Gaia in Turmoil

Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis

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One Grand Organic Whole

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In 1876 Alfred Russel Wallace, co-progenitor with Charles Darwin of the theory of evolution by natural selection, wrote in his classic book, *The Geographical Distribution of Animals*, that naturalists "who are disposed to turn aside from the beaten track of research may find...a study which will surely lead them to an increased appreciation of the complex relations and mutual interdependence." These, he continued, "link together every animal and vegetable form, with the ever-changing Earth which supports them, into one grand organic whole" (1876: vol. 2, 553).

One could hardly find a more succinct description of Gaia than "one grand organic whole." It submits that biota and their environments have been integral since the early eons of our ancient water world. It provides for feedback on multiple scales—from global processes like climate change and biogeochemical cycles to the minutiae of local environments. It highlights the primary impact of living beings and processes on the physiognomy of that world that even observers from the outer reaches of the galaxy would recognize as a life-bearing planet. It describes Gaia in a language of consilience that both scientists and religious thinkers can understand.[1] It underscores the unity and grandeur of the Earth by choosing the capital "E" spelling over the lowercase alternative that, regrettably, is still in extensive use. Gaia theory honors systems thinking on a planetary scale. James Lovelock and Lynn Margulis established the foundations of the paradigm decades ago, working assiduously and collaborating since those founding days to show its applicability across disciplines and even in everyday society.

The Gaian perspective emerged from the observation that physical and chemical conditions on Earth are inseparable from life's ubiquitous presence. Powerful influences crisscross living and nonliving domains binding them inextricably. With the birth of Gaian science some forty years ago, this intuitively grasped integration became the empirical subject matter of an ever-burgeoning body of researchers. At a theoretical level, the integration of living and nonliving domains was conceptualized as an amalgamation so profound as to form a biogeochemical entity that behaves as a self-regulating system. How the Earth system is best conceived, and what metaphors should be deployed to describe it, are matters of ongoing discussion and debate in the literature. James Lovelock has often drawn on cybernetics to represent this system; Lynn Margulis has called it a symbiotic planet and a global ecosystem; Tyler Volk has invoked the concept of holarchy. Regardless of what metaphors are chosen, and what power is ascribed (or not) to the Earth system's regulative abilities, Gaian thinkers converge on the idea that, as a whole, the Earth has emergent properties that make it a drastically different type of planet than a lifeless one (Lovelock 1979; Margulis 1998; Volk 1998).

Before the emergence of Gaian inquiry, conventional wisdom maintained that due to the wonderful serendipity of our planet being just the right distance from the sun, the appropriate chemical and physical conditions have existed for the emergence and continued presence of life on Earth. Based on a comparison of the three sister-planets (Venus, Mars, and Earth), this conception of a region in space favorable for life has been called the *habitable zone*—or, more playfully, "the Goldilocks view" in honor of Goldilocks' exclamations upon tasting the three bowls of porridge: Too hot! Too cold! Ah, *just right*!

What Gaian thinkers submit may one day be regarded as less extravagant than the Goldilocks view of life's persistence on Earth. Instead of conditions being assessed as "just right" on account of the good fortune of our planet's positioning and size, viable conditions are regarded as actively maintained by the biosphere.[2] To put it starkly, the biosphere is not simply *in* a habitable zone but also *makes* a habitable zone. Large-scale physical and chemical environments of atmosphere, hydrosphere, and upper lithosphere, along with the climates that these domains contribute to forging, have been—for 3.8 billion unbroken years of life's existence—viable contexts for an ever-changing, increasingly complex, and most often abundant biota. Gaia theory proposes that life's endurance during the unimaginable time span of over three and a half eons is unlikely to be just a matter of luck: alternatively, early in life's history living and nonliving matter became entangled as *a single entity* within

which organisms themselves may have been shaping conditions to their adaptive advantage.

Many concepts have been used to describe this single entity: Gaia, biosphere, geophysiology, and Earth system, as well as (more controversially) living organism and superorganism. Originally the primal personification of the Earth in classic Greek mythology, *Gaia* has its counterparts in many prehistoric and historic cultures around the world: the Middle East, Rome, Europe, India, Mexico, the High Andes, and elsewhere. In its mythological guises, Gaia represents humanity's visceral grasp of origins, interdependency, and nurturing. The neologism *biosphere* was coined by geologist Eduard Suess in 1875 and elaborated by Russian geochemist Vladimir Vernadsky in his pioneering work, *The Biosphere* (originally published in 1929 but not available in English until 1979). Vernadsky elaborated a scientific argument for life as a geological force, and his ideas are now seen as anticipating Gaian science. *Geophysiology* was offered by Lovelock to highlight the interconnectedness of all the Earth's ecosystems on the analogy of the interrelations of organs and systems within the physiology of an organism. *Earth system* encompasses the planet's interacting domains of biota, atmosphere, lithosphere, and hydrosphere as a unity. *Earth system science* (inspired in part by Lovelock's thought) is the interdisciplinary inquiry into the complex workings of the Earth system, synthesizing such seemingly disparate disciplines as biochemistry, geology, climatology, microbiology, and ecology (see Wilkinson 2006).

Whatever name or conception best summarizes it, the Gaian perspective posits that "organisms and their material environment evolve as a single coupled system from which emerges the sustained self-regulation of climate and chemistry at a habitable state for whatever is the current biota" (Lovelock 2003: 769). While in ordinary language the concept of regulation connotes agency, in the context of Gaian science it is used analogically with the nonconscious, complex ways an organism's body regulates its own temperature and chemical parameters: not at set points but within acceptable ranges. According to Gaia theory, perturbations that would tend to shift conditions away from their relatively stable viable ranges are counteracted especially by means of negative feedback; such counteracting responses are termed the system's homeostatic tendencies. In the early days of Gaian thinking, most especially, *homeostasis* was identified—openly and implicitly—as the biosphere's signal feature. Over time, however, homeostasis has come to be seen as too static a paradigm to deliver the essence of a dynamic planet that has exhibited extremely varied physicochemical states and biota types over geological time. Homeostasis gave way conceptually to *homeorrhesis*, an idea cognate to the evolutionary model of punctuated equilibrium proposed by Niles Eldredge and Stephen Jay Gould: long periods of stable parameters (e.g., of temperature, atmospheric composition, and elemental cycling) are punctuated by planetary shifts, instigated by strong internal or external forcings, into new stable states (Eldredge and Gould 1985; Margulis and Lovelock 1989; Lovelock 2006).

Perhaps no event illustrates more crucially the biosphere's ability to respond in an apparently nonrandom manner to an external forcing than the Earth's maintenance of a viable surface temperature despite the sun's 25 percent increase in luminosity from the Archean to the present. (While this change is quantitatively substantial, it has obviously unfolded very slowly.) Prominent among the mechanisms of tuning temperature—in a way that has preempted the Earth from linearly tracking this heat increase—has been the gradual removal from the atmosphere of the greenhouse gas CO_2. How CO_2 is removed illustrates the exquisite choreography of the Earth's blended living and nonliving forces to yield a consequence favorable to life overall. Carbon dioxide is removed by rainfall that chemically reacts on land with calcium-silicate rock to form the soluble compound calcium bicarbonate, eventually flowing seaward. The chemical reaction is known as rock weathering—or, in Gaian terms, *biologically enhanced* rock weathering because the reaction is amplified, by several orders of magnitude, by soil (a biological phenomenon), plants, and other organisms (Schwartzman and Volk 1989; Williams 1996). But this is only part of the story of CO_2 reduction. After the carbon molecules of the once free-floating gas reach the seas, they are snatched up by organisms known as coccolithophores and by other marine creatures for use in constructing their exoskeletons. When these organisms die, their exoskeletons sink to the ocean floors. Through plate tectonics and volcanism some of that carbon eventually returns to the atmosphere as CO_2, but the net result over time has been the reduction of this key greenhouse gas, thereby countering—as Gaian scientists conjecture—the sun's increasing output (Westbroek 1991; Harding 2006).

The Earth story just described, involving the complex interplay of solar energy, rocks, soil, chemistry, plants, water in many forms, microorganisms, marine life, and gravity (to mention a few of the obvious factors), illustrates the seminal role life plays in shaping its environment.

Indeed Gaians propose that life can only prevail over long spells of time in the universe if it becomes chemically so powerful and physically so abundant as to contribute significantly to molding its planetary home. "In that sense, life is probably a property of planets rather than individual organisms" (Morowitz in Volk 1998: 107).

In the first two decades of the Gaia hypothesis, Gaian ideas became mired in scientific controversy and, to Lovelock's chagrin, were often greeted with silence and stonewalling. A piece of the chilly reception had to do with the name *Gaia*—and its train of association with such nebulous (or presumably disreputable) expressions as myth, metaphor, gender, spirituality, and New Age culture brought into the arena of straight facts and grounded theories. Another piece of the scientific establishment's initial recoil from Gaia involved its resurrection of an animistic view of the Earth. After 400 years of being virtually shelved by dominant mechanistic and reductionist perspectives, not only is *anima mundi* unabashedly expressed in Gaian literature, it has been turned into a research program within an interdisciplinary field charged to investigate it (see Barlow 1991). While neither the nontechnical naming after the Greek Earth goddess nor the extra-scientific intention to "animate Earth" (to cite Stephan Harding's recent title) have been abandoned, scientific representations of Gaia have changed and diversified since the early period of the 1970s. Changes ensued in response to critiques of the Gaia hypothesis, and also as a consequence of the natural unfolding of a scientific framework—in which numerous investigators have contributed to its elaboration and refinement.

The early Gaia hypothesis boldly proposed that the biota controls the global environment in order to keep planetary conditions habitable, stable, and even optimal for all life. This definition of Gaia came to be known as "strong Gaia" (and sometimes "optimizing Gaia"), and while it is often still recited in nonscientific arenas, it is now downplayed in the scientific literature for both conceptual and empirical reasons. The conceptual reason involved the teleological overtones of the idea that the biota can strive toward sustaining livable conditions. The critique of the first Gaia concept as teleological was offered by neo-Darwinians (Doolittle 1981; Dawkins 1982; Kirchner 1991), and it inspired greater care in conceptualizing Gaia so as to avoid the scientifically unsupportable implication that life, as a unified whole, can have a goal. (The neo-Darwinian critique also inspired the creation of the Daisyworld model by Andrew Watson and James Lovelock to be discussed shortly.)

The empirical reason for the rejection of strong Gaia involved the deepening recognition that catastrophe and instability have been such integral and reoccurring aspects of Earth's history that notions of the biota being in control, creating optimal states, or maintaining homeostatic conditions seem unsustainable (see Huggett 2006). Geologists, in particular, challenged the proposal that the biota—a "paper-thin" layer on the planet's surface—could possibly govern geological processes and cycles that act on far slower time scales and vaster spatial scales than biological systems (see Holland 1984). Goaded by astute biological and geological critiques, the Gaia hypothesis evolved into Gaia theory, while Lovelock's intention to unify Earth and life sciences inspired the emergence of Earth system science—a field that is friendly toward but not coextensive with Gaian thinking (e.g., Jacobson et al. 2000).

While strong Gaia has thus been on the wane for three decades, its antipode, "weak Gaia" (also known as "influential Gaia"), was always regarded as too self-evident to merit central status in the definition of Gaia. Weak Gaia simply states that life physically and chemically influences the global environment—a fact with which few can disagree (e.g., the oceans' microorganisms, alone, make 40 percent of the atmosphere's oxygen). James Kirchner (2002) pithily summarized the widely shared verdict on the two perspectives: strong (or optimizing) Gaia is new but not true while weak (or influential) Gaia is true but not new. This leaves the mid terrain for articulating an empirically robust and theoretically tenable understating of Gaia. Some have called this middle ground "coevolutionary Gaia"—the view that, by constantly impinging on one another, geological and organismal domains form a coevolving unity that indeed has always been habitable (Schneider 1986). But are nonliving and living domains merely coevolving and otherwise coincidental influences, or are they coevolving as an integrated system that regulates planetary conditions to some degree or other? Co-evolutionary Gaia leaves the question unanswered but open.

As Jon Turney (2003) noted about the four decades of its transformations, Gaia theory has become more complex, richly associative, and open to modification. Gaian thinking evolved from the provocative hypothesis that life controls or optimizes planetary conditions for its own benefit to a more nuanced theoretical framework that submits life (within the co-evolving nexus of biotic and inorganic world) is a key player in shaping the planet. Working out the details of the intense interaction and feedbacks between the living and inorganic worlds, especially on large-scale and global levels, comprises the Gaian research program.

Perhaps the ultimate challenge of this program is to demonstrate that life's impact is so substantial as to be (or have been) the catalytic ingredient of keeping Earth livable in the face of inexorable, often stupendous cosmic, geophysical, and geochemical forces. To that end Gaian scientists examine to what extent, by what mechanisms, and by what patterns of (inter)action the biota may load the dice, so to speak, for its own persistence beyond the play of chance.

How might the biota contribute to its own persistence without purpose, intention, or as Richard Dawkins once quipped, public-minded collaboration for the good of all life? The creation of the computer model "Daisyworld" in the 1980s served to illustrate how organisms can tune global conditions to their own advantage simply by doing what organisms do best—growing abundantly (Watson and Lovelock 1983). In this model a hypothetical planet (like Earth), orbiting a star that is increasing in luminosity (like our sun), is seeded with daisies that come in black and white varieties. The black daisies absorb sunlight and thus do best in the early times of a cooler sun, while the white daisies reflect sunlight and thus prosper as the sun gets hotter. The average surface temperature of a Daisyworld without its daisies would directly correlate over time with the linear increase of the sun's output (assuming an unchanging atmosphere). In a Daisyworld with thriving daisies, however, the average surface temperature is stabilized over an extended period, within a daisy-friendly range, by the thermostat-mimicking play of black and white daisies growing; black ones predominating initially, followed by a black and white planetary tapestry, and concluding with mostly white-daisy cover. (The sun's overbearing heat eventually trumps all varieties.) The creation of Daisyworld *in silico* was a landmark moment in Gaian science. Its power did not lie in modeling the Earth but in representing conceptually and mathematically that a living mechanism on a planet—provided its global effects reinforce the benefits of its local effects—can literally tune a planetary variable such as temperature in an automatic, nondeliberate, and morally neutral (requiring neither collaboration nor competition) manner. Its simplicity notwithstanding, Daisyworld has remained a memorable biospheric model for its perspicacity in making a point.

Organisms' exquisite ability to adapt to environmental exigencies has been well established in the 150 years since the publication of Darwin's *On the Origin of Species*. The Gaian perspective complements this knowledge by investigating life's less explored capacity to tame the very exigencies that impinge on it. The biota can have global impact as a consequence of its abundant products and processes of metabolism, nutrition, respiration, and behavior. Its chemical and physical effects add up to a collection of forcings that tip the Earth into a state very different from what a lifeless one would be. A hypothetical Earth without life—but endowed with the same size, distance from the sun, and initial conditions—would be very different from the biosphere we know and biospheres past. So, while the evolution of life is largely driven by natural selection, Gaian scientists also insist on the significance of life itself modulating the selective forces that act upon it.

In an influential paper seeking to wed Darwinism with a Gaian understanding, Tim Lenton (1998) proposed that organisms altering their environment in ways that (happen to) benefit them could have greater likelihood of being favored by natural selection than those organisms creating effects that backfire on them (see also Lenton 2004; Lenton and Williams, chapter 5 of this volume). Organismal traits that benefit their carriers by increasing their short-term reproductive fitness certainly tend to be selected for. To this classic Darwinian view, Gaian thinking adds that if (many of) those same traits *also* perchance result in environmental effects (or by-products) that *eventually provide positive feedback* to their carriers, the latter may be doubly favored: for such traits will confer both short-term reproductive fitness and mid- to long-term reproductive fitness via environment-enhancing consequences.

The Gaian perspective has never diverged from the Darwinian tenet that life adapts to its conditions via, in large part, the mechanism of natural selection that favors those organisms better suited to their particular conditions. Gaian scientists have noted, however, that when natural selection is one-sidedly emphasized, as it is by some neo-Darwinian thinkers, the latent message is a representation of living organisms as more passive than they actually are: they are portrayed as bystanders within an environment that, on one extreme, rewards them with reproductive success, while on the other, wipes them out if they are misfits. Some critics of Gaia, for example, James Kirchner (2002), insist that the environment merely appears well-tailored to the needs of life on account of straightforward Darwinian adaptation—only those living organisms persist that were selected for their good fit to their conditions. Gaian scientists counter that physical and chemical variables are so inextricably entangled with the biological world—being either a product of the biological world or hugely modified by it—that it may make more sense to regard the environment as life's extended

phenotype, than to conceptualize the environment as a straightforward independent variable that molds life.

The integrated framing of Earth as a biogeochemical entity has generated new forms of inquiry since the early days of controversy. Components of the biosphere can now be investigated for their potential roles within the whole; and the maintenance of those components within certain ranges can be queried for the systemic functions thereby served. Gaia theory famously drew attention, for example, to the long-term stability of oxygen at around 21 percent. Inquiring into the potential function of oxygen within the biosphere, Gaians pointed out how the respiration of animals, on the one hand, and the fire regimes of forests, on the other, are both well served at this proportion; scientists also posited mechanisms or feedbacks maintaining it in a 21 percent range for perhaps 200 million years (Lovelock 2003). Emphasis on elemental cycles and interconnections within the biosphere led Gaian scientists to further suspect the existence of a mechanism by which sulphur and iodine, drained into the seas by rain and rivers, are returned to land; this eventuated the discovery that the biogenic gases methyl iodide and dimethyl sulfide cycle those elements back to land. The connection between dimethyl sulfide and cloud formation later added another chapter to the ways that organisms—marine creatures, in this case—influence temperature and create climate (Lovelock 1991).

In brief, much of the value of Gaian epistemology lies in offering a framework within which new questions, new hypotheses, and new knowledge can emerge. At the same time, and crucially for the present day, the value of Gaian thinking lies in the ways scientific ideas, ethical realizations, and environmental implications intersect within it: Gaia renews the ancient understanding of the Earth as a living subject rather than an inanimate object. As David Abram offered, Gaia compels us "to recognize, ever more vividly, our interdependence with the countless organisms that surround us, and ultimately encourages us to speak of the encompassing Earth in the manner of our oral ancestors, as an animate living presence" (1996a: 302). This extra-scientific resonance of Gaia evinces in the broader culture and in spiritual inquiry—a resonance that involves tropes of intuition, sensing, love, religion, and compassion inside the planet's living presence (Abram 1990, 1996b; Primavesi 2000; Harding 2006).

The environmental dimensions of Gaia theory revolve around two fundamental concepts: consequences of human-driven perturbations of the biosphere, and implications of habitat destruction and fragmentation of the Earth's ecosystems. While small-scale disturbances can be absorbed by the biosphere, large-scale perturbations sooner or later trigger far-reaching and uncontrollable consequences. Consider the matter of great contemporary anxiety—CO_2-loading of the atmosphere. The anthropogenic (or volcanic, for that matter) injection of relatively small amounts of CO_2 can be countered by the biosphere via their absorption by the oceans and the stimulation of the growth of photosynthetic organisms: these responses are indeed conceptualized by Gaians as negative feedback mechanisms of Earth's global metabolism countering additional atmospheric CO_2 (Williams 1996; Lenton 2002). But when CO_2 amounts exceed the biospheric capacity to respond, then the forcing can make the Earth system's current equilibrium break down, shifting it into unknown territory. As many scientists have warned, human beings and countless other organisms are perched on the knife-edge of such a global shift. Moreover the carbon cycle is only the most obvious and most publicized of the element cycles that humans are disturbing; we are in fact profoundly disturbing all the cycles of the Earth's fundamental elements, including sulfur, nitrogen, and phosphorus (see Williams 1996; Volk 2008). In some cases we are seeing the effects of adverse synergies: for example, the recent *increase of dead zones in coastal waters reflects the disturbance of both nitrogen and carbon cycles—as agricultural runoff is now spilling into* waters warmed by excess CO_2 in the air (Juncosa 2008).

As for anthropogenic habitat destruction and fragmentation, this process began hundreds of years ago but has been escalated recklessly in the last few centuries and decades. In a Gaian context of the Earth as a global ecosystem, or a geophysiology, all ecosystems are interconnected on a planetary scale—analogously to the ways that all organisms are connected within their specific ecological communities. (The global interconnection of ecosystems mediates biogeochemical cycles, the creation of climatic regimes, and the propagation of biodiversity via gene flow and population migrations.) The demolition of natural habitats has reached a level where it no longer constitutes a set of destructive local or regional events, but reverberates into global repercussions—as indeed humanity is experiencing with the effects of deforestation and desertification, for example, reaching beyond their specific locales. Gaian scientists—especially Lovelock and Harding—have emphasized that the Earth cannot afford any more habitat destruction: if, following current trends, the planet is turned into an agricultural, aqua-cultural, and farm factory to feed increasing human consumption and population, then the interconnected wild ecosystems of the Earth will no

longer fulfill their functions of creating familiar climate, cycling elements and nutrients, removing wastes, and birthing new life forms. From a Gaian perspective, we are perched on the knife-edge of converting the planet from a geophysiology—or a mantle of contiguous interwoven natural systems—into a sterile orb bearing life that merely serves or is compatible with narrow human interests.

No place exists in the Gaian paradigm for the inflated anthropocentric credo—be its origins religious or humanistic—that the Earth exists as an object of human dominion. To rip into the planet's rhythms, cycles, and interconnections, as the civilization we have created is doing, signals human folly not mastery. For one, the Earth system is ultimately unpredictable and more powerful than humanity's actions. Gaia theory proposes that organisms inflicting damage on their surroundings will eventually reap harsh consequences when feedback comes back to haunt them. We are currently experiencing such feedback in the form of climate change, ozone depletion, endocrine disruption, and desertification. Moreover there is no telling what other surprises await us, all the more as we are now disrupting the biology, physics, and chemistry of the oceans that cover three-quarters of the Earth's surface: they create and cycle huge components of the air we breathe, the climate we enjoy, not to mention the food we eat. As many scientists and analysts have noted, tempering so recklessly with the biosphere entrains the highest risks.

Further, by shredding the planet's rhythms, cycles, and interconnections, we forfeit a quality of human life that can be of the highest caliber in a world abundant in biodiversity and healthy ecosystems. Gaia teaches us that we live connected with all biotic and abiotic elements *inside* a planet that is more like a "physiology" than it is like a "spaceship" that carries a random crew of life-forms. Whatever we inflict on the biosphere does not only eventually have physical and survival consequences for human beings, it has immediate experiential repercussions. We submit that the increased entropy civilization is producing—through ecosystem destruction and impoverishment, habitat fragmentation, unending development, agro-industrial monocultures, and rampant extinction of species and subspecies—returns to us in the form of epidemics of violence, alienation, depression, disease, and nihilism across households, cultures, tribes, nations, and religions (Roszak et al. 1995; Fisher 2002; McKibben 2007).

"Human activities," Tim Lenton and his colleagues noted in a recent climate-change publication (2008: 1786), "may have the potential to push components of the Earth system past critical states into qualitatively different modes of operation, implying large-scale impacts on human and ecological systems." Such qualitative shifts can occur as a consequence of what are called *tipping points*, whereby relatively small changes in input have long-term, large-scale, and often irreversible output (ibid.). Improved climate models, recent climatic paleo-data, and on-the-ground observations and measurements are driving home the realization that such tipping points can make climate change manifest more like a switch than a dial (Linden 2006; Flannery 2006; Lovelock 2006). The anthropogenic amplification of the greenhouse effect underway is rapid and large enough that it may unleash positive feedback—via loss of albedo of light-reflecting surfaces (ice and snow), release of methane from the tundra (and possibly even sea floors), and other consequences: positive feedback, in turn, can trigger runaway heating. Such an eventuality will not only cause widespread human suffering, it will transform the Earth into a biological wasteland. Arriving at a time when the natural world is already severely wounded by human activities, rapid climate change is exacerbating biodepletion: it threatens to wipe out one million species or more and is jeopardizing entire classes of ecosystems, namely the Amazonian rainforest, coral reefs, boreal forests, polar landscapes, and marine microorganisms and krill at the base of the ocean food chain (Thomas et al. 2004; Lovejoy and Hannah 2005; Flannery 2006; Harding 2006).

While the specters of climate change now draw considerable attention from scientists, policy makers, politicians, and the general public, the equally if not more momentous event of the biodiversity crisis—which includes the current human-driven mass extinction—has yet to pass a critical threshold into collective awareness (Crist 2007). The impoverishment of ecosystems and the depletion of wild species have occurred for centuries (or longer), but these losses have escalated since the Industrial Revolution with consumption increase, population growth, and technological sophistication reaching dizzying levels. The Earth is estimated to be losing thousands or tens of thousands species yearly, and the 2005 Millennium Ecosystem Assessment found nearly two-thirds of the services provided by nature to humankind in decline worldwide (Watson et al. 2005). While the biodiversity crisis has yet to be assessed for its potential of destabilizing the Earth system—of overstepping a tipping point beyond which lies a different planet—such an event horizon should not be required to make the depletion of Earth's biological wealth a calamity of unthinkable proportions. Even though the mass extinction of species and the wholesale decline of ecosystems have yet to trump contemporary fixations on the economy, politics, peak oil, terrorism, and entertainment, biodepletion will undoubtedly be judged, in retrospect and not soon enough, as the most momentous, far-reaching event of our time.

We still live in the Holocene and should resist the sirens of realism that call for branding our human-dominated era by a new name.[3] We do not need the form of realism that surrenders to the seemingly unstoppable expansionism of human civilization in the biosphere, that resigns itself to more ecological losses, and that calls for coping in piecemeal fashion with consequences that come our way. Instead, we need an enlightened form of realism in order to undertake the tasks that can make the decisive difference: "at this point in our environmental freefall," as Paul Hawken (2007: 172) aptly surmised, "we need to *preserve* what remains and dedicate ourselves to *restoring* what we have lost" (emphasis added). While the tasks of preservation and restoration of Gaia's natural systems can be assisted by on and off the ground technologies, clearly, they cannot be effected by technological fixes. These tasks are rooted in a vision of conservation at landscape and seascape levels, involving the protection of natural areas and species, reconnecting fragmented habitats, reintroducing natives and removing invasives, growing and harvesting food ecologically and ethically, and allowing the richness of the biosphere to blossom again into a semblance of its erstwhile diversity and abundance. Such a conservation vision calls for concerted work at global, regional, and local levels. It requires what Lovelock (2006) has so frankly called *sustainable retreat*: we must scale down our consumption, shrink our ecological footprint, and generously share the biosphere with all living beings.

The attraction and power of Gaian inquiry have always extended beyond natural science to other academic disciplines and, of course, into the broader culture. Its interdisciplinary nature is evident in the welding of geological and life sciences, as reflected, for example, within the Gaia-influenced arena of Earth system science. The interdisciplinary nature of Gaia inquiry is also evident in the ongoing dialogues that Gaia has inspired between the natural sciences, social sciences, and the humanities, as reflected in major conferences as well as numerous edited works (e.g., Thompson 1987; Barlow 1991; Schneider and Boston 1991; Bunyard 1996; Schneider et al. 2004). A fascinating but also dismaying consequence of this intense interdisciplinarity is that "Gaia" is articulated in a bewildering diversity of ways, depending on the epistemological, political, ecological, or cultural contexts and purposes of its use. To mention a pointed example, the shorthand description of Gaia through the metaphor of "living planet" was first invoked by Lovelock himself (1979). Yet science is not equipped to address the question of whether the Earth is alive, since the question itself cannot be scientifically formulated. Even so expressions of the intuition of Earth-as-living abound in Gaia-inspired art, philosophy, spirituality, and even popularized science; such expressions are as much a part of the legacy of Gaia as, for example, strictly technical endeavors to describe Gaia as an emergent effect of organisms' waste by-products or to represent organisms' regulatory effects through computer modeling.

The present volume reflects Gaia's longstanding disciplinary richness and diversity of understanding. Some two dozen contributors—natural scientists, social scientists, philosophers, theorists, technologists, and educators among them—helped to shape it. We have partitioned the book into three sections. Chapters in part I focus on the science of Gaia: the fluxes of essential elements through the biosphere; the potentially critical role of life in retaining abundant water on the planet since the Archean; the interface between Earth-system thinking and levels of Darwinian selection; and Gaian feedback mechanics connecting canopy and soil organisms as a key ecological circuitry in the self-maintenance of forest systems. Contributions in part II examine global environmental quandaries: the urgent matter of biodiversity destruction, especially given the importance of biodiversity for the resilience of ecosystem functions and of the Earth system as a whole; the dangers of the rapid climate change underway, and the energy and policy shifts required to stabilize climate within familiar ranges; the imminent freshwater crisis poised to imperil millions (if not billions) of people, as well as freshwater species and natural systems; the need for large-scale, restorative conservation strategies—from assisted migrations in a world of shifting climate regimes and fragmented habitats, to rewilding landscapes for the protection species, ecosystems, and evolutionary processes. Chapters in part III explore the influence of Gaian thinking on sociocultural visions and discourses—environmental ethics, mind and experience, politics, technological systems, and education. Broadening Aldo Leopold's celebrated "land ethic" into an "Earth ethic" that can encompass—in thought and policy—the spatial and temporal scales of our global crises; remapping mind as a property of the Earth in which all beings participate, and considering the implications of such an understanding for human experience within

the Earth's elemental moods and beauties, as well as within the Earth's troubled times—now and ahead; dreaming a new (and hopefully rising) political culture in which Gaian principles of symbiosis and embeddedness displace the psychosis of the growth imperative; querying how emerging information technologies—able to document whole Earth processes—once available to a growing grassroots environmental and justice movement, can become a potent political tool and educational medium for restoring the Earth; and critically dissecting trajectories and uses of systems theory for understanding the biosphere.

After reading an advance copy of Darwin's *On the Origin of Species*, Thomas Henry Huxley, the widely proclaimed "bulldog" for the nascent theory of evolution by natural selection, exclaimed: "How exceedingly stupid not to have thought of that!" (see Huxley 1900). Like many of the best ideas, evolution by natural selection seemed obvious once someone had formulated it. A first reading of basic Gaia literature often provokes the same emotional response: Isn't that obvious? Yet it is not obvious to everyone, and sometimes its presentation has required a near-combativeness in its defense among its varied advocates. We hope that this volume will provide readers a compelling understanding of Gaia as a way of knowing: Earth, home to countless and evolving species, diverse ecosystems, and complex biogeochemical processes, all interconnected and awaiting not only discovery but, even more crucially, the awakening of our gratitude and awe.

Notes

1. See Wilson (1998).

2. Following Tyler Volk's convention, we use "Gaia" and "biosphere" interchangeably to signify the integrated whole of air, oceans, soil, and life that has emergent effects on the planet.

3. We are referring to the circulating ill-thought proposal to rename our era the Anthropocene.

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2

Our Sustainable Retreat

James Lovelock

It has been 42 years since the idea of a "living Earth" came to my mind at the Jet Propulsion Laboratory in California. Shortly after this, Nobel Prize winning novelist William Golding proposed that the hypothesis be called Gaia after the ancient Greek Earth goddess. There was nothing mystical in this proposal from a classical scholar since the name of the same goddess is the root of geo, geography, geology, geophysics, and so on. The concept of a live, self-regulating Earth was in the early 1970s welcomed by climatologists, by a few geologists, and by the eminent biologist Lynn Margulis, who joined with me in developing the science of Gaia. The first predictions of the hypothesis concerned the natural cycles of sulphur and iodine as were confirmed by direct measurements and established quantitatively by the ocean chemist Peter Liss.

Why therefore, despite successful predictions, mathematical models, and strong evidence, do many scientists still regard the concept of Gaia as New Age mysticism and not part of science? The answer lies mainly I think in the evolution of science during the two past centuries. The reductionist approach was a stunning success. It led to the triumphs in molecular biology and to the deconvolution of the code of life; in physics, from subatomic to cosmological levels, there were successes of comparable magnitude, all of this while science was integrating socially within the universities. The very natural ambitions of strong-minded professors encouraged and strengthened the separation of science into those tribal territories called "disciplines." In such a world there was no place for the holistic science of Gaia. At most, there were interdisciplinary gatherings that were oddly similar to international conferences of politicians—far more was said than done.

Somehow the systems sciences, physiology, and the theoretical side of engineering have managed to exist, despite their top-down not