



Relationships and *Causation* in Living Matter: Reframing Some Methods in Life Sciences?

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Abstract

In this paper I want to enrich, on the methodological and epistemological side, an earlier review of mine (in which there are more details on the physics of electrodynamic coherence), aiming to stimulate attention to some seemingly trivial or irrelevant aspects, but, in my opinion, very subtle and of crucial importance in the study of living dynamics in various disciplines (physics, biology, medicine, philosophy of science). The conceptual core is: to understand that a living system cannot be conceived, and therefore neither studied, as “an object”, “a body.”

The (in essence) *relational* nature of the living being finds its foundations in dissipation, symmetry breakings and field theories capable to count for multiple levels of *vacuum* (such as Quantum Field Theory, QFT), and sees the living phase of condensed matter (on an aqueous basis) as a consequence of bosonic condensation of correlation quanta (the well-known Nambu-Goldstone bosons) over an extended and interrelated hierarchy of degrees of freedom to which a (super)coherent is associated state. In there the matter and energy components of the biological system are subjected to phase correlations to give rise to a holo-state, shared over the whole system, from which a *self*, endowed with continuity, emerges and thus also a biological identity rooted in a dissipative thermodynamic history.

However, this “identity” is like the river of Heraclitus’ anecdote: it is a flow and not an object existing in itself, nor static; dynamics, change, are all that lasts, while water, is always different. So holds for an organism that is, in fact, an organizationally closed system, but (and precisely because) thermodynamically open.

This condition implies that the study of any biological system is de facto the study of a flow of relationships, and the living system (whether a cell, a complex organism, or an ecosystem) should be conceived as a *process dissipatively coupled* to its environment and as a producer of responses following an autopoietic order, inherent in the very condition of coherence (as long as it exists). Once this is recognized:

- We obtain the possibility of reducing (without ontological discontinuities) sophisticated emergent properties (such as sensing, perception, semantics, teleology, adaptation, memory) irreducible to the deterministic laws of the elementary components of which, nonetheless, the living matter is composed (and to the laws of which it is therefore equally subjected);
- Such properties result in the emergence of “biological laws” that, in addition to physical laws, dictating action-reaction relationships, describe stimulus-response relationships (with enormously greater logical openness) valid only for the living state;
- The existence of these “laws” (analogical, but now physically grounded) forces us to revisit the definition of *causality* in biology, understanding that the method of inquiry must be revisited on both the theory and praxis fronts (details in the text);
- It is understood that the *complex* view is to be applied *ab initio*, but also advanced to a further step (on a quantum-

electrodynamic basis) in which the occurrence of not-only-diachronic causality in the living matter would be uncontemplable through “classical” observables only, considered within dynamical systems theory, chaos physics and complexity science. This gives rise to constructive methodological provocations, significant for research in biology, biophysics, and medicine, and for their application within humankind and its relationships to technology and Nature, in the name of a respectful and sensitive gesture towards the web of Life.

Keywords: Emergent properties; Complexion; Physical reduction; Symmetry breaking; Bosonic condensation; Electrodynamic coherence; Stimulus-response relationships; Semantics; Teleology; Causality; Biological sense

Premise: Presentation of the Problem

If we know the state of motion of the balls in a billiard table at time t_0 , it is possible, under the ideal approximation of perfectly elastic/conservative collisions, to predetermine the state of the system at time t_1 (whatever $\Delta t = t_1 - t_0$). Under that ideal approximation, the predictive power of the laws of motion would, in principle, be the same whether the spheres were 10 or 1 million. For systems consisting of only a few elements, such as a common 15-ball billiard table, the difference between the ideal and real cases is minimal; in fact, while also considering the friction term, the description obtained by using the classical laws of motion works (for rather short times, of course, within which the damping of motion is complete). But when the spheres were really a million or more, the description of the state of motion at time t_1 in the real case becomes impractical (not only because of computational limitations, but because of the multitude of paths in phase space that can be travelled by the system, given the same initial conditions, as a result of the unmovable stochastic fluctuations producing deviations from the “ideal” trajectories at each collision between the spheres and against the walls).

This is old history now Baranger [1], Kellert [2], and has been well dealt with by the dynamical systems, chaos and complexity sciences, which have revealed to us the existence of metastable states, attractors, Lyapunov exponents, dissipation, cyclic fluctuations, fractal dimensions, emergent dynamics, etc [3,4].

Totally different issue, however, concerns those systems (i.e.: living ones) that, although also constituted, as in the previous example, by immense multitudes of material elements (also qualitatively heterogeneous), manifest dynamics and emergent properties not at all traceable to stochastic processes and/or describable *tout court* by laws of motion of material micro-components alone. When it concerns biological systems, in fact, categories come into play in the temporal evolution of states (such as *meaning*, *teleology*, *adaptation*, *memory*, etc.) that-even in the advanced complexity paradigm-are not reducible to interactions described by deterministic laws (those involving fundamental

components, such as atoms, molecules, electrical charges, photons, phonons, etc.), hence they are not even computer-modellable. Yet, to those deterministic laws the resulting system must still be subordinate as well, precisely because it is also made up of those elementary components.

Clearly, then there is a need for an additional conceptual shift to connect the various epistemological levels. Below I will briefly summarize this problem (addressed extensively here Renati P [5] and here Renati P [6]) by discursively showing how it is possible to physically trace a causal continuity between the level of material components and the emerging level of physiology or organism behaviour, without falling into ontological discontinuities. In this way, it is possible to recompose a Cartesian split between *function* and *structure* that is still hard to die (just see how it has survived even in the constructivist theoretical scaffolding [7]) and irremediable within the still semi-classical approach of Quantum Mechanics (QM).

Another crucial aspect that radically distinguishes a living system from a “merely complex” inanimate system (such as an array of coupled pendulums, a heap of sand grains on an oblique plane, a set of seismic discharges, the magnetofluid dynamics of plasma in a nuclear fusion reactor) is that the living, as we shall see, in its intrinsic essence:

- Consists of “relation to,” of constant “trespassing” of and from itself in space and time (forward-purposes, fulfilment of needs-and backward-memory, phylogeny, “instinct”),
- Is characterized by an irremovable transcendence of itself, precisely in order to produce itself as a *self*, endowed with continuity [8],
- And therefore it does not exist as an observable system in itself (unlike a billiard table that also has a million spheres, or from a mass of gas that even exchanges work and heat with the environment), although we all have the illusion that we can take any portion of reality (whether it is a cube of niobium or a fox or a lymphocyte), place it in a controlled environment (a box or a petri dish), make measurements, and obtain data that are meaningful. In reality for living systems this is so only for a small subset of aspects and cases.

All of this forces us to problematize (as much philosophically as physically) the question of “what” we are studying, and “how” we have identified/isolated it, when we speak of a biological system, or organism, and poses profound critiques of the methodologies by which we identify cause-effect relationships in living matter.

Defining, indeed, a causal relationship between two or more physical events, within contexts composed of inanimate (i.e.: non-living) objects – disposing of laws that rigorously describe the constraints under which changes in states of motion, entropy variation, conservations of charge, energy, angular momentum, invariance relations (gauge, Coulomb, Lorentz, etc.), those of symmetry and their possible violations (like for CPT symmetry [9,10]) – is, under a minimum of approximation, usually quite simple, straightforward. And the effective methodology for determining or verifying such a causal relationship has long been well established: it is the empirical method of Galilean parentage; the one that, once we have identified the components (postulated isolable in time and space) and observables of an arbitrarily confined portion of physical reality, allows us to determine whether an event “A” is the cause of an event “B.” This approach is the only one used to date on the experimental front and is the backbone of the current “scientific method.”

This simplicity with which causal relationships can be defined in inanimate (macro- and microscopic) systems is basically due to the fact that in such “ordinary” material systems only action-reaction laws that are either perfectly deterministic (at meso and macroscopic scales) or that are deterministic, but (at very small scales) also subjected to a randomness implied by quantum fluctuations [11]. In any case, the transition of an electron from one state to another, for example, although described by a quantum probability function, is in essence a process governed by, and describable through, precise action-reaction laws that, on large numbers or long timescales, converge to the classical, bluntly mechanistic ones.

But when we concern living systems, as is well known, it is no longer possible to make use of a “comfortable” surjective relationship between a given input and a (predeterminable) output, as there are in force not only *action-reaction* relationships, but also *stimulus-response* relationships [12]. Indeed, kicking a stone is an event that is well describable by Newton’s laws, while kicking a cat is not, or is only so for part of the process (since a cat, in addition to changing its state of motion as a result of the transfer of energy and momentum, might also run away, attack us, make squeals or not, etc., without considering the kind of “perception” and physiology activated in the cat as a response to the “experience” it has undergone).

We all know this very well, but it is not so obvious that we really know *why*. Explaining further, let us ask: Why are material systems, such as living beings anyway – inasmuch as they are still made up of the same quanta of matter and energy as inanimate matter – no longer describable by deterministic laws (despite the fact that they must always be subjected to such laws anyway)? To that question, one could also associate this one: what is the difference between “making a measurement” of the energy of a photon by a semiconductor diode and “experiencing” light (by a cell, or a seeing eye)?

These questions, as is easy to guess, all converge to a fundamental question. If we have already understood that, for example, the biochemistry found within biological matter is the *outcome* of precise conditions (i.e.: well-defined and non-ordinary physical states) that connote it (a fact well evidenced by the near impossibility of reproducing such biochemistry *in vitro* [13,14]), the point lies in what is the difference between the physical states underlying a living system and those proper to an inanimate system: what is the real difference, physically speaking, between a living and a non-living (between a living cat and a just-dead cat¹)?

Perhaps by deepening insight on this point, it becomes possible to answer in a well-founded way the initial question regarding *why* in living systems a description by action-reaction laws only is not possible and *why* it is not so obvious to define *causal relationships* between inputs and outputs in general.

Complexion and false autonomy of the “parts”

Living systems are highly ordered systems, whose structural states and developments do not occur according to random succession, but neither do they occur according to predetermined series (E. Schrödinger spoke of “aperiodic crystals” endowed, that is, with order without repetition [15]). Within living biological matter, entropy is minimized [16-21] – and in the following we will briefly review why – and the level of ordering is pushed to the limits of possibility, simultaneously involving spatiotemporal scales ranging from electron transfers, protein folding rates, cellular respiration cycles, membrane pulsations, to endocrine and circadian rhythms, and beyond to the life cycle of the considered living being. Yet despite this very high degree of ordering, even under perfectly known boundary conditions, they are not

¹ Keeping in mind that the absence of “functioning,” which made the cat “alive”, cannot be traced, in the just dead cat, to a change in chemical composition, since it is still absent. Clearly, there is the cessation of certain conditions (states) underlying the “concertation” of material and energetic components in the living state, which, as we shall see, are necessarily structural conditions as well (otherwise they would be just an abstract idea).

describable a priori by any set of states: placing, for example, an earthworm in a volume of earth of known composition, we cannot tell what it will do at each instant.

Precisely because there is such a high degree of ordering, the argument that would impute the impossibility of adopting apodictic descriptions to the wide range of states that can be occupied according to statistical and probabilistic criteria (as in the case of the million spheres mentioned above), would be immediately refuted by the fact that, if this were the case, then to speak of “functioning” and “order” in biological matter would be impossible. Indeed, just the multitude of events (chemical and physical) per unit of time that are carried out by even a single cell, if they were conducted probabilistically, would mark the cessation of that cell’s very organization and its existence; or, in a multicellular system such as a human being, such randomness would imply that if certain molecules were encountered, someone would say “good morning”; whereas if others were reacting with each other, a certain hormone would be synthesized; and if even others were doing so, a “cancerous” cell would be created. And it is here that the problem arises of what we can really and logically consider to be the “cause” of biological phenomenology (such as physiology) and “where” (and how) to look for it. This is a key issue for the decoding of what we usually call “disease” and for a more consistent understanding of the related aetiology (we discuss this in Section 6).

Of course, on the question of why in living systems a deterministic description conducted through action-reaction type laws no longer applies, many try to trace the answer (not completely wrong) to the dynamics of complexity and *emergent properties* [3,22,23]: a system that develops successive levels of organization, typically consisting of a large number of agents (and a great variety of them, like a living being), not only expresses an evolution of its phase space that is impossible to predetermine even under the same initial conditions (either because of computational limitations or nonlinear divergence dynamics) [2,4], but develops new descriptive categories, physical quantities and observables that are absent at the level of individual components (such as, for example, the index of refraction or the density of a diamond are quantities that are meaningless and not attributable to the level of individual carbon atoms).

Such a perspective is already a good step forward, epistemologically speaking, as it sets forth the problem of the *logical openness* of a process, that is, the amplitude of output configurations that can be adopted with the same stimulus and initial conditions in input [24] and it validates the limiting and naive position of certain reductionisms [25].

However, this view is not sufficient to explain the non-

randomness and surprising “appropriateness” (*sense*) found in biological functioning (evident, for example, in all phenomena of adaptation), and it still leaves unresolved the physical (and, we might say, ontological) question concerning the true reasons for a self-updating ordering like the one observable in organisms, in which phenomena appear (such as memory, evolution, behaviour, perception, sensing, semantics, etc.) which:

- a) in that approach are totally irreducible to a purely *bottom-up* description, that is, starting from the microscopic level of components and then producing the system as a *whole*.
- b) and imply a type of synchronic causality, in which the ‘causes’ are even aims, purposes (i.e.: teleology).

Therefore, unless one invokes vitalistic, such as ‘entelechy’, ‘vis vitalis’, or metaphysical supplements such as a ‘soul’ (thought of as an entity in its own right), infused from the outside (an option I would avoid, as it would only move the problem one step further, implying, moreover an untenable ontological dualism in which reality is no longer one [26,27]) the central issue is to succeed in defining, at least qualitatively, a physical principle, a framing of the question, which is capable of reducing the unfolding dynamics of the living system to *first principles* without, however, collapsing its intrinsically holistic, relational and semantic nature.

Before delving into the merits of which physical states characterise the living phase of matter, and which motivate *e fundamento* why a living being is never “*per se*”, and before exploring what these states imply from a methodological point of view, it is useful to recall what it means to be capable of a properly and factually *complex vision*.

Already in 1917, D’Arcy W. Thompson, in his biological physics essay *Growth and Form*, reminded us that «when we analyse a thing in separate parts, we tend to give them undue importance, exaggerating their apparent independence, hiding (at least for the moment) the essential integrity of the composite whole» [28]. To ‘over-emphasise’ and not mediate the arbitrary “parts” within the ontological relations they have with each other and with the context is to describe “things” without the relations and to omit the intrinsic complexity given by the ontological primacy of the relations over the eidetic and represented “parts” [27], even if only ‘for the moment’. Because then, shortly afterwards, this momentary reduction unfortunately becomes permanent.

In ‘scientific’ biology and medicine, this practice is ubiquitous and the price we are paying is very high: besides the reductionist and de-personalised approach to the individual by ‘protocol medicine’, which in fact collapses a living (human) being to its clinical parameters, there is in

the field of research the continuous generation of multitudes of data from studying at the microscopic level (with very expensive experimental setups) details such as replacement of functional groups on proteins, methylation of genome tracts, markers, steric variations of enzymes, pH changes, blood concentrations of hormones, etc. ... taking it for granted that they are the reason (the *why*) of what a living system expresses, when in fact they are, at a different scale of observation, only the way (the *how*) by which the living being itself conducts its vital *logos*, its physiology and its homeostatic/homeoretic [29] coping with its environment. This applies as much to an amoeba as to a mammal or an olive tree plantation.

From the criticism just made, which we will substantiate in a moment, it is clear that looking for *causes* in the microscopic scale of what is observed in physiology, for example, is an error of method and a conceptual misunderstanding. Investigation in the microscopic, capable of characterising the species and reactions involved, is undoubtedly very useful for becoming aware of the detail of the process and understanding its modalities (and in some cases for knowing where to intervene productively to divert a potentially dangerous pathway), but it tells us very little about the *why*, and *why* precisely that type of observed physiology occurs. More importantly, such an approach *a priori* prevents one from viewing that process with an open-mindedness and a questioning necessary to leave a cognitive space to understand the *biological sense* of that event (of that *response*).

It is obvious that, in order to legitimise such stances, it is first necessary to describe how and why a living being is a process of coupling to the environment in which every configuration physically 'means' something for the homeostasis of the living being itself, which acts as a *hólos*. As we shall see in a moment, the emergence of a biological *self* makes it necessary to speak of any living thing in terms of a *perceptive process*, and thus to understand it as a flow of meanings, and not as a 'physical object' in the ordinary sense.

The observation of living matter that seeks causes in resolving microscopic events, forgetting that living matter is a *semantic process*, runs the risk of producing the same *defiance* as studying bridges resting on lands or slopes without roads and/or canyons: taken out of their contexts, it is impossible to grasp their role and meaning. And so, for example, the simple shape of the bones in an animal, their mutual connection, the architecture and distribution of apatite structures in the various zones of the bone, cannot be understood as if those bones were pieces of a puzzle created before the puzzle itself, and without that 'puzzle' (called an organism) were alive and those bones were stimulated.

In fact, D'Arcy W. Thompson said about individual aspects and "parts": "we can study them separately, but that is a concession to the weakness and narrow vision of our minds" and again "[they] are separate entities only in the sense that they are parts of a whole that when it loses its overall integrity ceases to exist" [28].

The culture of complexity has always (since around the 1960s Kauffman [30]) denounced this type of reduction that begins as provisory and then - due to cognitive necessity and cultural choices - mistakes the unrelated object for the real object, losing a cognitive gesture, a *complexion* (in the words of the ontologist Alexius Meinong [31]) that must be acted upon before any reduction, not out of ideology, but out of ontology of the real [27].

Symmetry Breakings

If, on the one hand, complex thinking is the condition without which we can create the cognitive space necessary for a critical attitude towards the methodological problem in order to move towards more refined and truthful approaches in the scientific investigation of the living realm, on the other hand, the picture cannot be completed if on the physics side, we are not provided with the basics, the laws at play, to reduce the typical features of the living realm and to understand how they emerge from the interactions between the fundamental components of condensed matter (atoms, ions, molecules, electrical charges, and various types of excitation).

Over the last 50 years, physics, in support of the important branch of theoretical biology (nowadays, compared to the greater ferment at the beginning of the last century, too neglected in favour of an experimental and molecular approach²) is allowing us to delve more and more into the questions of how condensed matter is able to produce itself in its *living phase* [19,32-35]. The entire discussion will not be reported here, so we refer readers to Renati P [6], but we shall however review the most salient aspects concerning the physical basis of living matter, which are useful in developing the theme we wish to focus on (which in a nutshell is: understanding why we cannot apply a general empirical method to the investigation of causes in biological matter).

What emerged from the refined and articulate theoretical foundations laid by outstanding scholars in Quantum Field Theory (QFT) [36-40], of Spontaneous Symmetry Breakings (SSB) [41] of isomorphisms between

² That does not consider how much the experimentum, from the conception of its layout, to what it is supposed to be looked for, to the interpretation of its results, is a direct consequence of the *Weltanschauung* of the one who is studying and what factors and observables it contemplates as 'variables' in the process it intends to investigate.

fractal (*scale free*) systems and *squeezed* coherent quantum states [42,43] and the dissipativity and thermodynamics of open systems [44-49] is that the structural and functional ordering of a biological system (obviously not stochastic, but also not predetermined starting from fundamental laws), is a condition that dynamically emerges as a consequence of symmetry breaking over a wide range of degrees of freedom of the system [33,39].

In the mechanism of spontaneous symmetry breaking (SSB), the symmetrical properties of microscopic dynamics imply the existence of fields that, delocalised over the entire system, induce the formation of ordered configurations of the elementary components. In quantum physics, the wavelike nature of these fields is associated with quanta, whose role is that of messengers, or 'carriers', responsible for the correlation and ordering between the quanta of matter and the sharing of their quantum state between them.

The quanta associated with such dynamics (i.e. spontaneous symmetry breaking) are called Nambu-Goldstone (NG) quanta (or particles or modes) [50-53] and, in QFT, the dynamics that governs the behaviour of the elementary components of a physical system in such a way as to generate the formation of ordered structures has general characteristics because, *order is the absence of symmetry* [39,42]. The theorem proving the existence of NG quanta, also called the *NG theorem*, has been validated by robust experimental evidence in both high-energy physics and condensed matter physics [40]. For example, the phonons in crystals, magnons in ferromagnets, polarons in ferroelectrics, etc. ... are quanta of NG and are responsible for the space-time arrangements observed in such systems, carrying the specific correlations that produce the observed order, depending on the case (geometric, magnetic, rotational, electric, etc.). Similarly, even at very different scales, as in cosmology [54], or where non-trivial forms of order emerge, as in biological systems, the condensation of NG bosons relative to the degrees of freedom on which symmetry is broken, underlies the emergence of *order parameters*.

The NG quanta are bosons (i.e. many of them can occupy the same physical state), under ideal conditions (i.e. in the absence of 'edge effects') they have zero mass and in their low-momentum state they do not contribute to the energy of the fundamental (vacuum) state: the emergence of order is therefore the manifestation of the condensation of NG bosons in the vacuum (ground) state.

To make it clear that order is the dynamic consequence of symmetry breaking (where correlation bosons condensation occurs between the components of the system), let us start with a simple example: the creation of a crystal lattice from the cooling of a liquid or vapour.

In a liquid or a gas, the atoms (or molecules) experience a condition such that their positions can be translated in space without implying a change of the macro-state, i.e. translation in any direction of space generates a configuration equivalent to others, which therefore has an identical free energy (and entropic content): in practice, a gas or a liquid are symmetrical systems on the degrees of freedom of spatial translations. When the system is, for example, cooled below a critical threshold (the solidification temperature or, in general, the condensation temperature), this spatial translational symmetry is broken, such that the atoms can occupy only defined sites at defined reciprocal distances (i.e.: integer multiples of the lattice step). This condition, in a field view of condensed matter, does not refer to short-range forces, as is often approximated in the generally accepted corpuscular view (see the critique in [37,38]), but to the establishment of long-range correlations in the form of stationary elastic waves (in the case, the phonons) emerging from the intrinsic oscillation that the components already have when isolated (due to quantum fluctuations) and that, having passed a density threshold, they set in phase because they are able to reach a level of minimum energy (vacuum) lower than the one they had when isolated (in the vapour) or less correlated (in the liquid).

For this reason, if the system is open and can dissipate an amount of energy in the form of entropy (i.e. the latent heat of condensation), a phase transition from a disordered, disordered state to a more ordered one occurs spontaneously [38,39].

In this new state, whose vacuum level is lower than the previous one by a quantity called the *energy gap* (which, in electron volts, expresses its thermodynamic stability, i.e. how much energy has to be expended to send each component out of the ordered phase), translational symmetry is broken as it is no longer possible to move along any direction of the system while encountering the same *potential landscapes*: moving along one crystalline direction, for example, is not equivalent to moving along another arbitrarily chosen one (unlike in steam).

This suggests that (i) order is a lack of symmetry and (ii) is the consequence of quantum dynamics in which the components of the matter field phase their oscillations, creating a correlation that manifests itself as a field composed of a discrete set of bosons (phonons, in the case) [55]. This correlation field is as a matter of fact a *classical field* (the *order parameter*) as it is insensitive to quantum fluctuations and gives rise to the macroscopic (classical) stability of large quantum systems of matter (such as a piece of diamond) [39]. The crystalline ordering of atoms in their lattice sites thus appears as the dynamic effect of spatial translational symmetry breaking; the ordering on other degrees of

freedom is produced by other relative broken symmetries.

The quanta of NG enter fully the list of elementary components of the system, i.e. the mediators of correlation are *structural* elements! They are an integral part of the structure, true elementary components, which can be measured by scattering techniques and of which a spectrum can be defined [56].

However, they cannot be ‘extracted’ from the system, as can be done, for example, by extracting an atom or group of atoms from their lattice sites in a crystal. For example, there are no freely propagating phonons outside a crystal, since they exist only as long as, if and only if, the crystal exists. Above the crystal’s melting point, only the atoms that made up the crystal prior to melting remain, but not the phonons. The latter are *the collective way of being* of the atoms in the ‘crystal’ state function. Thus, the quanta of NG are identified with the *function* of the specific order for which they are responsible, and thus they also express the functionality, the system’s way of being. Without them, the system ‘is another system’, i.e. a system with completely different physical properties (functionality and thus structure) (in which there is no “that kind of ordering”).

Since the NG bosons, as already noted, determine the phase correlation over large distances of the elementary components, a change in the degree of condensation is equivalent to a change in the intensity of the correlation over long distances. It is this correlation that is called *coherence* and the condensed state is called a *coherent state* (over a defined degree of freedom). The stability of the condensed state referred to is thus the (thermodynamic) stability of the coherent state [38].

As we can see, what the QFT approach dissolves is precisely the Cartesian dualism (of previous Platonic and then Aristotelian inheritance) between *structure* and *function*, which, depending on the context, takes on many declinations (e.g.: form-substance, information-matter, software-hardware, psyche-soma, soul-body, mind-brain, god-cosmos, and so on...) [27].

The formalism of QFT produces a *unified vision* because it describes a multiplicity of non-trivial phenomena through the dynamic relationship between the microscopic and macroscopic (mesoscopic) levels, without the need for *ad hoc* added operations: it is precisely the coherence of bosonic condensates that makes this transformation or transition of scale (from the micro to the macro) possible. The *order parameter* classical field characterises the physical properties of the system as a whole; hence its macroscopic behaviour is not “superimposed” but rooted in the quantum description of the microscopic components. Systems in

which some sort of ordering is observed are therefore called *macroscopic quantum systems* [55] not because they are composed of elementary quantum components (atoms and molecules), which is trivially true for any physical system; but because their macroscopic properties are incomprehensible except in terms of the underlying quantum dynamics of the elementary components.

As can be understood from what has been discussed so far, the transcendence of Cartesian dualism (in scientific disciplines often declined as the “matter-information” duality) is only possible within a theoretical frame of reference that admits the existence of a multiplicity of void levels, such as QFT, so that phase transitions and symmetry breaks can be described dynamically. Such descriptive power is not practicable in any classical or semi-classical theoretical framework, like the (incomplete [57]) QM within which, according to von Neumann’s fundamental theorem [58,38], a set of molecules, or atoms, or electric charges, interacting by means of forces, admits a unique ground state (a single vacuum level and, hence, a phase) and phase transitions are thus not allowed [39].

Dissipation

The condensation of bosons to form the coherent state clearly expresses that the biological system, being a (super) coherent system, as we shall see in the next session, is permanently coupled with the external environment; it is therefore an intrinsically open system. Isolating it implies the elimination of its functionality, its destruction (its death). As Vitiello has well pointed out [52,55], the thermodynamics accessible today (suitable for isolated or closed systems) requires that in the study of an open system, let us say the ‘ α system’, we proceed to ‘close it’ by also considering the environment in which it is immersed, so as to constantly have the equilibrium of the flows of matter, energy, etc., between the α system and the environment. We can refer to the latter as ‘system β ’; focusing on energy exchange, the energy leaving α , $E(\alpha)$, must be equal to that entering β , $E(\beta)$, and vice versa. It must hold in each case that $E(\alpha) - E(\beta) = 0$. The set (α, β) of systems α and β thus behaves as a “closed” system, for which there is no flow of energy either into or out of the system.

In order to respect the energy balance (and the flux balance of any other quantity exchanged between α and β), the β system behaves like a copy of the α system, in the sense that it behaves just like the α system as far as fluxes are concerned, provided that the direction is reversed: in fact, what is an input for α , is an output for β , and vice versa. Clearly, reversing the direction of flow is equivalent to exchanging α for β , or vice versa.

Since technically the direction of the flow is reversed by changing the sign of the variable 'time', we can say that β behaves like the copy of α for which the direction of time has been reversed (β is the reversed time copy - *time mirror image* - of α). In summary, β is the system that describes the environment in terms of the equilibrium of the energy flow of α and is also the mirror image of α in a reflection in the time axis: Vitiello expressed this effectively by saying that β is the *double* of α [55].

Thus, in the case of open systems (such as living organisms, for example), we must consider their doubles, and this offers some interesting points for reflection.

First of all, given that α denotes the living system considered (organism, cell, brain, ecosystem, etc.) and β its thermodynamic *double*, the energy balance $E(\alpha) - E(\beta) = 0$ is equivalent to the relation $N(\alpha) - N(\beta) = 0$, since $E(\alpha)$ and $E(\beta)$ denote the energies due to the number of quanta involved in the exchange. $N(\alpha)$ and $N(\beta)$ of α and β , respectively, are condensates of quanta in the fundamental state of (α, β) , i.e.: $E(\alpha) = \Omega N(\alpha)$ and $E(\beta) = \Omega N(\beta)$, with Ω the energy of a single quantum. This relationship, which describes the energy balance between α and β , is rich with meanings. For example, it tells us that $N(\alpha)$ and $N(\beta)$ can certainly vary, provided, however, that these variations compensate each other. The fundamental state of the entire system (α, β) must be the condensate of an equal number of quanta referable to the system α and (oppositely) to the system β , so that the correspondence $N(\alpha) = N(\beta)$ holds at any time in the history of the system α .

Another consequence of the relation $N(\alpha) - N(\beta) = 0$ is that it does not establish either the value of $N(\alpha)$ or that of $N(\beta)$. It only requires that they be equal. There is therefore an infinity of values for $N(\alpha)$, and correspondingly for $N(\beta)$, for which the relation is satisfied. Corresponding to these (infinite) values there exist as many fundamental (*vacua*) states of (α, β) indexed by those values of $N(\alpha)$, which are orthogonal to each other (technically they are said to be "*unitarily unequal*") [39,55]. The most profound consequence of this fact is that, as already mentioned, we are forced to use a theory that, to be true, admits infinite fundamental states. Such a theory is precisely the QFT, and not the QM [50].

This is very important for understanding living matter, since the amazing degrees of order by which it is characterised implies that symmetry with respect to temporal (before/after) and spatial (translations and rotations, etc.) transformations is broken: here and now is not the same as there and then [59]. Thus, when ordered arrangements appear, corresponding symmetries and invariances in space-time break down [32]. It is understood that living matter is a system of constraints and configurations, rather than a

collection of interacting (albeit sophisticated) components.

Therefore, the formation of each configuration (α, β) is made possible by symmetry breaking induced by external stimuli, whereby:

- a) A *multiplicity* of possible configurations is permitted by the existence of multiple (infinite) possible fundamental states in the scenario offered by the QFT;
- b) The *coexistence* of these multiple configurations in the space of states is given by the fact that these fundamental states are *orthogonal* to each other;
- c) Their *succession* in time is given by the *dissipative dynamics*, i.e. the thermodynamic history, i.e. all possible pairs of values of $N(\alpha)$ and $N(\beta)$, satisfying the relation $N(\alpha) - N(\beta) = 0$, which are assumed.

The succession of states of the living system is actually a time-dependent (dissipative) thermodynamic history, along which successive states depend on the previous ones in a deterministic manner, but a priori unpredictable due to the dialectic with its thermodynamic *double* (the environment, including every possible quality and type of stimulus).

It can already be understood here that the *semantic* aspect [60] of an "environment + living being" relationship, of a stimulus, is in fact always a *physical configuration* (and not something abstract or superimposed on the energetic/quantitative term of the stimulus itself). Therefore, when speaking of living systems, one can never speak of 'physical events' per se, but always of the *meaning* of events for that specific living being [61], in that specific state of its thermodynamic history, in that specific configuration [5,45,46,62]. Here the term meaning takes a physical root in 'what the given configuration thermodynamically implies for the thermodynamic stability of the living being' and is not an invariant, as well as being a particularly analogical, qualitative observable, but not unworthy of inclusion in observation [26]. Quite the contrary.

In the next section, we also see why the thermodynamic stability of the living coincides with the tension to maintain homeostasis (i.e. coherence).

Coherence: The Living Phase of Matter

The thermodynamic openness, in addition to the dissipation of entropy required to configure an ordered phase and for the inalienable continuous exchange of quanta of matter and energy, is even better understood by delving into what the coherence condition really implies.

Living systems, both individual cells and those of multicellular organisms, are generally made, by molar

fraction (not by weight!), of a percentage of water close to 99% [63,19,64]. This fact essentially makes them 'aqueous matrix sculptures', in which water is organised in a special electrodynamic configuration through the dialectics with other molecular species [63,65]. As Albert Szent-Gyorgyi already recalled [66,67], to study biological systems without understanding the role of water (far from being a mere chemical solvent or a mere 'filler') is equivalent to not having the vaguest idea of how and why living matter produces the phenomenologies we are narrating [19,63].

More and more experimental evidences [68-71] and descriptive approaches [72] have shown that ordinary liquid water is a biphasic system.

In particular, within the description of Quantum Electrodynamics (QED) conducted without the approximations usually used in the perturbative regime [38], it is possible to demonstrate from *first principles* that many of the anomalies typical of this element (such as trends in density, specific heat, coefficient of thermal expansion as a function of temperature, which cannot be justified from molecular dynamics models that only take short-range interactions into account [73-76,38] are ascribed to the fact that a fraction of molecules in the system (whose abundance is inversely dependent on temperature [77,68] is organized in collective, coherent oscillations.

Such coherent oscillations exist within regions roughly as large as the wavelength of the electromagnetic mode coupled to the aforementioned oscillation between two electronic levels and whose energy size is equal to the spectral distance between the two levels on which the electron of each water molecule oscillates in this dynamic [77,78]. These regions are called *coherence domains* (CD) and, for liquid water, coherence being established between sp^3 and $5d$ levels, their size is nominally about 100 nm. In reality, at temperatures other than zero Kelvin, this size is reduced due to thermal noise, which sends a fraction of molecules *out of tune* (which goes to feed the incoherent, gas-like part of the system) [36,77,78].

As mentioned above, the new fundamental (vacuum) state of the coherent phase has a lower energy than that of the incoherent molecules by an amount called the energy gap, which expresses the thermodynamic stability of the coherent state with respect to de-cohering agents from outside (such as temperature, photons, fields in general and mechanical forces). If the excitations are small enough (smaller than the energy gap), the CD receives them acting as a whole, if they are larger, one or more oscillators are put out of coherence and 'poured' into the normal (incoherent) fraction [76,38,75]. For ordinary liquid water - where coherence is established on the oscillation of the electron cloud per each

molecule (in practice 1 electron per molecule) - this energy gap is of the order of 0.2 eV, depending on temperature and position within the CD (it is smaller in the periphery than in the centre, of course) [75].

The molecules belonging to the coherent fraction constitute a set in which the phase is well defined: their common wave function is defined by eigenstates of the phase (φ), which is the quantum observable complementary to the 'number' observable (N): the uncertainty (Δ) relationships expressed in natural units (where $h/2\pi = c = k_B = 1$, where 'h' is Planck's constant, 'c' is the speed of light in vacuum, 'k_B' is Boltzmann's constant) turns out to be $\Delta\varphi - \Delta N \geq 1/2$ [38].

In a perfectly coherent state, the number of oscillators becomes completely uncertain, while the phase, the wave-like aspect of the field (in fact 'classical' in that it is stable) is precisely defined. This implies that in a coherent state the individuality (and countability) of the oscillators loses physical significance, since a field of uncountable quanta (in this case a matter field, coupled to an electromagnetic field, whose massless part is self-confined in the coherent phase as a *quasiparticle* [79-81,41,42] is the only definable object [57,38].

This is equivalent to having a minimisation of the uncertainty of the phase ($\Delta\varphi$) and thus a maximization of the uncertainty of the number of quanta (ΔN). For this to happen, the system tends to have a large number (N) of quanta because $\Delta N \leq N$, and to have a continuous cross-over, an exchange, of the same between the coherent phase and the external environment. Since the coherent state is thermodynamically more stable, as it has a lower vacuum level than the disordered state, coherent systems have a tendency to share their oscillations with other systems with which they are able to resonate (so as to increase N) and are open systems in which ΔN is further increased by continuous exchange with the environment. This is a fundamental characteristic for understanding how a living system, de facto a (super)coherent system, is in essence an open flow of quanta of matter and energy, i.e.: it exists as an *exchange*, as a *coupled process*, as a *relationship*, as a resonator that shares its oscillation phase with everything that can.

Therefore, as phase correlations are non-local correlations, which do not imply the exchange of any travelling energy (consider the Bohm-Aharonov effect [82,83]), always within the theoretical framework of QED, the coherent essence of living systems has suggested a more mature definition of 'ecosystem' as region of space-time within which living systems share the oscillation phase on specific electromagnetic modes that, at large wavelengths, cover very large spatial ranges (even of the order of

kilometres and more) [84,45].

Within biological matter, due to interplay with other molecular and ionic species, as well as the ubiquitous presence of interfaces and niches that further stabilise coherent water domains [17,85] compared to ordinary bulk liquid (where, at room temperature and pressure, this fraction would be less than 50% [75]) the degrees of coherence are many and all interrelated with one another so that the system is also mechanically rather constrained [19,63,65], this is why biological matter, although consisting of 90% or more water, is in a sol-gel state and is somewhat 'solid' [86,87].

The size of the various types of coherent domains that can be established (on different degrees of freedom, such as oscillations of the electron cloud on different possible excited levels, dipole spins, ortho-para spin fluctuations [88,89] and many others relating to the water molecule alone [90]) is never smaller than the maximum distance between any surface (membrane, molecular chain, etc.) and another [91]. Thus, the entire water matrix in living matter experiences multimodal coherence, termed *supercoherence*, which allows for general 'multiplexed' phase correlation throughout the system (be it a single cell or a multi-cellular organism, but to different degrees) [63,85].

One of the most difficult aspects to understand within molecular biology - capable of identifying the 'building blocks' participating as reagents in biochemical events and defining their products - has always been the fact that such events occur with incredible efficiency, an extraordinary degree of precision and timing [35,65]. This ability to perform biochemical activity also allows living matter to express one of its most sophisticated characteristics, impossible to simulate in vitro, which is the capacity to perform *cycles of chemical reactions*, [65] i.e. series of reactions between reagents perfectly selected out of a variety of others, co-present in the cellular landscape and capable of reaching a step that is the same from which the series can restart (think of the Krebs or Calvin cycles, for example). How can this be explained...?

Trying to summarise this very articulate aspect (for more in-depth discussion see [6,63]), it should be remembered that every chemical species is first and foremost a physical species, i.e. an oscillator characterised by its own precise frequencies (modes). Given that the coherence established on a given mode is a dynamics in which only oscillators capable of resonating on that mode (i.e., oscillating at that frequency) can participate, it is clear that the chemical species participating in the construction of biological matter are those that possess proper modes of oscillation (we could say spectral lines, over the entire electromagnetic range) shared with those of the super-coherent aqueous matrix and

with at least some of the other molecular species present different from H₂O.

Where there is a coherent phase, there are regions within which a background field (oscillating on defined modes) acts as a director and coordinator of the molecular encounters. More precisely, where there is a gradient ($\nabla(A^2)$) of the electromagnetic field, \mathbf{A} , such as that self-trapped within a CD of water molecules and decaying exponentially outwards, having frequency at a given instant ω_{CD} , the following dynamical laws apply for the molecular or ionic species present [65]:

$$\mathbf{F}_{rep} = -\frac{Q^2}{M} \nabla(A^2) \quad (1)$$

$$\mathbf{F}_{i-CD} = C \frac{(\omega_{CD}^2 - \omega_i^2)}{(\omega_{CD}^2 - \omega_i^2)^2 + \Gamma^2} \nabla(A^2) \quad (2)$$

$$\mathbf{F}_{i1-2} = C \frac{(\omega_1^2 - \omega_2^2)}{\left[(\omega_1^2 - \omega_{CD}^2)^2 - (\omega_2^2 - \omega_{CD}^2)^2 \right] + \Gamma^2} \nabla(A^2) \quad (3)$$

The first equation applies to every electric charge and describes the ponderomotive force term, always repulsive, with intensity proportional to the quantity q^2/m (where q is the electric charge and m the mass of that charge); the second equation expresses the selective attraction/repulsion force in relation to the difference in the "eigenfrequencies" (i.e. between that of the background field and that of an i -th species, ω_i , present in the system); the third expresses the same selective interaction on a resonant basis in the presence of two chemical species (1 and 2, and respective eigenfrequencies ω_1 and ω_2); C is a constant and Γ a damping term [78].

These algebraic relationships describe the reason why ordered and efficient reaction paths exist within living matter. The first reaction, in fact, expresses how each set of electrical charges arriving on the periphery of a CD is strongly polarised by decentralising the lighter charges (typically electrons) much more outwardly than the heavy charges (nuclei): this polarisation leads the molecules to a strong instability that makes them much easier to react, accelerating the reaction kinetics as the activation threshold is reduced [63]. The other two equations express how only certain species arrive at the CD surface not randomly: at a given instant, only molecules with the appropriate proper (resonant) frequency can be brought to encounter one another (typically at the CD interface, where the field gradient is maximum).

Once the reactant species have been convened and activated, it is the water CD that catalyses the biochemical reaction (typically an oxidation-reduction reaction) by

releasing electrons (which in the coherent phase occupy states very close to the ionisation threshold and are therefore easily released at charges below 0.4 eV [78]) or by emitting field quanta (biophotons [17,92-94]). This intermediation implies, however, a change in the state of the CD, with a consequent change in its own frequency, now making that CD capable of attracting other reagent species and thus enabling a second reaction step. And so on.

The interesting aspect is that the undertaken reaction paths (decided by the succession of modes of oscillation of the coherent fraction) are deterministic and not random at all, but not predetermined, since they are governed (i) by the entire thermodynamic history that preceded a certain instant and that determined the coherent configuration of the CD at that moment [78] and (ii) the current boundary conditions regarding various factors (reagents and their concentrations, environmental fields, phase correlations, macroscopic thermodynamic variables, etc.) that influence the modulation of the CDs' own frequencies and thus how a given input will be transduced into output.

The supercoherence of living matter consists in the establishment of further levels of coherence due to the dialectics of coherent water with other molecular species, which act as recipients of quanta of free energy released by CDs (in the form of electrons or photons or rotary excitations in which angular momentum transfer occurs [38,77] that are not allowed to relax thermally (otherwise it would mean that they would lose coherence and that would cost energy [76,77]). Coherent domains in collaboration with other biomolecules then act as multimodal *lasing* devices, extending coherence to the next step, from which others and further ones stem, in a retroactive and dialectical genesis [65,78,91].

Supercoherence is a crucial condition regarding the emergence of 'stimulus-response' laws because each stimulus, if small enough not to destroy coherence in its entirety, is received by the unicum of the coherent whole, not by individual, numerable portions of it. This aspect expresses what is physically meant by the emergence of a *self* within which a single molecular event affects the entire organism as it is concerted by the entire supercoherence (since each species of oscillator shares, on at least one degree of freedom, the eigenstate of the phase with others that, in turn, share it on still other degrees, etc., so that it ultimately results in a network of interrelated and interdependent coherences) [63].

A nutrient detected (*sensed*) by an amoeba, for example, implies that the possible interaction between receptor and ligand is in fact an event 'known' by the whole amoeba because that receptor is part of a *choir* of oscillators that

share a phase eigenstate (the state change of 'one of them' is the state change of the whole). This is why the single event of the interaction between nutrient and membrane is 'known' by the whole amoeba: because, as long as a system is (super)coherent, only the field of matter having a well-defined phase has physical reality (not its numerable components) [38,39,44]. This is a first point that dictates the difference between 'making a measurement', e.g. of the chemical composition of a food, and 'experiencing' it, up to the emergent property of 'taste') [6].

The Emergence of Perception, Memory, Adaptation, Meanings and Biological Laws

As it's clear from what has been said so far, an elementarily coherent system, such as a CD of liquid water, could be said to be already a system capable of producing "responses to stimuli" and not just "reactions to actions." This could apply because, acting as a *unicum* that depends on the antecedent thermodynamic history and that has at its disposal multiple possible configurations (ordered and coherent) at essentially the same energy, it can produce – as a result of a known input (that does not destroy the coherent state) – a variety of states in output.

However, this is obviously not sufficient to speak properly of "responses" and "perception" (*features* typical of the living state only). The distinction - now we explain it better - lies in the term of supercoherence, which implies total correlation over all living matter in the organism. It should be made clear that such a high degree of ordering, by no means implies rigidity and stereotyping of responses, since the hierarchy of coherence ("nested") does not concern a total and fixed *phase-locking* of all oscillators, but rather implies a complete interrelation of each level of organization, though permitting its organizational closure.

This is possible because of the tunability of the relationships that are in force between working frequencies proper to the various hierarchical levels of biological matter and its topological compartmentation [18,85,95] in which fractal properties are found [96], a condition that also allows the management of free energy transfers from one coherent scale to another *on demand* (i.e., by modulating the eigenfrequencies so that they enter a condition of resonance, quasi-periodicity, or complete incommensurability, like when their ratios equate irrational values, e.g., the *golden mean*) [6,5,97-99]. The presence of multiplexed coherence extended over the whole system, even to the point of allowing the emergence of the *self* in which the whole is the new "character," compressive to the possibility of having various districts work independently, can be understood with the metaphor of the *jazz band* in which the common phase (i.e.: the musicians' being a *tempo*) does not imply their having

to play the same notes and at the same moments, but also allows (and indeed encourages) improvisation (generated moment by moment by what happens as they go along in the music itself). Indeed, wisely Mae-wan Ho spoke of biological matter as a *jazz quantum* in which there is no “conductor,” but an autopoiesis of the music from the music itself played on the supercoherent water connectome [100,101].

A simple CD cannot already be said to be a living thing, therefore, because where coherence is in force over a small number of degrees of freedom (such as, for example, within an ordinary volume of water, over the oscillation of the electronic cloud of the molecule, over dipole spins, over the plasma oscillations of any dissolved electrolytes [90]), sorting and entropy minimization are not sufficient to zero out the number of thermodynamically equipollent microstates, so the system is allowed to still be “itself” (macrostate) although its components can still take on multiple other microstates (and thus other partially random configurations).

This residual multiplicity of energetically equivalent microstates, obviously, corresponds to a residual entropy quota and is incompatible with the need to produce the highly refined array of constraints implied by the ordered biological syntax [16]. Living matter, moreover, not being a homogeneous system, certainly cannot accommodate a manifold of “equipollent” microstates (as would be the case in a volume of ordinary matter, albeit in a condensed phase) without its integrity and functioning being compromised, since any slightest change conducted on an entropic basis would imply the alteration of structural configurations (electronic, molecular, and supramolecular) in which, a substitution of a functional group or a change of chirality (for example) would suffice to disrupt the ordering and functionality [19,102].

Moreover, an entropic residual would not even be compatible with the proven emergence of a self, according to which every oscillator in the system “knows” about every other, as sharing more or less directly phase correlations, within the hierarchy of *nested* coherences.

Thus, summarizing in a simplified example, if coherence is present on one degree of freedom only, the components are still entropic on other degrees and thus the system still has a multiplicity of equivalent states, i.e., it still possesses entropy; therefore, it cannot produce integrally ordered responses or with a criterion that aims at maintaining/maximizing the coherence already present (homeostasis/homeoeresis), as is typical for a living system.

This last property, which – because of the existence of energy gaps associated with coherent states [28,39,44]

– corresponds to the spontaneous tendency to minimize the energy of the vacuum level (since thermodynamically pursued by the biological system, as it is an open system), is possible only when the internal entropy is close to zero, a condition in which (ideally) a single microstate yields a unitary corresponding macrostate. Approximation to the entropic “zero” is possible due to the existence of the hierarchy of nested coherences and corresponding work cycles, within which any entropic fraction possibly produced is expendable as free energy in subsequent levels, with longer *characteristic times* (see [5,6,98], to deepen details).

To state it again, such a tendency to zero entropy is the condition that allows, in the dissipative relationship with the environment, the spontaneous tendency to minimize the vacuum energy while being able to comply with the constraint of assuming successive macrostates that are also at entropy close to zero (ideally), to which, therefore, specific, and unique microstates are subtended, updated at each step of the thermodynamic history.

This idea would explain the physical basis of the ubiquitous and fruitful dynamics of adaptation, in which the physiological response is exactly what is needed to perform the *coping* with stimuli of whatever nature. Namely, one could thus explain why at every stimulus/situation (either cohering or decohering) the “turned on” state in the living being is precisely that configuration (or one of the possible ones) that already produces processes and arrangements suitable to implement or maintain its own coherence (i.e., thermodynamic stability, i.e., homeostasis) by restoring it right on the very front where it was compromised. Thus it would be clarified, for example, why, contextually to a stimulus involving a structural injury, a physiology is activated that involves biochemical and electrodynamic events aimed precisely to tissue repair; or why, contextually to a hindered biological function (felt) necessary to be performed, such as the digestion of a “nutritive morsel,” a physiology corresponding to the enhancement of that faculty is expressed [103,104].

In practice, every input in the living implies the configuration of a new state to which a “sensible” response pertains, precisely for thermodynamic and quantum-electrodynamic reasons, in the sense that this response is aimed at maintaining or restoring homeostasis (supercoherence). This is the step that, from physical laws, could explain the emergence of “biological laws” [103,105], within which the stimulus is endowed with a “meaning,” not invariant, which depends on the unique and unrepeatable configuration of that system and, therefore, which depends on its entire history (first and foremost) and purpose (as we see in the next section).

Teleology (the fact that there are for the living being “final causes,” as already expressed by Luigi Fantappié [106]) is a property obviously related to the just-invoked ability “to know” and “to head” toward thermodynamically favourable states (and coincident with the minimization of entropy and energy of the fundamental level). Obviously, however, unless this idea is relegated to the level of an arbitrary (and perhaps anti-scientific) inference, it needs to be physically substantiated and supported. In reference to this, it is important to remember that, in a quantum fashion, a coherent system is able to collectively explore (via fluctuations at the Planck scale of the number operator) the space of potential coherent states (phase eigenstates) and somehow to know and access (as in the tunnel effect [50]) the thermodynamically most favourable configurations.

Reinforcing this, in a series of fundamental articles, theoretical physicist Ke-Hsueh Li has shown that the concept of coherence is actually rooted in the Heisenberg uncertainty principle and that the space-time within which coherence holds is actually equivalent to the space-time within which Heisenberg uncertainty holds [107-109]. As Li showed, the insight, regarding the fact that the uncertainty relation is just an alternative approach to describing the coherence properties of fields and quanta of matter, can be traced back to Heisenberg himself [110]. The coherence time and length, of the order of the spatial size (the wavelength) and the period of oscillation of the coherent mode in force, are respectively that duration and spatial range within which the wave aspect is the only definable one (the phase of the field and not the number of quanta) and within which the interference pattern (“Thomas Young-like”, to understand [111]) is conserved.

As we have already pointed out, within the coherent state, properties cannot be attributed to any countable “particle,” while outside it (or when coherence is broken, even by measurement) phase information is completely lost. Within the coherence volume, since phase correlations are in force, it is as if all phenomena occur “at the same time” and are in an elective form of entanglement [57,112,113] giving rise to an «unbroken whole without parts» in which causality is synchronic and no longer diachronic [107].

If coherence is organized on increasing levels of spatial and temporal extension, as it is the case with living matter, this synchronic “suspension” and temporal verticality within which (within a certain interval) past, present and future coincide can be extended. This aspect would be a crucial factor in the emergence of biological self, a condition from which the experience of identity and continuity of experience emerges, on the threshold between memory of the before and tension toward the after.

In this regard, important confirmations emerged on the spectroscopy front: the modelling of the imaginary part of the dielectric function of liquid water in the THz range, in order to match the experimental data, in addition to the partitioning over two fractions of the liquid system (the normal and the coherent one, in proportions dictated by temperature), also required the insertion of a linear term that implied the violation of the Kramers-Kronig relations within a time span of the order of magnitude precisely of the duration of the oscillation period of the coherent domains of water [114]. As to say that the cause-and-effect relationship between the forcing field of the incident radiation of the probe beam and the dipole reaction of the water molecules of the coherent fraction needs a term expressing a non-local relationship of instantaneousness and “time suspension.” This, in addition to being consistent with the fact that coherence leans precisely on phase (non-local) correlations, further substantiates that, within the space-time scales typical of a given coherence domain, there is a suspension of diachronic causality and the system is found to experience as “present” and “contemporaneous” states of the recent past and recent future.

Clearly for a water CD, whose spatial range is of the order of 100 nm maximum and whose period of oscillation (renormalized by field self-trapping) is around a hundred femtoseconds [77,114], this range of exploration is very small. But when there are many levels of coherence (nested) in each other up to oscillations that have wavelengths as large as fractions of a meter and having periods on the order of the Hertz (such as those in the brain, or heart [115], the range of exploration of states on the time axis becomes considerable.

This could be the explanation for a living system’s exploration of a plethora of thermodynamically favourable and non-randomly occupiable configurations. And, perhaps, this could also be the explanation for the well-measured “anticipatory response” phenomena conducted by neuroscience researchers who reported how human subjects exposed to images with content that was emotionally significant to them showed physiological activation (such as changes in skin conductance [116,117] or in the heartbeat rate [118]) up to few hundreds of milliseconds before viewing the target pictures.

Finally, it is important to emphasize how entropy minimization is also performed through another crucial attribute of biological matter: heterogeneity and ultrastructure, i.e., the very fine spatial variance of components, niches, interfaces, folds, vesicles, and (just think of the structural complexity of cytoplasm [95]). This impossibility of treating living matter as a homogeneous “bulk” of “average composition” (as could be done for

ordinary condensed matter), in addition to seeing necessary a modification of the second principle of thermodynamics within the living phase of matter [5,6,98,119,120] involves two central aspects that we stress again:

- the minimization of entropy possibly produced at an (n)-th spatiotemporal level, through its exploitation as work at the ($n+1$)-th dimensionally larger one (see here for further discussion [6,98,121].
- the tension toward a principle of ideal “univocal correspondence” between each microstate and a macrostate such that the configuration is also characterized by the super-differentiated and precise spatial and temporal subdivision of identifiable molecules, structures (1D, 2D, 3D), and their dynamics.

Replacing an atom in a diamond crystal with its neighbour changes nothing, but in a living system, replacing a molecule with its neighbour or causing an electron transfer to take place now rather than later disrupts the entire biochemical syntax.

All this gives us a way to physically root the variable of *meaning* in relation to a *history* and a teleology that find in the network of coherences implicating the living, to the point of providing the emergence of a biological self, the etiological and reasonable basis for understanding every living being as a *flow of meanings*, memory and purposes, as a *perceptive process*, a system of thermodynamic constraints taken to their maximisation up to the point that no molecular event in living matter is attributable to chance [6,67,100].

Major Implications

I am well aware that what has been examined so far, perhaps in a forced synthesis (but purposely so as to allow as much cross-sectional framing as possible of various aspects, all of which are salient), has very profound implications and calls for a considerable revision of many scientific ‘beliefs’ and practices currently in vogue in the life sciences (from philosophy to physics, biology, medicine, and neurosciences).

If the physical condition underpinning the living state is necessarily (super)coherence, a fact that cannot be denied (since, if it were not so, the prerequisites for the most characteristic and evident phenomenologies of living organisms would be directly lacking), the main changes in perspective concern the following topics:

- a) the idea of “cause” attributed to factors that are external/internal to the living being in relation to the latter’s physiology;
- b) the method of investigation conducted at the level of genetics, biochemistry, cytology, and histology

- c) the role of the genome
- d) the epigenetic dynamics
- e) the concept of “disease” and its aetiology
- f) the germ theory
- g) abiogenesis and pleomorphism
- h) the theory of evolution of the species
- i) the psyche-soma dualism and the stress-physiology relationship
- j) medical practice and the definition of *therapy*
- k) relationships in the “nature-human-technology” triad

I discuss the various points in a general reflection, also because each of them constitutes a very extensive topic that would require dedicated development space (partly explorable here [122]).

We have seen that the living organism is a *responsive* system since it is endowed with order in space and time, therefore the outputs produced as a consequence of stimuli can be of three types: i) a response (when the stimulus has involved no local decoherence); ii) a reaction + a response (when the stimulus involves partial decoherence of the system, such as mechanical, electromagnetic, thermal, chemical damage); iii) only a reaction when the system, due to the stimulus, ceases to be in a living phase (total decoherence). In the first and second case, it is very important to understand, for the reasons we have examined, that the response is always a process *acted out by the living being*, not directly “provoked by the stimulus per se”, and that it has an adaptive sense (of maintenance, restoration of homeostasis) whose causes cannot be traced in microscopic investigation, because this method will only deliver us *how* this process is performed and not its *why*. A beating on the head is not really the cause of the bump: it is the cause of tissue damage (the ‘reaction’ level), and the bump is the process in physiology to repair that damage (the ‘response’ level). Or, similarly, the scar following a burn is not really ‘caused’ by the scar following a burn is not really ‘caused’ by the lit cigarette touching the skin, but by the organism responding to that damage with biological intelligence. The lit butt is the cause of the damage, the burn, (the ‘reaction’ level), but not of cicatrization, the scar, (the ‘response’ level) acted upon solely and exclusively by the supercoherence in the living (and which is totally absent in a dead body).

Likewise, we would be committing a conceptual error by saying that ‘the cause’ of my writing these lines, typing them on the keyboard, lies in the electrical discharges of my motor cortex and the action potentials that reach the motor neurons of the muscles in my arms and hands (with membrane depolarisation, release of Ca^{2+} ions, etc.) and finally in the motion of my fingers. This is how it happens. The why, the cause, is a whole other story.

This remark, even ridiculous to some, is actually crucial because, just as coughing is welcomed and understood as 'intelligent' to expel an extraneous corpuscle away from the respiratory tract, or a thickening of the skin (callus) is understood to be equally intelligent to cope with an extraordinary mechanical pressure that risks to damage the underlying tissues over time (and we could give hundreds of examples), it must be admitted that there is no threshold, no line drawn, beyond which the processes, the responses, acted by the soma cease to be intelligent and become senseless. This is logically incompatible with the intrinsically coherent, hence organised, connotation of the living state.

It is one thing to say that there is a threshold beyond which (adaptive) responses may involve violent, or even lethal, symptoms (such as an anaphylactic shock) that must be managed, it is quite another to imply that the symptomatic process is 'an error' and that from the outside we must correct something that is an expression of disorder.

This point is fundamental with regard to the definition of "cause" of a process in biological matter, especially when it is labelled as 'disease', as well as in regard to the idea that the reasons for a neoplasia are, for example, 'in the genes' or in a substance called 'carcinogenic'. I explain better.

Right like the analysis of neuro-motor processes does not give us *why* I am writing, but only *how*, so too, looking for the causes of non-ordinary physiology (as, for example, in a neoplastic process) in the genes will only give us (albeit useful) information on how that process occurs, and how to describe it on a microscopic scale. In order to understand the causes, we must bear in mind the definition of a living being that emerges from the conceptual framework we have outlined here (the result of the descriptive tools provided to us in QFT, SSB, open systems thermodynamics and QED coherence): that is, a system of semantic relationships coupled to its environment.

This means that what dictates the type of process in living matter (such as a specific physiology) is always the *biological meaning* that such a process has as an adaptive response to an environmental configuration, to a stimulus, which implies a precise type of decoherence, of impairment to that specific organism. If, for example, gamma radiation, or a toxic substance, damages a tissue or suspends its physiology, the organism responds with a series of processes that necessarily have an order, therefore a biological meaning, as in the case of the bump on the head, or the burn on the skin.

From here, the definition and approach changes completely with respect to the physiology developed as a result: as long as there is a response, it means that there is order and it makes no sense to speak of 'cells gone mad',

rather we should understand that manifestation as a tissue repair or the enhancement of a biological function [123,124].

It is obviously less evident when 'the bump' is invisible from a material point of view, but is real from a semantic point of view, i.e. about how the living being perceives its biological condition in a given context (for the human being also abstract and symbolic). Through the overview we have presented so far, much of what has been documented by the important strand of research on the relationship between 'stress' and 'disease' is accounted for and scientifically supported [104,123-126,]. With the conceptual tools provided by QFT and symmetry breaking, it can be understood that the relationship between stress and physiology has a precise physical and biological basis: it makes no sense to speak of "stress" in a general sense, but one must always consider the biological 'quality' of the stimulus, i.e. which type of function of the living being is called upon to adapt, according to the biological significance that that specific stimulus has in that specific case. In this sense, it is advisable to familiarise ourselves with the perspectives opened up by Dr Hamer's discoveries [103,105], which are still too much censored because their profound usefulness for medical practice is not understood. It is a matter of realising that the perspective we are presenting here does not imply a 'scrapping' *tout court* of the medico-biological knowledge acquired so far, but rather to make it even more profound, precise and productive.

Concomitant to the one just illustrated, the other aetiological front concerns the fact that - coherent states being the fruit of the succession of those that have previously occurred - the coherence of a living being holds within itself all the adaptive memory developed along the course of the phylogeny (and ontogeny of that specific living being). Thus, the physiologically expressed response (including neoplasia) is caused by the existence of a *meaning* for the living being of its experienced *biological condition* (with semantic quality, as well as a merely chemical and physical one), and by the existence of a strategy, developed in the course of the global biological *historia* and usable at present moment because "conserved" in the electrodynamic configurations of the organism's living matter.

Coming to the role of genes, a different reading is possible from what is usually accepted [64]: In this relational and semantic perspective of the living being, genetic mutations (implausible to occur according to random processes [127], as they are contextual to an ordered system) are understood not as the cause of 'alterations' at the cellular and tissue level, but as the *consequence* of the need to perform a 'special' physiology, in which a tissue or a cell must perform non-ordinary activities, such that it must express different genome features. Genome-scale events, like molecular ones, are orchestrated by the network of coherences within which the system's mode of oscillation decides the frequencies

of work to which the *biochemical pathways* performed correspond [16,63,100].

In truth, one would have to look at the function of ribonucleic acids (DNA and RNA) within a broader vision, not limiting their role to that of mere 'cookbooks' for protein synthesis, otherwise we couldn't explain why my nose, for example, is shaped like this (resembling my mother's) if the DNA and RNA of my cells were merely a substrate to be 'biochemically read' [128]. Protein synthesis, in fact, tells us nothing about where to put these proteins, or how to arrange cells in a tissue, let alone what size and shape organisms should be. In practice, the dynamics of morphogenesis remain totally unknown.

Considering DNA and RNA (thanks also to the coherent water in which they are housed) as physical actors capable of producing precise spatial configurations of electromagnetic field [129], instead allows us to give a rational basis to their morphogenetic role and understand why alteration or modification of the genome implies corresponding changes in the organism.

In fact, the first objection, which would arise with respect to what has been expressed above about the role of genes (as 'executors' rather than 'causers' with respect to physiological processes), would be to point out the rich possibilities to engineer the genome, or modify its expressions, to change the somatic outcome of various species (from bacteria to ornamental plants and vegetables, up to farm animals and laboratory mice, bearing specific characteristics) [130]. This possibility of modifying the characteristics and connotations of an organism (such as the molecules that can be synthesized by a bacterium or the cholera of a rose) would seem to disprove what I argued earlier.

Instead, the existence of genetic engineering [122] is, in my opinion, further evidence in support of the fact that nucleic acids act as coherent electromagnetic (and phononic) devices, both in reception and emission [129]. In fact, it is not for nothing that researches has been published showing how, in addition to the process of transcription and protein synthesis [131], also the dialogue between nucleic acids and other biochemical species occurs by mediating phase correlations and dipole waves within the coherent aqueous matrix [132,133]. The signals involved, especially their vector potential component, A , [134-136], through the mechanisms described in Section 4, are able to manage the arrangement and molecular encounters in the super coherent water-based matrix of living matter [17,63].

What just said about genome makes us realise how, even in epigenetics research, if we do not understand that the expressed or non-expressed genome tracts are chosen on

an oscillatory basis, i.e. driven by the working frequencies of the system, we make two gross mistakes in interpretation. The first still consists in erroneously attributing to genes the causal role in the onset of tumours or other so-called 'pathological' processes, when in fact they are part of the tools with which the living realises a physiology that finds its logic in the perception of the environment and the responses felt to be appropriate in reference to that perception (all biological, nothing 'mental'). The second error consists in constructing 'visions' on the functioning of the living inhabited by heavy contradictions: the example of the "health-generating" role attributed to foods rich in micronutrients such as folic acid or B vitamins is emblematic. In some studies (such as the case of mice carrying the Agouti gene [137], it is concluded that the expression of certain genes 'responsible' for disease (such as obesity and tendency to diabetes) is profitably silenced by a diet rich in folates and B-group vitamins, since these substances are said to be methylating agents. In another case, it was concluded that, in a group of smokers fed on a diet rich in fruit and vegetables (folates and vitamins), the risk of lung cancer was reduced since the micronutrients provided by such a diet are imputed to prevent the hyper-methylation of eight genes whose expression is associated with onco-suppression [138].

Now - apart from the fact that it is unclear whether substances such as folates would be 'protective' from pathological expression because they are methylating or because they prevent methylation - the central question remains: what would direct any methyl groups to specific sites in a genome segment rather than others, and what mechanism would promote their specific binding to them, so as to make them 'unreadable'? According to the two cases above, the difference between methylating one trait of a genome or another would cause an immense difference (between health and disease) and would imply that eating fruit and vegetables could imply staying healthy or risking to get sick (!).

These discrepancies, perhaps veiled by statistics and 'screenings', should be observed, and discussed *e fundamento* in order to allow a real step forward in the knowledge of nature, rather than the continuation of methods of investigation that do not take into account the unrepeatable semantics of the individual subject and without considering that the 'model' of the living being subscribed to by this line of approaches would be totally unrealistic and implausible. It is, however, an encouraging fact, in my view, that even in the epigenetic field, genome expressions are being correlated on the basis of so-called 'stress' [139,140], although, like commented before, such 'stress' must be more precisely characterised from a biological point of view (i.e. the meaning implied by the 'stressful' stimulus, for that organism), so as to be able to understand why a certain type of response (genetic/

physiological expression) or another is expressed [105].

In essence, 'the cause' of events and configurations in the living lies in the *relationship* (always also semantic) of the living with its context and its perceptual and phylogenetic history. In a word, the 'cause' lies in 'how the living being feels' (i.e. in what configuration, electrodynamic state it is oscillating in coupling with its environment) and what has been adapted and 'written' into coherence along the path of evolution as an appropriate response to that configuration. The construct of 'mind', cognition, has nothing to do here: the fact applies as much to an amoeba (which, without neurons, knows how to 'choose' to move towards a nutrient or away from a toxin) as to a cat or a human being. The causes of what is expressed physiologically lie in the *biological* (and thus thermodynamic and electrodynamic) *meaning* that a «living + environment» configuration has for the former.

"To feel", as we briefly discussed (for further details see [6]), is a physical process pertaining to the adjustment of the entire holo-state (described by the *electromagnetic phase operator*) of the living being coupled to its thermodynamic double (the environment). "Feeling something" means modifying the oscillatory configuration of the whole living being when it is in some physical (even non-local [27,141,142]) relationship with that "something", and thus means modifying the working frequencies and the corresponding physiological/biochemical expression. Tasting a candy is not an event concerning the mouth only, but an experience that reconfigures our entire state, which is why we 'feel' in a certain way and have an 'experience of taste', which is a phenomenon delocalised over the entire *self* precisely because there is a holonomic state function that is shared in an articulate manner by all the components of the living being. All of this further supports the unity of 'psyche' and 'soma' (arbitrarily defined and illusorily distinguishable) and corroborates the studies of A. Damasio, who defined (in its *Descartes' Error* [143]) emotion as a somatic marker, i.e. a necessarily material process, a very precise somatic configuration (the way the system oscillates).

Thus, in the field of molecular biology, much of the method of investigation, the way of doing research, needs to be reviewed: we cannot look for causes in the fragmentation of the microscopic realm, because there we will only find 'how' the process happens, the way it materialises, but not *why* it is the way it is. In terms of medical practice, we must revise the meaning of *therapy* as a consequence of understanding the intelligence of the physiological response and its relationship to the meanings of what the organism perceives. Two definable levels of therapy can be distinguished: the *symptomatic* one, which addresses to manage the emergency, the danger, the symptom, the pain, the unease; and the *causal* one, which works on the circumstances that triggered responses whose biological meaning is now understood

(by changing them or reconfiguring the living being's interpretative models towards those same circumstances) [103,104,124].

This paradigmatically *different* panorama, undoubtedly indigestible or even inadmissible for many colleagues, also suggests the *reframing* of other nodal themes for the construction of a *Weltanschauung* (view of the world) as close to reality as possible. Among these there is fore sure the *germ theory*, of Pasteurian mould, which considers germs as the "cause" of disease *tout court*, [144] to be integrated with the *terrain theory*, of Bechampian mould [145], which opens up to a primarily cooperative role of the so called "germs" with respect to the fulfilment of certain physiological processes [103,105] as for example has already been shown in the case of *Helicobacter pylori* in the context of gastroduodenal ulcers [146].

The interesting aspect within the view that I have summarised here is that germs - such as fungi, mycobacteria, bacteria, yeasts, up to viruses (in fact only fragments of biological material and not at all ascribable to living beings and indistinguishable from those particles, such as exosomes and extracellular vesicles, through which cells exchange material or degrade [147], especially if they are part of the organism's microbiota - are also involved in the hierarchy of coherences. Therefore, like other cellular species, it makes physical and biological sense for them to be modulated in their expression and functioning by the choral organisation of the living, which in some cases sees their involvement in physiological responses on specific tissues as meaningful and biologically useful.

The framework offered by quantum-electrodynamic coherence provided the basis for understanding, without ontological discontinuities, the transition - through successive and further levels of coherence articulated on the aqueous matrix and other molecular and structural partners (such as interfaces) - from inanimate to living phase of matter, reopening the plausibility of the a-biogenetic perspective on the manifestation of life within the natural realm [148-151]. The demiurgic role of coherent water, as an agent capable of supporting and organising biological molecules (from sugars to amino acids, lipids to proteins and so on) has been suggested (i) both by the ability to reassemble a nucleotide sequence from the electromagnetic signals sampled by dilutions of the original genome fragments [132,152,153], and (ii) by the detection of organic substances created by the flow of pure water in which atmospheric CO₂ was dissolved [156], (iii) and by the chiral behaviour in purely aqueous structures generated by iterated contact with hydrophilic surfaces, which led, after freeze-drying, to the isolation of a solid-phase residue, at room temperature and pressure, composed almost entirely of hydrogen and oxygen, stable

up to more than 600°C, presenting a spectral fingerprint at circular dichroism corresponding to that of the β -sheets of many biological proteins [155,157]. Some very significant work has also been done concerning the dependence of the functioning of biological molecules on the coherent phase of the water surrounding them [131,133].

With regard to a different conception of evolutionary dynamics, I limit myself here to pointing out that, given the phase correlations possible between coherent systems within eco-dynamic contexts [84], evolutionary dynamics can neither be considered random (except for the aspect concerning adaptation to conditions relevant to the biotope - climatic and geological events - and anthropogenic activities [158,127], nor of a “single species” (also due to the genome sharing and transfer that occurs from the beginning of phylogeny [159]) and that allows for the fact that every existing species has a genome built on 4 bases.

Furthermore, if evolution of the species (as it is conceived, according to which each species ‘competes’ with the others) were true, we would have that almost all plant species, to give an example, would have developed strategies to avoid being eatable; or, some animal species (insects, to give an example) would have implemented and increased certain biometric characteristics so as to be ‘invincible’. So if, for example, we were to ask: why does grass in the meadows allow itself to be grazed by an immensity of herbivores? Or: why haven’t ants become as big as mice?

The answers to these questions, naïve if we like, cannot be found ‘in the grass’ or ‘in the ants’, but in the living network in which these identifiable species are contextualized and in the sense in which those species can produce themselves within that eco-dynamic context. In fact, there is a tendency towards the maintenance of an ‘order’, which produces ‘equilibrium’, even at ecosystem scales, a fact that can be explained by the phase correlations described so far between coherent systems and that implies a different conception of *ecodynamics* [84,45,46].

Summary and Conclusions

In the course of this general reflection, the delicate problem of the *physical reduction* of the sophisticated properties exhibited by living systems (such as semantics, memory, adaptation, finality, organisational closure, thermodynamic openness) was taken up, emphasising how, from a condensed matter *field perspective* (including the living phase) it is possible to stitch up the structure-function dualism (also conceivable as matter-information, or soma-psyche) in the acknowledgement that every form of ordering has a fundamentally dynamic origin, and not a static one, by starting from the breaking of symmetries on certain degrees

of freedom to which is associated the bosonic condensation of correlation quanta that are as much structural as determinant for the functionality of the system. Such bosonic condensations and symmetry breakings are associated with the formation of a new state of the system, coherence, characterized by the existence of phase correlations that set in order the motion (and in certain cases also the position) of the material components that, in this new state, have a lower vacuum level than in the incoherent state.

Within living matter, the coherent dynamic is further extended by the dialectics played out between the aqueous matrix and the molecules participating in its coherence, resulting in the establishment of a hierarchy of interrelated levels embedded within one another, to which are associated cycles of work covering a wide range of space-time scales (from electronic motions up to circadian rhythms and ecosystem fluctuations).

As long as coherence exists, for thermodynamic reasons, every state assumed by the living (ordinary or otherwise) should be understood as a *response* endowed with intrinsic order with the purpose of maintaining/restoring coherence, and therefore endowed with *biological meaning*. Thus, the “cause” that dictates through which physiological or biochemical state the living being is manifesting itself is not directly identifiable with any stimulus/event/situation but concerns the fact that there is always a *meaning* that such stimulus/event/situation has for that living being and implies that the response is a process of adaptation developed along a thermodynamic and phylogenetic history. The real causal link is, therefore, to be found by focusing on the relationship implied by meanings and on their dependence on the context, rather than microscopic investigation which, at most, can return *how* the response occurs and not *why*.

In essence, to be even clearer, the subtle point I wanted to underpin in this analysis is the shift from a stance which considers a reaction carried out at the molecular level (biochemistry) to be the cause, for example, of a given state of the physiology, to a stance that understands that such a reaction is still the same physiology just observed at a microscopic scale, and that this process (biochemistry/physiology) is indeed the medium (the *how*) by which a response takes place whose real cause lies in the semantic quality (now physically rooted, and no longer a category possible within a cognitive/ “psychic” horizon only) that each event has for a given living system.

To give an example, let us consider a mouse that is sprayed with formaldehyde on its nose and develops a melanoma in that area of the snout: this physiological process does not happen because the formaldehyde directly “provokes it” (making cells or tissues ‘go mad’ and thus

producing “errors”), but because that “special” physiology (the melanoma) is the desired and necessary *response* of the “mouse” organism in relation to the encounter with the formaldehyde and the way in which that encounter took place. This event, i.e. the encounter/contact with formaldehyde, can no longer be understood merely as a chemical/physical event describable by mechanistic laws of action-reaction at the level of the fundamental material components (atoms, electrical charges, molecules, ions, etc.), but must also be understood as an *experience*, describable analogically by *biological laws*, in which it necessarily acquires a *meaning* (entirely ontological and having nothing to do with cognitive/psychological aspects) that can only be referred to the entire organism, and which is the result of the unrepeatable semantic-dissipative-thermodynamic history of that organism.

All of this, of course, also brings with it a radical reinterpretation of what we call “disease” (in the case of the mouse, melanoma), which from being a condition of disorder simplistically “caused from the outside” or “from the microscopic” of biochemistry, turns out to be an ordered and *sensible* response (as it is adaptive) desired “from the inside” to preserve/restore a biological order, an electrodynamic coherence (compromised by meaning, i.e. by the physical, chemical, thermodynamic and... biological implication that any given event or circumstance has for the living).

This perspective grounds the impossibility of considering the living as a ‘physical object’ (as generally understood and, therefore, as isolable) and highlights the need for a change in the method to investigate its connotations and functioning. There emerges the need to adapt the *scientific method* to a more analogical mode, capable of understanding cause-effect relationships between stimuli and biological states (such as physiology, implicated, for example, in the definition of health and disease and its aetiologies).

In addition to show that the causal factor lies in the biological meaning, i.e. in the thermodynamic and electrodynamic implication that the stimulus, or configuration, has for the living being in that precise state of its history, this framework justifies how the search for the ‘causes’ of living dynamics is to be found in the (semantic) relationship with a context without which – as complex thinking teaches us – it makes no sense either physically or logically to speak of the living being itself.

From here I reviewed a series of relevant implications following the acknowledgement of such physical and thermodynamic foundations for the existence of the living phase of matter. First and foremost the critical review of certain models of interpretation and the necessity to include, within hard sciences (such as physics, biology, biochemistry,

physiology) and other ‘softer’ disciplines (such as medicine, neuroscience and philosophy), the analogical and semantic features of the studied living systems (and their contexts).

My heartfelt wish is that researchers in the fields of physics, biochemistry, genomics, biology, medicine, etc. could soon become the protagonists of a change of mentality, such that, instead of wondering «... what are the ‘errors’ within this cell, or tissue, that make it behave in a ‘strange’ way . . .?» already assuming that the observed event, as non-ordinary, is the manifestation of a ‘disorder’, they could instead wonder «what could be the *biological sense* according to which this cell, or tissue, behaves differently?». A small change in perspective, a huge enrichment in knowledge.

Conflicts of Interest

The author declares no conflicts of interest.

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