Extending the Domain of Freedom, or Why Gaia Is So Hard to Understand

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The Gaia hypothesis implies that the stable state of our planet includes man as part of, or partner in, a very democratic entity.

—James Lovelock[1]

Ever since Dipesh Chakrabarty opened a Pandora's box on the definition of humanity during the Anthropocene, the question of establishing a new continuity between the domain of necessity (nature) and the domain of freedom (society) has been raised.[2] In this paper we claim that freedom, understood as the capacity to obey one's own laws—that is, autonomy—could offer a common ground for ecological politics, on the condition of revising some of the commonly held views of what the concept of Gaia consists of. To do so, we wish to look in a new way at Gaia as James Lovelock and Lynn Margulis have proposed it, thanks to research done in natural and social science since the inception of this concept.

A Common-Sense View That Is Not So Common

The public discourse about the state of the planet is currently in a paradoxical situation: on the one hand, everyone involved in the politics of climate accepts the idea that Earth *behaves as* a regulated system that has

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1. James Lovelock, *Gaia: A New Look at Life on Earth* (1979; New York, 2000), p. 137.

2. Chakrabarty is right that all the difficulties in giving political traction to ecological questions arise from such incommensurability between long-term geological history and short-term human history; see Dipesh Chakrabarty, "The Climate of History: Four Theses," *Critical Inquiry* 35 (Winter 2009): 197–222.

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been dangerously pushed by human action out of its normal conditions of operation; on the other hand, the hypothesis that Earth is indeed a *self-regulating system* remains highly controversial—and most people do not connect the idea of Earth regulation with Lovelock's and Margulis's "discovery" of Gaia. Thus, the common horizon of political action and moral commitment—Earth is a system put out of whack that should be brought back inside some form of order through the regulation of human activity—remains a local and disputed intellectual and scientific idea.

The reason for this paradox is that the Gaia theory has either been embraced with too much enthusiasm or rejected with too much scepticism, both without unpacking its exact content. No wonder, as *order* and *regulation* are terms that pertain jointly to science and to politics. Those for whom it is obvious that there is some order in the regulation of the Earth, as well as those for whom it remains a vague metaphor, might not have zoomed in on the precise ways through which Gaia was introduced. No matter if they come from philosophy or from science, they seem to have pigeonholed the argument to suit their preconceptions of how nature is supposed to rule, rather than being sensitive to the originality of the phenomena offered for inquiry.[3] The result is that half a century from its inception, it is still hard to find a widely shared definition of Gaia.

There are of course good reasons for that. The first is that any new phenomenon is defined by comparison with some already familiar situation. Gaia however is a *unique phenomenon*—at least as long as we have no proof of another planet modified by life to provide some sort of baseline. So, it's no wonder that metaphors don't help much in defining Gaia: if you are happy with one version, it is sure to be wrong. You cannot zoom in on its specificity by just considering nature as a whole. Hence the many misunderstandings accumulated over the years around the idea that the Earth is alive, that it is an organism, a superorganism, a machine, a cybernetic feedback control device, a spaceship, a body politic, and so on. Even the tamed notion of system is no more than a fragile simile, in spite of the now common expression Earth System Science (ESS)—the polite euphe-

3. See for instance how the philosophical work of Michael Ruse, *The Gaia Hypothesis: Science on a Pagan Planet* (Chicago, 2013) and the scientific work of Toby Tyrrell, *On Gaia: A Critical Investigation of the Relationship between Life and Earth* (Princeton, N.J., 2013) include Lovelock's Gaia into a holistic view without trying to understand its originality.

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mism sometimes used to avoid naming Gaia too directly.[4] While there is a fairly widely held perception that ESS has replaced the idea of Gaia, we argue it is important to differentiate them. Specifically, Gaia originated and expanded in space and time from within a preexisting Earth system. Strangely, defining such a phenomenon requires a sort of negative geology reminiscent of the apophatic ways that theologians had recourse to when trying to probe God's uniqueness.[5]

The second reason for the difficulty of making sense of Gaia is that it's not clear if it's a discovery of a new phenomenon or the introduction in science, as well as in philosophy, of a new way of looking at all phenomena on Earth. As Sébastien Dutreuil has shown in a meticulous inquiry into its historical development, Gaia is simultaneously a hypothesis, a testable theory, a summary of highly specific facts, a worldview, and a philosophy of nature all mixed together.[6] Not to mention the claim made by some of its proponents that it might be a new religion or a new spirituality. This uncertainty explains the wide range of reactions triggered by any utterance of the word *Gaia*.

It is the aim of the present paper *not* to choose too fast what Gaia consists of because we claim that Lovelock's and Margulis's discovery might be just as unique as the object it tried to describe. In other words, Gaia might be the name of a shift in understanding how to approach many phenomena previously lumped together in the notion of nature. This is why we are—one coming from social science and the other from natural science—joining forces to keep open the possibility that we are dealing with a change in what could be called a *worldview*, by which we mean a distribution of traits affecting science as well as politics, morality, and the arts. In brief, a cultural paradigm shift, comparable in scope to the one introduced at the time of the scientific revolution by Galileo Galilei.

It is actually this shift in worldview that justifies our use of *Gaia* unapologetically in what follows—not in spite of but *because* of its mythological baggage. Even though many scientists have preferred ESS because it avoids any connection with mythology and the problem of evolutionary theory, we believe that Gaia is a distinct phenomenon and, because of

4. See Tim Lenton, "Home," *Earth System Science: A Very Short Introduction* (New York, 2016), pp. 1–17.

5. See Etienne Gilson, *La Philosophie au moyen âge: De Scot Erigène à G. d'Occam* (Paris, 1925).

6. See Sébastien Dutreuil, "Gaïa: hypothèse, programme de recherche pour le système Terre, ou philosophie de la Nature?" (PhD diss., University of Paris 1, 2016) and, for an English summary, "James Lovelock's Gaia Hypothesis: 'A New Look at Life on Earth' . . . for the Life and the Earth Sciences," in *Dreamers, Visionaries, and Revolutionaries in the Life Sciences*, ed. Oren Harman and Michael R. Dietrich (Chicago, 2018), pp. 272–88.

its several meanings, maintains some of the radicality necessary to make both science and society tackle the new "climate of history."[7] Although it has strictly the same etymology as *geo*, when it is used as a prefix in words like *Gaia-logy*, *Gaia-graphy*, *Gaia-chemistry* or *Gaia-politics*, *Gaia* focuses attention on the uniqueness of the situation at hand—a uniqueness that we believe has not attracted enough scrutiny.[8] What the prefix *geo* downplays or ignores, *Gaia* forces us to underline again.

Gaia Theory Is Contemporary to the Anthropocene

To fathom Gaia's uniqueness, it is convenient to reflect first on the historical situation in which its formulation came about. It was so peculiar that it would be a mistake to try to establish too much continuity between Gaia and earlier views of the balance or harmony of nature. The idea was born in a setting marked by the explosion of wholly new technical and industrial infrastructure. Not only was its formulation strictly contemporary with what was later called the Anthropocene, but, in addition, its first description by Lovelock depended fully on an analysis of how *human industry* had been able to modify the chemical balance of the Earth at a global scale.[9]

As has been told many times by Lovelock and described by Dutreuil in great detail, the invention of exquisitely sensitive instruments—especially the electron capture detector—allowed Lovelock to quantify the extent of *industrial pollution* in a new way. His inventions were used to detect the global spread of anthropogenic pollutants, including DDT and later CFCs. And it was Lovelock's resulting reputation for instrument design that led NASA to employ him in the design of life detection experiments for what were to become the Viking missions to Mars. As is well known, Lovelock puts his Eureka moment of discovering Gaia in 1965, while he was working for NASA at the Jet Propulsion Laboratory in Pasadena, California.[10] In many ways, his insight to look at the Earth as if from Mars was to extend *to all life forms* the analogy that their disseminations of chemical byproducts were like those of modern factories.

In brief, Gaia was discovered through a level of human technology and the self-awareness of the planetary consequences of that technology, which

7. See Chakrabarty, "The Climate of History."

8. Actually, as one of us has shown elsewhere, Gaia carries a lighter and more secular baggage than the highly complex and multilayered notion of nature; see Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime*, trans. Catherine Porter (Medford, Mass., 2017).

9. See Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us*, trans. David Fernbach (New York, 2016).

10. See Lovelock, *Homage to Gaia: The Life of an Independent Scientist* (New York, 2001).

coincided with the start of what has been called the Great Acceleration—one of the dates chosen for the beginning of the Anthropocene.[11] So, if the concept of Gaia is unique, it is largely because it was born in the middle of the extraordinary ambiance of the postwar high-technology boom and space missions.[12] It can almost be said that, conceptually, the idea of the Anthropocene *precedes* Gaia, even though, obviously, when the long history of the planet is told, the Anthropocene is portrayed as no more than a short episode within the deep history of Gaia.

Such an original birth might explain why the search for predecessors does not help much in clarifying the innovation. Several attempts to orient Gaia within preceding traditions of scientific thought have been fairly misleading. Gaia is not continuous with older ideas of the *balance* or *order* of nature. It is true that Lovelock credits James Hutton's idea that the Earth is like an animal that repairs itself as an inspiration.[13] But what Hutton was describing was the cycling of sedimentary rocks, without any particular agency for life or any real notion of history except endless cycles. As we discuss below, his choice of an animal metaphor—a crude reuse of the old image of the body politic—is wholly inappropriate for Gaia.

Even though Margulis was fond of seeing Vladimir Vernadsky as a forerunner, Lovelock has never agreed with this, and we concur. While Vernadsky brings all life forms within one homogeneous sphere—the biosphere—he gives them no agency whatsoever, such that any organism could be replaced by any other.[14] Furthermore, this system has no more history than Hutton's.[15] Historians are fond of continuity and of discovering precursors, and it is often true that Alexander von Humboldt or Vernadsky read like Lovelock, but, as is well known, precursors are often dis-

11. See Colin N. Waters et al., "The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene," *Science*, 8 Jan. 2016, science.sciencemag.org/content/351/6269/aad2622

12. See the remarkable *The Whole Earth Catalog: California and the Disappeance of the Outside*, ed. Dietrich Diederichsen and Anselm Franke (exhibition catalog, Haus der Kulturen der Welt, Berlin, 2013).

13. See Martin J. S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago, 2005).

14. See for instance at the end of *Biosphere*: "Life remains unalterable in its essential traits throughout all geological times and changes only in form. All the vital films (plankton, bottom and soil) and all the vital concentrations (littoral, sargassic, and fresh water) have always existed" (Vladimir I. Vernadsky, *The Biosphere*, trans. David B. Langmuir [New York, 1998], p. 149).

15. Perhaps the closest forerunner to Gaia is Alfred Redfield's work on the "biological control of chemical factors in the environment," which at least grasps a cybernetic view where living agents maintain conditions preferable to them; see Alfred C. Redfield, "The Biological Control of Chemical Factors in the Environment," *American Scientist* 46 (Sept. 1958): 205–21.

covered only *after* their successors retrospectively shine a new light on discoveries that once had a different meaning.

By contrast with those precursors, the novelty introduced in the notion of Earth by the joint efforts of Lovelock and Margulis consists in granting *historicity and agency to all life forms*, that is, in attributing to the life forms themselves the task of creating the conditions for lasting in time and expanding in space. It is in that sense that they can be said to obey their own laws. What is especially telling is that Lovelock and Margulis succeeded in doing so because they took on the problem of the planet at opposite scales—the largest planetary view for Lovelock and the oldest and smallest cellular view for Margulis.[16] In doing so, they established a clear break with older notions of the order and regulation of the planet.

Earlier notions of nature were always situating life forms *inside* a larger frame. Whatever the name given to such a frame—God's providential dispensation, neo-Darwinist natural selection, strictly mechanistic laws of nature, ecological systems, biosphere—it was from this larger frame that life forms found their limits and their definitions. They were not supposed to generate their own world, or to participate in anything like a history. Strictly speaking, life forms had no real agency compared to the frame that determined the order of nature. But with Lovelock's and Margulis's Gaia there is *no other order*, and certainly *no order superior* to what those intertwined agents have been producing through their entanglements.[17] This is why we believe that the best way to clarify such a shift in worldview consists in *resisting* the addition of any supplementary frame. To be sure, as we shall see, there is an order in Gaia that has political consequences, but it is not the same conception of order implied by the previous concept of nature divided from that of society. Such is the line we will follow in the rest of this essay.

Using All Means Available to Trace a Portrait of Gaia

The uniqueness of the concept explains the multiplicity of versions given by Lovelock through his long writing career, a multiplicity that, to be fair, accounts for some of the confusion. His hesitations go so far that

16. A connection well summarized by Lynn Margulis and Gregory Hinkle: "The conclusion is inescapable: geophysicists and atmospheric scientists must study biology and biologists must know something of geophysics and atmospheric science. For too long, we have had atmospheric chemists wondering 'Where does all that methane come from?,' and biologists ignorant of 'Where all that methane goes'" (Lynn Margulis and Gregory Hinkle, "The Biota and Gaia: 150 Years of Support for Environmental Sciences," in *Scientists on Gaia*, ed. Stephen H. Schneider and Penelope J. Boston [Cambridge, Mass., 1991], p. 12).

17. See Latour, "Why Gaia Is Not a God of Totality," *Theory, Culture and Society* 34, nos. 2–3 (2017): 61–81.

he often presents Gaia as an intuition, an invention, which defies linear logical description. He explicitly likens his realization of Gaia to his process of inventing technological instruments, which achieve their desired function but without any explanation about how precisely they work.[18] Although this appeal to technical invention instead of scientific explanation seems puzzling, it is actually essential for understanding the shift he is trying to express.

Mechanistic explanations do not look at all the same as a worldview when proposed by scientists as they do by philosophers or when inventors use them to describe the act of invention. It appears that inventors are well aware that no mechanism behaves in a mechanistic way when it is brought into the world. Something else is at work—another mode in which agency and history counts.[19] Lovelock's insistence on opposing engineering and academic science explains the ways he simultaneously multiplies, discards, and then combines metaphors in order to approximate the originality of the phenomenon at work.

Although Gaia is often portrayed as a complex system, specifically as a complex adaptive system,[20] this broad category fails to distinguish some of its unique features. As an engineer/inventor, Lovelock naturally reaches for cybernetic language to describe the workings of Gaia, such as *feedback*, *homeostasis*, *self-regulation*, and *optimization*.[21] But he equally reaches for biological language to describe the perceived entity and its functioning, such as *super-organism* and *geophysiology*. All the while, Margulis explicitly and repeatedly reminds him that Gaia is not an organism.[22] In addition, as a past medical researcher with an extraordinary personal history of medical issues (and thus a great admiration for good doctors and nurses), Lovelock

18. "I am an inventor. I find it easy to invent a self-regulating device by first imagining it as a mental picture. . . . In many ways Gaia, like an invention, is difficult to describe" (Lovelock, *Gaia: The Practical Science of Planetary Medicine* [New York, 2000], p. 11).

19. See John Law, *Aircraft Stories: Decentering the Object in Technoscience* (Durham, N.C., 2002). See also the telling example of biologists at work on the tertiary structure of proteins in Natasha Myers, *Rendering Life Molecular: Models, Modelers, and Excitable Matter* (Durham, N.C., 2015).

20. See Simon A. Levin, "Self-Organization and the Emergence of Complexity in Ecological Systems" *BioScience* 55 (Dec. 2005): 1075–79.

21. This problem is tackled by Bruce Clarke, "Neocybernetics of Gaia: The Emergence of Second-Order Gaia Theory," in *Gaia in Turmoil: Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis*, ed. Eileen Crist and H. Bruce Rinker (Cambridge, Mass., 2010), pp. 293–314. See also *Earth, Life, and System: Evolution and Ecology on a Gaian Planet*, ed. Clarke (New York, 2015).

22. See Clarke, "Gaia Is Not an Organism: Scenes from the Early Scientific Collaboration between Lynn Margulis and James Lovelock," in *Lynn Margulis: The Life And Legacy of a Scientific Rebel*, ed. Dorion Sagan (White River Junction, Vt., 2012), pp. 32–43.

is also drawn to physician's language when he speaks of "planetary medicine" even though he might dismiss such a comparison later.[23]

The main point in this constant shuffling of images is to avoid the connection between a mechanism and the idea that there is a machine in the traditional sense, that is, one built by some engineer situated above and in addition to the invention. Lovelock is at pains to make clear that Gaia is not a spaceship; that would imply an engineer or a designer exterior to Gaia, a move that would immediately reaffirm the presence of some sort of purpose or teleology—not to say providential theology. This is why he constantly has to fumble with slightly contradictory images in order to avoid using just one of them.

It is crucial to understand that to combat the dangers of the mechanistic metaphor neither Lovelock nor Margulis can rely on the main traditional alternative, that of organism. If the idea of a machine at the scale of the planet has no meaning—in case of a mechanical failure of the Earth system there is no Cape Kennedy and no Houston to turn to—the absurdity is even greater if the notion of organism is inflated to the size of the Earth. No matter how tempting it is to lump all life forms into one huge, unified, and continuous biosphere of some sort, or to invoke a superorganism, any idea of a giant composite planetary body should be resisted as much as the myth of the machine. Those who project onto Gaia the image of a global body, or even worse that of a female body, simplify Lovelock and Margulis's common project.[24] And it is certain that they are not aware of Gaia's mythical pedigree. Any look at Hesiod will show that there is nothing maternal, womanly, or even godly in such a dangerous, archaic, cunning, and chthonic figure that precedes all the gods.[25]

Even if Lovelock had succumbed to the metaphor of the organism, he would have been redressed by Margulis's own long fight against any idea of *individual* isolated life forms anyway. This is where the collaboration between the two coinventors is so important and under-recognized. Not only does Margulis bring a knowledge of biology and deep time to the conceptual innovation that Lovelock does not possess, but she makes impossible any use of a simplified version of an organism that could reside *inside* an environment that would be *exterior* to its history. Margulis's own discoveries and insights—a topic that has become more and more mainstream in

23. See Lovelock, *Gaia: The Practical Science of Planetary Medicine*.

24. Nothing shows that better than Margulis, "Gaia Is a Tough Bitch," in *The Third Culture*, ed. John Brockman (New York, 1995), pp. 129–46.

25. Especially useful is Jean-Pierre Vernant, introduction to Hésiode, *Théogonie: La Naissance Des Dieux*, trans. Anne Bonnafé (Paris, 1993). For more references, see Latour, *Facing Gaia*, pp. 81–83.

recent years—make it impossible to separate any life form from its outside and impossible to take it as an atomic entity within its own distinct boundaries.[26] "Holobionts" cannot be invoked to play the role of organisms submitted to a natural selection whose history would be forced upon them.

This is where the main difference with neo-Darwinism lies and the reason why both discoverers of Gaia ran into trouble at first with so many biologists.[27] While Darwinian organisms don't have to create the situation in which they find themselves, Lovelockian agents have to take on their shoulders, so to speak, the task of bootstrapping the very environment into which they fold themselves. Natural selection for Lovelock appears as a simplified and on the whole local way to account for life forms' engineering capacity; for Margulis, on the other hand, natural selection is not even a creative process but rather just the culling of "unfit" variations.

To be sure, this constant shuffling of contradictory metaphors interfering with one another is confusing, but it's not a reason to dismiss the theory or to focus on one of the many images the authors proposed. It just means that Lovelock and Margulis have been struggling to find the right way to approach a new historical situation on which they, and the rest of the planet, were embarked.[28] To do so, they had no other way than to make use of all means available, just as other scientists have done when faced with the problem of describing a major paradigm shift.

Actually, this offers a clear parallel with Galileo's efforts at describing falling bodies.[29] These hesitations prove that in the same way that it is difficult to invent Galilean *objects*, it is just as hard to dis-invent them in order to repopulate the Earth with what could be called Lovelockian or Margulisian agents.

Why Gaia Is Not an Organism

Given the explosion of new knowledge available from ESS, it is no wonder that none of the usual metaphors worked. It is clear today that Gaia

26. See the recent textbook in this paradigm Scott F. Gilbert and David Epel, *Ecological Developmental Biology: The Environmental Regulation of Development, Health, and Evolution* (Sunderland, Mass., 2015), and the recently released film *Symbiotic Earth: How Lynn Margulis Rocked the Boat and Started a Scientific Revolution* (dir. John Feldman, 2017). See also Margulis, *Symbiotic Planet: A New Look at Evolution* (New York, 1998).

27. See Dutreuil, *Gaïa* for what amounted to a complete clash of paradigms: what life is for Lovelock and Margulis is not what life is for, let's say, Richard Dawkins.

28. Two recent books summarize best the new situations where conceptions of organisms, evolution, and politics are being simultaneously modified; see Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, N.C., 2016), and Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton, N.J., 2015).

29. See H. J. Schellnhuber, "'Earth System' Analysis and the Second Copernican Revolution," *Nature* 402 (Dec. 1999): C19–C23.

could not possibly have been considered an organism for at least three reasons.

The first is the level of exterior resources Gaia depends on to survive. If Gaia is clearly not like an animal, it's because animals are *heterotrophs*, meaning that they feed on organic matter, whether alive or dead. This is the reason why comparisons of Gaia to literally *any kind of body*, be it the Earth mother, an animal, or a body politic, cannot be anything but wildly inaccurate metaphors. In technical terms, Gaia is *autotrophic*, meaning that it makes itself out of inorganic materials, or more accurately *photoautotrophic* as it is powered by sunlight. However, Gaia cannot be compared to a plant, alga, or cyanobacterium because those are open systems continually exchanging matter and energy with their surroundings. In contrast, Gaia is nearly *a materially closed system*, with minimal matter exchanges between the inner Earth and space but with a vast degree of internal recycling.[30]

This is another difference with the Darwinian formulation of nature in which organisms are continually interacting with other organisms in their environment, as well as continually exchanging materials with their outside. Gaia is not interacting with other Gaias. While any organism has an environment, strictly speaking Gaia *has no environment* except itself, if by environment we mean what with which any entity engages in a reciprocal relation. To be sure, the rest of nature can be said to reside "around Gaia" but only from an astronomical point of view of someone residing in outer space. Viewed from the inside of Gaia, the rest of the universe is simply *beyond* the outer limits of its system. Properly speaking, Gaia resides inside itself.

The second reason why Gaia cannot be compared to an organism is that it has no homogeneous internal milieu. In other words, not only does it not have an outside, *it does not have a coherent inside either*. It is that sort of heterogeneity in the many cycles that have been discovered over the years that makes the idea of a homogeneous biosphere so misleading. Shylock was sure of killing Antonio by carving "a pound of flesh," but Gaia does not have such a unity that extracting a pound of life would kill the whole. It has no whole in the way an animal body is whole.[31] This is what makes the question of deciding if it is alive or not especially moot and why it does not make much sense to defend or to attack the belief that the Earth is alive.

30. For perhaps the most comprehensive source on this point, see Tyler Volk, *Gaia's Body: Toward a Physiology of Earth* (New York, 1998).

31. William Shakespeare, *The Merchant of Venice*, ed. Jay L. Halio (New York, 2008), p. 180.

The question of what is alive and what is not in Gaia is so hard to pinpoint that some solid mineral forms are directly produced by life (biomineralization), some are indirectly due to life because they rely on the oxygenation of the atmosphere, and some are fully abiotic. Similarly, some gases are uniquely biogenic (isoprene, dimethyl sulphide), many others have their abundance massively altered by life, and some do not interact with life (noble gases). In other words, Gaia is very much a patchwork and *not a unified* domain, sphere, region or entity. Depending on which chemical cycle you consider, you will have to pass through a long chain of living forms or none at all.[32]

The main point is that in Gaia the cycling of materials through the intermediary of life forms will vary enormously depending on their biological function (or lack of it). For the six most important elements for life (carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur), most of the matter being cycled has passed through a life form—in some cases many times. For other biologically essential elements, the intensity of cycling will vary, to use an economic metaphor, according to the balance between the demand made by life forms and the supply of nonliving elements. Even in cases when the aggregate requirement of all life is comparable to the physical and chemical supply (such as calcium from weathering and erosion), there is still considerable biological control of the cycling. In general, the more we discover about biochemistry, the more the list of elements for which there is *no biological requirement* dwindles. For those still on that list are not generally cycled through life except by accident. This is the case for noble gases for which there is no cycling at all. So this nuance of different degrees and types of cycling does not fit a monolithic conception of Gaia.

The third reason why Gaia is not an organism is the disconnect between the immense amount of energy falling on Earth that activates its enormous machinery and the tiny but distributed amount that life forms have been able to piggyback on. We always tend to forget that only a small fraction of the total energy (electromagnetic radiation) being absorbed at or near the Earth's surface and powering the climate is captured by a life form and converted to electrochemical form (although in parts of the visible spectrum the fraction captured by life is significant). This energy flux into life is readily dwarfed by the energy fluxes of the great heat engines of the atmosphere and ocean. The Earth absorbs roughly 120 petawatts of solar

32. For a general overview, see Lenton and Andrew Watson, *Revolutions that Made the Earth* (New York, 2011). For more specialized references see Lenton and Stuart J. Daines, "Biogeochemical Transformations in the History of the Ocean," *Annual Review of Marine Science* 9 (2017): 31–58 and "Matworld—The Biogeochemical Effects of Early Life on Land," *New Phytologist* 215 (July 2017): 531–37.

radiation; for example, the heat flux carried by the Gulf Stream alone is approaching one petawatt. That is an order of magnitude *bigger* than the roughly 0.1 petawatt captured by life forms.

Nevertheless, living agents use this tiny fraction of the free energy flux to extraordinary effect, creating material cycles, altering the chemical composition of the atmosphere, creating aerosols and cloud condensation nuclei, and thus profoundly affecting the energy balance of the planet and the climate. This suggests that the particular utilisation of free energy by life, notably in information storage and processing, gives it unusual agency relative to abiotic climate processes. In a way, we should consider that Gaia is folded, distributed, and inserted inside an Earth system that existed long before its development and will persist long after its demise, and that life has learned to modify but only partially. The result of this disconnect is that any portrait of Gaia is difficult to stabilize. If you look at energy transfer, life is barely visible; but if you look at the amount of new information and the fluxes of key biological elements, Gaia is everywhere and has modified the whole system —except it is not a "whole system."

Those three sets of scientific facts are what make the uniqueness of Gaia so difficult to portray. Far from looking like a biosphere added to other spheres, Gaia appears as a reticular, lacunar, dappled, distributed sort of entity for which there is no precedent nor comparison possible. The allusion we made above about a negative or apophatic way of portraying Gaia is clearly not a cop-out; it is the only way to first tackle what the topic requires. And that explains why Lovelock had to resort so often to a somewhat mysterious way of speaking of Gaia as a nonlinear *sui generis* invention—a solution that had the unfortunate consequence of nurturing a magical "soft" view of a mystical Gaia very far from the hard-nosed fully reductionist view of science that Lovelock was *also* pursuing. Lovelock and Margulis did not overanimate a dead earth for some mystical reason; they simply refused, for strictly scientific reasons, to deanimate it, that is, to deny the agency of life forms.[33] Although it's true that Gaia requires a special effort from science, neither Lovelock nor Margulis entertained the idea of an alternative, more intuitive and superior Gaian science.

There Is One Gaia but Gaia Is Not One

The difficulty of approaching the uniqueness of Gaia is visible not only when one considers the many heterogeneous *ingredients* mobilised by its cycles but also when the bewildering heterogeneity of the *processes* re-

33. That Gaia, for this reason, is the first fully secular and nonprovidential figure of life; see Latour, *Facing Gaia*, pp. 75–145.

sponsible for those cycles is taken into account. This is a point that was not so clear in the seventies, but it has been increasingly emphasized by the various results coming from ESS. In all of the discussions about Gaia that either reject or embrace it too quickly, it has always been implied that Gaia has a *wholeness* and an *integrity* that it does not in fact possess. While those could have been adjectives applied to nature, they don't work for Gaia. Or rather, wholeness and integrity are exactly the key questions implied by older philosophies of nature and thrown into doubt by the discovery of Gaia.

One could ask, if such a wide distribution of mechanisms is true, then what is the sense of invoking the name of Gaia at all, as if it had, through the use of a personal name, some sort of unified character? But this would again be a way to skip what the discovery is about: even though life forms are not submitted to a frame that would be *superior* to them, they do produce such a frame, or more exactly they generate *as many frames* as their intertwined history has locally produced. In other words, the reason why any notion of whole has to be put into question is because life forms produce their *own extension in space and time*. If there is one thing that we should not apply any a priori form of space and time to, it is the way life forms extend and last. A Kantian view of space and time is not applicable to Gaia.

That Gaia makes its own (changing) boundaries in space and time is shown by the fact that the spatial extent of life's influence has changed over time, reaching farther down into the Earth's crust and farther up into the atmosphere.[34] Furthermore, the temporal extent of life's influence is internally determined—by altering its own survival probability or collective persistence—to the extent that some studies suggest an Earth that had never had life would have undergone the runaway greenhouse fate of Venus by now; that is, it would have left what astrophysicists describe as the "habitable zone" around the sun, where liquid water is present.[35]

In a different sense, the spatial boundaries of Gaia are somewhat dependent on the temporal scale of consideration. Thus, when considering the short-term response to perturbations such as human fossil fuel burning, only interactions among the atmosphere, ocean, and life matter, but

34. "Life has had a profound effect on surface geological processes, and even on modulated tectonics and the rise of continents. . . . The net effect is Gaian . . . ; that is, life has modified Earth to its net advantage" (Norman H. Sleep, Dennis K. Bird, and Emily Pope, "Paleontology of Earth's Mantle," *Annual Review of Earth and Planetary Sciences* 40 [May 2012]: 293). We thank Bruce Clarke for this reference.

35. See Lenton and Werner Von Bloh, "Biotic Feedback Extends the Life Span of the Biosphere" *Geophysical Research Letters* 28 (May 2001): 1715–18.

when considering the longer-timescale response to perturbations, we have to examine exchanges with the crust and sedimentary rocks. When considering the response to geological drivers and the slow brightening of the sun on geological timescales, we also look at the cycling of materials through sedimentary rock reservoirs in the crust.

To reveal these important aspects, we need to break apart the unity and homogeneity of Gaia. We need to somehow show that Gaia is a heterogeneous phenomenon created by the actions and interactions of many diverse biological free agents and aspects of their abiotic world, the result of which is a risky and provisional extension in space and duration in time (fig. 1).

Paradoxically, although as we noticed above *Earth system* is often taken as a synonym of Gaia, Gaia is distinct from the Earth system and not strictly speaking a system—certainly not *one* system. As we explained earlier, this is why the concept of Gaia is distinct from the concept of ESS, which grew out of it. While ESS remains as close as possible to physics and chemistry, Gaia absorbs as much of biology and ecology as possible. It is as if the second were folded into the first in multiple ways. Although ESS can be defined and described in terms of a Carnot heat engine, Gaia cannot because it continually creates its own domain and behavior through information and evolution, that is, through some sort of learning. What is observable is only the relative success of life forms in extending in space and lasting slightly longer in time—no more and no less. There is no guarantee of its continuity—no destiny superior to that of the life forms themselves. In a parody of Hutton we could say that in Gaia "we find many vestiges of a beginning and many prospects of an end."[36]

The best way to understand this lack of unity is to consider that Gaia is a heterarchy with variations in the strength of coupling between the living and nonliving across spatial and temporal scales and across different features (nutrient cycling, climate). A look at figure 2 will show the vast diversity of mechanisms depending on the scale of time and space (fig. 2).[37]

It is clear that there are variations in the type and strength of selection mechanisms that can arrive at and refine properties such as cycling and stability at different time and space scales. Nutrient (re)cycling is partic-

36. See James Hutton, "Theory of the Earth; or an Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land upon the Globe," *Transactions of the Royal Society of Edinburgh* 1, no. 2 (1788) 209–304. The phrase with which he invented the notion of Earth as a cycle of material ("no vestige of a beginning,—no prospect of an end") ends the paper (p. 304).

37. See Lenton et al., "Selection for Gaia across Multiple Scales," *Trends in Ecology and Evolution* 33 (Aug. 2018): 633–45.

Quality/property/process	Abiotic planet	Biotic planet
Energy	Ocean-atmosphere circulation is a heat engine	Photoautotrophy captures a small fraction of free energy but uses it to transform matter
Information	Minimal information content and abiotic processing	Massive storage and processing in biosphere
Bio-essential matter	Minimal cycling by physical and chemical processes	Massive (re)cycling of C, H, N, O, P, S and other essential elements by life
Other matter	Minimal cycling by physical and chemical processes	Minimal cycling by physical and chemical processes
Natural selection	No	Yes
Ecological sorting (niche construction, ecosystem engineering, community assembly)	No	Yes
Sequential selection (of stable configurations)	Maybe, but only in a crude way and not for habitable attractors	Yes, for habitable attractors
Selection by survival	No, because no means of acquiring new persistence-enhancing properties	Yes, biological innovation can generate new persistence-enhancing properties

FIGURE 1. Items defined by the test: biotic and abiotic planets.

ularly strong at localized scales (for example within a forest) and can be understood as refined and reinforced by forms of conventional natural selection. Natural selection has also refined an amazing level of homeostasis for some organisms (such as human body temperature regulation), but such homeostasis is not detectable at the same level of coupling, at other scales. In contrast, global climate on long timescales appears less strongly regulated because it is understood to have arisen by simpler mechanisms. First it is a simple principle that unstable configurations (in this case of the coupling between living things and the climate), should they arise, will not tend to persist, whereas stable configurations, when found, tend to persist

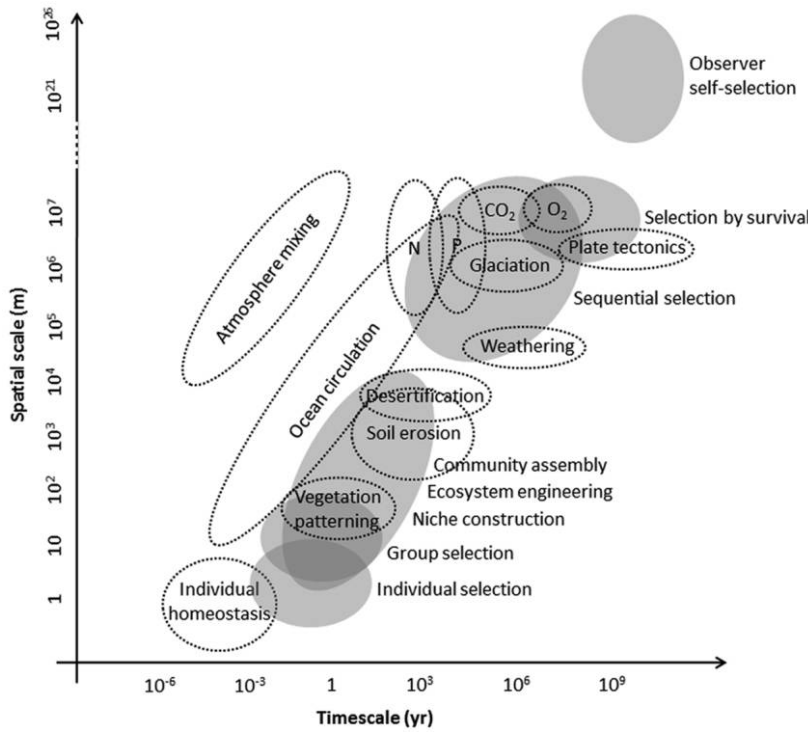

FIGURE 2. Space and timescales of Earth and Gaia processes. Some key Earth system processes, feedback mechanisms, and regulated variables (N, P, CO_2, O_2) are shown as black dashed ovals. Selection and self-organization mechanisms are shown as gray shaded ovals.

("sequential selection" in figures 1 and 2). Second, that very persistence, combined with the incessant innovation accompanying the evolution of living agents, gives a greater chance of acquiring further persistence-enhancing properties ("selection by survival" in figures 1 and 2).[38]

This is not the place to develop the argument, but it is clear that no understanding of Gaia is possible without breaking down its spurious unity and making clear which of the many phenomena composing it are being pointed out. We argue that so many people have misunderstood Gaia because they have chosen one scale and generalized to all the others. Such a multiplicity of processes cannot be lumped into one coherent entity even though coupling provides some sort of overall order. It is this contradiction that is at the heart of Lovelock's and Margulis's discovery: *there is one Gaia, but Gaia is not "a whole."*

38. See W. Ford Doolittle, "Darwinizing Gaia," *Journal of Theoretical Biology* 434 (Dec. 2017): 11–19.

It is in this sense that the notion of Gaia is so different from that of nature. When Earth was understood as a set of Galilean objects *obeying* laws of nature, it had a consistency, a homogeneity, a continuity that Gaia entirely lacks. The domain of necessity that could be opposed to that of freedom was entirely made up of Galilean objects generating what René Descartes called *res extensa*. But if you try to compose the planet out of Lovelockian or Margulisian agents, it has a completely different feel. When scholars attempt to oppose *life* (biological life) with *life* (moral and social *human* life), they imply a form of unity and of continuity fitting for the idea of nature but ill-adapted to the specificity of Gaia.[39] In consequence, human agents don't have the same role to play whether they reside "in nature" or see themselves as participating in Gaia. This is where the notions of order and regulation take a different political meaning.

The Tyranny of the Globe

In our view, this new conception of Gaia should modify political concepts on both sides of the older division between nature and society. Unfortunately, the traffic of images between biology and politics has been going on for so long that it is very difficult to extricate from its embrace a unique phenomenon such as Gaia.[40]

If it is difficult to focus on Gaia, it is because any appraisal of a body in an environment is immediately confused with, not to say kidnapped by, the metaphor of the globe. And it is true that when you pretend to consider Gaia as a whole you immediately summon the image of the "blue planet" viewed from outer space—in addition to an ample circular gesture of the two hands. But no matter how powerful the influence of such an iconic photograph, no matter how often you agitate your hands, the impulse to globalize should be resisted because nobody who claims to have "a global view" actually resides *in any real space*. They imagine themselves *as if* they were looking from the outside at the Earth taken as one body among all celestial bodies, just as Galileo did. The global view is strictly speaking a view *from nowhere*—or from an office looking at a computer screen.

39. See, for example, the confusing idiom of *zoe* and *bios* resurrected in Chakrabarty, "The Human Condition in the Anthropocene," The Tanner Lectures in Human Values, Yale University, 18–19 Feb. 2015, tannerlectures.utah.edu/Chakrabarty%20manuscript.pdf

40. See Michel Foucault, *The Birth of Biopolitics: Lectures at the Collège De France, 1978–1979*, trans. Graham Burchell, ed. Michael Senellart (New York, 2008), and Evelyn Fox Keller, *Making Sense of Life: Explaining Biological Development with Models, Metaphors, and Machines* (Cambridge, Mass., 2003).

The difficulty of abandoning such a position is compounded by the confusion between the cartographic globe and the rich artistic repertoire of older symbols of ancient Roman and Christian dominion.[41] The symbol of *orbis terrarum* held by the emperor or by God is certainly not the best way to recognize the limited, entangled, highly complex and lacunar forms of Gaia. In addition, and to render the situation even more inextricable, any allusion to the global is immediately fused with a social and political metaphor of the body politic. To see the polity as a big organism made of parts obeying the dictates of the whole will be conjured at once in every description of order and system.

To combat such confusion, we should recognize that Gaia is not a globe at all but a thin biofilm, a surface, a pellicle no more than a few kilometers thick that has not made inroads very far up in the atmosphere nor very far down in the deep earth below, no matter how long you consider the history of life forms. This is why it is important to shift from the global vision of Gaia to what some scientists now call the "critical zone."[42] Such a critical zone, because it does not have any way of being summed up in one classical image of the globe, resists being immediately fused with a view of the planet viewed from the outside.[43] What Galileo succeeded in doing—establishing the Earth as just one body among all of the other bodies in the infinite universe—the critical zone decomposes: Gaia requires a new situation for the observer as well as for what is observed. In addition, the great advantage of the critical zone is that it does not fit at all in any metaphor of the globe held in the hand of a God, a prince, or an emperor. There is no dominion to be exerted at all when the idea of Gaia as a thin biofilm is introduced into the picture. Nothing rules anymore *above* the life forms. It's in that sense that we propose to say that those life forms literally *make their own laws.*

This is why it is so important to extract Gaia from being immediately lumped in with a social and political idea of the body politic.[44] The reason is again that the metaphors of organism and superorganisms have been used to solve the question of the relations between parts and whole, that

41. See Peter Sloterdijk, *Globes*, vol. 2 of *Spheres* (Cambridge, Mass., 2014).

42. See Susan L. Brantley, Martin B. Goldhaber, and K. Vala Ragnarsdottir, "Crossing Disciplines and Scales to Understand the Critical Zone," *Elements* 3 (2007): 307–14, and Brantley et al., "Designing a Network of Critical Zone Observatories to Explore the Living Skin of the Terrestrial Earth," *Earth Surface Dynamics* 5 (Dec. 2017): 841.

43. See Alexandra Arènes, Latour, and Jérôme Gaillardet, "Giving Depth to the Surface—An Exercise in the Gaia-raphy of Critical Zones," *The Anthropocene Review* 5, no. 2 (2018): 120–35.

44. See Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture* (Medford, Mass., 2019).

is, to distinguish a frame from what is being framed just as much in biology as in sociology.[45] To talk of Gaia as one organism is to suggest that organisms are, on one level, parts and, *on another level*, some whole that has distributed roles and functions to the parts. This is what is called the *organicist* view, beautifully summarized in the fable of The Members and the Stomach.[46] The idea that there are two levels does not change much when you suggest that the parts, defined as so many individual agents, once they interact, generate what are called emergent properties, a metaphor summarized admirably in Bernard Mandeville's *The Fable of the Bees* (1705) and associated with a "liberal" view. Although the two sets of images seem very different politically, they actually obey exactly the same pattern because they resort to two levels. In both cases—in both fables—there is a whole superior to the parts, either a whole *before* in the organicist view or a whole *after* the interaction of the agents in the liberal view.

The problem is that those ubiquitous metaphors amalgamating social, physical, political, economic, and biological visions break down when applied to Gaia. And this is again where the Lovelock and Margulis collaboration is so important: the idea of parts and whole does not make much sense in Margulis's definition of *holobionts*—indeed in any definition of life forms—because every element is simultaneously the whole and a part of the whole.[47] For Gaia, to speak of a system above and beyond the parts makes no sense—whether you use a mechanical, cybernetic, or biological metaphor—and to appeal to the notion of emergent properties so as to cross the distance between the levels of the parts and the level of the whole would be a cop-out.

In the same way that Gaia is autotrophic, it is also a phenomenon *sui generis*, that is, it generates itself in a unique ad hoc way. That we have no good concepts to describe this situation is a proof that we relied too much on the usual repertoire coming from older amalgamations of political and biological order. To extricate Gaia from such history, we should find a way to say that the whole is not above the parts but is *in continuity* with the parts—the word *part* being a way to name rather clumsily how elements are *overlapping* with one another.[48] This is what was true in the earlier somewhat romantic descriptions of Gaia as a whole. It's true that it can-

45. This is in keeping with the principles of methods in social theory offered in Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (New York, 2005).

46. See Shakespeare, *Coriolanus*, ed. R. B. Parker (New York, 2008).

47. See Raymond Ruyer, *Neofinalism*, trans. Alyosha Edlebi (Minneapolis, 2016).

48. See Gabriel Tarde, *Monadology and Sociology*, trans. and ed. Theo Lorenc (1895; Melbourne, 2012); and Latour et al., "'The Whole Is Always Smaller Than Its Parts': A Digital Test of Gabriel Tarde's Monads," *British Journal of Sociology* 63, no. 4 (2012): 590–615.

not strictly be composed of parts sitting—as philosophers say, *partes extra partes*—side by side, just like Galilean objects used to do, waiting to be framed, explained, moved, possessed by laws of nature. It does not mean that "everything is connected" but that Lovelockian agents have different ways of being intertwined. It is in that sense that Lovelock's and Margulis's discovery of Gaia should play havoc on the age-old commerce between social and biological metaphors. The sociobiology of Gaia could not be the same as the sociobiology based on earlier definitions of the natural world.

Conclusion: An Extension of the Domain of Freedom

By this attempt at portraying Gaia as it cannot possibly be (the apophatic way), we might have shed light on the essay's epigraph. At first sight, it might seem counterintuitive to expect a lesson on democracy from an author known for his contrarian and even reactionary views on a number of issues regarding human politics. However, what we are interested in are his contributions to what could be called the politics of *nonhumans*.

The uniqueness of Gaia opens a new definition of a polity just at the time when the situation summarized by the term *Anthropocene* reopens the connection between what philosophers used to call the *domain of necessity*—that is, nature—and the *domain of freedom*—namely, politics and morality. It would be odd, indeed, not to consider the new climatic regime as an occasion to draw new connections between the two domains. Drawing lessons from nature to define the order and regulation of society has been going on for as long as political thought. The question raised by Lovelock's and Margulis's Gaia is whether those lessons change when the two domains are being *symmetrically challenged*. Does it make a difference to draw lessons from nature or from Gaia?

If history is a good guide, the specter of naturalization is sure to trigger in social scientists and those in the humanities a recoil of horror, and rightly so. It's enough to remember social Darwinism, sociobiology, dialectic materialism, eugenics, the intelligence quotient (IQ) controversies, or for that matter much of economic science that purports to make human societies "obey the laws of nature." Against those attempts at ordering and regulating humans in the name of nature's "iron cage," the domain of human freedom should be protected at all cost. On the other hand, the new climatic regime obliges us to revise such a reaction because the situation is now upside down; it is the Earth that now has to be "protected at all cost" against the encroaching of human (dis)order and (de) regulation. So, the Anthropocene puts political philosophy in a double bind: we should not expect nature to dictate human behavior, and yet we can

no longer abstain from drawing lessons from the Earth's behavior because of the way it reacts to human behavior. So far, discussions about the new political role humanity should play has not be able to escape from such a quandary.[49]

Because Lovelock's and Margulis's Gaia, in our rendering of their theory, grants agency and historicity *to all life forms*, the situation might now be opened again because it is cracked *on both sides* of the ancient dichotomy between necessity and freedom. That is the novelty to be addressed and the chance to be seized. When humans look at Gaia, they do not encounter the inflexible domain of necessity but, strangely enough, what is largely a domain of freedom, where life forms have, in some extraordinary ways, made their own laws, to the point of generating over eons multiple, heterogeneous, intricate, and fragile ways of lasting longer in time and extending further in space—nothing more, nothing less.

Conversely, any human trying to situate himself or herself as part or participating in this history can no longer be defined only as "free" but, on the contrary, must be defined as being *dependent* on the same sort of intricate and intertwined events revealed by Gaia.[50] More freedom in the domain of necessity is fully matched by more necessity in the domain of freedom. This is what is meant by this extraordinary expression of being "part of, or partner in, a very democratic entity." To play on Aristotle's famous saying, democracy is an expression designating an entity composed of all the political animals, that is, all the beings taken as people (*demos* in Greek) making their own laws and who do not simply fall into any sort of preordained order or obey any superior transcendent regulation.

It is for this reason that it is so important to define as precisely as possible the contribution made to this extended democracy by the discovery of Gaia; instead of replaying one more episode in the frustrating attempts at naturalizing human conduct, Gaia opens the possibility of extending the domain of freedom by sharing it more widely on both sides. If Roquentin had held such a view in the canonical scene of Jean-Paul Sartre's *Nausea*, he would not have vomited on the root of the tree, horrified by the totally senseless and superficial feeling of freedom to which he was condemned by his opposition to the equally senseless piece of wood.[51] Nor do we pro-

49. See Clive Hamilton, *Defiant Earth: The Fate of Humans in the Anthropocene* (Malden, Mass., 2017).

50. See Lenton and Latour, "Gaia 2.0: Could Humans Add Some Level of Self-Awareness to Earth's Self-Regulation?" *Science*, 14 Sept. 2018, science.sciencemag.org/content/361/6407/1066

51. See Jean-Paul Sartre, *Nausea*, trans. Lloyd Alexander (New York, 2013).

pose that he feels suddenly some sort of effusion by becoming part and parcel of the evolution of trees. We just propose to suggest that they both share the feeling of freedom placing life forms *at a distance from one another* but not the distance that used to paralyze humans and nature: rather, the wary, puzzled, enigmatic, and shifting distance polities have always entertained with one another.[52] One additional advantage would be to offer an alternative to the word *ecology* and to help scientists and activists to collaborate around what could be simply called *politics of life agents*.

52. This distance has been fine-tuned by Baptiste Morizot, *Les Diplomates: Cohabiter avec les loups sur une nouvelle carte du vivant* (Marseille, 2016), and Coccia, *The Life of Plants*, but no social scientist did it more radically than the novelist Richard Powers in *The Overstory* (New York, 2018).