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How I Found Gaia: Systems Theory and the Development of Gaia Discourse

I will begin by retracing the path that led me to Gaia-- a simultaneous exposure to neocybernetic systems theory on the one hand, and the work of the American evolutionary thinker Lynn Margulis on the other, in particular, in its connection with the Gaia hypothesis first formulated by the British scientist James Lovelock. As cybernetics has mutated and diverged over the decades, so have the descriptions of Gaia as a system. Lovelock and Margulis’s seminal writings were also the first to bring multiple lines of systems discourses and theories to bear on the Gaia concept. Margulis’s Gaia discourse in particular develops a systems theory of “autopoietic Gaia” and articulates an intellectual style of “Gaian thought,” an pragmatic ethics for planetary citizenship.

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How I Found Gaia: Systems Theory and the Development of Gaia Discourse

You could say that I found Gaia by way of chaos theory. In my part of academe chaos theory arrived in 1987.[[1]](#endnote-1) By the 1990s, inspired partly by the avid interdisciplinary reception of this more technically denominated *dynamical systems theory*, I began in earnest to cultivate a post-tenure specialization in literature and science. But as I set about to reschool myself in physics, chemistry, and biology, to come up to speed on chaos and complexity theory, thermodynamics and information theory, and then cybernetics and systems theories, where Gaia was concerned, not much came to hand. Even after it had crossed my threshold, for a while I was reluctant to take it seriously. I had absorbed the nebulous notion that what “Gaia” named in scientific context was not quite real science but some kind of New Age notion connected to god knows what exactly. I took it to be the sort of idea that I, a recent interloper into the discourse of the sciences, in order to establish or maintain some minimal credibility, should avoid.

 Around 2000 I was searching for an accessible introduction to biology for my undergraduate literature and science classes, looking for something in the vein of the well-known medical researcher Lewis Thomas’s popular text of 1974, *The Lives of a Cell*, but more recent.[[2]](#endnote-2) *The Lives of a Cell* did not mention Gaia by name, but in retrospect it closely anticipated early Gaia discourse: “I have been trying to think of the earth as a kind of organism, but it is no go. I cannot think of it this way. It is too big, too complex I wondered about this. If not like an organism, what is it like, what is it *most* like? Then, satisfactorily for that moment, it came to me; it is *most* like a single cell.”[[3]](#endnote-3) The face and figure of the Gaia hypothesis, I was to learn, would also shift about like this, appearing now as “a single cell,” other times as “a kind of organism” or as a “complex” entity of some sort.

As it turned out, what I did find that day was Lynn Margulis’s popular exposition of her evolutionary theories in the recently released paperback edition of *What is Life?,* written with her son, Dorion Sagan.[[4]](#endnote-4) I recollected then that *The Lives of a Cell* had copped many of its best riffs from Margulis’s early work. Popularizing her first book, *Origin of Eukaryotic Cells*, these “Notes of a Biology Watcher” also vetted its arguments for the starring role of symbiosis in cell evolution.[[5]](#endnote-5) By the time Thomas was writing those pieces in *The Lives of a Cell*, in fact, Margulis had already formed a decisive association with the independent British scientist James Lovelock, and they were at work on their original run of co-authored papers on the Gaia hypothesis. Here now in *What is Life?* wasMargulis’s own expansive updating of her evolutionary narrative, set forth in equally vigorous and elegant co-authored prose.

 So I began teaching *What is Life?* flanked by various works of bioscience fiction. It introduced the Gaia concept, and this was probably my first encounter with an authoritative account. However, itdid not bring Gaia forward so emphatically that one had to confront it head-on. I taught this text for several years, concentrating on its main account of deep evolution while otherwise sweeping Gaia off to the side. Then the semester arrived when instead of assigning the relatively lengthy and rigorous *What is Life?* I went with Margulis’s terse 1998 memoir, *Symbiotic Planet*. Its final chapter, simply titled “Gaia,” retells the name-of-Gaia origin story, with a cautionary twist:

The term *Gaia* was suggested to Lovelock by the novelist William Golding, author of *Lord of the Flies*. . . . They both lived in Bowerchalke, Wiltshire, England. Lovelock asked his neighbor whether he could replace the cumbersome phrase “a cybernetic system with homeostatic tendencies as detected by chemical anomalies in the Earth’s atmosphere” with a term meaning “Earth.” “I need a good four-letter word,” he said. On walks around the countryside in that gorgeous part of southern England near the chalk downs, Golding suggested Gaia. . . . The name caught on all too well.[[6]](#endnote-6)

Following upon her intensive collaborations with Lovelock in the 1970s and 1980s, by the later 1990s *Symbiotic Planet* intimated Margulis’s longstanding concern that “Gaia” as a trademark had exposed the science it covered to severe misconstructions. In an interview early in this century with Canadian science broadcaster David Suzuki, Lovelock confirmed his awareness of Margulis’s mixed feelings. Regarding the name of Gaia: “Nobody, not even Lynn, liked it. She tolerated it, and was very understanding of its origins and went along with it. But her first reaction was that it wasn’t a very good idea at all. It kind of brought up the idea of pagan goddesses and all and didn’t fit at all with the atheistic view of science. But of course it almost instantly appealed to the New Age. And I don’t say the New Age in any pejorative sense. Because in those days it *was* a new age.”[[7]](#endnote-7) Lovelock’s remarks capture my own experience prior to encountering Margulis’s advocacy for the Gaia concept.

In *Symbiotic Planet*, however, one passage in particular finally made the idea of Gaia click for me. It began with this statement—possibly a distant echo of Lewis Thomas, whom she knew well—regarding the proper sense of Gaia theory: “As detailed in Jim’s theory about the planetary system, Gaia is not an organism” (119). Nor was it a single cell. Margulis’s negative propositions regarding Gaia proper (not “the earth” altogether) began to cut away from my misunderstanding of Gaia the things I had been vaguely worrying about—the fringe metaphysics or planetary vitalisms kept alive, so to speak, by the name of Gaia itself having “caught on all too well,” and also, by Lovelock’s inclination to foreground organic metaphors in describing Gaia. For her own part, in this passage Margulis rehearsed the finer points of Lovelock’s developed presentation of the theory, tethering metaphors tightly to the science, and gave her own articulation of the concept. “Gaia itself is not an organism,” she continued, “directly selected among many. It is an emergent property of interaction among organisms, the spherical planet on which they reside, and an energy source, the sun” (119). So it happened that my initiation to Gaia theory did not come directly from the work of Lovelock, Gaia’s primary author, but from the science writing of Margulis. *Partial Earth*, my forthcoming book on these matters, retains this initial orientation in tracing the particular signature of Lynn Margulis on the evolution of Gaia theory. This talk touches some further details taken up in *Partial Earth*, and I sincerely hope that these samples will make you want to buy the whole thing.

 Margulis’s point at that moment was that, even if you want to consider Gaia as a “living” entity of some sort, it cannot be reasonably submitted to standard evolutionary expectations of reproduction, random variation, survival in competition, and natural selection. Rather, she countered, Gaia is a living *system*. Having placed the organic metaphor into this more abstract perspective, Margulis then figured Gaia’s status, not as an “organism,” precisely, but as a *body*: “Gaia, the system, emerges from ten million or more connected living species that form its incessantly active body” (119). This exposition was my Eureka moment. If Gaia is a system, then Gaia theory is systems theory. And not only that: in the fullness of her engagement with it—for instance, in *What is Life?*—Margulis would go on to treat Gaia theory as *autopoietic* systems theory. She would also incorporate the concept of autopoiesis into a range of her popular expositions on living beings altogether. As some of you will be aware, the concept of autopoiesis is the centerpiece of a systems discourse that first emerged in the 1970s under the title “second-order cybernetics.” The discourse of autopoiesis will mingle productively with Margulis’s mature pronunciations of Gaia theory.By the 1990s, Lynn Margulis was coordinating the Gaia concept with a suite of autopoietic systems theories also making their paradigm-changing way against institutional and ideological headwinds.[[8]](#endnote-8)

NST: Neocybernetic Systems Theory

NST, the neocybernetic line of autopoietic systems theory, has developed by expanding the concept of autopoiesis beyond its origin in biological systems theory. For its inventors, the Chilean biologists Humberto Maturana and Francisco Varela, the premier instance of an autopoietic system is the living cell. Regarding the original, biotic form of the concept, living cells are autopoietic in that they perform their own production. The fundamental processes of living systems are recursive. Their operations are primordially self-referring. Living systems continuously select and transform the elements they take from their environmental mediums to produce their own continuation and transformation out of their own continuing production of selective transformations. By such incrementally renovating means they maintain both their operational form and their metabolic processes—the possibility of successfully consorting and coupling with other material, biotic, and metabiotic systems and their environments.

Social systems theory effectively extends the concept of autopoiesis beyond this biotic application. Niklas Luhmann differentiated self-producing systems into living and nonliving, or biotic and metabiotic registers, in that, while “nonliving,” the precise forms of differentiations processed in psychic and social systems (events of consciousness and communication) can emerge only from living systems. So when Margulis and Sagan write, “The biosphere as a whole is autopoietic in the sense that it maintains itself,” following Luhmann’s conceptual opening, such an autopoietic conception of the Gaian system may denote it not a living system precisely, but rather, as another kind of metabiotic system—a self-generating, self-maintaining planetary constellation emerging from the interactions of living and nonliving elements, embodying their integrated inter-modulations.

 Cognition is a mark of autopoietic operation. Already in Maturana and Varela’s theory of autopoiesis, cellular life’s self-referential processes yield a form of biotic cognition, a cognition of molecular forms and cellular events. In *What is Life?* Margulis and Sagan name this ubiquitous self-feeling of living systems *sentience*. Other authors call it “sense-making,” a mode of basic knowing placing any living system in embodied relation to its own communal and material environments. In addition, the nutritive, metabolic, and excretory processes of any living system are at all times, if even infinitesimally, remaking their own niche from moment to moment. Now parlay those micro-dynamics to the worldly macrocosm. Bruno Latour has recently stated this Gaian recognition in his own idiom: “Each agency modifies its neighbors, however slightly, so as to make its own survival slightly less improbable. . . . [T]he concept of Gaia captures the distributed intentionality of all the agents, each of which modifies its surroundings for its own purposes.”[[9]](#endnote-9) As I have now come to think, autopoietic Gaia taps its own modes of planetary cognition from the deep wells of these microcosmic points of biotic sensation.

 Be that as it may, this episode of my finding Gaia story ends back when, at work at once on two seemingly separate strands of autopoietic systems theory, I saw them come together. I could now construct Margulis and Sagan’s phrasings in *What is Life?* in a fully neocybernetic sense. Margulis’s biotic strand, directly responding to Maturana and Varela’s original conceptuality, joined Luhmann’s metabiotic strand to resolve one of Gaia theory’s most persistent equivocations—the matter of whether Gaia is itself “alive.” As an autopoietic system in the metabiotic register, Gaia need not be identified with the form of life *per se*. Rather, *Gaia participates in an essential quality of individual living systems—the autopoietic form of organization*, an emergent, recursive form of self-production and self-maintenance, *within a metabiotic coupling of abiotic and biotic dynamics*. Autopoietic Gaia arises as a “property of interactions” from the inextricable interpenetration of the biota with the seas, the skies, and the rocks, after eons of their own extra-biotic commerce with the dying generations of living forms. Materially, the Gaia of this planet emerges in a fashion unique to the peculiarities of its situation. Although Gaian processes, “other Gaias,” are entirely conceivable on other planets harboring life, our Gaia is a planetary one-off. Perhaps this Gaia will produce buds in the form of space-faring closed environments launched from Earth. In the meantime, as a population of one, its autopoiesis may be the most universal property of its organization.

When Lovelock singly or in concert with Margulis brought the Gaia hypothesis forward in the early 1970s, they introduced it at specialized locations in normal corners of geoscience. However, the incursion of biological considerations necessary to fill out Lovelock’s original physico-chemical arguments for a planetary state of atmospheric homeostasis carried the Gaia hypothesis into uncharted regions of disciplinary hybridity and conceptual heresy. Even prior to Margulis’s collaboration, no previous scientific argument had suggested the presence of a planetary “homeostat” comprised of circular worldly mechanisms by which life modulated its environment to maintain the composition of the atmosphere in a state fit for its continued flourishing. Yet within a few years, this rangy and seemingly improbable biocybernetic concept began to infiltrate and provoke mainstream scientific discussion.

 “The presence of a biological cybernetic system able to homeostat the planet for an optimum physical and chemical state appropriate to its current biosphere becomes a possibility.”[[10]](#endnote-10) This is the initial form of Lovelock’s hypothesis regarding the self-regulation of the planetary atmosphere, at the moment that it started its scientific career under the name of Gaia. It is a crude sketch, but it captures Gaia’s introduction as an application of cybernetic systems theory. We might say that cybernetics is in Gaia’s DNA. But this would be a misleading figure for the system itself, because Gaia has no single or dedicated genome devoted to its own reproduction. This alone makes it different in kind from any living “organism,” all of which reproduce one way or another. And as cybernetics has mutated and diverged over the decades, so have the descriptions of Gaia as a system. Lovelock and Margulis’s seminal writings were also the first to bring multiple lines of systems discourses and theories to bear on the Gaia concept. It turned out to be particularly significant for Gaia’s discursive evolution that a primary outlet for its hypothesis was *CoEvolution Quarterly*, the periodical successor to the *Whole Earth Catalog*. As a result, early in their mutual and partially parallel developments, Gaia theory directly encountered second-order cybernetics, a leading edge of system’s theory’s own epoch of countercultural transformation. We will come back to this.

The Gaia hypothesis also underwent an unusually vigorous extra-scientific development into a spectrum of Gaia figures ranging from naive and outlandish to inspired and indispensable.[[11]](#endnote-11) Two reasons at least stand out for the unusual and abiding mobility of this scientific turn on the name of an archaic female deity. The first, of course, is “Gaia,” the name itself, and its manifold resonances as a term with which to conjure a wide swath of cultural responses. But the other is equally profound—the creative chemistry of the scientific collaboration fashioned by Lovelock and Margulis. Combining his expertise in chemistry, geology, physiology, and cybernetics with her profound grounding in microbial evolution and ecology, over time they established a fully geobiological Gaia concept whose worldview-shaking import was not lost on its progenitors. Nor should it be lost sight of now.

Contemporary scientific and scholarly attention and debate at large have precipitated a bona fide discourse of Gaia theory.[[12]](#endnote-12) The academic mainstreaming of many of Lovelock and Margulis’s formerly controversial ideas has coalesced in research fronts from biogeochemistry to Earth system science and astrobiology. Informed evocations of Gaia theory now accompany a growing sense of emergency over an Earth system in peril of entering a new regime unconducive to many current life forms, including, of course, our own. The rise of Gaia theory preceded and prepared for the current recognitions of a global climatic and environmental crisis. These trends have run together with the arrival of a discourse of the Anthropocene through which to acknowledge that the massive accumulation of humanity’s activities has now altered the functioning of the Earth system.[[13]](#endnote-13) Nevertheless, whatever we take to be its current state, the Earth system of our present concern is most effectively observed through the Gaia concept, a massively complex but newly concrete presence for our planetary imagination to grasp. The current phrase “Earth system” is just the normalized locution for and the legitimized offspring of the “biological cybernetic system” upon which Lovelock’s thought of Gaia originally speculated over half a century ago. Gaia is systems thinking at and for the planetary level.

Gaian Thought

Thanks to the particular sensibilities of its progenitors, then, the development of Gaia discourse has enjoyed an unusual emancipation from the usual domains of normal scientific cultivation. This does not mean that it simply rode the waves of cultural free association. In particular, Margulis encountered the discourse of autopoietic cognition at Lindisfarne Association meetings attended by biocyberneticians Humberto Maturana, Henri Atlan, Heinz von Foerster, the neuroscientist Francisco Varela, and the poet and essayist William Irwin Thompson.[[14]](#endnote-14) Focused on the Gaia hypothesis and the systems concept of autopoiesis in the context of planetary cultural dynamics, these intellectual events culminated an era of thought I treat in *Partial Earth* as the time of the *systems counterculture*. Gaian thought at Lindisfarne in the 1980s sees perception a co-construction or distributed operation actively embedding the observer—along with an open-ended contingent of co-observers—in their own observations. Consider this passage from *Symbiotic Planet*:

Analogous to proprioception, Gaian patterns appear to be planned but occur in the absence of any central "head" or "brain." Proprioception, as self-awareness, evolved long before animals evolved, and long before their brains did. Sensitivity, awareness, and responses of plants, protoctists, fungi, bacteria and animals, each in its local environment, constitute the repeating pattern that ultimately underlies global sensitivity and the response of Gaia "herself."[[15]](#endnote-15)

Lynn Margulis performs Gaian thought as the thinking of Gaia’s own responsiveness to its ever-changing environments. Consider now what is being called the Anthropocene stratum of humanity’s residual works and effects. Witness as well the increasingly acidic oceans and atmosphere. Does Gaia not encompass these phenomena as well with its geobiological rejoinders? If there is a boundary between the operations of the biosphere and those of the technosphere, does it lie within Gaia or without? Gaia will be responding to humanity’s geological force one way or another with the emergence of a different planetary system. What will happen to evolve upon a post-Anthropocene Earth? What is the repeating pattern here, if any? How to make sense of what Latour terms the “muddle” of Gaia’s reactive and proactive responses is ours to figure out.[[16]](#endnote-16) I suggest that we proceed from here on the assumption that the operations of the technosphere lie within Gaia, not without.

With scare-quotes around Gaia “herself,” here in *Symbiotic Planet* Margulis undercuts the gendered anthropomorphism in the name. The entity so named is not a person but a system. Its theory posits the production of systemic responses to its environment. Gaia’s planetary responses join the non-random productions of the particular sensitivities of which worldly systems are capable. Gaian responses both define and transform environments with changes that rebound upon the system. They are thus recursive, both regulative and creative, thus unpredictable. Gaian thought is also the thinking and tracing of the forms of closure of the planetary system. Systemic closures allow the patterns to form. Looking through the distinction of closure, lines become loops that become lines again, fractal and non-returning, non-deterministic. By thinking the dynamism of systemic closures, Gaian thought stays alert to the open evolution of Gaia’s operations. Thanks to the material or virtual closure that makes them possible, every autopoietic being perceives something of its environment (never everything, but not nothing), however intimate or local, and so alters it as well. By these modulations of the environment, each also participates in producing what others perceive.

In a 1987 think piece, “Gaia and the Evolution of Machines,” Sagan and Margulis reflect on Gaian thought: “A whole Gaian style of thought is emerging in which perception is seen as a participatory phenomenon, and with which we become more aware of the sum of organisms within the biosphere. . . . Gaian perceptions . . . link people inextricably, and in subordinate fashion, to the biota, that is, to the sum of plant, animal, and microbial life.”[[[17]](#endnote-17)](#bookmark1) I understand Margulis in particular here to be describing the Gaian style of thought to which she contributed at the Lindisfarne Fellows meetings. Gaian thought is, so to speak, non-dominational—there is no final or definitive, no singularly dominant construction of knowledge. And yet, Sagan and Margulis continue, “All the weight of Western history and success attach to political groups that subscribe to the idea of man’s domination of nature. The Gaian thought style, however, extends ‘horizontally’ to other organisms and ‘vertically’ beyond human history. In it, human beings and technology may be seen as environments in the biosphere.”[[18]](#endnote-18)

Perceptual participation *with* one’s environment overcomes the thought if not always the act of dominating it. Or, stated otherwise, to think “man’s domination of nature” demands the non-reception of the Gaian perception of participatory pan-biotic couplings. The Gaian thought in the passage just quoted also acknowledges (Sagan and Margulis wrote several decades before the onset of Anthropocene discourse) the interpenetration of the technosphere with the biosphere, while also observing the heterogeneity of their functions and effects, the plurality of their environments. Simultaneous but differential closures and linkages traverse social and technological systems and their environments. Social systems may enforce political enclosures, but because “a Gaian view increases public awareness of our dependence upon other life forms, it is extremely valuable in battling the prevailing ideologies of selfishness: that nature is either pristine and should be preserved or is simply a bunch of resources to be plundered. The truth is that we are deeply connected to all other organisms, cannot help altering them, yet must be conscious of and responsible for our actions” (16).

I narrate this textual history of Lovelock and Margulis, Margulis and Sagan, and other Gaian thinkers with the conviction that this mode of self-orientation of mind and feeling participates to some small degree in the thing that it contemplates and so is worth the labor of its communication. To maintain the sensitivity of that registration, Gaian thought cannot be hardened into human prescriptions. Lovelock stated this clearly in his first book: “There can be no prescription, no set of rules, for living within Gaia. For each of our different actions there are only consequences.”[[19]](#endnote-19) Except that, as the French thinker Bruno Latour suggests, especially in the “new climatic regime” into which we have been precipitated, there is no description of Gaia that is not also an implicit prescription: “Such is in fact the paradox of the invocation of ‘nature’: a formidable prescriptive charge conveyed by what is not supposed to possess any prescriptive dimension.”[[20]](#endnote-20) To describe the state of Gaia’s response to current perturbations is virtually to prescribe a commensurate human reply of some sort. But if that is the case, then I will be content to describe what I am able to observe and let others draw out what policy prescriptions they may. All I can prescribe to my audience here is a conviction that Gaia matters, that the further communication of its discourse can make positive differences in the lives, thoughts, and actions of those who encounter it.

Some candid remarks of Sagan and Margulis, again from “Gaia and the Evolution of Machines,” put the matter of conviction in a Gaian light:

The reader may wonder whether we are advocating belief in an unproven assertion: Gaia, the modulated biosphere. We are, but only so far as it is necessary to replace outmoded thought styles. Since perception is impossible without assumptions (i.e., belief), and since all science is the result of perception, the objection that such a view is unscientific is vain.[[21]](#endnote-21)

“Perception is impossible without assumptions.”[[22]](#endnote-22) Whether we care to see Gaia as a self- referential system in planetary operation rests on our choice of worldview. These theoretical vectors participate in the travails of an epistemological transition for which the contingencies of self-referential systems now determine the limits of observation.[[23]](#endnote-23) Gaia’s periodic ups and downs have crossed between scientific and cultural discourses at large. It has borne the clash of challenged and challenging assumptions and beliefs in the growing pains of shifting paradigms. However, with the current upheavals in the Earth system as observed with reference to the place of the human within planetary dynamics, the new climatic regime has made the stakes of these throes of transformation even clearer. If we are to render our technoscientific culture fit for the long term, then we will have to replace outmoded thought styles and complete a pervasive redistribution of the ways that knowledge, scientific and otherwise, is constructed and communicated. A systems-theoretical observation of our geobiological situation within the planet we inhabit is a good place to start an update of the interrelations between science and society.

1. James Gleick, *Chaos: Making a New Science* (New York: Penguin Books, 1987). [↑](#endnote-ref-1)
2. Lewis Thomas, *The Lives of a Cell: Notes of a Biology Watcher* (New York: Bantam, 1974). Its contents had originally appeared between 1971 and 1974 as columns in the *New England Journal of Medicine*. See Bruce Clarke, “Life, Language, and Identity: Lewis Thomas’s Biomythology in *The Lives of a Cell*,” in *The Body and the Text: Comparative Essays in Literature and Medicine*, eds. Bruce Clarke and Wendell Aycock (Lubbock: Texas Tech University Press, 1990), pp. 207-17. For more on the relations between Lewis Thomas and Lynn Margulis, see my “Evolutionary Equality: Neocybernetic Posthumanism and Margulis and Sagan’s Writing Practice,” in *Writing Posthumanism, Posthuman Writing*, ed. Sidney I. Dobrin (Parlor Press, 2015), pp. 275-97. [↑](#endnote-ref-2)
3. Thomas, *The Lives of a Cell*, p.4. [↑](#endnote-ref-3)
4. Lynn Margulis and Dorion Sagan, *What is Life?* (Berkeley: University of California Press, 2000). [↑](#endnote-ref-4)
5. Lynn Margulis, *Origin of Eukaryotic Cells: Evidence and Research Implications for a Theory of the Origin and Evolution of Microbial, Plant, and Animal Cells on the Precambrian Earth* (New Haven: Yale University Press, 1970). [↑](#endnote-ref-5)
6. Lynn Margulis, *Symbiotic Planet: A New Look at Evolution* (New York: Basic Books, 1998), p.118. [↑](#endnote-ref-6)
7. David Suzuki, “Journey into New Worlds: Lovelock’s Gaia,” *The Sacred Balance* (Toronto, 2002), VHS. [↑](#endnote-ref-7)
8. For intellectual bearings here, see Margaret A Boden, “Autopoiesis and Life,” *Cognitive Science Quarterly* 1 (2000): 117-145; Bruce Clarke and Mark B. N. Hansen, eds., *Emergence and Embodiment: New Essays in Second-Order Systems Theory* (Durham: Duke University Press, 2009); and in particular, Niklas Luhmann, “Self-Organization and Autopoiesis,” in Clarke and Hansen, eds., *Emergence and Embodiment*, pp.143-56. [↑](#endnote-ref-8)
9. Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime*, trans. Catherine Porter (Medford, MA: Polity Press, 2017), p.98. [↑](#endnote-ref-9)
10. James E. Lovelock, “Gaia as Seen through the Atmosphere,” in *Atmospheric Environment* 6 (1972): 579. [↑](#endnote-ref-10)
11. For the former, see Michael Ruse, *The Gaia Hypothesis: Science on a Pagan Planet* (Chicago: University of Chicago Press, 2013). For the latter, see Tyler Volk, Gaia’s Body: Toward a Physiology of Earth (Cambridge: MIT Press, 2003); Eileen Crist and H. Bruce Rinker, eds., *Gaia in Turmoil: Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis* (Cambridge: MIT Press, 2009); Isabelle Stengers, *In Catastrophic Times: Resisting the Coming Barbarism*, trans. Andrew Goffey (2009; Ann Arbor: Open Humanities Press, 2015). [↑](#endnote-ref-11)
12. For instance, James Lovelock, *The Ages of Gaia: A Biography of Our Living Earth* (New York: Norton, 1988); Peter Westbroek, *Life as a Geological Force: Dynamics of the Earth* (New York: Norton. 1991); Stephen H. Schneider and Penelope J. Boston, eds., *Scientists on Gaia* (Cambridge: MIT Press 1993); Lynn Margulis and Dorion Sagan, *Slanted Truths: Essays on Gaia, Symbiosis, and Evolution* (New York: Copernicus, 1997); Stephen H. Schneider et al, eds., *Scientists Debate Gaia: The Next Century* (Cambridge: MIT Press 2004; Timothy Lenton and Andrew Watson, *Revolutions that Made the Earth* (Oxford: Oxford University Press, 2011); and Bruce Clarke, ed., *Earth, Life, and System: Evolution and Ecology on a Gaian Planet* (New York: Fordham University Press, 2015). [↑](#endnote-ref-12)
13. See Clive Hamilton, François Gemenne, and Christophe Bonneuil, eds., *The Anthropocene and the Global Environmental Crisis: Rethinking Modernity in a New Epoch* (New York: Routledge, 2015). [↑](#endnote-ref-13)
14. We will return to this in chapters 5 and 6. Thompson’s own name for Gaian thought applied to society is *Gaia politique*. “Gaia and the Evolution of Machines” is in the mode of Gaia politique. See William Irwin Thompson, ed., *Gaia—A Way of Knowing: Political Implications of the New Biology* (Great Barrington, Vermont: Lindisfarne Press, 1987). [↑](#endnote-ref-14)
15. Margulis, *Symbiotic Planet*, p.126. [↑](#endnote-ref-15)
16. Latour, *Facing Gaia* (2017), p.100. [↑](#endnote-ref-16)
17. Dorion Sagan and Lynn Margulis, “Gaia and the Evolution of Machines,” *Whole Earth Review* 55 (Summer 1987): 16. [↑](#endnote-ref-17)
18. Sagan and Margulis, “Gaia and the Evolution of Machines,” p.16. [↑](#endnote-ref-18)
19. James Lovelock, *Gaia: A New Look at Life on Earth* (1979; New York: Oxford University Press, 1989), p.140. [↑](#endnote-ref-19)
20. Latour, *Facing Gaia* (2017), p.23. [↑](#endnote-ref-20)
21. Sagan and Margulis, “Gaia and the Evolution of Machines,” p.17. [↑](#endnote-ref-21)
22. For a contemporary treatment of this neocybernetic proposition as applied to living systems in general, see Alexander Wilson, “Biosphere, Noosphere, Infosphere: Epistemo-Aesthetics and the Age Of Big Data,” *Parallax* 23:2 (2017): 202-219. “In the organism there is a perpetual production of horizon corresponding to its constant renormalization; there is no base-state where the organism is merely passively identifying, sampling, discerning various discrepancies in its environment prior to coming to discern something that is of specific relevance to its on-going self-constitution. This further suggests that there is an identity between an organism’s dynamic functional structure, and its sensation or cognition of the environment” (212). Biosemiotician Victoria Alexander comments: “the organism's dynamic functional structure is a model of its external world. And the organism shapes its environment. It goes both ways. Co-creation of self and environment, co-modeling. And therefore, both models are relatively objective,” personal communication. [↑](#endnote-ref-22)
23. As Niklas Luhmann has pointed out, “Constructivism is the form assumed in reflection on the system of science facing its own extravagances.” See “The Cognitive Program of Constructivism and a Reality that Remains Unknown,” in Niklas Luhmann, *Theories of Distinction: Redescribing the Descriptions of Modernity*, ed. William Rasch (Stanford: Stanford University Press, 2002), p.151. [↑](#endnote-ref-23)