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Entangled Stories of Life: Narrative Agencies and "Ethics of Worlding" in the Quantum Realm

by Serpil Oppermann

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Abstract

The foundational principle of quantum physics is the notion of entanglement, which can best be described as the ontological inseparability of subatomic particles in such a way that the measurement of one particle's quantum state determines the possible quantum states of all other particles. Supported by hard data in quantum physics, this nonlocal connectedness comprises the internal relatedness of all existence at all levels of reality, which is also an expressive (or, narrative) interconnectedness material ecocriticism labels as narrative agencies of storied matter. Matter's expressive capacity is best observable in the subatomic particles that have a certain degree of creative expression when they communicate nonlocally. I argue that being part of this reality means being part of the entangled stories of life, which compels us to act responsibly and develop a new ethical attention toward our interconnections in the indivisible field of existence. Ethical responsibility here is accountable "becoming with each other" (Haraway 2008), which Karen Barad calls "ethics of worlding" (2007) necessary to sustain our storied existence (from the subatomic particles all the way up).

Keywords: Quantum entanglement, subatomic particles, nonlocal communication, narrative agency, storied matter, material ecocriticism

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About the Author

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Entangled Stories of Life: Narrative Agencies and "Ethics of Worlding" in the Quantum Realm

Serpil Oppermann

The foundational principle of quantum physics is the notion of entanglement, which explains how the measurement of one particle's quantum state determines the possible quantum states of all other particles even if they are separated by great distances. That is, even if galaxies apart, all subatomic particles display nonlocal connections in a unified quantum state. Particles, as theoretical physicist Sean Carroll explains, "come in two types: the particles that makeup matter, known as 'fermions,' and the particles that carry forces, known as 'bosons.' The difference between the two is that fermions take up space, while bosons can pile on top of one another" (2012, 52). Among the fermions are leptons and quarks[1] that constitute protons, neutrons, atoms, and molecules, while the carriers of forces—gluons, photons, and the Higgs particle—constitute bosons. Being a "fuzzy, amorphous, probabilistic mixture of all possibilities" (Greene 2004, 112), a particle is defined by its mass, including zero mass, and with its charge, which produces electromagnetism. Particles also carry nonzero energy. Particles with zero masses (photons) are puzzling in their behavior, but quarks, leptons, and weak gauge bosons that have nonzero masses are even more mysterious, because they are both everywhere and nowhere, both absent and present. Fermions with zero mass leave a trail by emitting radiation when they leap from one state to another, and whenever an observation is made during high-velocity collisions, these absent/present particles appear only for two-millionths of a second before they disappear like the tau lepton that decays the moment it appears. Since at the subatomic level these particles are "quantized" both as wave and particle, their coming into existence depends on the measurement process. This means that "both matter and light consist of discrete units known as quanta" (Randall 2005, 148), which are energy packets exhibiting wave-like patterns of probabilities that involve undecidability, indeterminacy, and unpredictability, or as Werner Heisenberg postulated in 1927, the "Uncertainty Principle." This is because a particle's position and velocity can never be measured at

the same time, implying an indivisible link between them, which is the state of quantum entanglement.

In their co-authored book *The Undivided Universe: An Ontological Interpretation of Quantum Theory*, David Bohm, the proponent of hidden variables theory,[2] and B. J. Hiley explain this indivisible link (or quantum entanglement) as "a strong nonlocal connection of distant particles and a strong dependence of the particle on its general environmental context. The forces between particles depend on the wave function of the whole system so that we have what we may call 'indivisible wholeness'" (1993, 177). Another famed physicist, Bernard d'Espagnat confirms through quantum coherence experiments "that the kind of physical reality whose regularities the principles of physics are expected to map must presumably be a nonseparable whole, with properties quite different from those we are accustomed to attribute to any kind of reality" ([1976] 2018, 239). A striking example of this dynamic is the "delayed choice experiment," otherwise called the "double-slit experiment," which was first proposed as a "Gedankenexperiment" (thought experiment) by John A. Wheeler. In his famed essay "The 'Past' and the 'Delayed-Choice' Double-Slit Experiment" (1978), Wheeler claimed that a photon would know in advance whether an observation was going to be made, change its behavior to that of a wave or particle accordingly, and respond to the experimenter's delayed-choice instantly, which was confirmed by experiential evidence later. Many quantum experiments with entangled photons have been conducted in recent years to prove that *entanglement* defines the subatomic world. The first experimental verification was reported in 2007. In their paper "Experimental Realization of Wheeler's Delayed-Choice Gedanken Experiment," published in *Science* on February 16, 2007, French physicist Vincent Jacques and his colleagues announced, "an almost ideal realization of that gedanken experiment with single photons allowing unambiguous which-way measurements" (2007, 966). As they explain in detail:

> Our realization of Wheeler's delayed choice Gedanken Experiment demonstrates beyond any doubt that the behavior of the photon in the interferometer depends on the choice of the observable that is measured, even when that choice is made at a position and a time such that it is separated from the entrance of the photon in the interferometer by a space-like interval. (Jacques et al. 2007, 968)

Another experiment was conducted in 2009 in the Canary Islands, between La Palma and Tenerife, where "the successful transmission of one photon of an entangled pair was recently achieved" (Fedrizzi et al. 2009, 389). These experiments leave no doubt that photons separated by long distances are inextricably entangled, and that the behavior of one automatically determines the behavior of the other. There are no

borderlines between them, nor can the observer remain detached from this complex web of interrelationships, which John A. Wheeler describes as "the acts of observer-participancy" (2002, 321). In quantum theory, as expressed by Fritjof Capra, this is also explained in terms of "probabilities of interconnections": "The subatomic particles have no meaning as isolated entities but can be understood only as interconnections, or correlations, between various processes of observation and measurement . . . In quantum theory we never end up with 'things'; we always deal with interconnections" (1997, 30). When David Bohm describes quantum interactions, he also underlines the same dynamics operating in the subatomic realm: "both observer and observed are merging and interpenetrating aspects of one whole reality, which is indivisible" (Bohm [1980] 1995, 9). According to Karen Barad, too, "the objects and the agencies of observation are inseparable parts of a single phenomenon" (2007, 315). "*Phenomena*" in her definition "*are the ontological inseparability/entanglement of intra-acting 'agencies*'" (2007, 139). She argues that reality is constituted by phenomena within which there is an "ongoing flow of agency through which part of the world makes itself differentially intelligible to another part of the world" (2007, 140). What is particularly significant here is the experimental confirmation that photons "know" the presence of an observer before they are emitted, and "knowing," in Barad's words, "is a distributed practice that includes the larger material arrangements" (2007, 379), which she explains as being "part of the larger material configurations of the world and its ongoing open-ended articulations" (2007, 379).

My argument is grounded in this new understanding of matter that is expressive and has a narrative dimension, because, in a world beset by expanding ecological troubles, this new interpretation of matter as being storied can be read as a "call upon us to reorient ourselves profoundly in relation to the world, to one another, and to ourselves" (Coole and Frost 2010, 6). As "the defining property of all matter beyond and including the biological world" (Oppermann 2018, 412), storied matter also opens supplemental pathways for articulating ethical relationalities in the "entangled communities and processes of cobecoming" (van Dooren, Kirksey, and Münster 2016, 15), which has profound ecological significance.

Ensuing from the quantum principle of nonseparability in its broader ecosocial contexts, storied matter engages us ethically as well, because the entangled stories of all entities can change the way we perceive the nonhuman in all its various forms and consequently our exploitative relationships with the world. Such a perceptual change then enables us to relate to the Earth in a noninvasive way. After all, we are all part of an undivided universe and thus part of all material configurations that material ecocriticism labels as storied matter.

Storied Matter in the Subatomic Realm

The communication process observed among subatomic particles can be interpreted as a display of purposeful articulations imbued with meanings. Meaning, according to Barad, is "an ongoing performance of the world in its *differential intelligibility*" (2003, 821; italics added), and intelligibility is "an ontological performance of the world in its ongoing articulation" (2007, 149). This is entirely congruent with the material ecocritical vision of *storied matter* whereby matter and meaning are always already entangled. Material ecocriticism formulates creative expressions encoded in all material configurations as *storied matter* constituted by *narrative agencies*. Since all material agencies are characterized by "material-semiotic means of relating" (Haraway 2008a, 26), they are *narrative agencies*. Storied matter signifies a nonlinguistic performance inherent in every material formation whether it is submicroscopic, microscopic, or macroscopic in form; that is, from biotic and abiotic matter to subatomic particles, all matter is endowed with performative enactments, internal relations, and meaningful expressions; all matter is thus storied matter.

But should we believe in material agencies that are meaningfully articulate? Like many new materialists and material ecocritics, Jeffrey J. Cohen responds affirmatively: "if you believe in physics or the insights of ecological theory and material feminism, then yes, you kind of have to" (2014). And, if material agency is defined as a "dynamic expression/articulation of the world in its intra-active becoming" as Barad does (2007, 392), then we have to acknowledge the existence of storied matter and narrative agencies as "particular material articulations of the world" that is, indeed, as "meaningful" (Barad 2012, 77). At the subatomic level, meaningful expressions emerge from the entanglement of photons when they are in a process of what late biosemiotician Wendy Wheeler (1949–2020) has called "co-operative communication" (2006, 13), which makes them primordial narrative agencies of storied matter.

As the invisible architects of the universe and the perennial scribes of cosmic and terrestrial stories, atoms and subatomic particles are in fact the planet's first elusive and unpredictable narrative agencies endowed with the ability to *know* the presence of an observer. They are the subtle authors behind all processes of life, carefully engaged in what in Donna Haraway would call "world-making entanglements" (2008a, 4) in countless plots. The leaps and spasms and twitches of those plots make us, other species, and all material forms and processes, with varying degrees of compounding relationships, ontologically inseparable. Their creative and participatory becoming is a clear indication of the nature of reality characterized by wholeness. This underlying interconnectedness forms the basis of the ecological and ethical meaning of life and

casts a vision of the physical world as a material-semiotic phenomenon that projects "a stunning narrative . . . of structural-functional complexity" (Haraway 2008b, 163). Thus, electrons, photons, quarks, leptons, fermions, and bosons constitute *storied matter* in its most elemental form. They are timeless texts with rich narrative efficacy, often unnoticed but always exerting their influence in world-making and our conceptual and material habitats.

If experience, internal relations, go all the way down to subatomic particles, then, all matter must have rudimentary forms of memory, some degree of creativity, expressive capacity, and thus agency. As we have seen, this conception of matter that expresses itself meaningfully is the foundational premise of material ecocriticism, which derives its inspiration from the new materialist reconceptualization of matter as "self-creative, productive, unpredictable" (Coole and Frost 2010, 9). The narrative creativity embodied in nature's most basic constituents in their mutual entanglements is a gift of world-making through multiple temporalities. Let us recall that entanglement, as Alessandro Fedrizzi et al. explains, "is at the heart of many peculiarities encountered in quantum mechanics and has enabled many groundbreaking tests on the fundamentals of nature" (2009, 389). Although their "set-up contain[ed] some of the basic building blocks of a quantum communication system" (2009, 391), their interpretation of "quantum communication experiments" was carried out with "weak coherent laser pulses and entangled photons . . . on ever-larger distance scales and with increasing bit rates" (2009, 389). This experiment validates Donna Haraway's claim about matter being always "semiotically active" (2008a, 250) with an expressive force that endures far longer than ourselves and our stories. The entangled photons in this experiment reveal a capacity for self-organization, productive agency, intrinsic vitality, effectivity, and purposeful communication. It then follows that unfolding in the indivisibility of quantum processes with meaningful communications and "occasions of experience" (Griffin 1998, 157), all subatomic particles project a view of creativity as "an integral part of the total flux of process" (Bohm [1980] 1995, 63). As the building blocks of storied matter with creative experiences, they must also "have the power for partial self-creation" (Griffin 1998, 184).

When particles communicate intelligibly with other entities, like the entangled photons in double-slit experiments, they produce telling encounters with everything else around them as narrative agencies. Embodying meaning and intelligibility, narrative agency reveals itself through "nonlinguistic inscription" (Cohen 2015, 35), which is a means of communicating other than human languages, such as signals, sounds, colors, gestures, shapes, scents, patterns, and vibrations that are enriched with meanings. Thus, when we speak of the narrative agencies of storied matter in the

subatomic realm, we are acknowledging them as vibrating texts filled with often elusive narratives that can open a way to emancipate matter from silence and passivity, and liberate us from the images, discourses, and practices of our dualistic mindset. Whether biotic or not, subatomic or geological, all material agencies are then storied subjects of an ever-unfolding earthly tale, revealing "nature's literacy" (Kirby 1997, 127). In fact, for about four and a half billion years, the Earth has housed many forms of literacy, or expressiveness, that pervade nature at large, unveiling thus nature's literacy as one of "the deepest tendencies in our planet" (Swimme and Tucker 2011, 51). That is why material ecocriticism affirms the astonishing dance of evolution on this living planet of communicative agencies, which undoubtedly disclose some essential form of narrativity even at the most elemental levels of existence in the shaping of life at large. From the material ecocritical perspective, material agencies are not "screens upon which humans project their intentions, meanings, signs, and discourses" (Bryant 2011, 247), but full-fledged *narrative* agencies that we can acknowledge "without making them completely anthropomorphized characters" (Maufort 2021, 243).

Creativity unfolds in all agential components of materiality, producing meaningful acts of expressions in which anthropocentrism inevitably dissolves into a space of oblivion. The entire biotic and abiotic existence thus ensues through the entangled stories of life. It is then time to reimagine the foundations of life's perennial stories that unfold in myriad forms of narrative potentialities and multiple varieties of innate meanings originating at the most elemental levels of existence. Narrative as such emerges in the form of signifying forces revealing the world's dynamic self-articulation. As astrophysicist Eric Chaisson notes, this ongoing worlding process chronicles "an amazing story of life on Earth" (2005, 299). He writes that "[b]iochemists who amass digital genomes are now pooling their talents with paleontologists who scour fossilized bones. The results provide increasingly robust details of that story, regularly revealing torn and tattered pages here, occasionally uncovering whole new chapters there" (2005, 299). The robust details of the story, in short, are in every bit of matter, which are all enmeshed in performative acts of narrativity all the way down to the submicroscopic realms making themselves "differentially intelligible" (Barad 2007, 140) to the human observer. "In the end," however, as Margaret Atwood perceptively wrote, "we'll all become stories" (2006, 188).

What follows sheds light on the expressive entities at the intersections of biology and quantum physics; that is, on the narrative agencies of "biophotons." This is a term that denotes photon emissions detected in biological systems. As biophysicist Charles L. Sanders expresses it: "Each living cell 'talks' with other cells with incredible

precision and accuracy to maintain synchrony, unity of purpose, and health" (2017, 245–46).

Biophotons as Narrative Agencies

Since quantum physics unveiled the ultimate truth about life as a dynamic unity, it has become easier to think of our existence as human beings as part of a continuous reality of communicative material agencies that project a complex vision of matter as a site of narrativity, a site of creative becoming and lively expressions. The communicative capacity of matter from subatomic particles to molecules and cells is an indication of matter's internal experiences, which endorses the idea that no entity can exist independently of its environment, and that human experience is "a high-level exemplification of entities in general, be they cells or atoms or electrons. All are subjects. All have internal relations" (Birch 1988, 71). And all internal relations that unfold in the form of creative expressions exist between the subatomic particles, between atoms, molecules, cells, plants, animals, culminating in human beings, and all matter possesses some form of experience, some degree of freedom, and the capacity to be expressive. If electrons, for example, can experience their environment to some minimal degree, an ethical principle follows that humans ought to respect the complexity and richness of the experience of life, because what makes us "specifically human . . . makes us "part of that self-same nature," as theoretical physicist Carlo Rovelli confirms in his short book *Seven Brief Lessons on Physics* (2014, 76). Human beings, he notes, are a part of "the infinite play of its combinations, through the reciprocal influencing and exchanging of correlations and information among its parts" (2014, 76). The Australian geneticist Charles Birch quoted above similarly argues that if all entities have internal relations and intrinsic value, we can more easily acknowledge the interrelatedness of all life, so that human exploitation of the environment becomes a moral issue. Closely related to Alfred North Whitehead's process philosophy, which acknowledges that all entities are endowed with intrinsic value in the processes of creative becomings, Birch's ecological model anticipates Karen Barad's ethics of worlding in that humans have an ethical responsibility not to disrupt the sustainability of biotic existence and not to interfere with the response-ability of the nonhuman. Charles Birch also conceded that Niels Bohr knew that "the laws of physics were most likely to be discovered in biology" (1988, 71), which indeed came into view in the field known as quantum biology that investigates "cell communication with electromagnetic waves within all living systems" (Sanders 2017, 246). Thus, the photon emissions from biological systems, in a way, validate Bohr's anticipation that expressive relationalities and quantum correlations can also be detected at the molecular level. Seeing cells as a complex quantum system, quantum biology applies "quantum mechanics and

theoretical chemistry to biological objects and problems" (Sanders 2017, 246). That is why quantum biology is defined as the entanglements of physics and biology.

When electromagnetic cell-to-cell communication was discovered as a potent signaling system with ultra-weak photon emissions in living cells, the German biophysicist Fritz-Albert Popp coined the term "biophoton" to denote "non-thermal photon emission" (2003a, 389) from a biological system. This enables the transfer of information. In his 2003 article "About the Coherence of Biophotons," Popp explains further how the "term 'photons' in the word 'biophotons' has been chosen to express the fact that the phenomenon is characterized by measuring single photons, indicating that this phenomenon has to be considered as a subject of Quantum optics rather than of Classical physics" (2003b, 2). Popp also claims that "biophoton emission displays a rather reliable and sensitive fingerprint of a living system," and their measurements "provide a powerful tool for identifying biological systems as well as for characterizing their response to external influences" (2003a, 404). Biophotons, however, should not be confused with standard bioluminescence, as they refer to UV photons emitted by the biological organisms that can be detected as "radiation with bio-informational character" (Van Wijk 2001, 183). As low-energy thermal photons, biophotons can transmit information and thus enable communication among cells, which Popp calls "biocommunication by means of mutual interference of the biophoton field" (Popp 2003a, 401).

Although Fritz-Albert Popp emerges as the pioneer in this research, the idea of living tissues transferring information was first proposed by the Russian biologist Alexander G. Gurwitsch (1874–1954) who claimed in 1923 that cell division seems to be triggered by "a very weak ultraviolet photo-current originating from the cells themselves" (Van Wijk 2001, 183). His observation of biological photon emissions as weak electromagnetic waves has led to a growing body of evidence at the level of molecular processes that suggests cellular communication is indeed conducted through biophotons emitted by living cells. Thus, having a weak but ongoing photon flux in the ultraviolet range, all biological systems seem to be characterized by an intercellular communication process. In living systems "biophotons originate from a coherent (or/and squeezed) photon field within the living organism, its function being intra- and inter-cellular regulation and communication" (Popp 2003b, 1). According to Popp, the coherence detected in the biophoton evinces that there is an "information transfer within-and-between cells, answering then the crucial question of intra- and extra-cellular biocommunication including the regulation of the metabolic activities of cells as well as of growth and differentiation and even of Evolutionary development" (Popp 2003b, 3). Another important name in this field of research is Serguey Mayburov from

the Lebedev Institute of Physics in Moscow who also confirms "effective signaling between distant bio-systems" (2011, 260). This exchange of biophotonic information in living cells, or the exchange of information in photon emissions, explains, in the German biophysicist Roeland Van Wijk's words, "the existence of a coherent electromagnetic field within cell populations" that has "led to the introduction of the term biophotons"; which are "characterized by their quantum character" (2001, 184). The evidence of cell communication in the form of biophoton emissions, according to Charles L. Sanders, another notable biophysicist, is a form of intelligent activity:

> Each cell may be envisioned as communicating intelligence. The vehicle for cell signaling and passing information is either chemical reaction, electromagnetic wave or by quantum transfer, or all of the above. Data communication of unbelievable complexity occurs within each cell millions of times a second and among nearby cells and cells at a distance. The speed of communication may be of light for bio-photons or faster or even instantaneous for quantum transfer. (2017, 246)

In light of all this information, it becomes apparent that there is an elegant and compelling logic to the biophysical research and findings on intelligent expressivity that inspires us to read the biophotons as captivating narrative agencies of storied matter at the cellular level. These narrative agencies seem to proclaim the inherent value of life, which, as Fritjoff Capra claims, binds every being and entity "in a network of interdependencies" (1997, 11). For Capra, "living systems at all levels" unfold "in an inseparable web of relationships" (1997, 35, 37) within which all life, as Wendy Wheeler also concedes, "from the cell all the way up to us—is characterized by communication, or semiosis" (2011, 270). If signs permeate the living world and communication is an inherent property of all entities, from the subatomic particles onwards, then agentic creativity, performative enactments, and innate meanings of biophotons emerge from "material-semiotic means of relating" (Haraway 2008a, 26). Their becoming with one another unfolds through intelligible communications, which makes them narrative agencies bodying forth a plenitude of narrative potentialities and astonishing storied articulations of their intricate relations. Telling their stories from the intertwined zones of quantum physics and biology, biophotons affirm that "life is made of stories" (Wheeler 2014, 77) and that nothing is inseparable in these entangled stories of life.

If "there is a tremendous degree of coherence involving cell communication with electromagnetic waves within all living systems," and if "[u]ltra-weak light photons may communicate intracellular and extracellular data at the speed of light or greater," their signaling is most definitely "like a language that could be learned" (Sanders 2017, 246, 247). Using this language to establish efficient cellular communication networks,

biophotons emerge as the perennial narrators of elemental creativity in all biological organisms and as undeniable authors of biotic life on Earth. Biophotons produce configurations of meaningful expressions through which one can, for example, read stories of intracellular relations and even evolutionary processes. Biophotons also make all species, with varying degrees of compounding relationships, ontologically inseparable, thus urging us to review our coevolution in the earth's phenomenal story. The quantum-biological atlas crafted by biophotons may lie beyond the scope of our mind's eye, but their narratives with plots designed by their intelligence not only make us who we are but also inspire us to take ecological responsibility for the planetary biotic existence. If we appreciate the role of biophotons in radically structuring interdependent narratives at the deepest levels of existence in ongoing creative becoming, their poetics can prompt ethical attentiveness to our intra-actions with every being inhabiting the planet. Revealing that all that exists, exists in astonishing alliances, despite our differences at the level of macrophysical reality, biophotons also invite us to heed their narratives for a more expansive understanding of the processes of entanglement and to reflect on the ethics of worlding in our ecological destiny converging on the fate of the planet's more-than-human entities.

Although our simultaneously pleasurable and ferocious entanglements in the world's narratives of becoming are increasingly encumbered by anthropocentric potencies, the narrative agencies populating the realms of quantum physics and quantum biology have the efficacy to pull us back to a life-sustaining ecological trajectory. Reading subatomic particles and biophotons as crucial narrative agencies in the sedimented stories of life-composing processes can, therefore, attune us to the book of life, making us more aware of our part in the collective biographies of all things, and help develop what Karen Barad calls "an ethics of worlding." In this regard, understanding what it means to be human begins with understanding connections and interrelations in the subatomic realm of our bodies. In this lesson, the meaning of being changes. The biophotonic narratives take us beyond the human-centered relations into a realm of entanglements where there are no "separate entities but rather irreducible relations of responsibility" (Barad 2012, 46), and where agential performances can flourish. That is why atomic, subatomic, and biophotonic storytelling matters in helping us imagine the world differently and in doing so from an ethical perspective that is inclusive of all that is beyond the human. If we embrace our ethical accountability to the world, we can easily provide the conditions of respond-ability for the nonhuman entities to intra-act with the world. This signals an ethics of worlding energetically infused into the very act of creation itself. Since the quantum narratives of entanglements are all about the ontological inseparability of intra-acting agencies, they

can help bring about the ethics of worlding to open ecologically constructive futures for the human entangled with life and its stories in the deepest levels of being. Last but not least, the material ecocritical account of the entangled stories of life carries us beyond the mere scientification of nature and opens a new path to "a new kind of creative surge . . . needed to meet" the challenge humanity is facing (Bohm and Peat 1989, 207): most visible in climate change, melting glaciers, burning forests, dangerous viruses, and species extinctions. We can face these challenges through the entangled stories of life that call into question all notions of domination, subjugation, violence, closure, and totalization produced by the anthropocentric mindset. Such questioning would necessarily extend ethical relations "to the other-than-human" beyond the familiar "humanist ethics." As Barad claims, "[a] humanist ethics won't suffice when the 'face' of the other that is 'looking' back at me is all eyes, or has no eyes, or is otherwise unrecognizable in human terms. What is needed is . . . an ethics of worlding" (2007, 392).

Ethics of Worlding

Agentic matter encourages more ecological and ethical attention toward our relations and interconnections with everything other-than-human in the indivisible field of existence. Being part of the entangled stories of life in this field makes us ethically responsible for the world, and ethical responsibility should be understood as human beings' accountable "becoming with" "each other" (Haraway 2008a, 27). Learning to become with each other enables the human agency to catalyze better ethical relations with all that is more-than-human, leading to Barad's "ethics of worlding" (2007, 392) in which ethics is "about responsibility and accountability for the lively relationalities of becoming of which we are part" (2007, 393). But responsibility and accountability should not be confused with voluntary moral attitudes that can be renounced at any time by the human subject (Griffin 1998, 211, 212). Responsibility, as Barad notes, "entails providing opportunities for the organisms to respond" that she explains as organisms insisting their "agential performances be taken into account" (2012, 38). Briefly stated, ethics is about "enabling the response of the Other;" it is about inviting, or welcoming, what Barad calls "the conditions of possibility of response-ability" (quoted in Kleinman 2012, 81). That is why ethics is not merely "responsible action in relation to human experiences of the world; rather it is a question of material entanglements" (Barad 2007, 160) in which there is no separation between self and the Other. Responsibility, then, "entails an ongoing responsiveness to the entanglements of self and others" (Barad 2007, 394), while accountability signifies "an ethico-onto-epistemological commitment" to the processes of becoming "from within, not without"

(Barad 2012, 46–47). Such a commitment fundamentally transforms the traditional conception of insular subjects/entities into one of mutual entanglements.

Allowing creative acts of becoming to flourish within mutual entanglements of agencies, which Barad defines as "relations of obligation," binds together all agencies, making the so-called Other "materially bound to, threaded through, the 'self'" (2012, 47). Barad emphatically underlines how *our* intra-actions as human beings are "sedimented into our becoming . . . And yet even in our becoming there is no 'I' separate from the intra-active becoming of the world" (2007, 394). We need to understand that the world "is never merely an external place but always the very substance of our selves and others" (Alaimo 2010, 158). It is important to emphasize this point in macroscopic reality because the social relevance of the scientific validation of indivisibility provides the stipulation for ethical accountability for planetary ecological crises and the undoing of all social dualisms and problems, including racism and sexism.

On this new conceptual map of the expanded ethical community, the human category is read in post-anthropocentric terms and, thus, "in terms of co-emergence within a shared field of existence marked by the interdependency of life" (Oppermann 2016, 276). Barad's ethics of worlding thus stimulates our imagination by calling for a new awareness of ecological responsibility and inspires new hopes for sustainable biotic existence and sustaining multispecies interconnections. It communicates a message of revaluing all Earthly agencies facing threats of extinction, generating the creativity to imagine better ethical responses that consider the voices of everything that is more-than-human—the diverse communities of flora and fauna that make our planet livable. In the ecological framework, ethical responsibility naturally emerges from the non-dualist, environmentally sustainable, and, above all, respectful ways of living together, which are contingent upon healing the wounded geographies that "shape who we are and the ways in which we are able to 'become with' others" (Rose et al. 2012, 2). Implementing an ethics of worlding in our social systems and cultural practices necessitates thinking from this awareness and enlarging our understanding of reality with ethical accountability for our entanglements, which means "intra-act[ing] responsibly as part of the world" (Barad 2007, 391). Barad's notion of intra-action is the key element that "*signifies the mutual constitution of entangled agencies*" (2007, 33). Intra-action clarifies well the ontological inseparability of the observers and the observed, as well as of ontology and epistemology in which practices of knowing and being are inextricably linked. If all living processes of nature from the subatomic to the human realm ineluctably participate in intra-active becomings, we can then re-imagine the entangled subatomic particles and biophotons with internal relations as specific kinds of material agencies disseminating their own stories with sedimenting effects in the

unfolding of reality. Hence the ethical implications of narrativity and creativity in the spinning subatomic world are defined by instantaneous connections and nonlocal communications whereby the process of entanglement obscures all boundaries.

Notes

[1] Light is made up of photons, but the material world is constituted by atoms with a nucleus packed with protons and neutrons, which are made up of quarks, named as such by the American physicist Murray Gell-Mann who was inspired by James Joyce's novel *Finnegans Wake* (1939) in which he saw the word "quarks." See Carlo Rovelli (2014, 31).

[2] David Bohm suggested "hidden-variables theory" as a possible explanation of the wave-particle duality. Since the experimenter either measures the momentum or the location of a particle but not both at the same time, Bohm thought that there must be a "hidden" guiding wave that determines the motion of a particle. In the double-slit experiments, particles do not go through one slit or another randomly but by choice, a choice Bohm claimed must be governed by a "guiding wave" when it results in the observable wave pattern. This is known as the "de Broglie-Bohm pilot wave," which unites the wave and the particle. Thus, according to Bohm, the hidden states must be real as they give the particle a real position alongside a real momentum at each point.

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