Planetary Memory and Trans-species Immunity

Memoria planetaria e inmunidad transespecífica

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Abstract

Drawing on Vladimir I. Vernadsky, Lynn Margulis, Alfred N. Whitehead, Karen Barad, and relevant immunological studies, this paper proposes a trans-species noösphere, embracing the *zoe-techne* of innumerable nonhuman lifeforms, especially infinitesimal microscale agents, viruses included. In doing so, I also articulate the coevolutionary perspective of diffractive mattering on planetary life, map several diffraction patterns of immunity, and present a possibility of political life as a heterogeneous co-constitution.

Keywords: *diffraction, immune patterns, noösphere, planetary memory, trans-species immunity.*

Resumen

Basándose en Vladimir I. Vernadsky, Lynn Margulis, Alfred N. Whitehead, Karen Barad, y en estudios inmunológicos relevantes, este artículo propone una noosfera transespecífica, que abarca la zootecnia de innumerables formas de vida no humanas, especialmente agentes de microescala infinitesimales, incluidos los virus. Al hacerlo, también articulo la perspectiva coevolutiva de la materia difractiva en la vida planetaria, mapeo varios patrones de difracción de la inmunidad, y presento una posibilidad de vida política como una co-constitución heterogénea.

Palabras clave: *difracción, patrones de inmunidad, noösfera, memoria planetaria, inmunidad trans-específica*

I am the daughter of Earth and Water,
And the nursling of the Sky;
I pass through the pores of the ocean and shores;
I change, but I cannot die.

Percy Bysshe Shelley, *The Cloud*

For a Trans-species Noösphere

In the era of Covid-19, we are drawing an increasingly entangled molecular picture of immune memory with growing planetary awareness about the intrinsic relationship between knowledge and life. The pandemic has expanded the horizon of the philosophy and politics of immunology. The ever more sophisticated multiscale apparatuses of extended sensory devices present a profound trans-disciplinary challenge: the reconfiguration of senses and the reorganization of sensibilities; in other words, the creative evolution of human intuition.

As Vladimir I. Vernadsky wrote almost a century ago, one has to put science back into its context to understand it scientifically, as a historically specific "framework of the scientific analysis of reality" (Vernadsky 1997: 62-63). Vernadsky points out three levels of reality identified by science in the 20th century.

> These levels are: the phenomena of space; the planetary phenomena of the "nature" akin to us; and the microscopic phenomena in which gravitation loses its importance. (Vernadsky 1997: 63)

In the 21st century, the subatomic scientific narratives have gradually become our epistemic and affective resources for worlding—the continually evolving molecular sensibilities to remember the future. Such are sensible evolutionary inclinations that we, as living organisms, embody when our observation activities and measurement scales change.

Life as a microscopic and planetary phenomenon has gained currency, although still wanting the necessary depth for a radical socio-economic transformation. The pandemic has demonstrated the critical importance of genomic surveillance technology. On March 30, 2022, World Health Organization (WHO) released a 10-year strategy to bolster the genomic surveillance of pathogens worldwide. However,

one in three countries still cannot use the critical gene sequencing tool. Besides access, they also need appropriate infrastructures and networks (Carter et al. 2022).

The significance of genomic surveillance must be understood in the broader context of multiscale microscopic politics that marks our times. Nowadays, scientists constantly conduct sub/molecular mapping of microscale entities/relations/processes elusive to our naked senses and everyday human intuition. The genomic surveillance of SARS-CoV2 as live tracking of viral mutation that ensures early detection of potential variants is a timely reminder of the intricate relationship between the biosphere and the noösphere, *the sphere of mind*, which is at the center of the Anthropocene predicament.

Both life and science are planetary phenomena, as Vernadsky asserts (1997, 1998). According to Vernadsky's concept of the biosphere, Lynn Margulis and James Lovelock's Gaia hypothesis, and many geobiologists, *life* has always been a geological force. Indeed, "life is *the* geological force" (Margulis et al. 1998: 15). Meanwhile, geology has long been a life force. Without life as we know it, "the crustal mechanism of the Earth would not exist" (Vernadsky 1998: 58).

The biosphere is a "region of transformation of cosmic energy" (47), roughly 20 kilometers from top to bottom, comprising the atmosphere, lithosphere, hydrosphere, and other interlocking elemental cycles, as well as the increasingly complicated circuits in the techno-cognisphere. The coevolutionary processes connecting matter, life, and thought are molecular, planetary, and cosmic, embedded within and energetically depending on the solar system.

For Vernadsky, it is reasonable that the biosphere should be transformed into the noösphere, a new world recreated with humanity's rational and technological achievements. But the narrow rationalist connotation of mind could be misleading. Vernadsky *felt* the crisis of his times, just like we do ours.

> The noösphere is a new geological phenomenon on our planet. In it for the first time man becomes a *large-scale geological force*. (Vernadsky 1997: 249)

Human expansion and development drastically amplify the integral connection between life and geology. Vernadsky admits that it is possible that "all the natural living bodies" possess the capacity for reason. Still, he insists that "the spiritual life of a human personality in its special manifestation" is crucial for the noösphere (222-223). Pondering the project, Vernadsky asked the following famous question.

> Thought is not a form of energy. How then can it change material processes? (Vernadsky 1997: 249)

What if thought is not only a form of energy but precisely energy that makes the trans-species connections in and for a creative noösphere possible? I contend that the *spiritual* dimension of noösphere is by no means restricted to the humanist-linguistic model of thought and potentially opens up a trans-species posthumanist space of diffractive politics. Perhaps it is time to talk about a trans-species noösphere that comprises species and lifeforms at all scales, diverse human groups included, without privileging the abstract ideal of humanity.

Contemporary philosophy of science has gradually acknowledged that not only life sciences as research areas but all sciences can be regarded as "living sciences"—significant activities of human beings as lifeforms in historically specific coevolution. Human or nonhuman lifeforms are "purposeful," interacting and extending in a particular ecological environment (MacLennan 2015: 415). The planetary noösphere, in a dynamic sense, is about the evolutionary reconstruction of the boundaries between humans and nonhumans, as well as the material and epistemic landscapes inhabited and transformed.

In planetary life, negotiating and reconstituting different modes of *life-techne*, or *zoe-techne*, are common evolution strategies (Chuang 2021). Notable examples include the phenomena of endosymbiosis and symbiogenesis, both seriously questioned when first described. Different organisms may form symbiotic and/or parasitic relationships and internal symbiosis; sometimes, one organism becomes an inner part of another, with the original genome intact to a certain extent (Kozo-Polyansky 2010; Margulis (Sagan) 1967; Margulis 1998). Using next-generation gene-sequencing techniques, scientists are now confident that anaerobic microorganisms are rich in unique genes and metabolic pathways that allow them to survive in various extreme environments and perform element exchange and energy conversion, predating the evolution of photosynthesis technology (Colman et al. 2017).

In defiance of humanist pride, Margulis argues that life on earth will do just fine without us. Humans transform the biosphere incessantly, not unlike countless nonhuman beings, in particular, innumerable tiny microorganisms invisible to human eyes. The microscopic agents have rewritten the connotation of individuality, exceeding the humanistic framework in various ways. As the Gaia theory points out, the earth's atmosphere is biologically modulated, such as the oxygen ratio, atmospheric composition, acidity, temperature, and these conditions, in turn, affect the (re)distribution of life. Specific biotas coevolve with rocks and other environmental elements, co-creating life-sustaining conditions. These processes involve myriad feedback loops and the hybrid system's capacity to restore homeostasis when perturbed (Margulis and Lovelock 1974).

The noösphere should include the sphere of *microbial minds and consciousness* that Margulis and many microbiologists have revealed. Even the simplest bacteria and protists were already "conscious" entities at the beginning of evolution (Margulis 2001, 2000). The artificial tension between the biosphere and the noösphere can only be resolved with a radical reconceptualization that expands the spiritual scope of the noösphere to welcome the *zoe-techne* of innumerable nonhuman lifeforms and benefit from the invisible trans-species coevolution of sub/molecular sensibilities. It is time to explore the trans-species diffraction politics of immunity.

Diffractive Mattering of the Immune Self /Nonself Patterns

The idea of the immunological self successfully captured the public imagination in the late 20th century. Popularity also led to conceptual rigidity, overlooking historical conditions. The immunological self "has been reified into the governing principle of modern immunology" (Silverstein and Rose 1997: 198). The impact of self/nonself distinction on immune tolerance is controversial, and concerns both acquired and innate immune responses (Kaufmann 2019). Innate immunity relies on a system of receptors to recognize "pathogen-associated molecular patterns" unique to microbes distinct from the self. However, innate receptors may also identify self molecules not present in a healthy state (Gonzalez et al. 2011: 20).

Recent studies suggest our immune system's innate-adaptive distinction is not so clearly defined. For example, neutrophils, the first line of innate defense against invading microorganisms, can also modulate the adaptive immune response (Rosales 2020). Moreover, the immune system is increasingly viewed as "a highly diffuse organ" throughout the body, including its microbiome, which is vital to the host's health and "tightly intertwined with the immune system" (Kaufmann 2019).

After World War II, Frank Macfarlane Burnet proposed the "immunological self" concept without assuming a rigid binary. His research context includes the complicated relationship between bacteria and viruses. Regarding the contrast between lysogenic and lytic cycles, as Alfred I. Tauber and Scott H. Podolsky suggest, Burnet might have wondered, "was it lysing itself or being lysed by another, and what was the symbiotic relation of this other to the host?" (Tauber and Podolsky 1994: 536-537) The boundary between self, another, and other is neither absolute nor relative but involves symbiotic pathway connection among different lifeforms. Burnet explored immune self/nonself relation from an "ecological and evolutionary perspective" (534) and presented an "ecological/symbiotic orientation" (536, 538) since the early stage.

As Peter Brian Medawar puts it, the complex immune response to skin grafting embodies the "uniqueness" of the individual (Medawar 1952: 639). However, the combinatorial patterns of individual uniqueness are "virtually infinite" (634). Medawar succeeded in demonstrating the acquired immune tolerance of skin grafts in mice. Nevertheless, such experiments are difficult to apply clinically (Park 2018: 91). Selfhood is a highly abstract theoretical concept, perhaps even more than individuality, which has been deconstructed and reconstituted at many levels in recent biological studies (Pradeu 2016). The reified duality of self and nonself is not foreign to the modern mind based on "the cult of the person and individual dignity," as Emile Durkheim put it at the end of the 19th century (Durkheim 1984: 333). However, sometimes the so-called self is no more than a consistent patterning in the molecular field of fluctuation.

The composition of the immunological self is inseparable from the phenomenon of immunological tolerance. Burnet argues that embryonic life can distinguish between self and nonself patterns and can also develop a tolerance to foreign microorganisms (Silverstein and Rose 1997: 198). Burnet's notion of the immune pattern may be influenced by his admirable philosopher friend Alfred North Whitehead. According to Whitehead, in the ever-changing flow of life, it is a specific pattern, or "identity of pattern," that sustains through and in organisms (Anderson and Mackay 2014: 153). An event is the "ultimate unit of natural occurrence" (Whitehead 1997: 105), and patterns' emergence and persistence help us recognize an event.

> There is thus an intrinsic and an extrinsic reality of an event, namely, the event as in its own prehension, and the event as in the prehension of other events. The concept of an organism includes, therefore, the concept of the interaction of organisms. (Whitehead 1997: 105-106)

The continuation of a given being—its "self" or "identity"—is a process of ecological entanglement and differentiation of time, space, matter, and information in the multiscale fields of existence. All modes of patterns are scientifically detectable in the force field of organisms and their interaction, or rather *intra-action*, to borrow Karen Barad's term.

In the third year of the epidemic, what concerns us is the formation, maintenance, and decline of immunity. The temporality of immune memory, the superimposition of multiple infections, and the evolution, emergence, interference, reinforcement, and evasion of immunity, all involve microscale diffractive politics and semiosis and boundary negotiation.

Due to the limits of human sense organs, the phenomena of diffraction, reflection, and refraction are far more common than we thought. Donna Haraway stresses that diffraction is a better trope for critical thinking than reflection and refraction because diffraction can produce modes of interferences and differences ins-

tead of displacing the same (Haraway 1992: 300; 1997: 16). Barad emphasizes that "diffraction is a matter of differential entanglements;" that is, about "*the entangled nature of differences that matter"* (Barad 2007: 381). The relation between diffraction and mattering is onto-epistemological, that is, about practice and living together.

> *That is, every finite being is always already threaded through with an infinite alterity diffracted through being and time.* (Barad 2015: 401)

When the analytical boundaries between time, space, and matter are constantly challenged, their ontological becoming-together and intra-action are also manifested. The production of a difference is simultaneously producing an entanglement and vice versa. Nevertheless, they are not in a linear context but a theoretically infinitely divisible present. Entanglement and differentiation co-constitute at all possible scales. The scale problem is also complicated, as the concept of space now implicates both time and matter.

> Difference is not some universal concept for all places and times, but is itself a multiplicity within/of itself. Difference itself is diffracted. Diffraction is a matter of differences at every scale, or rather in the making and remaking of scale (spacetimematterings). Each bit of matter, each moment of time, each position in space is a multiplicity, a superposition/entanglement of (seemingly) disparate parts. (Barad 2014: 176)

Just as Whitehead's organic philosophy cuts through the distinction between the organic and the inorganic with the energetic persistence of patterns, or patternings, so does mattering as the emergence of events traverses the division of time and space. Barad's concept of spacetimematterings can be understood as the multiple evolutionary and historical specificities sedimented in active becomings.

Emergence, formation, mattering, and patterning are not merely about epistemological enacts of the human subject. They are coevolutionary processes of all agents becoming with the world they inhabit, measure, and transform. From the perspective of *diffractive mattering*, mutual interference in the coevolution of planetary life has contributed to the perceptible immune memory and the co-constitution of self and nonself.

Mapping Diffraction Patterns of Immunity

The visualization of viruses in the late 1930s and several major pandemics have made the coevolution between viruses and cellular organisms an essential field for

rethinking immunity. By mapping the diffraction patterns of immunity and uncovering hidden ecological entanglements, we can reconstruct the trans-species memory embodied in the diffractive mattering of our planetary biosphere.

Learning from other lifeforms and natural forces has always been one of the most indispensable resources in human technology. The 2020 Nobel Prize in Chemistry was jointly awarded to two chemists for developing CRISPR/Cas9 "genetic scissors," named "one of gene technology's sharpest tools." CRISPR clustered, regularly interspaced short palindromic repeats is the bacterial immune system defending against viruses, and Cas9 stands for CRISPR-associated protein 9. In short, the bacterial CRISPR system incorporates a viral-derived new spacer while destroying the invading viral genome and thereby acquires sequence-specific adaptive immunity. The system's operation mainly includes three steps, adaptation, crRNA (CRISPR RNAs) biogenesis, and interference. The most critical and challenging to determine is adaptation, i.e., immunization and spacer acquisition (Heler et al. 2014: 2).

Recent research has revealed remarkable diversity in these systems' mechanisms. At the same time, the prokaryotes need to develop mechanisms to avoid autoimmunity since the foreign antigenic sequences have been inserted into their memory array (Nussenzweig and Marraffini 2020: 104). In some cases, it can even "vaccinate" cells against "undesirable genetic elements" acquired in the process (Barrangou and Marraffini 2014: 239). Moreover, CRISPR systems can optimize their immune response against the newest invaders by ordering spacers chronologically, deploying the so-called "differential expression" of crRNAs across the array (McGinn and Marraffini 2019: 8).

Maintaining immune memory is a great challenge, although not all immune cells have the ability to memorize. According to a review paper by Sandra C. Garrett, the frequency of spacer additions depends on species, system, and many conditions. The length of spacer arrays is typically no more than 50 spacers in bacteria and 100 in archaea, although there are a few exceptions. Also, some genomes may include more than one CRISPR system. New spacers are continuously added to the array in response to new invaders, thus clearing some old spacers. However, the spacers are not always ordered chronologically, and sometimes the arrays collapse or rearrange. Understanding how immune memory is acquired, maintained, and rearranged requires a better understanding of the dynamics of CRISPR arrays (Garrett 2021).

The foreign sequence spacers employed to remember invaders are not rigid but maintain the structural integrity within which evolutionary selection and adapta-

tion can work, allowing specific patterns to persist amid change. Spacer acquisition, maintenance, and change are critical events in evolution at the molecular level.

The system sometimes forms "self-targeting spacers" that cause damage to its own cells. The researchers found that this kind of "endogenous CRISPR-Cas system" may play other functions, belonging to a mechanism of programmable gene regulation. The trouble is that viruses often exploit this situation for immune escape, driving the host's CRISPR-Cas system for autoimmunity rather than striking the pathogens. In saving oneself, the host may mutate or delete the system and lose the function of defending against invaders (Wimmer and Beisel 2020). The two conceptual sets of protection/attack and self/nonself do not entirely overlap but require a broader space-time scope allowing for a spiral dynamic of boundary maintenance, confusion, negotiation, and reorganization.

Symbiosis is ubiquitous. As Thomas Pradeu points out, scientists have discovered the phenomenon of "co-immunity": microorganisms participate in the host's immune defense against pathogens (Pradeu 2019: 20). The concept of biological individuality still plays a crucial role, but with greater emphasis on the continuous reconfiguration of heterogeneous elements. We need to reassess the negotiation of molecular boundaries between self and nonself through the lens of reticular evolution. As Nathalie Gontier explains,

> Reticulate evolution today is a *vernacular concept* for evolutionary change induced by mechanisms and processes of *symbiosis, symbiogenesis, lateral gene transfer, hybridization or divergence with gene flow, and infectious heredity*. (Gontier 2015: 21)

In 2003, researchers confirmed that the unidentified bacteria discovered ten years ago were giant viruses. They were called Mimivirus because of the characteristics of "mimicking microbes." Giant viruses are not uncommon and are highly diverse and structurally complex. Their genome size is bigger than some smaller bacteria (La Scola et al. 2003). Later it was discovered that giant viruses could also be infected by smaller viruses called "virophages," which were named "Sputnik" because they behave like satellite viruses that co-infect cellular hosts with giant viruses. While satellite viruses replicate in the cellular host nucleus, Sputnik virophage must use virus factories established by their viral host in the cellular cell and cause giant viruses to produce defective particles (La Scola et al. 2008; Desjardins 2012: 117; Desnues et al. 2012). Studies show constant genetic interaction between cellular organisms, giant viruses, and virophages. In other words, during the co- and super-infections of cellular hosts, there is "an intricate, multilayered network" (Diesend et al. 2018).

Just as bacteria invented the CRISPR system against bacteriophages, giant viruses formed their unique immune memory system concerning virophages, named "MMIVIRE, mimivirus virophage resistance element) (Levasseur et al. 2016: 250). Some researchers questioned this analogy, pointing out that MIMIVIRE is unlikely to be an adaptive immune system because it lacks many key properties of CRISPR, especially the process of distinguishing between self and nonself; after all, virophages are "absolute parasites" of the giant viruses (Claverie and Abergel 2016: 202).

Another diffraction pattern is about the way virophages assist cellular organisms in developing "anti-giant virus immunity." In a lab co-infection system, where a giant virus and its virophage simultaneously infect a protist, the cellular host integrates the virophage genome, whose gene expression can be activated later as an agent of "adaptive immunity" when a giant virus superinfects the host. The process is similar to the CRISPR-Cas system of prokaryotes (Koonin and Krupovic 2017: 12). The analogy between the two mechanisms is incomplete, especially regarding the degree to which foreign sequences are "domesticated." The connection between protist hosts and virophages is more like a symbiotic state than an immune system and can be regarded as a different stage of defense system evolution (13).

Tracking the trans-species coevolution of planetary life, we now understand the omnipresence of microorganisms and their multilevel symbiotic networks at all scales of life. The politico-ecological significance of these findings is not in the analogy but in the fact that microscopic biological entities such as virophages, viruses, bacteriophages, archaea, bacteria, and protists—substantial forces invisible to the human eye—play a vital role in the comprehensive immune and memory system of the earth's biosphere. These all involve microscale interface dynamism in which immunity and memory are interlaced, revealing the pluralist temporalities of immunological self/nonself patterns.

Recent discoveries, including the aforementioned giant viruses, their virophages, and corresponding complex interaction networks, have contributed to the emerging ecological perspective in virology (Brandes and Linial 2019). Both capitalism and climate change have dramatically increased the chances of viral transmission across species barriers. Viral surveillance and biodiversity surveys are central to preventing future zoonotic disease outbreaks (Carlson et al. 2020).

Much research on the structure and function of SARS-Cov-2 has focused on its pathways into the cell because it instructs us on the possible way to block it effectively. The virus' spike protein, the front line of entry into the cell, is the hotspot for its rapid mutation (Jackson et al. 2022). All available vaccines produce nonvirulent SARS-Cov-2 spike proteins directly or indirectly, stimulating the body's antigen-presenting cells, triggering a series of immune responses, producing antibodies,

killer T cells, and finally generating specific memory B cells and memory T cells (Corum and Zimmer 2021).

In the early days of the pandemic, the public was concerned about herd immunity. Today, the high mutation rate and immune escape exhibited by SARS-Cov-2 have made herd immunity nearly impossible. Instead, deploying hybrid immunity has become an essential research focus (Hall et al. 2022; Goldblatt 2022; Nordström 2022). Vaccines remain a necessary strategy to reduce infection rates and severe conditions. With vaccines, we inject critical parts of the virus or its genetic instructions into the body to acquire an immune memory against the virus. Memories are tricky things irreducible to a rational formula, especially at the sub/molecular level. Intimacy replaces hostility.

Planetary Trans-scale Streams of Consciousness

Every particular lifeform measures its world primarily with itself, i.e., its own body and senses, constituting the world and itself as phenomena. As Barad says, when we enact a measurement, "we are 'peeking' inside a phenomenon" (Barad 2007: 345). As levels of observation, scales are not merely an epistemic problem but reflect the observer's changing conditions.

In bacteria, bacteriophages, viruses, virophages, protists, and even multicellular organisms like humans, the diffraction patterns of immunity show multiple superimpositions and subtle boundary negotiation between self and nonself, endogenous and exogenous, internal and external forces. At the sub/molecular level, the dynamic configuration of boundaries is like countless minuscule Gaias, sharing, exchanging, negotiating, and transforming in the chain feedback loops of information and matter.

Difference is a site of contestation in our times, not only in the cultural field but also in the life sciences, particularly regarding microscale differentiation. Gilles Deleuze praises Charles Darwin for his "great novelty" of "inaugurating the thought of individual difference" (Deleuze 1994: 248). Nevertheless, it is not always possible to make sense of individual differences because we can never sense all of them. As Deleuze suggests, body parts are composed of "actualised pre-individual singularities" (Deleuze 1994: 279). A pre-individual singularity is an infinitely differentiating site of multiplicity, for instance, a molecular species. An antigen is a specific molecular species that elicits a particular response upon entry into an organism's substance, including antibodies' production (Burnet and Fenner 1948: 290). In so far as the immune system functions at the sub/molecular level of diffe-

rential multiplicity, the self/nonself distinction evades a holistic definition. In that case, the identification between molecules can only concern patterning in dynamic configurations.

The trans-scale diffraction patterns of immunity and memory make the concept of self turbulent, continuously forming a non-linear spiral feedback loop. One of Burnet's most famous quotes is his description of a virus as "a stream of biological patterns" (qtd. in Lwoff 1957: 248). Life is consciousness. Margulis's notion of microbial consciousness is not a metaphor but a vital clue manifesting a nonhuman embodied perspective in the coevolution of planetary life. As such, viruses as streams of biological patterns are like trans-species and trans-scale streams of consciousness that constantly co-write the planetary memory with cellular lifeforms via vibrant information/matter shuttles. The diffraction patterns of immunity mapped here are only a tiny slice of the 3.7 billion-year-long life/consciousness duration stream. Today, we know that every little piece is a site of infinitely differentiating multiplicity, nourishing our molecular sensibility to remember the future.

Besides technology and rationality, a trans-species noösphere is also about sensation, pleasure, pride, humility, and affective intoxication. Rationality and affectivity are enmeshed in living corporeality. Viruses—latecomers in the territory of human knowledge, volatile and potent agents of infection and immunity—have a lot to teach us about sense and nonsense, between self and nonself, form the sensible and insensible, and the evolutionary urge for a molecular intuition mutation. The possibility of political life as a heterogeneous co-constitution lies in this ongoing lesson about sense and sensibility.

Tomorrow is yesterday. NASA just released the first images on July 12, 2022, of the James Webb Space Telescope (JWST), launched on December 25, 2021. JWST is an infrared eye at minus 266 degrees Celsius that can visualize the first galaxies formed after the universe was born 13.5 billion years ago (Witze 2021). As the universe continues to expand, the lights of these distant spacetimematterings have been stretched over a long time.

In a sense, our immune systems are not unlike distant galaxies. When we study them, we look at the unknown origin and prolonged coevolving infection and immunity of planetary life and mind, that is, the trans-species intertwined enfolding of the biosphere and noösphere. The past and the future are infinitely differentiable multiplicities, condensed in the imperceptible singularities of the present, both at the beginning of galaxies and the winding memory of life. Our immune memories, which appear so short in duration, also stretch into eternity in an instant.

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