transfer among metabolically diverse strains, yet even here with what Woods terms “a kind of biotechnics at work in the prokaryotic milieus of the ancient Earth” (174). Certain of these ancient recombinations led to the invention of photosynthesis in cyanobacteria and oxygen respiration in alphaproteobacteria, on the way to their endosymbiotic incorporation, as chloroplasts and mitochondria respectively, into diverse iterations of the eukaryotic or nucleated cell at the base of the post-bacterial biological kingdoms.



And coming back now to the phenomenology of the lichen, its fungal and photosynthetic partners—the autopoietic entities available for mutual prosthesis through the lichen’s symbiogenesis—have a place on this phylogenetic diagram. They are standard *phylogenetic* organisms in that, once their symbiogenesis is stabilized, the progeny of these organisms directly descend from progenitors by vertical heredity. However, unlike its symbiotic partners, lichens are *not* explicitly indicated on this diagram. That is to say, their reproduction and evolutionary descent is *not* phylogenetic, but rather, *epiphylogenetic*, or again, “passed down via technical externalization rather than genetics” (175). In the celebrated symbiosis from which lichen bodies emerge, “prosthetic symbiosis brings at least two autopoietic systems into a close relationship. . . . Lichens, but not their fungi or algae, are . . . already *epiphylogenetic* in Stiegler’s sense of the term” (175-77), that is, in our phrase, a form of natural technicity.



Let us review the French philosopher Bernard Stiegler's schemas from his *Technics and Time* in this context, along with Derek Woods's glosses and my own short elaborations. Stiegler distinguishes three kinds of memory:

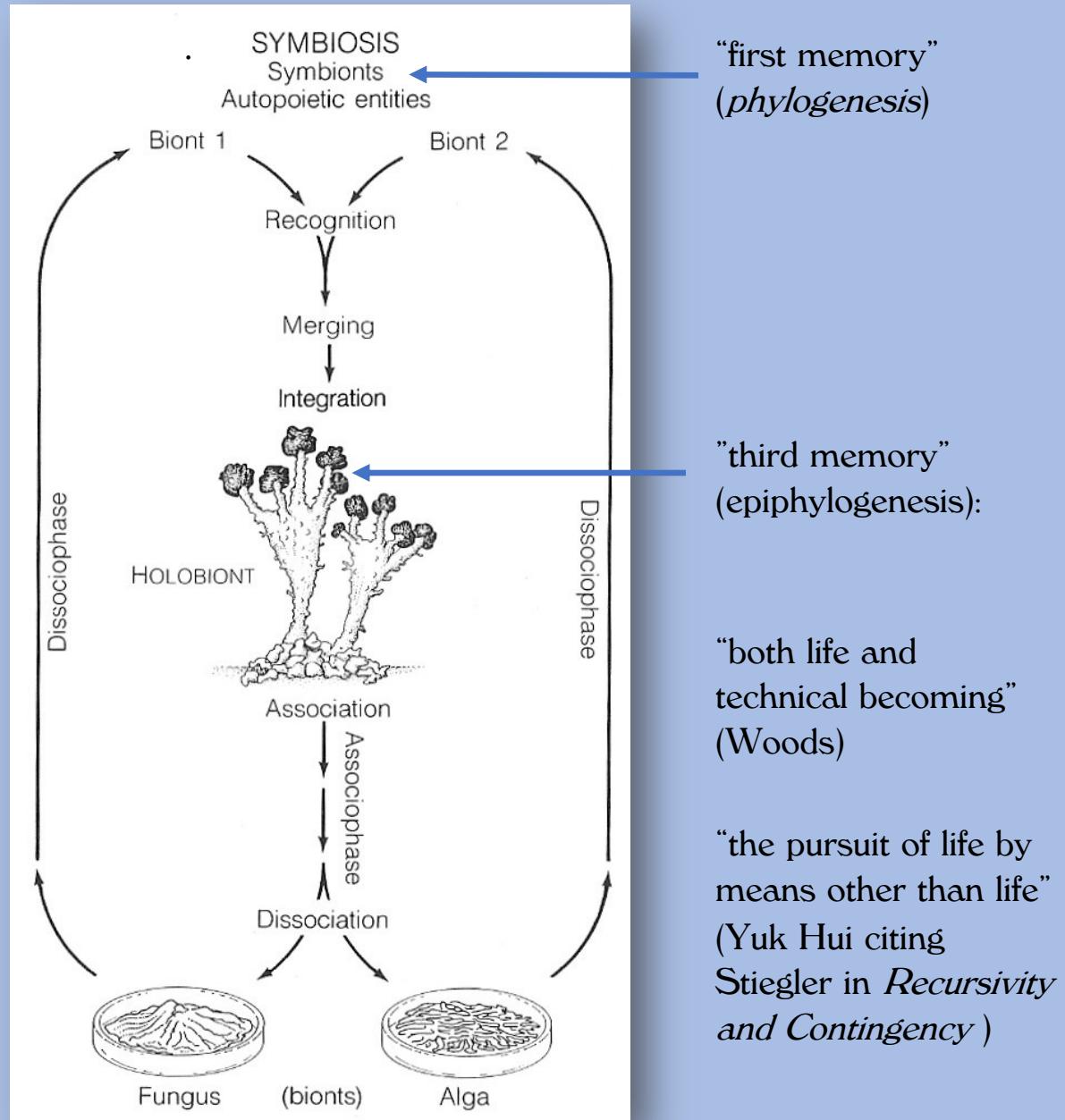
- “First memory” is *phylogenetic*, “the heritable organic” (173)—the “vertical” inheritance involved in biological reproduction and descent through the replication of genomes.
- “Second memory” is *epigenetic*, the “ephemeral organic” (173)—“memory” in traditional parlance, the embodied reflex or experience of somatic or psychic recollection.
- “Third memory” is *epiphylogenetic*, “the organized inorganic that exteriorizes organic functions into technical objects and systems” (173)—here is technics proper, concretized in external information-transfer systems, such as writing, or inscription in general.\*

In Stiegler's own system, third memory or “tertiary retention” is largely restricted to matters of anthropogenesis: “unlike animals,” philosopher of technology Yuk Hui summarizes, with “technology, human beings are able to pass their memory from generation to generation, without affecting the soma and gene cell.”† However, the concept of prosthetic symbiosis displaces the epiphylogenetic process of prosthetic supplementation from anthropology to the natural technicity already operating in biological or organismal symbiosis as far back as the first eons of autopoiesis and symbiosis

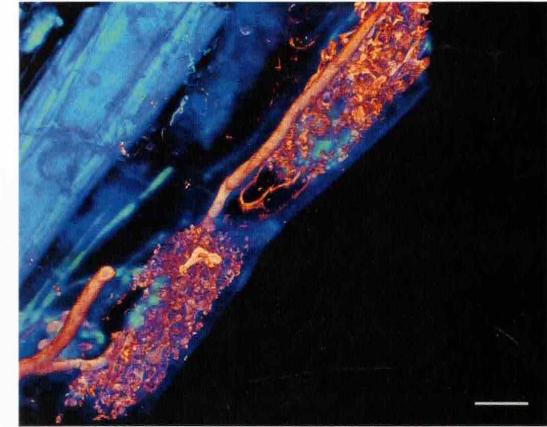
\* On the “organized inorganic,” see Hui, *Recursivity and Contingency*, chapter 3, “Organizing Inorganic.” On epiphylogenesis, see in particular Robert A. Gorny and Andrej Radman, eds., “Introduction: From Epiphylogenesis to General Organology,” in *The Epiphylogenetic Turn and Architecture In (Tertiary) Memory of Bernard Stiegler*, in *Footprint* 16:1 (Spring/Summer 2022): 3-20.

† Hui, *Recursivity and Contingency*, 204.

As applied to the lichen, here autopoiesis belongs to the first memory of the fungal and algal or bacterial *symbionts*, but not to the third memory of the lichen *symbiosis*, which is “both life and technical becoming” (Woods 177), or in Stiegler’s phrase, as cited in *Recursivity and Contingency*, “the pursuit of life by means other than life” (205). Thus, once again, the symiotic lichen is as much a technical mediation as it is a biological organism, a communal housing project built by diverse biotic actors for the sake of mutual shelter and to sequester available water.

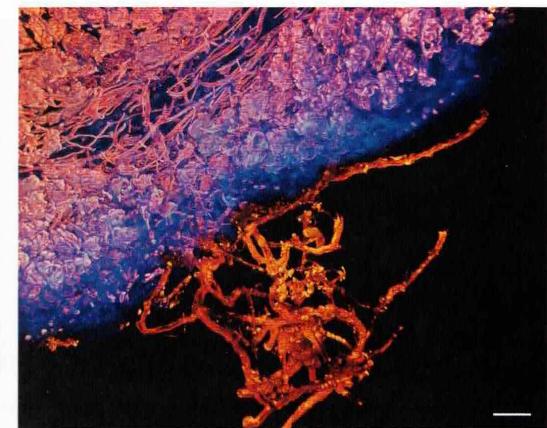


The lichen and its symbiotic analogues arise from a cross-over between two or more different eukaryotic kingdoms alongside a mutual boundedness that maintains their autopoietic and phylogenetic differentiations, and which operates without crossing out their autopoietic and phylogenetic differentiations. In these examples of natural technicity, then, we also have instances of a *Gaian* technics precisely insofar as the autopoietic processes of specific biota, even when aggregated with their symbiotic fellows, operate across a boundary that simultaneously divides and connects them to the externalized, hence environmental affordances produced by their very aggregation. It could be said that our own human or animal lichen-likeness is equally a product of our own *technogenesis*, which derives in the last instance from a long archaeological history of modulations mediated by epiphylogenetic natural technicity alongside an evolving phylogenetic heredity. All of which is to say, here with extreme compression, that the human technosphere as well has its deepest roots in the mechanicities contrived by the evolution of organicity.



Mycorrhizal fungus living inside a plant root. The fungus is depicted in red, and the plant in blue. The finely branched structures within the plant cells are known as "arbuscules" ("little trees") and are the site of exchange between the plant and fungus. Scale bar = 20 micrometers.

COURTESY OF THE AUTHOR



Mycorrhizal fungus growing into a plant root. The fungus is depicted in red, and the edge of the plant's root in blue. The inside of the root is densely inhabited by fungus. Scale bar = 50 micrometers. COURTESY OF THE AUTHOR

—Mycorrhizal fungus inside plant roots,  
from Sheldrake, *Entangled Life*

- Natural technicities are the biosphere's original sampling technology. Their primary productions are new biological phenotypes and fortuitous sympoietic congregations along with diverse ecological accommodations.
- Concepts of sympoiesis—like those of its engendering processes, symbiosis and autopoiesis—are grounded both in the molecular operations of living organisms and in the mechanics of aggregation or natural technicities that emerge from evolving life's self-involution.
- Culturally extended readings of sympoiesis may be seen as wider ecological and social mappings of the natural technicity afforded in symbiotic and symbiogenetic processes.
- Gaian technicities built on the supplemental differentiation of symbiosis and autopoiesis trouble the demarcation, not between life and technology per se, but between two modes of externality: natural technical constructions, such as shells or lichens, and human cultural constructions, such as texts, sculptures, or built environments.
- Natural technicity is a metabiotic processes, a structural recursion of the biotic contingencies involved in the symbiotic and symbiogenetic dynamics of living systems. The concept of sympoiesis celebrates natural technicity from within an organicist frame.

**SYMBIOTS:  
CONTEMPORARY ARTISTS  
AND THE BIOSPHERE**



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For more, see:

**MARGULIS, AUTOPOIESIS,  
AND SYMPOIESIS**

Bruce Clarke and Scott F. Gilbert

Thanks!

**INTRODUCTION**

Since the decoding of the DNA molecule during the mid-twentieth century, a genomic “replicative/reproductive” characterization of life has occupied center stage in both the popular imagination and the scientific study of living processes.<sup>1</sup> However, in the 1970s, a generative contrarian viewpoint emerged on the margins of mainstream biology, advancing the concept of *autopoiesis* (from the Greek, *auto* for “self,” *poiesis* for “production”). Invented around 1972 by Chilean scientists Humberto Maturana and Francisco J. Varela, the concept of autopoiesis redirected attention to the “self-production” and continuous self-maintenance of living systems—a change of focus making the genome part of a much larger cellular apparatus characterized by cyclical metabolic processes. Here, life distinguished itself from its nonliving environment by an ability to retain its bounded identity while changing its chemical components.

Although the autopoiesis concept would have a significant if heterogeneous reception, both the genomic and the autopoietic views of life would become contested in their turn by major advances in our understanding of *symbiosis* as a decisive dynamic that binds living systems into multigenomic communities and collective consortiums. Symbiosis had been theorized for almost a century by the time the concept of autopoiesis emerged, and in 1990, the evolutionary theorist and champion of symbiosis Lynn

<sup>1</sup>—See Evelyn Fox Keller, “Nature, Nurture, and the Human Genome Project,” in *The Code of Codes*, ed. Daniel J. Kevles and Leroy Hood (Cambridge, MA: Harvard University Press, 1992), 281–99; Dorothy Nelkin and M. Susan Lindee, *The DNA Mystique: The Gene as a Cultural Icon* (New York: W. H. Freeman, 1996).

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