The Evolution of Matter:
The Quantal Unit of Evolution
A Sketch

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Abstract. The scientific notion of evolution is based on a group of phenomena intrinsic to matter and constitutive of the history of the cosmos in Space-Time. Given that matter can be regarded as a partially localised form of radiant energy, the *mechanical aspect* of its evolution is quantal. In addition, the continuity of energy flows in the cosmic context is best understood causally and expressed functionally in the patterning of observables. Within this general framework, two kinds of observations should be distinguished: those that pertain to the *core mechanism* underlying the evolution of matter and those that define what is meant by *diversification of natural systems.*

Given that all natural systems are material, the *basic mechanisms* that govern their construction should account for the genesis of the basic forms of matter and for the processes of their complexification. From which we infer that the *causal principles* that orchestrate the evolution of all material systems are to be sought in the *dynamical substrate* where energy transactions effect the genesis of all particles as well as their interactions.

By contrast, the *diversification* of natural systems is to be sought in the specific energy domains in which they emerge and where their behavior is observed. The *stratification* of these domains, which is apparent in the observed specificity of the modes of interaction of natural systems, is a quantal effect of the energy fields acting on them. The *energy gaps* separating adjacent modal strata are known to be opaque to the transactional processes on either side of them, ruling out the possibility of a multimodal reductionist strategy in the representation of the evolution of matter.

Nonetheless, the assumed dynamical unity of nature and the ubiquitous role of the underlying core mechanism in the evolution of natural systems, suggest the desirability of some form of reductionism in its representation. The relation of effects to their causes, when these belong to different domains of observation, as is the case in cosmic evolution, cannot be got by derivation from first principles in the sense of Lagrange. The causal principles must be taken to be operationally effective where the constructive action actually takes place rather than in the domain where their effects are apparent. This action is found in the high energy domains where the building blocks of all matter are constructed, a region whose emergence antecedes that of atomic matter, the point at which the diversification of natural systems may be said to begin.

This paper is a brief sketch of the mechanisms that govern the construction of natural systems. Consequently, relatively little will be said about the external circumstances of their diversification. As nature has relatively few tricks in its bag, what follows may be viewed as an overview of the *quantal unit of evolution (QUE)*, modally indexed.

INTRODUCTORY REMARKS

The scientific notion of evolution is based on a group of phenomena intrinsic to the concept of matter and constitutive of the history of the cosmos in Space-Time. The science of matter being causal, the continuity of the energy flows in the cosmic context is best expressed functionally in the patterning of observables.

The natural evolution of any unary system raises a number of difficult questions: How could it self-organize from non-existence? How could it isolate itself from its environment? How can it resist the perturbations from that environment? Why is it so very different from its historical antecedents? I.e. why did the Natural Systems all emerge at the same time? The first question is about the *origin* of the dynamism of nature, the second is about the *mechanism* of unitarity, the third is about its dynamical *stability*, and the fourth has to do with the apparent *weirdness* of the behavior of nature.

All four of these questions are about transformations of *energy*, the protean stuff out of which the dynamical cosmos is made. Its ultimate origin appears as the Zero-Point Field, also known as the Quantum Vacuum (QV), reminiscent of the Chaos of the Ancients whose ordering of matter was attributed to the injection of numbers by the Demiourgos. So the first answer is *the action of the QV* represented in some suitable mathematical form. The answer to the second question is given by the *entanglement of energy fields* whose action is to isolate the material constituents of the system from their environment. The answer to the third question is the creation of a protective shield by the *closure* of the entangled fields, an *energy gap* separating the internal regime from its external environment. The energy needed for this process is extracted from the material constituents of the system and activated by the QV. The answer to the last question raises the so-called *weirdness* of the quantum world, a psychological phenomenon due to widespread but mistaken classical assumptions, such as the view that the furnishings of nature are all material. The weirdness manifests itself in numerous contexts, for example in the transactional opacity of energy gaps, or in the so-called collapse of energy fields when they interact with matter. These then are the four types of energy transformations that collectively bring about the emergence of natural systems.

Although the energy transformations in the evolutionary process are relatively few in number, their pattern repeats itself, all natural systems being unitary. The completion of the evolutionary process is indicated by the appearance in the domain of emergence of a new type of behavior revealed by the symmetry properties of its representation, the joint effect of the greater complexity of its dynamical architecture and of the locality of quantum phenomena. Therefore, we may expect the *general pattern* of these energy processes to retain a characteristic form, but to be more finely structured by the minimal adjunction of new terms reflecting its internal complexification. This indeed is what we find [1].

Within this general framework, two kinds of transformational processes stand out: the *core mechanisms* of the construction of matter, and those underlying the *diversification* of natural systems. This paper is focused on the first of these.

THE MECHANISM

Given the abstract character of this discourse, it is best to begin with a well known example to illustrate the mechanism leading to the closure and to the complexification of evolving systems. These processes also determine the characteristics of the evolved system's environment.

An Example: The Liquid Drop Model for Atomic Nuclei

Following the historical path found in many good textbooks [2], let us consider a drop of non compressible liquid made by the accretion of n molecules in a non gravitational context to ensure its symmetry. If the radius of the drop is R, then its density will be $\propto Rn/3$. Let these molecules be acted upon by an intermolecular field a which is attractive if the distance d is greater than $2R$ but repulsive when $d \leq 2R$.

The energy needed to extract one molecule from the globular complex then is:

$$- an + 4\Pi R^2 T \qquad (1)$$

(the second expression is *the surface term*, with T standing for the surface tension of the spherical drop). This energy has

to be sufficient to neutralize the *binding energy* of the molecules:

$$B = an - \beta n^{2/3} \qquad (2)$$

(**β** includes all the constants in the surface term in (1) which are independent of **a**). Note that the molecules have lost their degrees of freedom, hence their autonomy: they cannot be counted and the density of the drop remains the only measurable parameter.

Now let us increase the complexity of this model a bit and assume that each molecule sports an electric charge ***q***. The total charge of the drop will be:

$$Q = nq$$

If this charge were distributed evenly on the surface of the drop, the Coulomb energy would be

$$Q^2/8\pi\varepsilon_o R$$

On the other hand, if the charge were distributed uniformly among the molecules, the Coulomb energy would be:

$$3\ Q^2/20\pi\varepsilon_o R$$

in which case the *binding energy* would decrease to:

$$B = an - \beta n^{2/3} - \gamma Q^2/n^{1/3} \qquad (3)$$

in which ***γ*** includes the Coulomb effect except for the dependence on ***Q*** and ***n***.

This is the so-called *liquid drop model* of nuclei, the molecules standing for the nucleons. Looking at the nuclear case in the light of this model, we let:

$$n \longrightarrow A \text{ and } Q \longrightarrow Z$$

in the equation for the binding energy which becomes:

$$B(Z,A) = a_v - a_s A^{2/3} - a_c Z^2/A^{1/3} \qquad (4)$$

where: a_V is the *volume term*, a_S the *surface term* and a_C the *Coulomb term*, which are constants in the nuclear case. Actually, this is not quite correct because of the hidden assumption inherent in this drop model that all nucleons are identical, which is contrary to fact. For example, if we were to let **Z = 0**, equation (4) would represent the binding energy for a nucleus made exclusively of neutrons, a beast not of our zoo.

However, given that in certain circumstances, such as ***β***-decay, some nucleons convert to the other type, it makes sense to examine the cases where **Z ----> N.** We may expect that some extra terms would have to be added to (4) to reflect the new distribution of electric charges in the nucleus. It was found that two terms were needed to make the liquid drop model useful. The first is the *asymmetry term* which reduces the binding energy when **Z≠N**:

$$- a_A (Z-N)^2 / A$$

The second one is the *pairing term,* designed to reflect the fact that two nucleons of the same type bind more strongly than do mixed pairs, as do birds of a feather. For nuclei with odd numbers of nucleons, where **Z≠N**, the pairing term is null, while for pairs of like nucleons, the pairing term is 1, a relation expressible as: **δ(Z,A)**, which is to be added to or subtracted from (4) when ***A*** is even, depending on whether the paired nucleons are both even or both odd.

The binding process sketched out here is actually more complex than it is made out to be as the number of nucleons

increases. It becomes even more so in the case of large molecular and cellular systems [3]. Before we complete this brief story of the evolution of atomic nuclei, let us examine some of the key notions involved.

Remarks on The Mechanism

The *Mechanism of Evolution* is observable in the domain where the basic forms of matter originate and where they interact, i.e. in the *dynamical substrate* of all natural systems. *Natural Systems* (NS) evolve in well defined energy strata (their cosmic 'window of opportunity') whose threshold value is at their high energy end. Their *genesis*, i.e. their material *construction,* has its origin in the Hot Bang and terminates with their emergence in the specific energy domain identified by their observable properties, particularly the symmetries of the canonical representation of their transactional behavior. Their *dynamic* properties are the effects of *field-field* transactions, although it is often expedient to represent their consequences in terms of the behavior of the particles subjected to these actions in experimental contexts. The ultimate source of all this energy is the so-called Quantum Vacuum.

The complex elaboration of the architecture of a Natural System is a distinctive feature of evolution closely related to the density of the ambient radiant energy. The *action of the energy fields* engaged in this construction is confined to the local domain where the material constituents are interacting. This action, which begins with their superposition, is completed by their entanglement and closure. With the completion of the constructive phase, the processes confined to the substrate of the newly evolved system become engaged in the maintenance of its dynamical stability.

Transactional processes are so-called because they are exchanges of energy between systems of the same modal character. Their full representation demands that both retarded and advanced solutions be considered, whence the need to square the amplitude of the equation of state for the system, e.g. the Schrödinger equation (squared), the Dirac equation, the Klein Gordon equation, etc. (The solution of the ordinary Schrödinger equation does not yield the advanced solution, and is thus incomplete)[4].

The *superposition* of energy fields, which involves their frequency and phase, are observable in such phenomena as interference, diffraction, etc.. Their *entanglement* is a process whose complexity is a function of the local energy profile. Although entanglement normally follows the prior superposition of fields, their functional roles are different. For instance, true quantum computation does not always require the entanglements of fields, their superposition and parallelism being sufficient in some contexts.

In the evolutionary context entanglements are the means by which energy is extracted from their material constituents, an essential step to the eventual *closure* of the interactional processes. The extracted energy is invested in the *self-organization* of the emergent system and in the establishment and maintenance of its *dynamical stability* in an external environment, all conditions on which its unitary behavior depends [???5].

STAGES OF EVOLUTION

The internal structure of the evolutionary process is complex. Its principal stages are: (i) the closure of the transactional processes, which is the foundation of the system's unary character, (ii) the resulting *energy boundary* (or *Cut* as Heisenberg called it), (iii) the *transactional opacity* of that boundary, which is the basis of its unitary behavior in the emergent environment.

Closure

All natural systems self-organize from a level of high radiant energy to a lower one, the energy difference being invested in the construction of dynamically stable systems. Their external properties are *unitary action* and *dynamical stability,* both direct consequences of the closure of internal processes.

The *closure* of the entangled energy fields constrains their material constituents within an enclosed space. This sheltered space is often represented mathematically by a *potential well*, the expression of its relative isolation from the external world and the warrant of its dynamical stability.

This is well illustrated by the *closure of atomic nuclei* whose material constituents are protons and neutrons [2] . Their confinement is controlled by internal factors, such as their proximity to each other and to the nucleus, which are encoded in the energy profile of the potential well. Within the well, their de Broglie wave functions get entangled and the nucleons lose their degrees of freedom, hence their independent identity, as do drops of rain in the sea, the whole process being accompanied by the partial redistribution of their original energy, including that stored in their rest mass [7???].

The energy stored in *the mass* of the emergent nucleus is less than the sum of the energies ***B*** stored in the masses of the nucleons prior to their entanglement: i.e.

$$M(Z,A)c^2 = ZM_pc^2 + (A-Z)M_nc^2 - B \qquad (5)$$

where **Z** is the number of protons, **A** the atomic number of the nucleus (the total number of nucleons in the nucleus) and $\mathbf{B} = \Sigma_A \mathbf{M_A c^2}$. When (5) is divided by the atomic number **A**, it yields the so-called *binding energy per nucleon* **B/A** for that particular nucleus. Ignoring the first few atomic elements, **B/A** remains remarkably constant across the atomic chart, reaching its maximum of **8.7 MeV** for **A = 60** (Nd), and then declining to **7.6 MeV** for Uranium **(A = 92)**. Furthermore, the *density of nuclear matter* is also found to be roughly constant across the periodic table of elements [2].

The *loss of mass* by the material constituents of the nuclei and the constancy of the internal *density of matter*, are two effects of the binding of the nucleons into a single unit of action similar to what we saw in the case of the liquid drop. These striking similarities led us to begin our story with a liquid drop model. Their significance lies in the effects that the dynamics of self organization has on the internal complexification of the energy structure prior to the closure and emergence of the new system.

The sensitivity and dependence of self-organization on the energy profile of the context in which it occurs explains why it is that a single formula cannot be got to represent the evolution of all natural systems without modal modifications. Therein lies a source of their diversification.

The Energy Gap

The unitary behavior of all natural systems means their individual segregation from the rest of the world, in the sense that their action in their emergent environment is both local and direct. The *locality* of their action is the expression of their material character and the symptom of their unity in Space-Time, while its *directness* is the result of the enablement of their external means of action by the energy extracted internally from material constituents of the system. The *directness* of their action is effected by the superposition of their wave function with the energy profile of their local environment, with their consequent behavior serving as the primary symptom of their unitarity.

The Opacity of the Energy Boundary

The *transactional impermeability* of the energy boundary is the means for the maintenance of the unitary coherence of the system's action in the emergent domain. It is an integral part of the shielding mechanism, and a necessary condition for its *internal stability* [7].

THE DYNAMICAL STABILITY OF NS

From time to time arguments have been put forward by distinguished physicists, among whom we find some Nobel laureates, e.g. Niels Bohr, Erwin Schrödinger, Brian Josephson [9], pondering the role of QM in the study of the genesis and functioning of human cognition and, more generally, of living organisms. We'll examine briefly some of the grounds underlying the difficulties encountered so far.

I shall mention only two groups of arguments here which appear to me to be the most significant. The first group clusters around the issue of the coherence of natural systems. More specifically, they raise the issue of the experimental determination of their dynamical structure based on the assumption that complex biosystems, including cognitive ones, are too fragile to retain their dynamical integrity when subjected to the perturbations inherent in the coupling with their environments. This is construed by many as evidence that their dynamical structure cannot be accounted for in terms of QM, given that these systems are known to be complex and to remain dynamically stable. The central issue for this group

of difficulties is therefore that of the *decoherence* of biosystems subjected to energy fluctuations, whether due to experimental probes or to environmental perturbations.

The second group of arguments is foundational in character and specific to the case of humans. They are consequential to the absence of an *epistemic domain* between the Cartesian Cut of *the observer* and the nature of the contents of *human experience* [10], a fact which rules out the very possibility of an empirically grounded *science of cognitive matter for humans*. We'll begin with the issue of decoherence and continue with that of the modal cuts.

DECOHERENCE

Because of the *non local* character of energy fields, the issue of decoherence must be examined in its *natural energy context* rather than in a contrived one in which a test system, bereft of any effective shielding, is perturbed by an external field, as many experimentalists and theorists have been inclined to do (e.g. Zurek [11], Tegmark [12]). If the issue is the evolution of life or that of consciousness, and if the relevance of QM to the evolution of matter is granted, then it is essential that one's attention be focused on natural systems rather than on engineered ones, given that the science of matter is inherently contextual.

A quantum system is naturally dependent on the energy field of which it is a local expression. It may also be dependent on other fields not necessarily implicated directly in its emergence, such as a gravitational field. Though *Energy Fields* are thought to be intimately related in the sufficiently high energies where they are expected to merge, they are orthogonal in the observation contexts discussed here. In any case, the fields set the tone for the behavior of all natural systems, symptoms of which are the *traces* left by their energy transactions in the domain of observation. A natural system is but a *unit of action* in some energy field: it has a *transactional identity*, observations being interactions between observer and observed.

Several experimental strategies have been designed specifically to illustrate the possibility of quantum coherence under assault from the environment. I shall mention two recent ones.

The first case is that of a fully engineered decoherence-free quantum memory of one qubit [13]. The qubit, stored in a single ion, is encoded into a *decoherence free subspace* (DFS) created by a pair of trapped $^{9}Be^{+}$ ions. The qubit of information is then found to be effectively shielded from the dephasing influence induced by applied external fields. The main points to be noted here are: (i) the boundaries of the space created by the trapped ions effectively insulate the subspace inhabited by the qubit from the external environment; (ii) the engineered perturbations of the external fields actually increase the effectiveness of the shield protecting the qubit by up to an order of magnitude; (iii) the effect of encoding an arbitrary qubit in a single ion is to transfer it reversibly to the DFS created by the energy boundary formed by the two $^{9}Be^{+}$ ions.

The second case is that of NMRI.(Nuclear Magnetic Resonance Imaging), a non invasive engineered system set in a biological environment [14]. It involves the creation of closed energy paths in organic tissues by energizing the magnetic moments of the protons present in the water molecules. This is done by applying external magnetic fields suitably modulated by radio frequency to separate the individual protonic orbits. The orbits are then projected onto a symplectic space, i.e. onto a flat Euclidean space, where after suitable treatment, the overall topology of whole organ slices can be displayed in space/time and observed. The main steps are: (i) the creation of forced cyclical processes in an organic milieu, (ii) their continued coherence in that same milieu after the fields and the radio modulation have been temporarily turned off, despite the relatively high absolute temperature of the human body.

In none of these experimental cases is the dynamical coherence of the internal régime compromised by the perturbations of the dynamical environment, whether due to external fields or to thermal agitation.

THE MODAL CUTS

The opacity of the *energy boundary* to the transactional processes on either side of it sets the observable limits of what is in fact a *Quantum Macro System* (QMS), with a unitary dynamical identity represented by its wave function. This modal boundary, whose existence was first noted by Heisenberg in the late 1920's, is now referred to as the *Heisenberg Cut* [15]. Another modal boundary separates the domain of the publically accessible, hence objective, transactional processes

external to the observer from those internal to him, which he experiences; this boundary, characteristic of human observers, was referred to earlier as the *Cartesian Cut* [16].

The grounds on which the second set of objections, the foundational ones, rests are the most serious of the two, because a necessary condition for the objectivity of observation is that the observer be external to what is being observed. In the case of conceptual systems - and science is a conceptual enterprise - the difficulty is compounded by the fact that the Cartesian Cut of the observer lies astride his Heisenberg Cut, in the sense that the observer accesses both what is in the public domain and what is in his private domain. The consequence is that any statement that depends for its *logical validation* on evidence lying within the scope of the Cartesian Cut, which is only accessible by the individual observer and hence subjective, fails to meet the main criterion for objectivity in the representation of what is the fact of the matter. The *Know Thyself* of the Pythic Oracle, construed as a research program, is not realizable.

This situation is clearly an accident of natural history, though it rules out the possibility of a causal account of human consciousness in its evolutionary context, i.e. the possible extension of the methodology of the sciences of matter beyond the threshold of human perception, as Descartes' methodological dualism first made clear. This does not entail that the transactional processes internal to the modal domain of human cognition are no longer quantal, nor does it mean that the evolution of larger systems of which Man is an integral part, for example social systems, aren't either. It only entails that the effects of these processes are no longer objectively accessible, though many of the traces they leave in the domain of observation are. For example, we may even imagine a *more evolved* observer, conceivably endowed with different endogeneous means of interaction - and therefore of observation - having their origin in a modal stratum different from that of human cognition, perhaps in ways somewhat analogous to those that separate us from animals. In this hypothetical situation, such a being could conceivably be in a position to study humans objectively and create a science of human mentation as a modality of the science of matter. However, given the assumption of the unity of Nature, we may infer that this hypothetical being would encounter similar kinds of limitations at his level of observation if he were to undertake a study of his own cognitive processes, and if QM in its present stage of development were to remain the only analytical instrument at his disposal.

RESOLUTION

Of the two sets of alleged difficulties encountered in trying to realize the expectations authorized by quantum mechanics in the modal contexts of human cognition, one is based on the decoherence of energy perturbations thought to be inevitable within any context of observation, and the other is grounded on foundational issues which arose as a result of the observed modal stratification of the processes of energy transformation.

Of the *experimental* set, the first case (that of the qubit of information encoded in a $^{9}Be^{+}$ ion) occurs at the microscopic level, the second case spans the modal distance between microscopic and macroscopic systems by linking the induced protonic ballets to the external topology of the macro system, e.g. that of an organ section. In these experimentally validated cases, decoherence fails to happen for what I suggest are similar reasons: the de Broglie wave functions of the material elements get entangled in the energy fields and become synergetically *enslaved* (Haken's expression). In this situation, energy is extracted from these material elements and partially reinvested in the macro system. Thus energized, the emergent QMS can function in its environment as a unitary system with a single wave function, the necessary requisites for its dynamical identity in external fields. Thus, we may conclude in all these cases that the news of the decoherence of the systems is grossly exaggerated and in need of empirical validation.

The *foundational issue* is, not surprisingly, more potent, its implications for a scientific account of human cognition dim. Three aspects are salient: (a) the quantal reality, (b) the modal boundaries, (c) the non reducibility of the modal sciences. Let's recall each briefly.

Quantal Reality. From the dynamical point of view inherent in the energy stance taken in cosmic evolution, the architecture of nature is made up of energy fields [17]. These, being conceptual, are not directly observable, though the traces left by their transactions in measurable space-time are [18]. The energy cuts are the distinctive signatures of the quantum energy fields in the domains of observation.

Modal Boundaries are opaque to all transactional processes. This means that there is no direct transactional path in the temporal evolution of the equation of state between the system's internal state and its emergent one, even though the causal link between the two domains is evident.

The main implication of the opacity of modal boundaries is the impossibility of a *direct*, linear connection between the underlying neurological substrate and the characteristics and properties of cognition: their *modalities are orthogonal*, a fact known to physics for a long time. What *is* of importance for the scientific study of human cognition are: *first*, the identification of the *functional path* that runs through the dynamical substrate *of mentation* and leads to the closure of the internal regime of normal, i.e. speaking, humans. This path is the concatenation of the quantal elements *of the core mechanism* that construct, energize and shield the operations of *mental*, i.e. *conceptualising, matter* (not simply cognitive) in its natural energy environment. *Second*, the tracing of the quantal dynamical architecture of the various forms of human mentation, e.g. conceptualisation, imagination, reasoning, intuiting, etc. ; and *third*, the correlation of individual sets of mental data gathered in the emergent domain of observation and the quantal patterns discovered in the substrate. While the first two are in principle doable, the last one can't be fully realized in a scientifically acceptable way for the reasons adduced earlier. More than this does not appear to be in the cards.

THE DIVERSIFICATION

The diversification of natural systems is the result of two distinct though related conditions: the first is internal to the system, the other external to it.

The *internal factor* is the dynamical complexity of the natural system discussed earlier. The treatment given to it there, by way of the liquid drop model, was semiclassical rather than quantal, and was chosen for its intuitive appeal to human experience. There are other approaches to the construction of natural systems, such as the effects of the *fine structure constant* $\boldsymbol{\alpha}$ which determines the size and several properties of atoms, including several levels of their stability.

The *external factor* is principally the *local energy profile* of the domain of emergence of the natural system. It is the effect of the superposition of the modally compatible wave functions of all systems present with those from other sources. All these factors are contingent and vary with the location of the emerging system, thereby introducing an external principle of diversification. Since this paper is primarily focused on the constructive mechanism of natural systems, a fuller discussion of diversification will not be attempted on this occasion.

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