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IMMATERIAL KNOWLEDGE AS ULTIMATE EMERGENCE

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Abstract

Current discussions on the philosophy of Nature hinge on the concept of emergence. Such a concept has long succeeded in the Life sciences and is increasingly receiving the focus of Physics and Philosophy of Physics alike. Remarkably enough, even for basic scientists, there is no agreement on whether emergence should be considered fundamental (ontological) or just an elegant and more straightforward (epistemic) way of referring to complex arrangements of basic stuff. In this paper: (1) I evince said disagreement by confronting two distinguished approaches, namely Bishop and Ellis's, and Sean Carroll's. (2) I intend to move beyond the loggerheads by supporting ontological emergence as a widespread feature in Nature. I invoke Penrose's argument of functional freedom as an epistemic hint for ontological emergence, i.e. the necessary recourse to additional - apparently non-fundamental - criteria to justify the coarse-graining of finer, lower levels into coarser, higher levels in Nature. Said move, if understood in keeping with a minimum scientific realism, points towards a different kind of causality at work in the universe, classically referred to as formal causation. (3) Once ontological emergence is naturalized, one can frame the emergence of immaterial knowledge as an ontological apex - dubbed ultimate emergence - that reverses the trend of coarse-graining.

Keywords: mind-body, problem, ontological, epistemic, emergence

1. Introduction

Emergence is a fashionable concept. After its rebirth thanks to the work of the British Emergentist tradition (19th century) and a winter period due to the new possibilities opened up by Relativity theory and Quantum mechanics in the wake of the 20th century, the concept of emergence seems mandatory when attempting to set up some continuity among the different scientific disciplines. Philosophers, biologists and physicists alike speak of emergence in Nature even if nobody can rigorously characterize the term. The concept of emergence, though, proves adequate at the time of referring to new patterns, structures, functions, or properties in Nature, which were absent in the past, and require

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new levels of description and, perhaps, new explanatory logics [1-3]. Especially, emergence seems the proper conceptualization for referring to particularly complex phenomena as living and thinking systems.

Despite the 'emergence' furore, little further agreement emerges among scholars regarding its aetiology, classification, or even characterization. One of the classifications - controversial in itself - considers epistemic and ontological emergence as the most relevant distinction between kinds of emergence: epistemic emergence being a linguistic phenomenon due to inherent limitations in our knowledge (and its expression) of a single-stuffed reality (ontological monism), and ontological emergence referring to phenomena that involve at least new causal principles if not new ontological stuff (ontological pluralism) [4-6]. Classifications may establish different criteria to speak about the emergence of theories, laws, properties, systems, levels of description and the like. However, all of these approaches need to explain how to understand the novelty proper to emergence and what is it that is novel - what does it emerge and what does it not?

Setting up the conditions to answer such questions requires dealing with relata and causal relations - a procedure that is commonly beset by the risk of circularity. If a cause, say the present gravitational interaction among two massive objects, is fully caused by previous causes, as the initial conditions of the Universe and the dynamical law described by Einstein field equations, is one entitled to grant existence to gravitational interaction? (I am here implicitly embracing the Eleatic Principle [7] that the existence of something implies its possessing causal power. Denial of this principle threatens all scientific endeavours in their search for causally explaining what exists in Nature.) It might seem that the recourse to modal epistemology provides a way out of the circularity by discussing necessary and sufficient conditions related to a particular phenomenon. However, 'necessary' and 'sufficient' themselves are contextually-laden terms, crucially dependent on other assumptions as relevant space-time scales and degree of exactness in our descriptions. In other words, necessary and sufficient conditions are heavily contingent upon a coherent network of assumptions conditioning our descriptions [8], and thus on the ontological weight that we concede to the referents of some of such assumptions.

Since the epistemic domain is unavoidable when dealing with emergence, a feasible goal to clarify the matter is to establish the conditions for properly talking about ontological emergence given a model or a theory, i.e. after strictly controlling all sorts of assumptions in establishing such a model. On the one hand, although promising attempts at characterizing ontological emergence via the failure of interpretation of and linkage between theories to commute have been recently carried out [9], the results are still too meagre and representation-dependent to provide a complete answer to the question of emergence in Nature. On the other hand, qualifying emergence as contextual [10-12] may provide a better route in filling the gaps between the epistemic and the ontic dimensions but offers a weak flank for the reductionist attack on contexts as not sufficiently fundamental. (In the sense of not stemming from first principles [13]) Could there be a better approach immune to such weaknesses? My answer is affirmative and, additionally, contains a bonus since any advance in characterizing ontological emergence, even if beginning from the epistemic levels of description, should offer some clarification on the kinds of causality involved in novel phenomena and especially regarding the emergence of immaterial knowledge.

This paper does not aim to engage in an overall discussion about emergence, for which the reader may benefit from several recent books and articles [14-17]. On the contrary, it initially aims to confront two remarkably different views of emergence in the field of Physics, namely Bishop and Ellis's (Section 2) and Carroll's (Section 3), in order to pinpoint the crux of the argument that, in our view, implies an exquisitely philosophical elucidation regarding said authors' assumptions. After recognizing the inherent limits of both argumentations, and inspired by one of Penrose's criticisms of superstring theories (Section 4), the paper turns towards a different argument that could be decisive to establish the need to go beyond mere physical causation to formal causation even within Science itself (Section 5). Last but not least, the paper will use such an argument to support the emergence of intellectual knowledge as a borderline case of formal (non-physical) causation that reverses the coarse-graining trend in Nature. The ultimate emergence of immaterial knowledge is thus the beginning of infinity in the Universe (Section 6). Said understanding of the emergence of immateriality might prove compatible with the scientific narrative. Final remarks appear in the Conclusions.

2. Bishop and Ellis's arguments for contextual emergence

Robert Bishop and George Ellis are well known as philosophers and physicists who discuss contextual emergence in different domains or levels of physical reality using, for instance, the properties of temperature and molecular shape as case studies [12]. For these authors, the idea of a fundamental level from which the remaining (emergent) levels of reality unravel is not as straightforward as assumed by reductionism. Relata and causal relata in a lower level of description (or domain) do not fully provide necessary and sufficient conditions for properties and behaviours at a higher level, pointing to the limitations of modal approaches to inter-level causality. However, Bishop and Ellis do not part with modality when affirming that cases "of contextual emergence arise when contingent conditions from the target domain or higher level are added to the necessary conditions in the underlying level or domain to create a complete set of necessary and sufficient conditions for the phenomena in the higher level or domain" [11].

For Bishop and Ellis, multiple realizability - that one entity at a higher level can correspond to many different configurations at a lower level - is concurrent with contextual emergence because there "are always numerous more entities at the lower levels than at the higher levels" [12]. One could retort that there are more different molecules than different atoms in Nature, analogously to there being more words than letters in most languages. Yet, when spatio-temporal locations of the lower-level basic stuff enter the counting of degrees of freedom, Bishop and Ellis guess right. Extant entities at higher levels enormously reduce the available spatio-temporal locations for their basic constituents - this is what lies behind the low entropy of living systems. Now, whereas multiple realizability could merely answer to a convenient epistemic way of arranging subsets of lower-level degrees of freedom in classes of equivalence, contextual emergence should offer the answer to the causal emergence of new entities. (A functionalist ontology could even use such equivalence classes [18] which, in my view, is better featured as an epistemic functionality: "[W]hat makes a tiger-structure 'real' is the phenomenal gain in our understanding of systems involving tigers, and the phenomenal predictive improvements that result, if we choose to describe the system using tiger-language rather than restricting ourselves to talking about the molecular constituents of the tigers" [19].) In fact, all the examples of contextual factors listed [12] assume the distinction of a system in an environment.

What then is a context? A "set of conditions that, when added to the necessary conditions contributed by an underlying domain or level of reality, form a set of jointly necessary and sufficient conditions leading to the existence and persistence of higher-level properties of the concrete context" [12]. Crucially, such novelty is not given or derivable from the lower level alone - nor, one could add, from any other lower levels. Moreover, "the context characterized by stability conditions endows the underlying state space with a new contextual topology" [12]. In other words, when focusing the scientific interest on the new system, defined in a specific spatio-temporal scale and, very likely, range of energies, a new description containing qualitatively new degrees of freedom and dynamics takes over. (See [20] for an explanation of the range of energies at play when considering physical systems and their components, enabling us to focus on different levels of description throughout Nature.)

Since my main interest here is to pursue causality - and not mere descriptions - as far as possible, let me stress that for Bishop and Ellis "[s]tability conditions associated with the higher levels, or target domains, induce a contextual topology by *picking out* particular reference states and observables" (my emphasis) [12]. There is a *selection* of lower-level physical interactions that does not equate to the mental operation dubbed 'abstraction'. In the latter, irrelevant information is neglected for the sake of the knower's interests - e.g. in a subway map. In the former, one deals with an actual selection that makes a difference in Nature, namely, the emergence of a new system with new properties in a specific range of energies. That which makes a difference in Nature is called a (natural) cause. Again, it is not that previous interactions disappear. One is free to delve into as much a detailed description as one desires. Nevertheless, among the bunch of possibilities at the lower level, only some specific lower-level interactions are selected, and others are rejected. (Deacon goes as far as speaking about causation by absence [21]. Even if such conceptualization highlights the lack of many other possible configurations and trajectories in the lower-level phase space, it hinders the active role of selection in causation.) The need for establishing boundary conditions in our epistemic description of systems, to just pick up one solution of the differential equations initially describing all possible dynamics, hints at this same phenomenon.

To sum up, the "most basic laws of Physics define what is physically possible in the world. Yet, not all of these possibilities are updated through the basic laws and particles of elementary particle physics by themselves. It is the specific, concrete contexts that make particular regions of possibility space accessible." [12] The dilemma that one faces here is: (1) either contexts are mere epistemic tools easing scientific descriptions; or (2) contexts are actual and, according to the Eleatic principle, possess causal power. If one assumes (1), emergence seems to always boil down to epistemic emergence, whereas embracing (2) implies defining a new kind of causality, beyond physical, for contexts. (We will show in the next section that, despite his compatibilist account, this is Sean Carroll's ultimate stance on reality. See also [22].) Otherwise, contexts themselves become (epistemic) monikers. Indeed, (1) seems a plausible choice when dealing with gauge symmetries as a convenient way of unifying fundamental physical interactions, and symmetry breakings as an epistemic tool to enforce an actual physical realization of Nature. Bishop and Ellis also refer to the problem of unitary inequivalence among possible ground states of a Quantum field theory, which in my view would still be explainable in terms of option (1). On the contrary, whether (the emergence of) temperature in a many-body system with the help of thermodynamic equilibrium should be ascribed to option (1) or (2) is moot. Remarkably enough, whereas the authors defend that temperature cannot be understood as molecular motion in any straightforward sense, they claim that the KMS states at its origin "result from the *noncausal* global stability constraints" (my emphasis) [12]. Of course, the quintessentially ambiguous case, fluctuating between (1) and (2) according to different interpretations, is Quantum mechanics and the reduction of the wave function after performing a measurement. Even decoherence can be understood as contextual emergence [12], badly requiring classical assumptions [23].

However, there seems to be more than symmetry breakings in the increasing complexity of natural systems, as the recourse to stability conditions show - let us not say of living and thinking systems' complexity.

Ultimately, Bishop and Ellis deem contexts as fundamental as the elementary particles and interactions. ("First principles are 'fundamental' in the sense of being universal: they establish the space of physical possibility holding for all of reality, but do not determine all of what happens in reality. Concrete contexts are restrictions under various kinds of constraints that lead to actual phenomena and events, and as such are just as important for the existence and behavior of physical phenomena as the first principles." [12]) Contexts thus provide a new way of thinking about natural causality, since "contextual emergence indicates we should not think in terms of governance but in terms of possibility and constraint. What the most elementary or underlying particles and forces contribute are the necessary conditions defining the space of physical possibility. What is required for the actualization of specific possibilities are stability conditions characterizing concrete contexts." [12] (In a previous paper, Bishop already explicitly mentioned "downward causation" in physical process as fluid convection [24]. One may consider such paper a forerunner of explicating ontological causation in Physics, even though it only refers to formal causes in p. 242.). But why then not all physicists see things similarly and hesitate to confer causal power to contexts updating possibilities?

3. Carroll's fundamentalism

Sean Carroll does not deny the intricate interleaving of levels [12]. However, his claim that "there are no non-QFT phenomena characteristic of the theory of everything that are relevant for the everyday-life regime" [25] empties contexts - at least everyday-life contexts - of importance, which makes him close in on option (1), as presented in the last section. The rationale for such a bold claim is that "everyday phenomena do not depend directly on deeper levels, only through the Core Theory" [25]. 'Core Theory' (CT) refers to our effective (low-energy-limit) theory dealing with quarks, leptons, and intermediate bosons that successfully explains the emergence of all material systems of the Universe. (Gravity could be left aside at this level of discussion, as it does not play a crucial role within the range of energies relevant in everyday life.) Carroll assumes that such theory is not a theory of everything (TOE) and, very likely, stems from a more fundamental theory in a well-defined (even if not well understood yet) limit. Nevertheless, the CT is deemed both accurate and complete within the everyday-life regime.

In other words, CT's robustness in the typical range of energies of everyday life strongly supports that "new particles or forces must interact too weakly with CT fields to be relevant to everyday-life phenomena" [25]. Were they relevant, it is very unclear how the fundamental equations should implement the necessary modifications. As far as CT's epistemic mediation is enough, the rules governing our particular, human-circumscribed, relevant level of reality are fully understood, and there are no good reasons to believe that "understanding complex phenomena such as life or consciousness will require departures from the tenets of the Core Theory" [25]. Since everyday phenomena do not depend directly on deeper levels, only through CT, the latter screens off the would-be TOE's effects. (Unsurprisingly, Carroll predicts a strong decoupling between fundamental Physics and technology, as the latter only uses the Core Theory.)

Carroll spends some time showing the technical assumptions that allow physicists to focus on effective theories: integrating out the ultraviolet modes of the fields, cluster decomposition as a kind of locality requirement (that amplitudes for widely-separated scattering events be roughly independent of each other), and that the world follows the rules of an effective field theory in the long-distance/low-energy perturbative regime. "There is no room for unknown fields or unanticipated dynamics to play a role in accounting for macroscopic phenomena in the everyday-life regime." [25] Possibly extant unknown particles should be electrically neutral and invisible to the strong nuclear force; otherwise, they would interact very noticeably and have been detected long ago. Unfortunately, "there are no unknown particles with masses less than half that of the *Z* [bosons] (about 4×10^{10} eV) that interact with Core Theory fermions with an interaction strength greater than or equal to that of neutrinos". "New particles may certainly exist, but they must be either short-lived, weakly-interacting, or extremely rare in the Universe" [25]. Particles that become irrelevant for living and thinking systems as we know them on Earth. "If this package of claims - physicalism, EFT, Core Theory - is correct, it has a number of immediate implications. There is no life after death, as the information in a person's mind is encoded in the physical configuration of atoms in their body, and there is no physical mechanism for that information to be carried away after death." [25]

Are there some possible loopholes within Carroll's train of thought? He still points to the possibility of violations of locality, the wave-function collapse beyond physicalism, or even the emergence of a new force produced by the 'effectively fundamental' particles (neutrons, protons and electrons) when they are in the configuration of a human brain, something though not very promising for him. "A simpler - though still extremely challenging - alternative is to work to understand how those dynamics give rise to the emergent levels of reality in our macroscopic world." [25] Needless to say, that is the problem of emergence: how sufficiently coherent and increasingly complex systems build themselves up from the tiny bits of reality dubbed fundamental particles and interactions.

In a certain sense, Carroll hits the mark by claiming that no new 'fundamental' particles or interactions are necessary for the physics of everyday life. Yet the problem lies in how to interpret that *more that is needed* to make heads or tails of complex systems. (Whether, ultimately, more is different or not [26].) Differently put, why fundamental particles and interactions arrange themselves to form such systems, and whether the *more that is needed* is also fundamental in a sense different to that in which particles, fields and interactions can be fundamental. Remarkably enough, Carroll does not mention the role that boundary conditions play in picking out a unique solution to the differential equations nor, more importantly, say a word about the causes (if any) responsible for the robustness of the Core Theory in its application range, the crucial issue for a critical approach to emergence.

4. Penrose's argument on reduction of degrees of freedom

How is it possible that knowledgeable physicists and philosophers of Physics, such as Bishop, Ellis, and Carroll, disagree so deeply about the physics of emergence? One may salvage Carroll's stance by reducing his position to answering the following question: how much 'fundamentality' is necessary for emergence? For Carroll, none. However, that is a smokescreen since one still needs to explain why Nature organizes itself following increasingly complex patterns of activity, amenable to effective physical theories - or, should one prefer the technical jargon, why something as the group of renormalization works in some scenarios. My point here is that one can still respond to such questions by embracing position (1), more akin to Carroll, or position (2), more akin to Bishop and Ellis. The burden of the proof may shift from (2)-supporters to (1)-supporters, when one acknowledges that the emergence of complex systems requires exceptional initial conditions and dynamics in the Universe - the density matrix and the Hamiltonian of the Universe are exceptional [20] - so that “classical behaviour becomes a feature of the Universe itself and not a choice of observers” [27]. (“[T]he elementary Ehrenfest analysis already exhibits two necessary requirements for classical behavior: Some coarseness is needed in the description of the system as well as some restriction on its initial condition.” [27]) Even so, one could still claim that the additional information contained in Bishop and Ellis’ constraints acting as stability conditions is reducible to configurations of the effective quantum fields, without further causality required. This is quintessentially reductive physicalism.

As a way out of physicists’ being at loggerheads, I will take a different path in this section, inspired by Roger Penrose’s criticisms of the explanatory power of superstring theories [28] based on functional freedom. Beware! I will here invoke Penrose’s arguments as an epistemic clue to support ontological and, more specifically, ultimate emergence of immaterial knowledge in Section 6: the necessary recourse to additional - apparently non-fundamental - criteria to justify the coarse-graining of finer, lower levels into coarser, higher levels in Nature. String theoreticians assume that strings are the most fundamental objects in a universe with 9+1 (or 10+1 for M-theory) dimensions. Such extra dimensions allow for finite answers to calculations in our 3+1-dimensional world when applying the technical apparatus. Yet some powerful physical arguments need to be invoked to explain such dimensional reduction: “How is it that the highly thermalized matter degrees of freedom in the very early 9-spatial supra-dimensional universe could somehow have adjusted themselves so as to leave the extra 6 dimensions so apparently completely unexcited, as string theory appears to demand? One must also ask what gravitational dynamics could have produced such an enormous discrepancy in the different spatial dimensions, and question especially how it could have so cleanly separated the 6 curled-up unexcited dimensions from the 3 expanding ones.” [28, p. 197]

But the problem not only lies in the questionable plausibility of concrete physical processes responsible for such reduction. “What happens to the floods of excessive degrees of freedom that now become available to the system, by virtue of the huge functional freedom that is potentially available in the extra spatial dimensions?” [28, p. 42] Penrose then argues for the instability of the whole space-time when six (or seven) wrapped spatial dimensions become part of the theory [28, p. 77]. One must reasonably hesitate on extra dimensions being under control. Even if restrictions for the ground state - e.g. using Calabi-Yau geometries for the extra dimensions - are concocted, infinities in the curvature of space-time are bound to occur. The singularity theorems of General relativity loom large [29] for string theories too.

More importantly, such criticism highlights the enormous difference between degrees of freedom in superstring theories and any effective theory - e.g. CT - in a four-dimensional manifold. For instance, the astronomical figure for inequivalent vacua (available ground states) in M-theories - of the order of 10^{500} possibilities in the case of Calabi-Yau spaces - makes it necessary to engage in dubious selection arguments hardly justifiable from Physics alone. Thus, apart from instability problems, string theories must face up to noted trouble in the Philosophy of science, namely, the lack of isomorphism between our most fundamental theories and the actual natural processes. In practical terms, further prescriptions and selection rules need to be introduced almost by fiat. To recap for our interests, Penrose's argument on functional freedom illustrates how extra dimensions enormously increase the number of possibilities because of their presence as exponents in the tally of degrees of freedom. The irony lies in a theoretically-motivated expansion that demands further reduction.

5. Why mapping between levels requires the immateriality of formal causation

Be as it may in the physical quarters, the subtle point from a philosophical viewpoint is that the reduction of dimensions - or, equivalently, the mapping of degrees of freedom from an (alleged) TOE to an effective theory - requires additional criteria that remain alien to the TOE. Whereas the latter has to deal with all its degrees of freedom on an equal footing, the additional criteria become essential for the TOE's translation into an effective theory. As Hans Primas has also shown, "The validity domain of the so constructed higher-level theory intersects nontrivially with the validity domain of the basic theory: neither domain is contained in the other" [13]. Moreover, in keeping with Bishop and Ellis's view on the relevance of contexts, one needs to restrict "the domain of the basic theory and the introduction of a new coarser topology" [13]. Consequently, new emergent properties (and degrees of freedom) arise as caused by such selected topologies. The crucial point here is to derive the ontological causal consequences of said (only apparently) epistemic procedures.

In other words, a fresher look at the ontological value of emergence must appear when elucidating the ontological value of the mapping between an (allegedly) fundamental (lower level) theory and an effective (upper level) theory. The gist of my argument, fully compatible with Bishop and Ellis's own interpretation, is that such mapping involves not just mere selection but selection as a new interpretation and actualization of possibilities, namely, the emergence of new degrees of freedom in a novel systemic organization according to new properties. That 'brute' fact, the requirement of a new level of description at the epistemic level, points to what is ontologically known as formal causation. The reason for such a leap is that no fundamental (in Carroll's sense) physical field, particle, or interaction can itself play such 'selective' actualization of possibilities in the lower level. 'Selection', here, means that the set of lower-level degrees of freedom that is coarse-grained to define a higher-level degree of freedom possesses some kind of structure, amenable to interpretation, and is not chosen randomly among the individual microscopic degrees of freedom. The whole point of invoking formal causation relies on the fact that the actualization rule cannot be derived only from lower-level information and dynamics.

Another way to illustrate the need for a kind of causation different from the usual physical causality responsible for dynamics, as described via differential equations derived from the fundamental laws of Nature, is the need for introducing higher-level information about the system under study through initial or boundary conditions to individuate the concrete system's dynamics and hence the emergence of the system itself. Such procedure is particularly pressing in the case of complex systems, as the current Neo-Aristotelian approaches to Philosophy of Science set out to show [6; 21, p. 230-234; 30-32].

To be more specific, any mapping *f*: M → N, where the number of elements of M is greater than the number of elements of N so that *f* is not an automorphism, requires formal criteria of selection which, in the case of M and N being actual sets of degrees of freedom in Nature, also requires formal causation. Somewhat surprisingly, the majority of the literature does not pay much attention to the need for invoking such kind of causation. The literature on emergence usually refers to mapping *f* under the generic term 'bridge law'. Like a bridge, *f* connects two different realms with two different dynamical laws; in that sense, *f* also induces a link between the lower-level and the higher-level law. However, the relationship between the degrees of freedom of the lower and higher levels via a specific coarse-graining is more fundamental than the relationship between the corresponding laws, as the latter must explain the degrees of freedom's measured values. The point, already hinted at by Ernest Nagel, is that "[i]f bridge laws should thus be conceived of as stating identities or relations among the relevant terms 'extensions, then clearly reduction on such a view incorporates essential reference to the theories' ontologies and is more than just a two-place relation holding among theories" [33]. Even if the "literature on reduction addresses these questions about the status of the bridge laws," [34] their ontological status as identity relations is controversial inasmuch as one forgets formal causation as a principle of identity [35].

The rationale behind the scenes is, in my opinion, that epistemic emergentists - i.e. (1)-defenders - only too freely use epistemic arguments without paying attention to their ontological consequences, namely, what is the ontological value of setting up a correspondence between two different sets. Even if one denies actuality to the emergent (higher level) set, the mapping contains an actual initial set that has not in itself any cue or preference for any particular subset of elements. Should one stick to the unique reality of set M and the unreality of both mapping *f* and the knowledge of *f*, the reality of M has no causal power to explain away both *f* and the knowledge of *f*, which stand as a *deus ex machina* for (1)-supporters.

Notice that neither supervenience nor non-reductive physicalism have a better ontology for the mapping *f*. For one, supervenience merely assumes that changing from element $n_1 \in N$ to $n_2 \in N$ necessarily implies a change in the initial subset $m_1 \subset M$ - defined as $f(m_1) = n_1$ - to $m_2 \subset M$ - defined as $f(m_2) = n_2$ [36]. Still, supervenience remains silent on the causal power of *f* and becomes just a moniker devoid of explanatory power, as it ultimately denies that something new emerges. For other, non-reductive physicalism must assume the existence of some physical law - as fundamental as the most fundamental set M defined as the set comprising every natural element that is not the image of any other natural element - that governs which mappings in the set {*f*} are realized or forbidden in Nature. Since, as far as we know, coarse-grainings do not enjoy a fundamental status in Nature [6, 29], they can only be justified a posteriori, namely, assuming the (fundamental) existence of higher levels, like N, that dictate the additional epistemic constraints to be invoked - should one aim to explain the emergence of N from M. "A quantum universe exhibits many different decoherent sets of alternative coarse-grained histories - many different realms. Two realms are compatible if each one can be fine-grained to yield the same realm. But there are also mutually incompatible realms for which there is no finer-grained realm of which they are both coarse-grainings. Quantum mechanics by itself does not prefer any one of these realms over the others. Why then do we as human (…) focus almost exclusively on quasiclassical realms?" [27] To give a glimpse of how the epistemic and the ontological are inextricably mixed, pace Carroll, suffice to say that "we do not have precise notions of the diffeomorphism invariant coarse-grainings that define the classical behaviour of geometry in everyday situations above the Planck scale" [27].

Is the non-reductive physicalist thus not safe by assuming the fundamentality of M, N, and the mapping *f*? No, for the very reason that whereas elements in M and N do keep their material character - as shown by their inter-level proper dynamical laws, d_M and d_N respectively - *f* does not, as it is unaffected by dynamical laws at play in both M and N. Moreover, *f* itself selects the specific dynamical law at N, d_N, as the dynamic that keeps *f* invariant in a spatiotemporal scale and range of energy. In other words, the specific f: M → N induces d_N as an endomorphism in N fully respectful of at least one d_M. It is such invariance that (epistemically) defines *f* as (ontologically) formal.

6. Immaterial knowledge as ultimate emergence

May one use such an argument to frame the emergence of immaterial knowledge within the more general framework of ontological emergence in Nature? For the time being, said argument provides a broader causal narrative for how contextual emergence occurs in Nature and ties the latter to multiple realizability whenever N possesses a lesser amount of degrees of freedom than M. Nevertheless, the bonus of allowing for a set of formal criteria *C* that specify the mapping *f* is as follows: it might be the case that N possesses more degrees of freedom than M, so that *f* stops being a many-to-one mapping, becoming a one-to-many mapping. As a borderline case, N could contain not only a countable infinite number of degrees of freedom (being equivalent to the set of natural numbers) but encompass all the sets of possible descriptions of the universe (a potentially much larger infinite, very likely of the continuum order). The coarse-graining trending from many lower-level degrees of freedom to one higher-level degree of freedom is reversed, eventually becoming a fine-graining from one to many.

Said inversion would imply rejecting the supervenience of immaterial knowledge but not its material and efficient causal dependence on its neural correlates (the lower-level degrees of freedom). The crux of the issue relies on the set of formal criteria *C* that, as far as remaining formal, can not only reduce the number of emergent degrees of freedom but, in this case, increase them by immaterial enhancement - i.e. not necessarily depending on the lower level. Were that the case, the mapping *f* could be eventually got rid of and N could enjoy its autonomy, even if still linked to M via *f*. (For instance, this is what occurs in the case of human language, thanks to its symbolic freedom. Even if conveying meaning requires some material basis, a formal agreement between communicators is sufficient to select any code. The existence of differences among the elements of the lower level is enough to create a higher-level language.) If one accepts the overall causal power of different *C*'s for the emergence of higher levels in nature, it could be the case that each *C* selects the neural correlates of immaterial knowledge by rapidly growing the cognitive degrees of freedom; *C*-criteria themselves becoming the new degrees of freedom. Formal causation may cause both in the many-to-one and in the one-to-many directions; the latter being the benchmark of immateriality. Hence, this description could help to illustrate what immaterial knowledge amounts to within a universe where ontological emergence naturally occurs.

To be sure, one here deals with a framework that does not solve the more general mind-body problem. Solving the latter would particularly imply knowing the set of formal criteria *C* defining the actual mapping *f* for each instantiation of immaterial knowledge. But it is unlikely that such psychophysical mapping is within the grasp of human knowledge. Let us consider, for instance, the difficulty of defining mappings between the natural numbers and the continuum. In Mathematics, such mappings are possible as limits of ordered, infinite sequences of natural numbers - a Cauchy sequence of rational numbers. But that would require a specific selection (a formal cause) of an ordering of potentially infinite physical degrees of freedom by the mental state of 'knowing a real number'. Whether thinking the continuum is itself the better proof of the immateriality of knowledge - as Georg Cantor's pains with the continuum hypothesis seems to suggest - requires, in my opinion, further consideration.

Unquestionably, this framework provides some gain, namely, a framework respectful of the continuity and discontinuity between the different levels of Nature. All levels of Nature are actual and need a certain amount of formal causation, namely, what selects subsets of elements in the most immediate lower level to define the new degrees of freedom at the higher level and the specific dynamics at the lower level that allow for a new dynamic at the higher level consistent with the mapping *f*. One could dub such a phenomenon 'contextual emergence' since the definition of *f* asks for higher-level information. The emergence of immaterial knowledge in nature dovetails with such an explanatory framework (continuity) but adds something else that one should dub not just contextual but ultimate. The emergence of immaterial knowledge is ultimate because, for the first time, a contextual coarse-graining trend is reversed in Nature (discontinuity). The emergence of immaterial knowledge, i.e. a formal mapping based on the physical dynamics of many lower levels but ultimately not necessarily dependent on them, may be considered the beginning of infinity in Nature [37]. The ultimate emergence of immaterial knowledge thus means the transition from a necessarily physical coarse-graining of degrees of freedom to a contingently physical fine-graining of new degrees of freedom.

Such ultimate emergence also makes sense from the evolutionary perspective. If complex adaptive systems optimally combine resilience and adaptability to keep their identity in a changing landscape, they should enjoy enough plasticity to devote only the needed resources to face environmental conditions. Now, immaterial knowledge - a prerogative of human beings as far as we know - offers the greatest possible plasticity, i.e. one that redefines each situation through a new ordering of potentially infinite physical degrees of freedom. As Basti puts it out: "Due to its capacity to generalize (abstraction) with respect to all conditioned and singular datum, human knowledge can be applied to, or focus on an infinity of similar cases […]. When it results inadequate for a new set of data ('knowing of not knowing'), the procedure of adaptation can repeat itself indefinitely. It is evident that, in order to avoid an infinite regression and to allow such a type of abstraction […] a transcendent 'closure' of the finite hierarchy of inner and external senses is needed. Such a closure is nothing but a self-consciousness of non-organic nature, hence not materially conditioned by the past, what the Ancients used to call *intellectus*, having the capacity to act immediately on itself […], and therefore capable of *intelligere se intelligere* (to know that it is knowing)." [38]

In other words, immaterial knowledge permits human beings to tackle new issues without unconditionally being subject to natural selection, i.e. totally conditioned by the physical environment, and without needing to risk their lives in many interactions with the environment. Contrary to genes, intellectual knowledge is shared and selected among humans in keeping with their intrinsic validity to describe the world. Therefore, even if formal causes in humans give unity to the whole bodily activities, their crucial and distinctive operations are not physiological but informational, allowing for actual knowledge of and the formulation of new hypotheses about the world in its intelligibility and immateriality. The duality between the physiological and the informational can be reframed within the hylomorphic basic duality between matter and form - which, thanks to evolution, attains its apex with the ultimate emergence of a formal cause in humans that enables immaterial knowledge. On how hylomorphism may circumnavigate the causal pairing problem [39]. Said duality can also frame Penrose's three worlds, otherwise remaining three deep mysteries [40], as well as the famous Whitehead's comment: "[T]he world for me is nothing else than how the functionings of my body present it for my experience. The world is thus wholly to be discerned within those functionings (…). And yet, on the other hand, the body is merely one society of functionings within the universal society of the world." [41]

7. Conclusions

This paper has proceeded via several steps. After discussing in the Introduction why the relationship between levels and causes should not be understood in modal terms, i.e. sufficient and necessary conditions, Sections 2-3 have attempted to show why ontological emergence is misapprehended by some physicists who, maybe inadvertently, end up by embracing science as dealing with an only-epistemic emergence. Not surprisingly, Frank Wilczek presents its ideal scientific goal as evincing the ultimate equation 'real = ideal' [42] - admittedly, the only sensible option available for a diehard reductionist. Consequently, in different degrees and with particular nuances, scientific realism should admit the ontological emergence of natural levels that enjoy an existence analogous to the (alleged) fundamental ones. The discussion between Bishop and Ellis, and Carroll illustrates their misunderstandings besides their background stances.

In a second part (Sections 4-6), this paper has tackled the transition between different levels of reality and has benefitted from Penrose's argument on extra dimensions against the explanatory power of any superstring theory in its current form. Nonetheless, the crux of the argument in favor of ontological emergence is not the instability of the extra-curled dimensions or their intrinsic instability. Any coarse-graining or mapping f between the different levels of a physical description of Nature requires a formal kind of causation. Formal causation picks out classes of equivalence among the elements of the most immediate lower level and the relevant dynamics that make f invariant in the physical regime featuring the emergent system anew.

Contextual emergence - the existence of formal criteria to define f contingent on upper-level information - and multiple realizability - different microstates at the lower level with the same macrostate at the higher level - are thus two sides of the same hylomorphic coin in a material universe. However, inspecting the natural trend helps us understand the ultimate emergence of immaterial knowledge as an inversion of the contextual emergence that occurs at many levels in Nature. Whereas a general M-to-N relationship, with M possessing more elements than N, features contextual emergence, the level proper to immaterial knowledge implies the emergence of finer degrees of freedom. In a way, this inversion represents an ultimate step in the gradation of ontological emergence and the renormalization of nature itself. The lift-off of immateriality occurs in continuity with the ontological emergence of new levels. Additionally, it introduces an ultimate discontinuity because of the possible decoupling of the physically immediate lower level. Such discontinuity stems from the power of formal causation to order and select among the physical degrees of freedom extant in the Universe.

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