CHAPTER 4

The Whole Earth Network

The systems counterculture nurtured by the Whole Earth network cultivated the first drafts of neocybernetic systems theory. In turn, NST provided the conceptual space for the merger of the Gaia hypothesis with the theory of autopoiesis in Lynn Margulis's discourse of autopoietic Gaia. In autopoietic theory, recursive causality constitutes systemic identities. Autopoietic Gaia takes this mode of systemic observation to its planetary conclusions. Recovering neocybernetic Gaia theory can refresh our recollection of the considerable accomplishments of the ecological milieu and coevolutionary imperatives of the 1970s. Part II opens up some of the ways that the systems counterculture in the milieu of the Whole Earth network cultivated the parallel, sometimes intersecting developments of NST and the Gaia concept.

The systems counterculture was a loosely collegial group of seminal scientific thinkers whose developments of cybernetics and systems theories led them beyond mainstream doctrines and institutions. The systems counterculture constellated in this study includes Buckminster Fuller, Gregory Bateson, Heinz von Foerster, George Spencer-Brown, Humberto Maturana, Francisco Varela, James Lovelock, and Lynn Margulis. The abiding cultural effect of their work has been to detoxify the system concept of its military, industrial, and corporate connotations of command and control and to redeploy it in the pursuit of holistic ideals and ecological values. In the United States, this disparate cybernetic reformation came to a head in the later 1960s and remained well defined throughout the 1970s and into the 1980s. In these thinkers a broadly shared body of NST shuttled between mathematics and the natural and engineering sciences and migrated from there to new residences in the social sciences, humanities, and arts, challenging prior epistemological assumptions and infiltrating both high academic theory and popular culture. The systems counterculture entered alternative

locations and venues where maverick collaborations became possible, where it could assemble and test idiosyncratic appropriations. Its coalescence was publically registered with the initial four-year run of the *Whole Earth Catalog* from 1968 to 1971. It arrived in full with its periodical continuation, *CoEvolution Quarterly,* from 1974 to 1984, followed by a gradual dispersal in the *Whole Earth Review.*

Fred Turner's canonical *From Counterculture to Cyberculture* has guided research in this area. But we may now be past our initial enthusiasms for digital utopia and ready to redirect our attention to an alternative series of nondigital but major intellectual developments that the *Catalog*'s creator and main editor, Stewart Brand, speaking about his discovery of the work of Gregory Bateson, termed *organic cybernetics.* "As a Bateson enthusiast and a publisher," Brand wrote in 1974, "I'll be printing sundry papers, speculation, gossip, tidbits, letters, etc. on cybernetics (well, organic cybernetics), in the periodic supplement to the revived *Whole Earth Catalog* . . . 'The CoEvolution Quarterly.'"[1] Moreover, looking over the larger growth of the Whole Earth network during these decades, one can track the emerging bifurcation noted in Brand's statement between first- and second-order cybernetics in the Whole Earth milieu of the 1970s, followed in the 1980s with the eventual eclipse of *CoEvolution Quarterly*'s bio-ecological orientation with the explosion of digital cyberculture.

Whole Earth Catalog

CYBERNETICS OF EARTHRISE

In their moment, the *Whole Earth* publications were the virtual house organ on the world stage for the informed general discussion of cybernetic ideas. These detailed systemic and ecological perspectives on local and global practices—in light of what was perceived as the planetary emergencies of *that* moment, such as explicit premonitions of global warming, the imminence of environmental devastation by nuclear war, rampant monoculture, and seemingly unsustainable human population explosion—are not just relics of the 1960s. They already had the planetary situation more right than not. The problems probed there, the sciences explored, the technological and political solutions debated, and the cultural and spiritual practices recommended have aged fairly well: many are as relevant as ever to our current abysmal quandaries.

The Gaia discourse within this venue is a case in point. Even prior to that, the *Catalog* cultivated cybernetics and systems theory in a prominent opening section titled "Understanding Whole Systems."

Between 1968 and 1971 the *Whole Earth Catalog* documented the NASA-inspired technophile wing of the American counterculture and motivated its perception of Earth as an ecological unity. As Lovelock was incubating the Gaia hypothesis at JPL in the decade before its formal introduction in 1972, this seminal countercultural publication—part magazine, part product and lifestyle guide—began its initial four-year run.[2] Seizing on a series of unprecedented NASA images as icons for a transformed ecological and environmental consciousness, the *Whole Earth Catalog*'s presentation of these celestial portraits premediated Lovelock's idea of Gaia as a "biological cybernetic system."[3] Apollo 8 brought back a strip of Earthrise images. What we now call the Earthrise photograph is the best of a series of shots taken on color film with a professional-grade camera. It was developed and transmitted to media outlets once the Apollo 8 mission returned home and then given a 90-degree rotation to the right to make the Earth rise over the Moon. No finer image of the Earth from space had ever been captured, and it was the first such image to enjoy universal distribution.[4] The *Whole Earth Catalog* smacked Earthrise on the front and back covers of its spring 1969 issue (Figure 2).

Aligning the Earthrise photograph with cybernetic themes, the *Whole Earth Catalog*'s visual rhetoric made a range of new observations on our planet's cosmic station ready for the taking. The *Catalog* capitalized at once on the iconography of this world seemingly seen whole—the living Earth observed from space as a systemic unity. Earthrise has assisted the way we have come to think about our planet astrobiologically, not as detached from but as bound up with the rest of the universe. Its gorgeous tableau inverted earlier perspectives by framing a distant Earth in relation to the near surface of its lunar neighbor. Other Earth-from-space images of that moment could seem to suggest that our planet just floats in space free of any attachments. By showing the Earth and Moon as gravitationally tethered and mutually constituting, Earthrise also evokes the solar system and the wider cosmos around us. At the same time, as has often been noted, it makes the difference starkly clear between a lifeless and a living world. In this spirit, the covers of nearly every iteration of the *Whole Earth Catalog* presented some NASA image

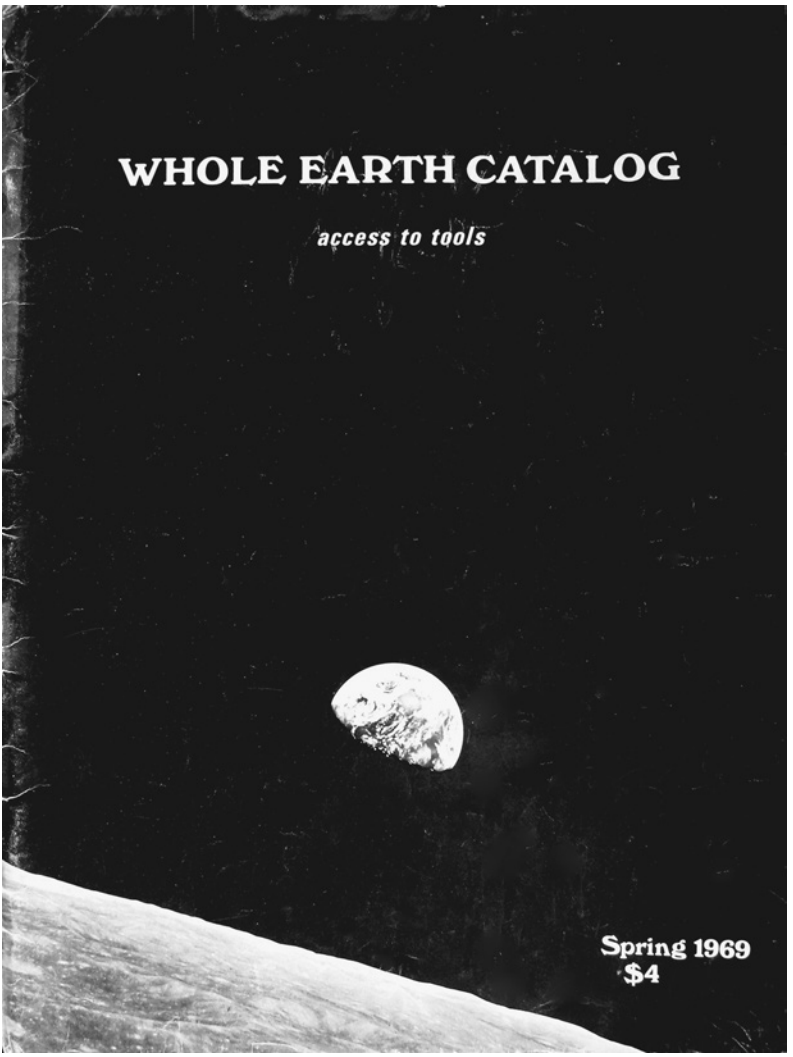


FIGURE 2. *The* Whole Earth Catalog, *front cover, spring 1969.*

of Earth taken from space. Here was a home planet newly visible in its own right and newly imaginable as a global ecosystem. Moreover, in parallel with nascent Gaian science, the *Whole Earth Catalog* pursued a whole-systems style of cybernetic thinking. Every iteration contained a section on "Whole Systems" that reviewed developments and retailed

information about systems theory. This particularly heady bastion of the American counterculture framed its uptake of NASA's Earthrise photograph with systems vibrations and cybernetic fascinations.[5]

On the back cover of its spring 1969 issue, the Earth rising over the horizon of the Moon now has a caption. It reads: "The flow of energy through a system acts to organize that system." The statement is from Harold Morowitz's *Energy Flow in Biology*.[6] Two years later, on the inside of the front cover of the *Last Whole Earth Catalog,* Earthrise appears again, with a different legend: "The famous Apollo 8 picture of Earthrise over the Moon that established our planetary facthood and beauty and rareness (dry moon, barren space) and began to bend human consciousness." The Earthrise photograph perfectly fuses a cybernetic vision of the Earth as a planetary system with the whole-systems concept that informs the *Whole Earth Catalog.* Moreover, the systems concept orients one to a synoptic view of things, presses one to a conceptual elevation from which the boundaries of complex entities show forth against their environments. It is in this spirit that one might construe the psychedelic afflatus that leads off the purpose statement prefacing every edition of the *Catalog*—"We are as gods and might as well get good at it." In emulation and material fulfillment of classical visions of the divine, we have now created mind-blowing technological systems that lift us to a transcendent view of ourselves and the world around us, a view previously reserved to whatever deities might have been imagined to be looking down on mundane affairs. The *Whole Earth Catalog* received the gifts of the space-age engineering gods at NASA responsible for the rebirth of Apollo and his new adventures trafficking with the heavens.

It was only a few years after the arrival of the Earthrise photograph that Gaia joined this new cybernetic pantheon. In 1986 the PBS science series *Nova* aired the documentary *Gaia: Goddess of the Earth.* Over a series of images from the *Whole Earth Catalog,* the narrator intoned: "It was the pro-environmental movement who found the most reason to appreciate Gaia. . . . Words like *ecosystem* entered the vernacular. . . . These ideas were reflected in counterculture publications, which also popularized the science of automatic control systems—cybernetics—in both living things and machines. Gaia came in on this rising tide of interest in whole systems." Just as the *Catalog*'s NASA graphics resonate with the spirit of "Understanding Whole Systems," Lovelock's original thesis regarding Gaia as an automatic or self-regulating system for

environmental homeostasis resonates profoundly with the *Catalog*'s cybernetic milieu.

INCIPIENT NEOCYBERNETICS

Second-order cybernetics was still in embryo when the *Whole Earth Catalog* began operation. Yet the systems thinking the *Catalog* already purveyed—in reviews of works by Norbert Wiener, H. Ross Ashby, Warren McCulloch, Gordon Pask, and Ludwig von Bertalanffy, in addition to Fuller—gave voice to the most liberal and visionary wings of the first cybernetic thinking. Margulis and Lovelock's initial formulations of the Gaia concept would soon join this chorus. But first, the fall 1969 issue registered something of a tremor in the ether of such advanced thought with a curt and uncharacteristically confounded review of a work titled *Laws of Form* by a British mathematician named George Spencer-Brown.[7] Brand's entire commentary on it reads: "Jesus Christ. I'm not ready to review this book. Who the hell is? It merely starts over, remakes logic and mathematics from a different beginning, from the Tao's beginning of the prime distinction. It's too simple to grasp. All I can make is the notes at the end of the book, and they keep raising the hair on my head. The book is pure revolution."[8]

At the end of that same year, Heinz von Foerster, the founder and director of the Biological Computer Laboratory at the University of Illinois from 1957 to 1975, sent Brand, with whom he had no previous relation, a gift copy of the *Whole University Catalog,* a seminar publication project produced in his classroom in large-format emulation of the *Whole Earth Catalog*.[9] Two months later, Brand sent von Foerster a request: "This book, *Laws of Form,* has everybody spinning. Like John Lilly has bought and given away 6 copies and keeps getting knocked into trance by the material in the book. Our problem is that nobody will review it. Will you?"[10] Brand had found his man. In setting forth von Foerster's avid review, a virtual introductory lecture on *Laws of Form,* the *Whole Earth Catalog* for spring 1970 documents a seminal moment in the gestation of NST.[11]

Marking that something long awaited had now come into the world, von Foerster began with this exclamation: "The laws of form have finally been written!" In an unusually lengthy entry, he expounded some of the rudiments of this "radical further step" toward the discourse of self-reference:

> Laws are not descriptions, they are commands, injunctions: "Do!" Thus, the first constructive proposition in this book is the injunction: "Draw a distinction!" an exhortation to perform the primordial creative act. After this, practically everything else follows smoothly: a rigorous foundation of arithmetic, of algebra, of logic, of a calculus of indications, intentions, and desires; a rigorous development of laws of form, may they be of logical relations, of descriptions of the universe by physicists and cosmologists, or of functions of the nervous system which generates descriptions of the universe of which it is a part.[12]

"The nervous system . . . generates descriptions of the universe of which it is a part" is to say that the operation of an observing system is self-referential in the first instance. Its possibility rests with a form of inner delimitation or closure that opens up a cognitive relation to its outside. As von Foerster's occasional colleague at the Biological Computer Laboratory, Gotthard Günther, had noted in a 1962 article on the logic of observation, "systems of self-reflection . . . could not behave as they do unless they are capable of 'drawing a line' between themselves and their environment. . . . This is something the Universe as a totality cannot do. It leads to the surprising conclusion that *parts of the Universe have a higher reflective power than the whole of it.*"[13] Concepts of observation and self-reference were already implicit throughout the *Whole Earth Catalog*'s considerations of whole systems by means of new observational technologies that allow us to look back at or down on our own world and see it and ourselves in a newly recursive way. Von Foerster then cited an excerpt from Spencer-Brown's notes to that volume that describes this self-observational dynamic at a powerful level of epistemological generalization. Here, too, as in Günther, what becomes clear is the inexorably partial outcome of any effort to achieve an encompassing view: "We cannot escape the fact," Spencer-Brown writes, "that the world we know is constructed in order (and thus in such a way as to be able) to see itself":

> This is indeed amazing.
>
> Not so much in view of what it sees, although this may appear fantastic enough, but in respect of the fact that it *can* see *at all.*
>
> But *in order* to do so, evidently it must first cut itself up into at least one state which sees, and at least one other state which is seen.

> In this severed and mutilated condition, whatever it sees is *only partially itself.* We may take it that the world undoubtedly is itself (i.e., is indistinct from itself), but, in any attempt to see itself as an object, it must, equally undoubtedly, act so as to make itself distinct from, and therefore false to, itself. In this condition it will always partially elude itself.[14]

In Spencer-Brown's technical terms, the production of observations—that is, the ability to know in the first place—depends upon acts of distinction that sever what is observed into marked and unmarked states. Acts of distinction produce a virtual division into the marked state of that specific indication and the unmarked state of everything else. To know what a distinction indicates demands in that moment the non-observation of what that distinction has left aside. Yet, as we noted in the previous chapter about all meaning-events, such states of cognitive division are evanescent: when the observer moves on to the next distinction, both possibilities remain ready for selection, or not. As a result, there will be a blind spot in any picture we can have of ourselves, at which point we cannot see the whole of which we are a part. This is a way of restating the self-referential basis of any heteroreferential observation. Any attempt at an objective view retains a subjective component that must be added into any full account of what cognition may perceive, even though the addition of that supplement undoes, or in-completes, the ostensible totality of what it supplements. And any attempt at an objective view of *ourselves* is an oxymoron or a paradox, necessarily throwing the part of ourselves we are viewing *with* into momentary eclipse. In brief, only self-referential meaning systems can reflect on the way that their inability to grasp the whole of what they are grounds their ability to know at all. With the inclusion of von Foerster's review of *Laws of Form,* the text of the *Whole Earth Catalog* virtually deconstructed its own holistic idealism. This was the "pure revolution" Brand intuited but could not yet articulate.

Many Cybernetic Frontiers

After bringing out the *Last Whole Earth Catalog* in 1971, Brand put *Catalog*-style publishing on a three-year hiatus to pursue other projects. One of these appeared in 1974 as the slim volume *II Cybernetic Frontiers,*

compiled from two separately published articles plus appendices. Brand's introductory remarks placed him squarely within the systems counterculture he had already done so much to define and promote:

> I came into cybernetics from preoccupation with biology, world-saving, and mysticism. What I found missing was any clear conceptual bonding of cybernetic whole-systems thinking with religious whole-systems thinking. Three years of scanning innumerable books for the *Whole Earth Catalog* didn't turn it up. Neither did considerable perusing of the two literatures and taking thought. All I did was increase my conviction that systemic intellectual clarity and moral clarity must reconvene, mingle some notion of what the hell consciousness is and is for, and evoke a shareable self-enhancing ethic of what is sacred, what is right for life.[15]

With a few strokes, Brand nailed the schizophrenia of modern American society—split then as now between military and corporate technocracies in the ascendant and ecosystems, communities, and psyches in splinters—and supplied the spiritual rationale for a countercultural supplement to the powerful but restricted "intellectual clarity" of mainstream control theory.[16] On the evidence of this presentation, the point of the whole-systems thinking Brand purveyed in the *Catalog* and beyond was to work out the possible forms of systemic integration between two cybernetic rationales, one intellectual, the other moral. "Tall order," Brand continued. Then he found Gregory Bateson:

> In the summer of '72 a book began to fill it for me: *Steps to an Ecology of Mind*. . . . Here in one single-minded book was highly original application of cybernetics, biology, linguistics, psychology, and formal logic to field work with New Guinea and Balinese natives, porpoises, alcoholics, schizophrenics, beetles, and national histories . . . a rigorous scientific refutation of the notion that rational science is adequate to save us. (9–10)

The first run of the *Whole Earth Catalog* foregrounded the writings of Buckminster Fuller, another whole-systems thinker of substantial proportions but quite different qualities. By 1973, Brand's primary cybernetic frontier was the work of Gregory Bateson. The chapter "Both Sides

of the Necessary Paradox" in *II Cybernetic Frontiers* begins: "Cybernetics is the science of communication and control. It has little to do with machines unless you want to pursue that special case. It has mostly to do with life, with maintaining circuit" (9). Brand's declaration at this moment may now sound odd, since the last fifty years have only reinforced the notion that cybernetics has little to do with anything *other* than machines. However, it accurately registered the particular valences of Bateson's cybernetic worldview. In that world, the notion of "circuit" is a prominent mental operator. Bateson's "circuit" puns on the term's electronic sense and resonates with the informatic sense of a communications system in which messages circulate. However, his cybernetics of "circuit" expand to concern the overall circularity of closed loops or cycles as these convey meaningful differences in systemic ensembles of any sort. This milieu of communicative loops is more or less what Bateson meant by his "ecology of mind." Perhaps the best passage in Brand's Bateson chapter wrestles precisely with Bateson's idea of "circuit":

> I'm still getting used to the way Gregory uses the term "circuit." It's appealing to me because it is at once more general than "feedback loops," more accurate somehow, and more open-system . . . as if it can include cycles of interactive learning (student teaches the teacher to teach the student better), of material (flesh to ashes to flesh), of slow recurrence (every so often an ice age stresses the system), of standard homeostatic feedback (the chilled body shivers until warm), and of observer interference (the watched porpoise bedevils his observer). Without circuit, without continual self-corrective adjustment, is no life. (29)

II Cybernetic Frontiers then segues to "Fanatic Life and Symbolic Death among the Computer Bums," republished from a 1972 *Rolling Stone* article for a treatment of *Spacewar*—the ur-computer game developed at Stanford University in the predawn of the personal computer. His approach to this second topic still sounds slightly odd, when Brand recurs to the same framing device he used for the Bateson chapter: "And now, to pursue *the 'special case' of machine cybernetics*—computers and computer science—the sovereign domain of rational purpose, of explicit goal-directed behavior" (38; my italics). And yet, a larger sample of

Brand's statements on this matter include his headnote a decade later to James Lovelock's 1983 article "Daisyworld: A Cybernetic Proof of the Gaia Hypothesis": "Since cybernetics was kidnapped by computer science a couple decades back, there have been few working applied cyberneticians loose in the world. Lovelock . . . is one."[17] At the end of this chapter we will come back to Daisyworld, a computer model for Gaian self-regulation. However, with due respect to Lovelock's Daisyworld, was there ever really a time when organic cybernetics, a cybernetics "mostly to do with life," was *not* the special case relative to the general case of "machine cybernetics" and its vast array of computational creations? We can see that by 1983, Brand's Batesonian *CoEvolution Quarterly* of the 1970s—the *CoEvolution Quarterly* of von Foerster, Lovelock, Margulis, and Varela—was already morphing into Kevin Kelly's digitopian *Whole Earth Review* of the later 1980s and beyond.[18] Instead, let us consolidate the recognition that there was an extended moment when organic cybernetics, or a cybernetics of natural as opposed to designed systems, teemed with fresh creations—most notably, the concept of autopoiesis and the Gaia hypothesis—and scattered these hardy spores across some receptive regions of the intellectual landscape. Particularly in the Batesonian milieu of the systems counterculture of the 1970s, a cybernetics "mostly to do with life" helped these neocybernetic productions to unfold.

CoEvolution Quarterly

Brand was well primed to receive with some enthusiasm an authentic cybernetic theory approaching life in relation to Earth's atmosphere as a "whole system." The Gaia hypothesis would make numerous appearances during the eleven-year span of *CoEvolution Quarterly*.[19] Underscoring our focus on the development of systems discourses as they informed Gaia concepts, Brand's evocation of organic cybernetics precisely names the spirit of the periodical he would spin off from the *Whole Earth Catalog*. *CoEvolution Quarterly* also carried forward much of the *Catalog*'s thematic formatting: every number of *CoEvolution Quarterly* also began with a section on "Understanding Whole Systems" or just, on occasion, "Whole Systems." *CoEvolution Quarterly*'s cast of contributors included Gregory Bateson, Paul Ehrlich, Howard Odum, Aldo Leopold, William Irwin Thompson, Wendell Berry, John Todd, Marshall

McLuhan, Ursula Le Guin, Ivan Illich, E. F. Schumacher, Gary Snyder, Margaret Mead, Garrett Hardin, Carl Sagan, Ramón Margalef, Roy Rappaport, Hazel Henderson, Kenneth Boulding, Peter Warshall, and Donella Meadows, among many others. This section of *Gaian Systems* samples selected contents of *CoEvolution Quarterly* as they relate to the neocybernetics of the Gaia hypothesis.

THE GAIA HYPOTHESIS

The front cover of the first number of *CoEvolution Quarterly* premediated the unfolding of Gaia's coevolutionary cosmology (Figure 3). While its point of self-reference remained the human observer, in this image the Earth seen from space has been exploded into a planetary or cosmic visage made up of microbes and galaxies and things in between.

Initially, Lovelock published his own preliminary Gaian work in specialized scientific periodicals.[20] Similarly, when *Science* and *Nature* rejected Lovelock and Margulis's first collaborative articles, they placed them in *Tellus, Icarus,* and *Origins of Life*.[21] And there the whole matter might have rested, buried in relative obscurity, were it not for *CoEvolution Quarterly*'s putting the Gaia hypothesis on the cover of its summer 1975 number. When Brand expressed interest that spring, Margulis welcomed the opportunity, as we learn from the draft of a letter to Lovelock written onboard a flight to a speaking engagement in St. Louis, "where I have to discuss the origin & evolution of everything in about ½ hour":

> Good news— . . . I've spoken today to Alan Ternes, editor of *Natural History* (a classy glossy job with a circulation of 370,000). He's apparently a friend of Stewart Brand, editor of the *Co-evolution Quarterly.* Brand, who has been pressuring me mightily, claims his mag. has a circulation of only 17,000. They apparently are in agreement that *Nat. Hist.* will publish the Gaia II & that appearance (even prior appearance) in *Coev. Q.* will not jeopardize a full article in *Nat. Hist.* . . . [Brand] is claiming that his journal is responsible and responsive, refuses to compartmentalize science and that my accusation that he's into food faddism & astrology is totally unfounded. At any rate, what he wants from us is permission to excerpt apparently nearly all Gaia II with the statement that [it] is from a full article coming out in *Nat. History.* I told him that I could not give him permission unilaterally but must consult you. Since he now has a definite commitment

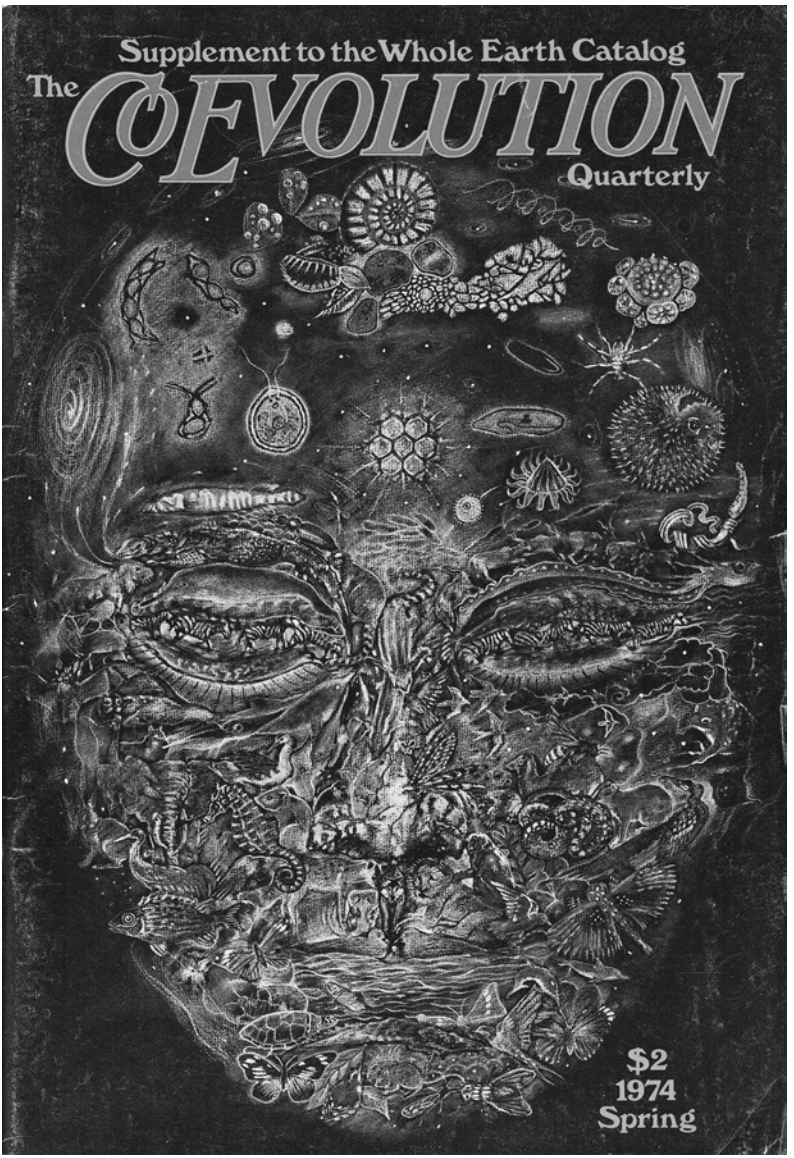


FIGURE 3. *The first* CoEvolution Quarterly, *front cover, spring 1974.*

> from Ternes at *Nat. Hist.* and since after reading CQ I find myself sympathetic to his goals, I would hope you will agree to this plan.[22]

As matters turned out, "Gaia II" got the royal treatment in the low-circulation, low-budget countercultural journal *CoEvolution Quarterly* but short shrift from the glossy mainstream magazine *Natural History.* It did appear there, over a year later, not expanded but condensed and reframed, as "Is Mars a Spaceship, Too?"[23] *Natural History* returned the Gaia hypothesis to the context of alien life detection then on the public's mind due to the imminent arrival on Mars that summer of two Viking landers. Margulis and Lovelock's concluding remarks put the best face on a high-circulation debut somewhat muffled for general consumption. Turning Lovelock's original logic around, they noted that if the landers did find life on Mars (if that planet is, like Earth, "a spaceship"), that would disprove his circumstantial Gaian claim that the presence of active life must leave a detectable signature in the atmosphere of a planet that possesses it: "Failure of the Viking mission to find life on Mars will not prove the existence of Gaia, but it will add support to the hypothesis. Most scientific experiments are designed to disprove a hypothesis; when they fail the hypothesis is thereby strengthened. At great cost and effort, a rare planetary experiment for the Gaia hypothesis is now speeding toward a conclusion" (90). As anticipated, the Viking's non-result left the Gaia hypothesis intact.

However, *CoEvolution Quarterly* had welcomed the Gaia hypothesis a year earlier with no such muted exposition, becoming the first non-scientific journal to treat the topic. Lead-authored by Lynn Margulis with what is still a distinctly specialized treatment, Brand lets "The Atmosphere as Circulatory System of the Biosphere: The Gaia Hypothesis" sprawl over ten pages in the midst of graphics, diagrams, data tables, and multiple excerpts from previously published articles. It anchors an "Understanding Whole Systems" section that also includes Earth-seen-from-space articles by Carl Sagan and former astronaut Rusty Schweickart and a glowing review of Margulis's first book, *Origin of Eukaryotic Cells,* by Beat poet Michael McClure. A substantial extract from Ramón Margalef's 1968 text *Perspectives in Ecological Theory,* featuring "The Ecosystem as a Cybernetic System," resonates with the Gaia article that precedes it.[24] The article itself led its reader into the topic with a reproduction of Sachs von Lewenheimb's 1664 engraving *Oceanus Macro-Microcosmicus* (procured by Margulis), embellishing

William Harvey's description of the circulatory system of the body with worldly imageries of rivers, oceans, and winds, as an analogy for the Gaian role of the atmosphere ensuring the circulation of nutrients and flushing of wastes for the planetary "body." The article's assorted illustrations include what is surely an editorial image—that is, not one that Margulis herself provided for publication—of an archaic sculpture of the Earth goddess as a popular hook for the scientific message. And so began the history of cross-currents in the reception of Gaia between its authors' quests for scientific bona fides and its lay enthusiasts' desire for mythic resonances.

Margulis and Lovelock's sober exposition of the Gaia hypothesis breaks the argument down into elemental ecological cycles (the carbon cycle, the nitrogen cycle, etc.) and their relation to living systems, emphasizing the complexity and multiplicity of the phenomena under review. These early Gaia arguments do not bear on the biosphere as a whole or the planet altogether but specifically on the planetary atmosphere enveloping the biosphere as both source and sink for metabolic processes. For instance, with the key biological elements (carbon, nitrogen, oxygen, hydrogen, sulphur, and phosphorus),

> cycling times must be short because biological growth is based on continual cell division that requires the doubling of cell masses in periods of time that are generally less than months and typically, days or hours. On lifeless planets there is no particular reason to expect this phenomenon of atmospheric cycling, nor on the Earth is it expected that gases of elements that do not enter metabolism as either metabolites or poisons will cycle rapidly. . . . Because biological solutions to problems tend to be varied, redundant, and complex, it is likely that all of the mechanisms of atmospheric homeostasis will involve complex feedback loops.[25]

Brand's headnote wryly observed that for some persons, such serious scientific fare might appear anomalous in his venue, to the detriment of its authors: "Margulis and Lovelock will doubtless take some flak for appearing in suspect company—condom evaluations, poetry, and such." Nevertheless, its inclusion in *CoEvolution Quarterly* was an inspired intervention for all concerned. The authors' own headnote began: "We would like to discuss the Earth's atmosphere from a new point of view—that it is an integral, regulated, and necessary part of the biosphere"

(30). In the article proper, they restate the main point: "The purpose of this paper is simply to present our reasons for believing the atmosphere is actively controlled" (32).

The issue of Gaia's material circulation frames their cybernetic hypothesis regarding its operational circularity leading to self-regulation effecting the homeostasis of atmospheric composition. The "control" of the atmosphere was the hypothesized emergent outcome of a closed loop of biogeochemical cycles held in homeostasis at the planetary level, that is, feedback-regulated throughout much of geological time. The notion that this took place both "by and for" the biota was a classic piece of Gaian hyperbole that seems by now perhaps less hyperbolic.[26] However, the abiding picture here is that Earth's atmosphere, the repository for the gaseous wastes circulating in and out of organic capture and use, has evolved along with the life that has pumped it up. In the Gaian view, the maintenance of the atmosphere in viable proportions of oxygen and nitrogen is not the abiotic lucky happenstance of traditional geology but a systemic outcome operationally integrated with and regulated by the coupling of life and Earth. The stable persistence of these proportions over eons of fluctuations depends on living, largely microbial processes coupled to geological dynamics.

Such a properly granular and tentative account of the Gaian system's production of atmospheric self-regulation can always give way to the smooth discursive space in which a holistic vision covers over the numerical immensity of biological forms and concrete complexity of geological cycles. Unsurprisingly, Brand's headnote to this article also seized the "whole Earth" potential of the argument: Gaia "treats the anomalous Earth atmosphere as an artifact of life and comprehends the planet itself as a single life" (31). Brand's editing reinforced this mode of appreciation a page later by interpolating underneath the main article an excerpt from "The Quest for Gaia," a previously published piece coauthored by Lovelock and Sydney Epton. Bundled together here are the extreme claims of the early Gaia hypothesis—cooperation, totality, optimality, "control" transferred from the abiotic environment to the biota—that ruffled the established science of that moment:

> The atmosphere looked like a contrivance put together co-operatively by the totality of living systems to carry out certain necessary control functions. This led us to the formulation of the proposition that living matter, the air, the oceans, the land surface were parts of a giant

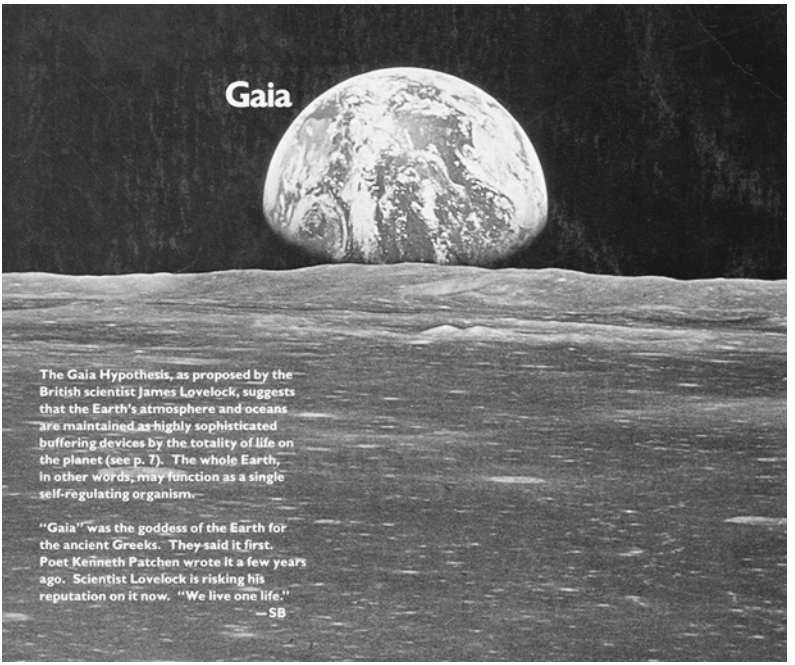


FIGURE 4. *The* Next Whole Earth Catalog, *back cover, fall 1980 (detail).*

> system which was able to control temperature, the composition of the air and sea, the pH of the soil and so on so as to be optimum for survival of the biosphere. The system seemed to exhibit the behavior of a single organism, even a living creature. (32)

However, for all the cultural play between cybernetic specificity, holistic generality, and archetypal profundity in the Gaia conception, it may now be evident why the Gaia discourse brilliantly mediated through this 1975 extravaganza would find a dedicated audience among the countercultural intelligentsia gathered by *CoEvolution Quarterly* and the wider Whole Earth network. Its promissory countervision of life taking care of business in its own house put to shame the "selfish gene" of the same moment.[27] Five years later, on the back cover of the *Next Whole Earth Catalog,* an oversized return to the compendious catalog format, the name of Gaia is now affixed to an image of Earthrise (Figure 4).[28] Brand's caption summed up the popular Gaia notions of totality and singularity that would take root in ensuing decades: "The Gaia

Hypothesis, as proposed by the British scientist James Lovelock, suggests that the Earth's atmosphere and oceans are maintained as highly sophisticated buffering devices by the totality of life on the planet. The whole Earth, in other words, may function as a single self-regulating organism."

"ECOLOGICAL CONSIDERATIONS FOR SPACE COLONIES"

Princeton physicist Gerard K. O'Neill's proposals for space habitats in high orbit and their memorable depictions by NASA artists were contemporaneous with the introduction of the Gaia hypothesis. *CoEvolution Quarterly*'s publication of Margulis and Lovelock's "The Atmosphere as Circulatory System" in the summer of 1975 immediately preceded a fall number devoting the first thirty pages to O'Neill's proposals for high-orbital space colonies around the Earth. O'Neill's speculative technological constructions presented images of environmental closure that translated Gaia's terrestrial implications into idealized visions of sustainable habitats.[29]

The planetary imaginary of the Gaia concept and the microplanetary imaginary of the massive space habitat called out to each other under the trope of Spaceship Earth. With the Apollo program now wound down, O'Neill envisioned a "high frontier" beyond JFK's New Frontier. He had already been working at this project for several years with modest preliminary support from NASA. *CoEvolution Quarterly* published a long transcript of his congressional testimony seeking a major NASA commitment. Six months later still, in its spring 1976 number, *CoEvolution Quarterly* devoted eighty pages to the controversy that erupted over its positive presentation of O'Neill's vision as a potential form of countercultural commune in the sky. Brand worked the space-colony debate for *CoEvolution Quarterly* content by pitting post-psychedelic space-oriented technophiles such as himself against Whole Earth–identifying environmentalists and green technophobes. Numerous supporters and detractors responded, including Buckminster Fuller and Paolo Soleri, novelists Ken Kesey and Wendell Berry, the poets Gary Snyder and Richard Brautigan, astronaut Rusty Schweickart, cultural observer William Irwin Thompson, scientists Lynn Margulis, Paul and Anne Ehrlich, and Carl Sagan. A year later, Brand gathered, republished, and expanded these materials as the freestanding paperback volume *Space Colonies*.[30]

In the midst of these developments, Margulis gathered with a band of fellow ecologists to take up the issue, and *CoEvolution Quarterly* co-published their two-page multiauthored position statement.[31] Brand's headnote to "Ecological Considerations for Space Colonies" identified Margulis and two of her colleagues from the Woods Hole Oceanographic Institution on Cape Cod as the prime movers of the piece. It began: "There appears to be growing interest in the possibility of establishing large space colonies capable of supporting hundreds or thousands of people in isolation from the earth for long periods. . . . Such colonies would present extremely difficult biological and ecological problems. These should be addressed at the very outset if any serious effort toward designing satellites or colonies on celestial bodies other than the earth is to proceed" (96). These cautionary sentiments are as cogent now as they were in 1976, but you would hardly know that from the coverage of Jeff Bezos's revival of O'Neill's colonies as a scheme worthy of serious reconsideration. Both of Gaia's authors were cited in "Ecological Considerations," for which text Margulis may have been largely responsible. Although this article never mentions the Gaia concept by name, it purveys a broadly Gaian sensibility applied to vexed issues in the capacity of closed environments to maintain habitability.

"Ecological Considerations" conveys the tight conceptual coupling we have noted between ecosystem ecology and the Gaia hypothesis. The basic proposition of such engineered habitats, once their shells are set in place, is the artificial but viable replication of the Earth's own "ecosystem services" within a materially closed vessel—in other words, the design and production of miniature Gaias (Figure 5). Margulis and Sagan would later observe that sending forth such constructions from the Earth was like Gaia itself bearing designed offspring through technological mediation: "The generation of new 'buds,' materially closed living systems, within the 'mother biosphere' resembles the structure of a fractal. Closed ecosystems are not artificial at all, but part of the natural processes of self-maintenance, reproduction, and evolution."[32] However, the opening passage of "Ecological Considerations" also rang the sobering note of Gaian complexity, the exceedingly recondite dynamics by which viable planetary regimes arose and maintained operations, the wicked difficulty of achieving working replicas of living ecosystems in artificial form. This text summarized O'Neill's proposal as the aim "to build a new meta-stable ecosystem, complete with biotic

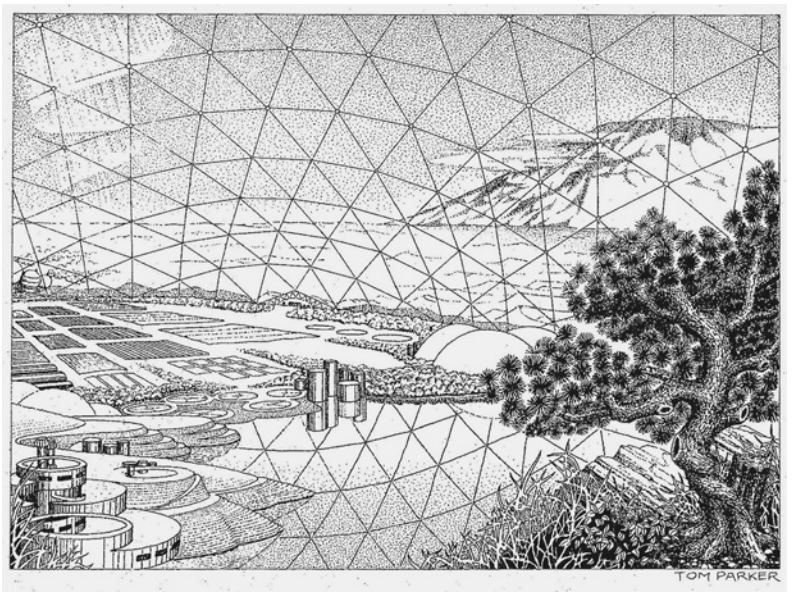


FIGURE 5. *Artist's rendering of a large materially closed ecology,* CoEvolution Quarterly, *spring 1976.*

resources and closed cycles for other essential resources, and capable of supporting man over long periods"; however, "No such system has ever been constructed on earth. The probability that such a system can be built and maintained indefinitely at present seems remote. It seems especially remote when we realize that we have no background in the analysis of the problem" (96). Sustained research into the Gaia hypothesis would amount precisely to an "analysis of the problem," but at that moment such efforts were confined to disparate and inconclusive research projects by ecosystem ecologists at the scale of terrariums and greenhouses.

O'Neill's own promotional materials provided scant recognition of this reasoned but downbeat assessment, assuming on the contrary that the interior ecologies of miniature self-supporting worlds fit for long-term human habitation were engineering problems to be mopped up once the structures were hurtled into orbit. In an interview with Brand under the title "Is the Surface of a Planet Really the Right Place for an Expanding Technological Civilization?" O'Neill explained the reason why

it was not. Why, he asked, just when we've perfected the rockets to lift us out of Earth's gravity hole, should we want to drop down another one?

> The classic science fiction idea of colonization is always you go off and you find another planetary surface, like the moon or Mars. . . . They're the wrong distance from the sun. . . . The sort of analogy I like to use nowadays is to say that, "Here we are at the bottom of a hole which is 4,000 miles deep. We're a little bit like an animal who lives down at the bottom of a hole. And one day he climbs up to the top of the hole, and he gets out, and here's all the green grass and the flowers and the sunshine coming down. And he goes around and it's all very lovely, and then he finds another hole, and he crawls down to the bottom of that hole.["] And if we go off and try to get serious about colonizing other planetary surfaces, we're really doing just that.[33]

Here is a curious sort of planetary imaginary in reverse. On the surface of Earth, gravity has been holding us down, but we can now be done with it by going off into space. Free space is not only there for free, it's also free of gravity, whose absence we can turn to our advantage in a high-orbital environment. In his article that opens the *Space Colonies* volume, "The High Frontier," O'Neill declared that "the L5 Earth-Moon Lagrange libration point . . . could be a far more attractive environment for living than most of the world's population now experiences."[34] But, he cautioned, we lose that advantage if we just capitulate to another, alien gravity hole. In contrast with life in a high-orbital space colony—the virginal pastoral Eden of an idealized outdoorsy Earth with "the green grass and the flowers and the sunshine coming down," life on Earth has always been mired at the bottom of a deep hole. The ironies within O'Neill's preposterous turns of phrase underscore the larger problems with his scheme. These were abundantly documented in the "Ecological Considerations" statement as well as the critical commentaries Brand published alongside O'Neill, which we will take a closer look at in chapter 7. It is simply that the range of knowledge needed to engineer materially closed ecologies making the proposed space colonies even temporarily habitable without constant resupply did not exist then, nor does it now. Sagan and Margulis would speculate a decade later that "the full scientific exploration of Gaian control mechanisms is probably the surest single road leading to the successful implementation of

self-supporting living habitats in space."[35] But in 1975, O'Neill took that implementation for granted.[36]

HEINZ VON FOERSTER

The early pages of *CoEvolution Quarterly* contain a number of items associated with Brand's resident expositor of *Laws of Form,* the spirited cyberneticist Heinz von Foerster. It was von Foerster who coined the phrase "second-order cybernetics" and developed its initial formulations.[37] In the early 1970s, with a strong push from the *Whole Earth Catalog*'s construction of the countercultural sensibility, key lines of cybernetic thought were morphing from grim control theory into playful explorations of the paradoxes of cognition. Von Foerster factored into systems discourse the logical binds of self-reference as a positive force, precisely as a cybernetics of cybernetics, that is, as a creative program to observe (at "second-order") cybernetics' own processes of system observation. His encyclopedia article on cybernetics later presented this as "the logic of autology, that is, concepts that can be applied to themselves."[38] A veteran of the Macy conferences and formidable authority in cybernetic matters, von Foerster was also a gracious and consequential facilitator of collegial connections within the systems counterculture.[39]

Let us come back to the composite text of the maiden appearance of the Gaia hypothesis in *CoEvolution Quarterly.* Running under a portion of "The Atmosphere as Circulatory System of the Biosphere" was a substantial excerpt from the Gaia article lead-authored by Lovelock, "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis." The content of this republished sidebar, subtitled "Gaia and Cybernetics," was concerned more precisely with those larger regions of systems theory extending the discourse of entropy from thermodynamics and statistical mechanics to information theory.[40] The Gaia concept grew out of Lovelock's seminal innovation with regard to life detection at the planetary level: instead of going to great lengths to make contact with planetary surfaces, one could analyze their atmospheres at a distance for signs of an entropy reduction. Here, too, Lovelock and Margulis located Gaia in relation to the entropy concept, as that complicated quantity offered a "first cautious approach to a classification of life, . . . as follows: 'Life is one member of the class of phenomena which are open or continuous reaction systems able to decrease their entropy at the expense of free energy taken from the environment and subsequently

rejected in a degraded form'" (36). The excerpt in question went on to give several mathematical formulas treating measures of both thermodynamic and informatic entropy.

As it happened, however, the next number of *CoEvolution Quarterly* devoted a full page to an extended letter to the editor from von Foerster. Titled "Gaia's Cybernetics Badly Expressed," it asserted defects in the mathematical treatments of entropy offered in "Gaia and Cybernetics." Von Foerster's objections were technical and did not touch one way or another on the main theme toward which Lovelock and Margulis were pointing their invocations of entropy, the properly cybernetic issue of the discrimination of boundaries between systems and their environments. It is by determining such boundaries that one can measure, in the current instance, entropy reductions within living systems and entropy increases without. I will dilate on this discussion for a moment, as we will be coming back to the issue of Gaia's boundaries in chapter 8. Lovelock's particular focus on entropy reduction as a systemic marker for life processes runs deeply through his development of the Gaia concept. *CoEvolution Quarterly*'s republished excerpt "Gaia and Cybernetics" returns to this topic:

> When the whole assembly of life is so seen it is clear that the true boundary is space. The outgoing entropy flux from the Earth indeed from Gaia "if she exists," is long wavelength infra-red radiation to space. This then, is the physical justification for delineating the boundary of life as the outer reaches of the atmosphere. There is also to a lesser extent an inner boundary represented by the interface with those inner parts of the Earth as yet unaffected by surface processes. We may now consider all that is encompassed by the bounds as putative life. Whether or not Gaia is real will depend upon the extent to which the entropy reduction within a compartment such as the atmosphere is recognizably different from the abiological steady state background.[41]

Von Foerster's critique left these cogent matters, which were consonant with his own treatments of entropy and self-organization, unremarked.[42] Instead, he offered a parting shot at Lovelock's participation in the widespread reification of "information," a concept by then mainstreamed in cybernetical deployments of information theory,

treating these quantities as real rather than virtual, that is, as if information theory measured physical substances rather than statistical differences.[43] This conceptual issue gave von Foerster an opportunity to rehearse his own conversion to the constructivist perspective unfolding at that moment in 1975 from Humberto Maturana's biology of cognition, from the theory of autopoiesis, and from von Foerster's own second-order cybernetic revisions of epistemological ideas:

> I would hope that we shall never tire of reminding ourselves and each other that "complexity," "disorder," "entropy," "information," "order," "organization," "simplicity," etc., are not names for properties of things, but those for properties of descriptions, or—if you wish—are names reflecting properties of the observer (describer), his vocabulary, his natural or chosen limits of discrimination, etc., in short, his idiosyncrasies at the time of his observation.[44]

This is a pure statement of neocybernetic epistemology. Von Foerster's lively response to Margulis and Lovelock's article in *CoEvolution Quarterly* did not dismiss the main ideas of the Gaia hypothesis. His tone was collegial and colloquial. However, he wrote, "I am unable to (re)-construct the proper representation of these equations' intent." There does appear to have been transmitted mistakes of mathematical expression in the excerpt from the "Atmospheric Homeostasis" article in *Tellus*.[45] Von Foerster continued, "Moreover, sitting in the boondocks I have no way to find out who is to be charged with these booboos: CQ who misprints Lovelock and Margulis; Lovelock and Margulis who misquote Denbigh (1951) and Evans (1969); or Denbigh and Evans who misunderstand. But this is not my job." However, despite the disagreements over philosophical semantics von Foerster noted above, his critique also affirmed that "I found Lovelock's and Margulis's ideas too important to see them becoming vulnerable because of deficiencies of a different kind. As a comment on their—or anybody else's—classification of Life I suggest that you reproduce 'Autopoiesis: The Organization of Living Systems, its Characterization and a Model.'" Clearing side issues away from matters of true import, von Foerster's commentary is to my knowledge the first and original suggestion of a relation between the Gaia hypothesis and the theory of autopoiesis as a noninformatic description of the recursive organization and operational closure of cognitive systems.[46]

FRANCISCO VARELA

CoEvolution Quarterly continued to introduce its readers to the newer cybernetics beyond the seminal instance of Gregory Bateson's ecology of mind. The summer 1976 number features back-to-back interviews. One is Brand's own lengthy interview with Bateson and his first wife, Margaret Mead, delving into their participation at the fabled Macy conferences on cybernetics.[47] Preceding this item is "On Observing Natural Systems," a fine interview conducted by Donna Johnson with the coauthor of the concept of autopoiesis, Francisco Varela. Von Foerster had recommended Varela, the brilliant young collaborator of his friend and colleague Humberto Maturana, to Brand, who arranged for his debut among the California systems intelligentsia. In his headnote to the interview, Brand situated Varela's work by rehearsing von Foerster's trademark epistemological themes and stock articulations of the distinction between first- and second-order cybernetics: "I share the opinion of Ludwig Wittgenstein, Gregory Bateson, G. Spencer Brown, Heinz von Foerster and others that failure to understand self-reference is the poison in the brain of most Western misbehavior, public and personal. In his recent landmark paper, 'A Calculus [for] Self-Reference' and in this interview, Francisco is helping build what von Foerster calls 'a cybernetics of *observing*-systems,' which is the rest of the story after 'the cybernetics of *observed*-systems'—feedback, goal-seeking, and such."[48]

"On Observing Natural Systems" encapsulated this very discourse, and in particular the confluence of Spencer-Brown's *Laws of Form* with von Foerster's cognitive constructivism, which would later prove seminal in particular for the full development of Luhmann's systems theory.[49] The following excerpts give the flavor of Varela's conversation. After some preliminary clarifications, his interviewer probed the discussion of "whole systems" further by asking, "So studying the organization of a whole system is studying the nature of its self-reference?"

> Varela: That's it. That is, the kind of self-referential organization that has provided the stable properties that it shows. And this is what gives the system its nature. When you have a closed interaction of chemical productions, you can have a cell, and not before that. When you have a closed interaction of descriptions, you can have self-consciousness, and not before. When you have a closed interaction of species, you have an ecological system, and not before. That is, the closure, the

> self-referential-ness, seem to be the hinges upon which the emergent properties of a system turn. (27)

In the following chapter we will look further into the history of contacts between Varela and Margulis. One could speculate on that basis that his formulation of "a closed interaction of species" may well have infiltrated her formulation of autopoietic Gaia as "the organismal-environmental regulatory system at the Earth's surface, comprised of more than thirty million extant species."[50] At the least, it is reasonable to think that Varela's neocybernetic style of systems theory first and effectively came to Margulis's attention in this *CoEvolution Quarterly* interview, which was published precisely one year after the *CoEvolution Quarterly* debut of her lead-authored article on the Gaia hypothesis. And regarding the epistemological discourse at the nexus of Maturana, von Foerster, and Spencer-Brown, just as von Foerster had insisted that descriptions primarily reflect the properties of the observer, Varela went on to underscore "the full importance of introducing the observer into the observation":

> Whatever we purposely distinguish will reveal not only the properties we are looking at but the fact that we are doing these interactions out of our own properties, that is, the properties we discover in systems will depend on our own properties. In its purest form, that means that whatever description we do of the world will be based on the act of splitting it apart in different ways. And the way we see the world, therefore, reveals what is our choice of cleavage, as it were, and that there are many of them precisely because there are many observers. (29)

The prior epistemological distinction between subjects and objects becomes relative to an observer's choice. *Laws of Form* conveyed an equivalent point: the cognitive paradox of self-reference cuts the ground out from under the pretense of unmediated objectivity. Presumably it was Brand who placed a sidebar next to the text of "On Observing Natural Systems" citing the same passage from *Laws of Form* that von Foerster had quoted in his review in the *Whole Earth Catalog*: "We may take it that the world undoubtedly is itself (i.e., is indistinct from itself), but, in any attempt to see itself as an object, it must, equally undoubtedly,

act so as to make itself distinct from, and therefore false to, itself. In this condition it will always partially elude itself."[51] Let us apply this epistemological statement to the observation of Gaia. The Gaian instance would be the final horizon of this epistemological reckoning: we cannot really fathom Gaia as a planetary system without looking, self-referentially, at ourselves, a part of Gaia, looking at Gaia. Objectivity is surpassed by participation. Moreover, Spencer-Brown's epistemological critique of holism informs Varela's constructivist looping of the properties of the observer into the attributes of their descriptions. It bears repeating that the partial Earth of our discussion in chapter 3 reappears here, hiding in plain sight in the glare of Whole Earth discourse.

In the summer of 1976, concurrently with the publication of "On Observing Natural Systems," Bateson and Brand organized a "Mind-Body Dualism Conference," also attended by von Foerster and Varela.[52] Varela returned to the pages of *CoEvolution Quarterly* that fall with "Not One, Not Two: Position Paper for the Mind-Body Conference," material he would streamline for incorporation into his first book, *Principles of Biological Autonomy,* published three years later.[53] In six packed pages of small type, "Not One, Not Two" addresses the conference theme of Cartesian dualism by formulating "Star cybernetics." "Star is (can be taken to be) a compact expression to signify a broad paradigm encompassing that series of convergencies rightly demanded by Bateson" in his invitational paper to the conference.[54] Varela lists this series as:

$$cybernetics \leftrightarrow epistemology \leftrightarrow evolution \leftrightarrow ethics \leftrightarrow cognition \leftrightarrow ecology$$ [55]

I will draw out Varela's cybernetic reasoning in this article up to the point that its relevance to Gaian thought becomes clear. A decade later Varela will address Gaia theory directly.

My exposition of Varela's Star cybernetics greatly condenses the detail of the argument and extracts it from Varela's own highly formalized presentation. So then, the formula for what Varela calls "the Star* statement" is:

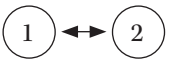
> "the it/the process leading to it" (62)

This formula has not two but three parts—the components on either side of the slash and the "whole system" computed by the integration

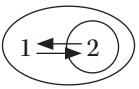
of those components. How then does one create a Star statement in any given instance? Varela explains:

> Take any situation (domain, process, entity, notion) which is holistic (total, closed, complete, full, stable, self-contained). Put it on the left side of the /. Put on the right side of it the corresponding processes (constituents, generators, dynamics). For example:
>
> | | |
> |---|---|
> | being/becoming | environment/system |
> | space/time | context/text . . . |
>
> In each case the dual elements become effectively complementary: they mutually *specify* each other. There is no more duality in the sense that they are effectively related; we can contemplate these dual pairs from a metalevel where they become a cognitive unity, a second-order whole. (63–64)

Star cybernetics flirts with philosophical holism but complicates it with a standard technique for resolving logical impasses: if one's view of a solution is blocked at one level, one adds another dimension to the view of the situation. The shift to a metalevel creates the conceptual space needed to sublate that obstruction. As we will see in a moment, placing affairs in a Star statement adds a second level to an observation. By contrast, Varela goes on, traditional idealism tends to stay on one level:

> In what I call the classic or Hegelian paradigm, the notion of dualities is tied to the idea of polarity, a clash of opposites:
>
> 
>
>
> The basic form of these kinds of dualities is *symmetry*: Both poles belong to the same level. The nerve of the logic behind this dialectic is *negation*; all pairs are of the form *A/not-A* (e.g., *+/-*, *oppressor/oppressed*). (64)

Fixing negative relations between polar opposites, classical dialectics tend to block the view beyond the opposition proper. Impasse is built into this style of observation, and in any real-world situation, solution by the synthesis of antithetical entities is difficult if not impossible. However:

> In our (shall we say) cybernetic or post-Hegelian paradigm, dualities are adequately represented by *imbrication* of levels, where one term of the pair emerges from the other.
>
> 
>
>
> The basic form of these dualities is *asymmetry*: Both terms extend across levels. The nerve of the logic behind this dialectics is *self-reference*: pairs of the form: *it/processes leading to it.* (64)

Let us formulate an instance corresponding to the theme of the meeting at which Varela was delivering this talk. If we map the mind–body dualism onto what Varela calls the classic or Hegelian paradigm, we get the Cartesian split. Negation rules, and self-division holds the field. However, if we map it as a Star statement, supplementarity absorbs negation, and self-reference heals self-division. In this form, both mind and body refer to the same self. The unity of their distinction emerges on the metalevel already implicit in the differentiation of levels constellated by the Star formation. Varela comments: "Pairs of the form Star *bridge* across one level, and this crossing is operational. They mutually specify each other" (64). Here is the strong neocybernetic note: "this crossing is operational" because both terms are now seized not as entrenched opposites but in their operational interdependence. Elsewhere I have called the logical modality of Star cybernetics *double positivity,* as in the imbricated or embedded and mutually supplementary relations of co-emergence between an autopoietic system and its environment. The system generates a boundary within which it carries out its dynamics and from which base of emergent possibilities it defines its environment not by negation but by operational distinction.[56] A Gaian observation of double positivity would be that from the moment of Gaia's coalescence, all earthly niches within the Gaian sphere have co-emerged from or in structural relation to the operations of living systems in the same measure that living beings have held their terms of existence in correlation with the contingencies, affordances, and limitations of their enabling environments.

In the fullness of "Not One, Not Two," Varela works the Star paradigm through numerous examples, but let us conclude with one that brings us back to "natural systems," Brand's "organic cybernetics," and our wider neocybernetic consideration of the Gaia concept:

> It is, of course, the case that when we look to natural systems, nowhere do we find opposition apart from our own projections of values. The pair predator/prey, say, does not *operate* as excluding opposites. Both generate a whole unity, their ecosystemic domain, where there is complementarity, mutual stabilization, and benefits in survival for both. So, although we can project values to the opposites predator/prey, the effective duality is a larger one, of Star form: *ecosystem/species interaction*. (64)

One of the oldest and most pointless debates over the Gaia hypothesis concerns its supposed contradiction of competition as a primary evolutionary driver. Gaia is said to flout the supposed competitive rule that would map evolutionary interactions among individuals and species onto the classic oppositional paradigm in the form *survivors/nonsurvivors* in the struggle for life. However, instead, let us map Gaia onto Varela's Star formation: Gaia would be *it,* and the recursive ecosystemic couplings of organisms to each other and to their dwelling places would be *the processes leading to it.* Geohistorically, Gaia would arrive toward the end of the Archean eon as the planetary metalevel arising from the aggregative dynamics of living systems (Margulis's "symbiotic Earth") coupled to the coevolution of environments compounded from abiotic processes and the residues of life. There is no final competition in *these* couplings, only *imbrication, complementarity,* and *mutual stabilization* between Earth and life processes and *benefits in survival* on the living side of the Gaian consortium.

Putting Varela's Star cybernetics next to Bruno Latour's critique of the cybernetic approach to Gaia, one might deem Varela's Star statements to be a consummate diagram of the way cybernetic discourse conceptualizes organization on multiple levels. Does this also or necessarily produce unwarranted totalizations of heterogeneous elements? Some of Varela's statements in this early draft of his later work are certainly equivocal. This is especially so in his remark, quoted above, that once one observes dualities in Star formation, "There is no more duality in the sense that they are effectively related; we can contemplate these dual pairs from a metalevel where they become a cognitive unity, a second-order whole." Were this to be read as full-blown holism, then Varela would be implying the possibility of an observer that could actually place itself in a terminal position to cognize simultaneously the

whole composed of a system *and* its environment, a move that would supersede the distinction between and so totalize system-environment differentiations. However, such a reading would need to dismiss the way Varela frames his scheme within a constructivist epistemology that adheres to Spencer-Brown's postulates regarding the inevitably partial, hence nonholistic nature of any possible observation.

Let us look more closely at the way Varela has constructed the Star statement regarding this particular duality. It reads "environment/system" and not the other way around. Here the environment is the "it" that emerges from the cognitive processes of the system that constitutes its alterity. In this framing, in good constructivist fashion, epistemology precedes ontology. Knowing produces being, a formulation that underscores how self-reference lays down the bridge between the imbricated levels implicated here. Moreover, seen in a biotic autopoietic view in which any living organization knows its world in the form of its own elements, Varela's Star statement "environment/system" encapsulates the core proposition of the Gaia hypothesis that *living systems produce their environments.* Let us now briefly observe this situation through the complementary conceptuality of another observer who operationalizes Spencer-Brown's *Laws of Form,* the theory of system differentiation in Luhmann's presentation. What we can then say for the Gaian instance is that Gaia is a system that "uses itself as environment in forming its own subsystems."[57] In other words, just as Varela diagrams the situation, the differentiation of levels works in both directions at once. And in that case, Varela's proposal does not erase dualities through holistic mergers but calls instead for complementary pairs that mutually specify each other once a bridge arises allowing the closure of their recursion. The crucial factor is thus not the multiplication of levels per se but the maintenance of differentiations such that events of systemic emergence have some environmental space in which to unfold.

Multiple orders emerge from the various neocybernetic schemes of the systems counterculture. From Fuller to Varela, with stops for von Foerster, Spencer-Brown, Bateson, and Lovelock and Margulis, these thinkers point their accounts of system dynamics toward material cycles, recursive forms, and circular operations that close the loop around preexisting elements such that their consortia bootstrap new orders of coherence and bring new beings and processes into the world. In the *Whole Earth Catalog,* Fuller set forward *synergy* to mean the "unique

behavior of whole systems, unpredicted by the behavior of their respective subsystems' events,"[58] while in *CoEvolution Quarterly,* Varela observed how "the simultaneity of interactions . . . gives whole systems the flavor of being what they are."[59] The main participant in these conversations responsible for giving "whole systems" a consistently holistic construction was the editor, Stewart Brand, adept at crafting popular mottos to ease the approach to the complexity of the systems discourses he curated. *CoEvolution Quarterly*'s framing operations certainly inflected its readers' reception of the Gaia concept. Nevertheless, Brand's curatorial instincts were keen, and the actual substance of both the neocybernetic discussions and the Gaia discourse Brand put forth to his readership may be more accurately described as, at the least, postholistic. In such neocybernetic descriptions, the situation of cognitive processes on multiple levels follows from the multiplicity as well as the finitude of observers.

DAISYWORLD

James Lovelock's statements regarding the cybernetics of Daisyworld provide a foil for our discussion of the neocybernetics of Gaia. Daisyworld is a model of automation rather than autopoiesis. It marks an increase in the sophistication of Lovelock's cybernetics but not a revolution in his cybernetic thinking. Lovelock declined the opportunity to engage with autopoietic systems theory. Similarly, after the arrival of chaos theory in the 1980s, on those occasions when he narrates Gaia in relation to the newer computational systems discourses—dynamical systems theory applied to population dynamics, the discourse of emergence in complex adaptive systems—he keeps them separate from his conceptuality of cybernetics proper. Cybernetics for Lovelock is set at control systems engineering and, notwithstanding occasional perturbations, stays at that steady conceptual state. His invention of the Daisyworld simulation brings out his ties to computational platforms for cybernetic model building. Daisyworld—a computer model of homeostatic self-regulation in the coupled interaction between an idealized biota and its virtual environment—is the culmination of Lovelock's heuristic exploration of Gaian parameters through cybernetic models. Moreover, its appearance in *CoEvolution Quarterly* under the modest title "Daisyworld: A Cybernetic Proof of the Gaia Hypothesis" is the climax of that periodical's sponsorship and spawning of the seminal

forms of Gaia theory, from the physiological Earth of "The Atmosphere as Circulatory System" in 1975 to the Daisyworld of 1983 modeled in differential equations run on a desktop.[60]

CoEvolution Quarterly's "Daisyworld" article is a revised republication of a paper in which Lovelock had recently announced Daisyworld to the participants of a meeting held in the Netherlands in June 1982, the Fourth International Symposium on Biomineralization. This interdisciplinary topic is of strong Gaian interest. It concerns the sedimentary precipitation of the postbiotic geosphere through various metabolic processes that evolve in the biosphere—lithification, calcification, silicification, and so on. Lovelock and Margulis appeared together in the section of the meeting on "Global Recycling and Biomineralization." Margulis and her coauthor situated Gaia in relation to biomineralization with a presentation on "Microbial Systematics and a Gaian View of the Sediments."[61] But Lovelock had something different in mind. He recycled the title of his paper here, "Gaia as Seen through the Atmosphere," whole cloth from his 1972 paper of the same name, in which he first published his theories about a self-regulating biosphere under the name of Gaia. Perhaps by this refrain Lovelock signaled another formative moment for Gaia theory, for his paper centered on a first rollout of the Daisyworld model to a specialist audience, accompanied by various atmospheric considerations.[62]

Lovelock begins by taking stock of the fortunes of the Gaia concept in its first decade. He refers to the paper coauthored with Margulis, "Atmospheric Homeostasis by and for the Biosphere: The Gaia Hypothesis," published in *Tellus* in 1974. Margulis gets full credit for her part in developing the effective public debut of the Gaia hypothesis. Reviewed ten years later, however, Lovelock concedes, Gaia's turn on the scientific stage has been inconclusive at best. By now the extent and tenor of scientific resistance to Gaia has taken shape. Lovelock notes similar fates for pre-Gaian observations of the active coupling of life to Earth processes. But he sees in this history of dismissal no insuperable counterargument but rather a larger philosophical disinclination to accept the premises of cybernetic reasoning. As with "earlier attempts to unify the biological and geochemical approaches to understanding the Earth, the gaia hypothesis has tended to be ignored rather than criticized by geochemists, almost as if Aristotle still ruled and anything moving towards a circular, even a nonlinear, argument was

forbidden. Gaia which uses the circular reasoning of cybernetics was taken to be teleological" (15).

Lovelock's presentation of Gaia has always rested on cybernetic control theory for the most plausible account of the Earth's evident maintenance of planetary conditions within the small range of geochemical states suitable for life's habitation. The Earth's abiotic history of massive perturbations from volcanic outgassings and planetesimal impacts, as well as life's own generation of atmospheric disequilibria between persistent levels of reactive gases, in particular, methane and oxygen, could well have driven the climate out of life's habitable range on a number of occasions. Thus, some mode of active control must account for the relatively steady state of Earth's planetary regime. The "presence of a control system, Gaia" (17), maintains the biota's active participation in these global processes of self-regulation. However, as Lovelock also concedes, regarding the precise mechanism by which this planetary coupling rises to operational efficacy, "It is not immediately obvious how such a course of events could lead to planetary homeostasis" (17). Moreover, responding directly to W. Ford Doolittle's critique of Gaia published in *CoEvolution Quarterly* in 1981, Lovelock notes the objection there that "the biota have no capacity for conscious foresight or planning and would not in the pursuit of local selfish interests evolve an altruistic system for planetary improvement and regulation" (17).[63]

Lovelock invents Daisyworld as a concrete rebuttal to those particular charges that the Gaia hypothesis *overanimates* (in Latour's idiom) the world with the imputation of conscious intentions, teleological aims, or some sort of planetary self capable of either selfish or altruistic ends. At the same time, he combats the critique of his application of control theory in the original hypothesis precisely by doubling down on the cybernetics of Gaia. He cannily notes how the logic of recursion goes against the linear grain of grammatical, narrative, and mathematical syntax:

> The sequential logic of descriptive writing is not designed for the concise explanation of control systems with their inherent circularity recursiveness and non-linearity. Even the formalism of mathematics loses its elegance when an attempt is made to describe a simple non-linear control system such as, for example, an electrical water heater controlled by a bimetallic strip thermostat. I have chosen therefore to

> present a simple model of an imaginary planet whose temperature is regulated at a biological optimum over a wide range of solar radiation levels as a working example of a Gaian mechanism. (17)

Daisyworld's nonlinear equations model a rudimentary planetary system, steadily forced, as is ours, by a sun gradually gaining in luminosity, whose biota are minimally composed of black daisies that thrive in cool conditions and white daisies that thrive when it's hot. Seeded with both varieties, Daisyworld starts out cool and is then externally forced toward warmer conditions. Due to their different albedos, or indexes of reflectivity, the two kinds of daisies feed back upon their climate to different effects. The low-albedo black daisies heat the planet by absorbing the sun's rays, while the high-albedo white daisies cool the planet by reflecting that same radiation back to space. The black daisies thrive at first as the initially cool conditions suppress the growth of the white daisies. But as the black daisies proliferate, the planet warms up enough to favor the spread of white daisies and suppress the growth of black daisies. The rising tide of white daisies diminishes the black daisies while also reflecting heat away from the planet. These countereffects settle down or regulate the positive amplification between the sun and the black daisies that had been driving up the temperature. Pushing back on the absorption of solar forcing, Daisyworld as a whole maintains its virtual climate at a steady level for as long as it can. It does so automatically, with no teleological impetus but only the mutual interplay of negative and positive feedbacks: "No foresight or planning is required by the daisies, only their opportunistic local growth when conditions favor them."[64] The black and white daisies model the mutual coupling of two Gaian feedback loops, either of which can exert a negative—that is, regulatory or stabilizing—effect on the other to achieve and conserve a virtual homeostasis, up until the model's solar forcing becomes too great for the system to control. Driven past that tipping point, Daisyworld's life goes extinct.

A technical article published later that year with his student Andrew Watson as first author presents a full mathematical treatment of the original Daisyworld. Watson and Lovelock write there: "The daisyworld equations form a system of non-linear, multiple feedback loops. The analysis of such systems is not a trivial problem, even for the highly simplified situation on daisyworld. Some information on the steady state

behavior of the equations can, however, be obtained without a disproportionate amount of mathematical effort."[65] In the *Biomineralization* paper, Lovelock provides a set of what will become iconic figures, graphs generated by the Daisyworld model that show how this mathematical parable of a biosphere–geosphere coupling automatically computes "a stable point around which the daisies can successfully homeostat the temperature over a wide range of luminosities."[66] The larger import of the Daisyworld parable in Lovelock's presentation is that this simulation of the postulated existence of a planetary control system models the stability and resilience of the biosphere even when confronted with massive shocks to the system. Daisyworld also models the limits of these natural controls once planetary variables pass beyond the range of possible regulation.

I will not engage the debate over the validity or usefulness of Daisyworld.[67] Suffice it to note, along with Timothy Lenton and his colleagues, that climate modelers and other researchers took up Daisyworld with some enthusiasm but did not thereby need to commit themselves to a full-bodied acceptance of the Gaia hypothesis. Daisyworld provided the Gaia hypothesis with computational interest at an opportune moment, fostering the sense that in some fashion it did constitute a "proof" of Gaia's operation as a planetary control system:

> Although Daisyworld was presented as a "parable," the model is so elegant, and so many studies have followed up on it, that it might have created a false impression of the likely nature of global regulatory mechanisms and their relationship with individual-based natural selection. Daisyworld is a special case in that traits selected at an individual scale also lead to global regulation. The microevolutionary dynamics are therefore stabilizing, addressing the persistence of regulation and illustrating a key feature of any plausible regulation mechanism—but providing no explanation for how or why a biota with these properties would arise.[68]

But as Lovelock himself made entirely clear when first presenting Daisyworld to his scientific peers, what Daisyworld models is a cybernetic *explanation* for Gaian dynamics without thereby proving their existence.

Coming back to Daisyworld's popular debut in *CoEvolution Quarterly,* I would speculate that the actual immodesty of the claim made in its

title, "Daisyworld: A Cybernetic Proof of the Gaia Hypothesis," was Stewart Brand's editorial fabrication. Nonetheless, Lovelock had already put the cybernetic language and its accompanying polemic into the prior *Biomineralization* article we have just been examining. For its *CoEvolution Quarterly* appearance, Lovelock only needed to extract that prior paper from its professional context through some rewriting of the opening section. This gave him (presumably) the opportunity of *CoEvolution Quarterly*'s nonspecialist venue to rehearse his observations about the state of cybernetics and its ongoing marginalization in the academy. Lovelock has never sounded more like a card-carrying member of the systems counterculture than in these remarks that seem made to his current editor's order.

The *CoEvolution Quarterly* article gained popular appeal with an informality and candor not present in the professional paper: "It is now just over ten years since Lynn Margulis and I published our first paper on the Gaia Hypothesis. You may be wondering what has happened in the meanwhile. You will have noted that the idea does not yet seem to have set big science on fire."[69] He again notes how "such names as Redfield, Hutchinson, and Sillen," whose statements, according to Lovelock, anticipated Gaian ideas, were not heeded. Again, Lovelock lays his own participation in this unfriendly reception on the fear of cybernetics: "One of the extraordinary things about science is that whilst it swallows the intricacies of relativity and of genetics, it has never been comfortable with whole systems; witness the unpopularity of cybernetics. How many universities, I wonder, have departments of cybernetics?" (66–67). He again pegs unreasoning metaphysical adherence to inherited models of Aristotelian causality as the culprit in Gaia's cool welcome. For most scientists, "The circular and recursive logic of whole systems is alien to them. This is especially true of geologists, geochemists, biochemists, and exobiologists who might otherwise have been interested in Gaia. It is true that engineers and physiologists are enlightened by their professional need to lift themselves from the narrow trough of linear thought. Unfortunately they tend to keep the conspicuous advantages of whole systems thinking to themselves" (67).

For the soft-spoken Lovelock, these remarks are particularly acerbic. Lovelock will often tweak the scientific academy from his hard-won position as a scientist whose independent status removes the duress of conformity within a university department or corporate laboratory.[70]

His critical tone and pro-whole systems polemic could also bear the mark of *CoEvolution Quarterly.* Moreover, it may be that they also come with a taste of the Lindisfarne Association, which had inducted Lovelock and Margulis together in 1981. We will examine this intellectual context more closely in the following chapter. Meanwhile, we should note that while she would dutifully expound it on later occasions, Margulis herself did not sign on to Daisyworld as a way of doing Gaian science. Her Gaian applications of autopoietic systems theory read like a counterstatement on her part with regard to the direction one could take the "circular and recursive logic of whole systems" that Lovelock sees in Gaia. In this pursuit, a decade later Margulis would cultivate the Lindisfarne ethos for her own round of polemical interventions on behalf of autopoietic Gaia. We will catch up with that story in chapter 6.