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The Origin and Evolution of Complex Enough Systems in Biology

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Abstract

Recent criticisms of Neo-Darwinism are considered and disputed within the setting of recent advances in chemical physics. A related query, *viz.*, the ontological thesis, that everything is physical, confronts a crucial test on the validity of reductionism as a fundamental approach to science. While traditional ‘physicalism’ interprets evolution as a sequence of physical accidents governed by the second law of thermodynamics, the concepts of biology concern processes that owe their goal-directedness to the influence of an evolved program. This disagreement is met by unifying basic aspects of chemistry and physics, formulating the Correlated Dissipative Ensemble, CDE, as a characterization of a ‘complex enough systems’, CES, in biology. The latter entreats dissipative dynamics; non-Hermitian quantum mechanics together with modern quantum statistics thereby establish a precise spatio-temporal order of significance for living systems. The CDE grants a unitary transformation structure that comprises communication protocols of embedded Poisson statistics for molecular recognition and cellular differentiation, providing cell-hierarchies in the organism. The present conception of evolution, founded on communication with a built-in self-referential order, offers a valid argument in favour of Neo-Darwinism, providing an altogether solid response and answer to the criticisms voiced above.

Keywords. Complex Enough System, CES, Correlated Dissipative Structure, CDS, Correlated Dissipative Ensemble, CDE, Central Nervous System, CNS, Liouville Equation.

1. Introductory Remarks

1.1 Reductionism in Natural Science

A frequent understanding of natural sciences contends that biology reduces to chemistry and chemistry to physics. Even if the traditional analytic interpretation of mathematics as a language or tool to convert knowledge about nature, *i.e.* a formal science not being incorporated amongst the branches of physical or life sciences, some recent propositions impart that also physics can be reduced to mathematics [1]. Within such views, based on strict reductionism, see more below, one argues that the present laws of physics are not only commensurate to biology, but also contain the necessary natural laws for expressing all the known biological facts.

There are numerous differences of opinion regarding the scheme outlined above, *e.g.* the impossibility to derive the Coulomb Hamiltonian corresponding to a molecule from first principles and the general problem of quantum chemistry to treat nuclei and electrons on a more or less equivalent basis, see Löwdin [2]. Other arguments concern the concepts of biology as the laws of physics, at present, exclude a fundamental understanding of biological processes governed by an evolved program [3, 4].

Observation and deliberate experiments instigate rational, deductive theory, formulated in the language of mathematics, with the so accumulated knowledge discussed and contained by the methods of philosophy in general and the concepts of biology in particular. Recognizing the acquired demarcation between the philosophy of science, including biology, and the enactment of reductionism as embodied in the laws of physics, the endwise connections between them should still be profound and significant. Nonetheless there seems to be a considerable gap between the reasoning and thinking between the two distinct spheres of influence as revealed by the dialogue below.

Steven Weinberg [5] in his brilliant essay *Dreams of a Final Theory. The Scientist Search for the Ultimate Laws of Nature* avers the verdict on Philosophers and of Philosophers of Science that they often carry notions of "scientific explanation" that are too strict for "real" scientists. This view is beautifully expressed in the quoted correspondence between the author of the book and his friend, the evolutionary biologist Ernst Mayr, who asserted that the book is *a horrible example of the way physicists think*, and that it reflected a serious lack of understanding regarding the three principal classes of scientific reduction in biology, i.e. the ontological, the epistemological, and the methodological reductionism.

Weinberg answered that *the main reason I reject this categorization is that none of these categories has much to do with what I am talking about (although I suppose theory reductionism comes closest). Each of these three categories is defined by what scientists actually do or have done or could do; I am talking about nature itself.*

The present exchange between the biologist and the physicist is not brought forward only to provide an example of the distinct ways of thinking between scientists that supposedly should have a lot (chemistry) in common. The argument does confer, as already stated above, on such questions as whether life sciences in practice can be reduced to chemistry and the latter to physics. Even if merely restricted to chemistry and physics, there continue to be many disagreements, like whether quantum mechanics can fully account for all atomic and molecular structures notwithstanding the famous statement of Dirac [6], without the use of specifying experimentally derived physical and chemical facts. These aspects raise controversial questions about the doctrine of 'physicalism' imparting consequences that justify a weaker ontological hierarchy, see e.g. Weisberg, Needham, Hendry [7] for more details. However, the introduction of biology in this setting introduces an important aspect, *viz.*, it incorporates the physicist and the biologist itself and, at the end of the day, you and me, into the picture.

Within this broader picture sits a deeper principal concern: whether, in the science and philosophy of biology, the theoretical origin and conceptual foundation of biology can be entirely reduced to the laws of physics and chemistry. As will be obvious in this paper, it is not possible to advance the case without belabouring the self-referential characteristics of living systems that do organize complex enough biological systems.

The notion of *Complex Enough System*, CES, imparts a new entity that extends the concept of traditional chemical physical systems in that their interactions / communications with their environments follows a teleonomic law that should be governed by an evolved program, cf. the genetic code. The mathematical formulation of this process derives from a correlated dissipative ensemble, which has a network topology of a quantum nature as well as exhibiting a

Poisson-type time evolution [8]. It is important to stress that the organization incorporates self-references and consequently must be interpreted within a framework of quantum logic¹.

By promoting a collection of established results from recent advances in chemical physics, we will, under the reading of the *Paradigm of Evolution* [9], provide its most general, yet specific features as well as embrace some important results and consequences. The argument will be arranged as follows. Included in the introductory remarks we will illustrate recent proposals and criticism regarding the physical origin of biology and various criticisms of Darwinism. In order to respond to these comments and suggestions we intersect the account by a brief exposition of current progress in theoretical chemistry and physics with a bearing on teleonomic, natural laws. In the final section we return to the criticism voiced here in the introduction as well as devising a possible solution to the controversy.

1.2 The Physicalist Origin of Biology and the Recent Criticism of Darwinism

In his last essay Ernst Mayr [4] addressed the question *What Makes Biology Unique?* His main contention and outlining of his ideas, implicated the understanding of, and agreement with, the laws of physics. While affirming that biology has the necessary characteristics of chemistry and physics, he nevertheless construed that *none of the autonomous features of biology can possibly be unified with any of the laws of physics*. In particular he confronted physical reductionism as not only necessary but also quite impossible in biology. In order to demonstrate why biology differs from physics, he recounted non-applicable ideas of the latter, like target-directed behaviour of biological functions, regulation, self-organization and adaptation, by an original clarification of the controversial concept of teleology. In addition to characterizing authentic teleomatic phenomena ruled by the natural laws of physics, he introduced the notion of so-called teleonomic processes as those governed by an evolved program. Thus, according to Mayr, there appears to be a gap in the knowledge of Nature, as the process of evolution does not, without a doubt, seem to follow unequivocally from physics.

In addition to the principal concern whether the theoretical and conceptual foundation of biology, as voiced above, can be entirely reduced to the laws of physics and chemistry, there has been several recent inveterate criticisms of Neo-Darwinism. Although Ernst Mayr did not like the term for historic reasons, we will use it as it is practiced today, see e.g. Dawkins [10], with all its evolutionary sub-theories included, counting fundamental addenda like the genetic code and other ingredients of the Darwinian paradigm. Even if somewhat divisive, we will for simplicity refer to the term also in the context of contemporary evolution theory unless a more specific detail has to be discussed.

In particular evolutionary theory has developed with a convincing focus on genetics, where hereditary variation to a large extent depends on randomly varying mutations and in lesser

¹ Note that the present representation of the spatio-temporal order is neither Boolean, Bayesian, scale free, decision making or any other classical version. It is neither strictly a quantum network, cf. quantum computational schemes lacking self-referentiability. Since the actual communication network includes self-references they are denoted as Gödelian networks.

part due to influences of developmental processes by environmental conditions. Within this perspective, Jablonka and Lamb [11] challenged this aspect of Darwinism. They advanced the idea of epigenetic inheritance systems (EIS), which incorporate environmental mechanisms that actively maintain differing patterns of gene expressions, structural organization etc. enabling transmission of information from mother- to daughter cells. It is important to understand that the term EIS essentially involves the inheritance of phenotypic variations which do not primarily originate in differences in DNA. Although the present insight into the evolutionary process encompasses Darwinism it also reaches out to the social and ecological domain. Although not principally in conflict with the concepts of Mayr, the authors do not propose fundamental interferences with respect to the laws of physics.

Recently, however, the materialist Neo-Darwinist comprehension of nature has been seriously criticised, scorned and even rejected, see e.g. Deacon [12], Nagel [13], Fodor and Piattelli-Palmarini [14]. Although Deacon's ambitious and challenging confrontation to validate in what way goal-directed progressions can arise from purely physical processes has met with appreciative understandings, see e.g. the positive review by Logan [15], the reactions to the more opinionated views of Fodor-Piattelli-Palmarini, accusing adaptionism of being circular, and the anti-reductionist, assertive teleological view of Nagel, have in contrast been unforgiving, see e.g. Orr [16], Ferguson [17], and Rosenberg [18].

The common denominator of the account above is the claims of incompleteness of the materialistic world-view and as a consequence criticism descends on the reductive research program including Darwin's theory of evolution. This is manifestly expressed in the opening sentence of the biological anthropologist and neuroscientist Terrence Deacon's treatise [12] viz.: *Science has advanced to the point where we can precisely arrange individual atoms yet ironically we lack a scientific understanding of how sentences in a book refers to atoms, DNA, or anything at all.* To give a general name to the set of problems related to the quote above, i.e. how to integrate purpose and intention into the picture, the author introduces the concept of *ententionality*.

This limitation is zealously expressed in Thomas Nagel's recent book *MIND & COSMOS* [13] where he essentially questions the entire naturalistic world picture, including physics, chemistry, and biology extending it to incorporate the theory of evolution and even cosmology. While Nagel grants that there appears to be a scientific consensus regarding the sources of variation in the evolutionary process and that accidental genetic variation is enough once reproducing organisms have come into existence, nevertheless, there is no convincing or credible argument that explains the origin of life itself. Quoting Nagel: *given what is known about the chemical basis of biology and genetics, what is the likelihood that self-reproducing life forms should have come into existence spontaneously on the early earth solely through the operation of the laws of physics and chemistry?*

Fodor and Piattelli-Palmarini [14] offer more detailed and scrupulous criticisms claiming that the Principle of Natural Selection (PNS) is flawed and can't be fixed. Utilizing the traditional problem of free-riders, cf. Gould and Lewontin [19], they deduce from the principle of sufficient reason that the argument concerning the mechanism of "selection for fitness" to explain the adaptation of a phenotype to its environment is circular and that phenotypes are explained not from PNS but from Natural History. Since the latter according

to the authors, rather than being a theory, should be inferred as a bundle of evolutionary scenarios, therefore evolutionary biology can't be viewed as an intensional science. As a consequence, biology is a science without its own proprietary laws just like any other so-called special sciences.

1.3 Responses to the Criticism

There are numerous attempts to confront these challenges. The general scientific query whether the unity of the language of science prompts physicalism in the strict sense, i.e. if all scientific laws can be derived from the laws of physics and further that they will reduce the different branches of science to physical theory, is not at all obvious, see Brändas [20] for a recent assessment. Mayr, a devote Darwinian, claimed, as already pointed out, that physical law is not enough to define an autonomous science and philosophy of biology. On the other hand, if we want to support a physicalist origin of biology, the criticism voiced above invites detailed response.

While Deacon's exposition has not so far excited any revolutions in the minds of the citizens of the scientific community, Nagel's book in particular has been met by ferocious receptions from the leading intellectual orthodoxy. A similar controversy surrounds the deep scepticism advanced by Piattelli-Palmarini [14]. In the most recent dispute Rosenberg [18] states in defence of Darwinism that contemporary physics rules out real goals, purposes, ends and teleology in general as causal forces. By referring to adaptation as an asymmetric process (i) driven by the second law, and (ii) requiring it to be wasteful processes, using up more order in producing adaptations than the order that the adaptations constitute and maintain, Rosenberg writes:

It's clear that the only way to build adaptations consistent with these two requirements is to start by processes that randomly build large numbers of alternative molecular structures just through the operation of thermodynamic noise and then wait. Wait for what? For one or more molecules to turn up randomly that combines thermodynamic stability with replicability. Eventually out of sheer thermodynamic noise there may come to be a molecular structure sufficient to withstand the local environment and that also encourages the emergence of copies of itself out of the atoms floating around in the thermodynamic noise. This can happen by templating, catalysing or otherwise producing copies of itself. You probably don't have to wait more than 500 million years, once the chemical constituents of the early earth were around for this to start to happen. Once it does happen, iteration of the same process will produce more and more adaptation, at greater and greater expense, just as the 2d law requires.

In contrast to Mayr [4, 21], Rosenberg [22] views biological issues within the same epistemological framework as the philosophy of physics. Such disagreements are central to the present discussion, and it provides sustenance for analysing the quote above further. The author ends the discussion in [18] with the declaration that such processes are the only

scenarios that physics will permit, and that this, in practice, is the principle of natural selection that Darwin discovered.

In Rosenberg's defence of Darwin, he makes in addition several arguments in favour of PNS including the criticism of Fodor's disjunction concept [23] as well as the important distinction between "selection for" and "selection against". At the heart of the matter lies the somewhat controversial issue of teleo-semantics, Macdonald and Papineau [24] that led Fodor and Piattelli-Palmarini to repudiate Darwinism. However, as Rosenberg points out, no causal theory whatever is so far able to account for a determinate semantic content and *ipso facto* a Darwinian theory could not do so.

It is obvious that the quote above, while defending Darwinism, or Neo-Darwinism as defined above, also confronts, not only the criticism of the materialist comprehension of Darwin's law of evolution, but also devout supporters like Mayr and Jablonka and Lamb. Thus we will have to make a twofold undertaking, i.e. defend Neo-Darwinism, while at the same time render, if possible, its physicalist origin.

1.4 Proposed Solutions to the Controversy

In view of the controversial assertions and confusing statements given above, it becomes indispensable to give an update of some relevant chemical-physics advances of significance for the present queries regarding the foundation of biological evolution. In this evaluation we start with the conceptual basis of genuine quantum chemistry, Löwdin [25, 26], and bring together appropriate findings in non-equilibrium statistical mechanics of dissipative systems, Prigogine [27], Obcemea and Brändas [28], and Yang's Off-Diagonal Long-Range Order, ODLRO [29], the structure of fermion density matrices, Sasaki [30] and Coleman [31].

To incorporate dissipative systems we mention an extension resting on a rigorous mathematical theory, i.e. the Balslev-Combes theorem [32], which is vital to understanding and appreciating non-Hermitian quantum mechanics [33-35] and its consequences for the dynamics of resonance states embedded in the continuum and their properties for higher order dynamics. These ingredients impart a prompt reordering and exposition of acquiescent microscopic self-organization [9, 20, 36] with direct bearings on Artificial Intelligence, AI, [36-40] including the formulation of Gödel's theorems in an extended logic based on the fundamental teleonomic concept of communication, extending from the microscopic- to the mesoscopic- and macroscopic levels [9].

In this undertaking we will show that Mayr's concept of teleonomy [3, 4], i.e. processes being influenced by an evolved program, is not only commensurate with, but derives from fundamental principles of physics and chemistry. It further follows that the extended framework of non-equilibrium statistical physics in combination with non-Hermitian representations give rise to a Spatio-Temporal Mnemonic structures [9], exhibiting thermally correlated structures for physical, chemical and biological evolution. As a consequence the "program state" is a sequence of transient germane state conversions of the developing, on-going dissipative (quantum and thermal) correlations, displayed by its reflexive complex enough characterization.

Since, by definition, this representation delineates CES, the latter, constituting a statistically correlated dissipative ensemble, CDE, accommodates anomalous lifetimes due to an intrinsic code forbidden protection of state decoherence [9]. The CDE operates endogenously with a characteristic built-in Poissonian type distribution, which gives way to something exogenous of ententional significance. This in turn imparts communication protocols, not only within the control of a genetic program, but also on the cellular- and higher order levels, including epigenetic inheritance programs, neurological spike trains etc., even suggesting more accurate and robust meme-like extensions, see e.g. Semon [41], Dawkins [10] and Deutsch [42].

2. The Theoretical Framework

2.1 Non-Hermitian Quantum Theory

Although the space in this document will not allow descriptions of the microscopically relevant formulations, we will try to develop a partial understanding of what needs to be explained and finally be employed in order to appreciate the consequences of the arguments and confrontations belaboured above. As is well known there appears to be a remarkable agreement between precise quantum chemical predictions and the most accurate experiments including sophisticated advanced instrumentation and precise measurements and therefore it is usually resolved that the many-body Schrödinger equation in particular and also quantum mechanics in general portray reality to an unmatched perfection. This anticipation acquiesced Per-Olov Löwdin [25] to found and establish a new journal, the International Journal of Quantum Chemistry. With the emergence of the computer revolution, the field of quantum chemistry prospered, and it is viewed today, despite the critical comments made above, as a fundamental area essentially synonymous with theoretical chemistry and chemical physics.

However, even with the numerous advances just mentioned, there are many inconsistencies and conundrums plaguing the fundamental formulation. Primas [43] in his thought provoking evaluation of the *myth* of universal laws brings up numerous profound problems connected with the ineptness of traditional quantum chemistry to take the necessary step from calculation to concept. Although many of the puzzles have a distinct metaphysical flavour, they aim at the deeper meaning of chemistry and a worldview, *unus mundus*, which integrates also the dimensions of semiotics. Some of the most serious ones have been discussed in [20] including in particular the well-known issues of the time irreversibility of the macro-world, the classical law of causality, not to mention questions related with general relativity, all inconsistent or incompatible with standard formulations of the microscopic domain.

Closely related is also the inquiry of the absolute nature of the second law, Sklar [44]. For example it is not possible to rigorously derive thermodynamics from microscopic dynamical laws without retaining statistical assumptions. Hence the proprietary character of the second law must be revisited and considered in the light of recent non-Hermitian quantum mechanics [33, 34, 35], possibly suggesting solutions to the “ignorance paradox”, see e.g. [9, 20], and further the conclusions below.

Much could be said about the necessity to realize and accomplish a quantum mechanical extension², but we refer to Refs. [9,20,32,45-48] for more details. The nomenclature non-Hermitian or non-self-adjoint operators hide an important aspect, *viz.* the possibility to diagonalize the proper Hermitian matrix representation. A key concept here is the notion of normal operators, i.e. operators, which commute with their Hermitian conjugate. Normal operator representations lead to matrices that can be diagonalized, while general non-selfadjoint operators are not normal, necessitating the inclusion of Jordan blocks and their Segrè characteristics, i.e. the dimension of the largest block, see e.g. Löwdin [26].

2.2 Statistical Mechanics for Dissipative Systems far from Equilibrium

Our particular objective befalls that of merging these aforementioned “unstable states” into a more general quantum theoretical picture, incorporating quantum statistics. While the standard spectrum of a self-adjoint Hamiltonian operator is real, a resonance eigenvalue of the extended Hamiltonian is characterized by a complex energy on the so-called second Riemann Sheet, see e.g. [20] for more details,

$$\varepsilon = E - i\epsilon; \epsilon = \gamma/2 = \hbar/2\tau \quad (2.2.1)$$

where $\hbar = h/2\pi$ with h being Planck’s constant, and the complex part ϵ relating, as usual, to the full width at half maximum, γ , with τ being the life time of the “state”.

Since we will be referring to quantum systems imbedded in an environment, to be specified later, we will not carry out any thermodynamic limits unless explicitly specified. It is therefore appropriate to start by specifying a general quantum theoretic system operator strictly defined as a reduced density matrix derived from of an abstract N -particle fermionic wave function $\Psi(x_1, x_2, \dots x_N)$, where in principle the variables represent space and spin and if necessary could also involve time. Strictly speaking the density matrix should contain both the light carriers, like the electrons, and the nuclei, see more below. Taking the trace over all particle variables except q (usually $q = 2$) the corresponding reduced density matrix writes in the Löwdin formulation [49], i.e. the matrix normalized to the number of pairings, but also other standards exist [29, 31],

$$\Gamma^{(q)}(x_1, x_2, \dots x_q | x'_1, x'_2, \dots x'_q) = \binom{N}{q} \int \Psi(x_1, x_2, \dots x_q, x_{q+1}, \dots x_N) \Psi^*(x'_1, x'_2, \dots x'_q, x_{q+1}, \dots x_N) dx_{q+1}, \dots dx_N \quad (2.2.2)$$

The energy of the state is easily expressed in terms of a suitable reduced Hamiltonian H_2 involving only standard two-particle atomic and molecular interactions of Coulomb type [31].

² This extension rests on a rigorous mathematical theory, based on the Balslev-Combes theorem [32] and it is vital to understand and appreciate non-Hermitian quantum mechanics and its consequences for the dynamics of resonance states embedded in the continuum and their properties for higher order dynamics.

$$E = \text{Tr}\{H_2 \Gamma^{(2)}\} \quad (2.2.3)$$

In principle the system operator should comprise all the electrons and nuclei of the quantum mechanical system, but it is often convenient to reduce the atomic and molecular degrees of freedom to the relevant ones that relate to the particular physical situation under examination. In certain cases, $\Gamma^{(2)}$ shows a large eigenvalue indicating the onset of superconductivity or superfluidity [29, 30, 31], provided the quantum states are sufficiently protected from the environment so as not destroying the build-up of long-range off-diagonal correlations.

In order to deal realistically with biological systems it is necessary to incorporate the occurrence and primary importance of temperature, i.e. the influence of thermally induced correlations. In passing we note that general theories of “macroscopic quantum theory” originate from quantum correlations of electron pairs in superconductivity [50, 51], spin dynamics in condensed disordered matter [52], coherent-dissipative structures in aqueous solutions [53] and in connection with complex enough systems in biology [36]. We will define an abstract Hilbert Space through a set of suitable basis vectors – they might be the molecular degrees of freedom in a cell, or in cells like neurons that are in their rest state or excited during a perception. The relevant degrees could be light carriers like electrons or electron holes, nuclear movements like the double proton tunnelling motion in DNA or the endogenous chemicals that enable neurotransmission. In these arrangements one should be aware of the mirroring relation between light carrier correlations – carriers like those of the electrons – and the doings in the nuclear skeleton produced by the apt quantum thermal correlations that subsists in the chaotic hot and wet environment in e.g. the brain [54, 55].

Continuing one forms a base set $|h_i\rangle, i=1,2,3\dots n$, where $n \gg N/2$ is the space dimension, based on these quasi-bosonic degrees of freedom (quasi since they might, from a quantum statistical standpoint, be paired fermions). In the following we will formally write the set as a bold face row vector $|\mathbf{h}\rangle$ with components $|h_i\rangle$. Note that one is dealing with a dissipative system so the dimension n will not be fixed from the beginning, but will change and fluctuate from one situation to another. For a given Hamiltonian (the full Hamiltonian H or the reduced one, H_q depending on q) the system operator and its reduced partners evolves according to the Liouville Equation

$$\begin{aligned} i\hbar \frac{\partial \Gamma^{(q)}}{\partial t} &= \mathcal{L}\Gamma^{(q)} \\ &= [H\Gamma^{(q)} - \Gamma^{(q)}H] \end{aligned} \quad (2.2.4)$$

In particular our N -particle system (if restricted to N electrons) involves $N(N-1)/2$ pairings with the total energy expressed as a sum of the corresponding pair energies see Eq.(2.2.3), with the fundamental electronic correlations, now hidden in a correctly N -representable and correlated $\Gamma^{(2)}$.

An interesting reduction to a statistically degenerate state, named the extreme configuration by Coleman [31], appears when the structure exhibits a large eigenvalue and the

population of states become statistical [9, 20, 36]. A specific situation develops when the system supports ODLRO³, Off-Diagonal Long-Range Order [29], and condenses to $M = N/2$ bosons (or fermionic pairs), e.g. to a superfluid or a superconducting phase, expected to arise for most systems at sufficiently low temperatures. In this particular representation, when the wavefunction, Eq.(2.2.2), is an antisymmetrized germinal power, $\Psi(g^{N/2}) \propto g \wedge g \wedge g \dots g$, where $g = g_1$, the density matrix becomes essentially [20]

$$\Gamma^{(2)} = \lambda_L |g_1\rangle\langle g_1| + \lambda_S \sum_{k,l=1}^n |h_k\rangle(\delta_{kl} - \frac{1}{n})\langle h_l| \quad (2.2.5)$$

or more compactly in the representation $|g\rangle$, see below

$$\Gamma^{(2)} = \lambda_L |g_1\rangle\langle g_1| + \lambda_S \sum_{k=2}^n |g_k\rangle\langle g_k| \quad (2.2.6)$$

$$\lambda_L = \frac{N}{2} - \frac{N(N-2)}{4n}; \lambda_S = \frac{N(N-2)}{4n(n-1)}$$

with $\lambda_L \rightarrow \frac{N}{2}$; $\lambda_S \rightarrow 0$; $n \rightarrow \infty$. The basis $|g\rangle$ is obtained from a preferred localized basis of geminals), $|h\rangle$, i.e. of paired fermions (antisymmetric with respect to permutation of the fermionic space-spin degree of freedom) and with $\omega = e^{i\pi/n}$, i.e.

$$|g\rangle = |h\rangle \mathbf{B}$$

$$\mathbf{B} = \frac{1}{\sqrt{n}} \begin{pmatrix} 1 & \omega & \omega^2 & \cdot & \omega^{n-1} \\ 1 & \omega^3 & \omega^6 & \cdot & \omega^{3(n-1)} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 1 & \omega^{2n-1} & \omega^{2(2n-1)} & \cdot & \omega^{(n-1)(2n-1)} \end{pmatrix} \quad (2.2.7)$$

Note that there is one large eigenvalue, λ_L , while λ_S , the small eigenvalue is $(n-1)$ -degenerate. To fulfil the full trace relationship of $\Gamma^{(2)}$ one needs to account for the unpaired contributions, which however will be neglected as being unimportant in these settings. The transformation $\mathbf{B}$ will serve two important purposes, i.e. diagonalizing $\Gamma^{(2)}$ as well as bringing the associated thermalized conversion to classical canonical form. As will be clear in the following its factorization properties will be the key to formulating teleomatic processes of thermally excited complex enough biological systems.

The actual time evolution should incorporate the analytically continued representations, i.e. the resonance states of the dilated Hamiltonian [28]. As regards the latter this is a technical

³ The celebrated concept of ODLRO was developed by Yang [29] about 15 years after the publication of the famous Bardeen - Cooper - Schrieffer theory of super-conductivity, for a comparison see [51]. The formulation does focus on the collective properties of matter at sufficiently low temperatures. For a physical system approaching zero temperature with a non-degenerate ground state the entropy goes to zero. Under specific conditions the system does develop ODLRO.

mathematical problem that either needs screening the Coulomb interactions, which is physically realistic, or alternatively introducing the notion of quasi-isometries converting non-scaled quasi-isometric evolution into contractive evolution of the scaled ones [56]. We will return to the actual time evolution further below, in connection with the characterization and the definition of the Correlated Dissipative Ensemble, CDE.

2.3 The Liouville Equation and the Prigogine Energy Operator

In order to examine the conditions that are commensurate with the thermal conditions of a living system, we return to the formulation above. As a precondition one must thermalize the extreme ensemble from isolation to a dissipative system at appropriate temperatures. The quantum-thermal correlations will be incorporated commensurate with a quantum extended canonical ensemble, adapted through a Bloch type equation using the Prigogine energy super operator [57], see also [58]. Since we will embark on a non-equilibrium description, yet close to equilibrium, the statistics of the ensemble will essentially turn out to be Poissonian.

The extension to the non-self-adjoint case requires proper dilations that maintain the analyticity of the scaling parameter in the space part of variables, i.e. $x_i \rightarrow \eta x_i$, with $\eta = |\eta|e^{i\theta}$ and θ some appropriately chosen positive angle. Hence Eq. (2.2.2) above should read (note the complex conjugate sign of the second set of coordinates)

$$\Gamma^{(q)}(x_1, x_2, \dots x_q | x_1'^*, x_2'^*, \dots x_q'^*) = \left(\frac{N}{q} \right) \int \Psi(x_1, x_2, \dots x_q, x_{q+1}, \dots x_N) \Psi^*(x_1'^*, x_2'^*, \dots x_q'^*, x_{q+1}^*, \dots x_N^*) dx_{q+1}, \dots dx_N \quad (2.3.1)$$

At the outset we have expressed our theoretical entity, i.e. a non-degenerate ground state of a molecular system, i.e. $\varrho = \Gamma^{(2)}$ of Eqs. (2.2.2) above. In passing we remark that there are two interdependent contiguous problems: (a) the thermal bath surrounding our open system and (b) the varied dynamics of, on one hand, the light fermion carriers and, on the other, the movements in the heavier nuclear skeleton. As already stated, it is unavoidable to go beyond the standard Born-Oppenheimer approximation. In principle there are essentially two ways to view the problem, e.g. as a scattering experiment, where the electrons impinge on the nuclei, see e.g. [20], or to work directly with the density matrix, where either the light fermionic portion or the nuclear degrees of freedom are traced out leaving in each case a nuclear- or an electronic dynamical problem. The crucial reading is that in both portrayals there exists a mirroring relation between the entangled subsystems entailing (I) the light fermion carriers and (II) the nuclear skeleton; see e.g. Löwdin [26] and Brändas and Hessmo [55].

Considering the relationship between (I) and (II), the formulation will be attended with a complementary understanding, reading the description of molecular systems as a dichotomy between mirroring degrees of freedom. Redefining the Liouvillian, i.e. the commutator with the Hamiltonian H , we introduce the corresponding anticommutator

$$\mathcal{L}_B \varrho = \frac{1}{2} (H\varrho + \varrho H) \quad (2.3.2)$$

where the Prigogine energy superoperator, [57], $\mathcal{L}_B$ is subject to the Bloch equation ($\beta = \frac{1}{kT}$)

$$-\frac{\partial \varrho}{\partial \beta} = \mathcal{L}_B \varrho \quad (2.3.3)$$

in which k is Boltzmann's constant and T the absolute temperature. Noting the difference between Eq.(2.3.2) and Eq.(2.2.4), it is imperative to provide a setup where the density matrix, during analytic continuation, must be represented by a complex symmetric form, i.e. $|\cdot\rangle\langle\cdot| \rightarrow |\cdot\rangle\langle\cdot^*|$, representing a complex conjugate in the bra-position. In particular for the density matrix given by Eq.(2.2.5) represented according to Eq.(2.3.1), one obtains directly the thermalized solution (note that e.g. the system I is open with respect to its coupling to system II and vice versa) at a given temperature T , choosing for simplicity the total energy threshold to be zero

$$e^{-\beta \mathcal{L}_B} \varrho = \lambda_L \sum_{k,l=1}^n |h_k\rangle e^{i\beta \frac{1}{2}(\epsilon_k + \epsilon_l)} \langle h_l| + \lambda_S \sum_{k,l=1}^n |h_k\rangle e^{i\beta \frac{1}{2}(\epsilon_k + \epsilon_l)} (\delta_{kl} - \frac{1}{n}) \langle h_l| \quad (2.3.4)$$

The derivation is straightforward resting on the convention that the basis functions h_l can be chosen real without restrictions. Employing the model of the nuclei as vibrating oscillators, we can e.g. use partitioning techniques to determine the complex energy of each oscillator dressed by the interactions from the other ones and the environment. Hence each oscillator yields, commensurate with the mirror theorem and the reciprocal relationship between the energy width ϵ_k and the lifetime τ_k matching the temperature of the environment)

$$z_k = E_k - i\epsilon_k = -i\epsilon_k = -i \hbar / 2\tau_k \quad (2.3.5)$$

where we have used the fact that the thermal excitations push the energy close to the threshold, i.e. at the zero energy level with each $E_k = 0$.

2.4 The Constructive Role of Quantum – Thermal Correlations

In this subsection we will demonstrate the constructive role of quantum – thermal correlations. As shown by Tegmark [1], quantum states in the hot and wet environment of a living system, like the human brain, are not likely to endure decoherence. Although there have been criticisms regarding the impossibility to invoke long-range coherence in biological systems, see e.g. [59], the conceivable irrelevance and disapproval of a number of coherence time relations do not solve the decoherence problem for the “survival” of quantum mechanics

in complex enough biological systems. In contrast we will identify a mainly different answer to the coherence – decoherence dilemma [9, 20, 36, 52, 53, 58, 60].

One way to establish a solution to this quandary, can be done via a simple thermal scattering guide of an open system involving n bosonic or paired fermionic degrees of freedom related with a relaxation process given by the time scale τ_{rel} , assumed to be distinct from the smaller thermal timescale. The system is dissipative, as it exchanges energy and entropy with its environment. For instance the system may consist of the various building blocks in biological systems, from molecular aggregates describing the order of DNA and RNA all the way up to the whole cell having its place in the proprietary arrangement of the living being either assigned to develop material constructions or to promote communication channels for the nervous system.

The present derivation has been given at various places before, so we will condense the discussion here and referring to previous reviews for more details [20, 58]. Defining the “incoming beam” of the light carriers reaching an area σ_{tot} , activated by the correlated nuclei, and corresponding to a spherically averaged total cross section, consistent with the physical constraints of the model. The protocol describes a procedure that one typically will detect one quasi particle degree of freedom in the differential solid-angle element $d\Omega$ during the timescale $\tau_{\text{corr}} = \hbar/kT$ here, given by Heisenberg’s uncertainty relation ($\tau_{\text{corr}} \approx 2.46 \cdot 10^{-14}\text{s}$ at 310 K)

From conventional scattering theory one obtains the incident flux, N_{inc} of the number of particles/degrees of freedom per unit area and time as

$$N_{\text{inc}} = \frac{n}{\sigma_{\text{tot}} \tau_{\text{rel}}} \quad (2.4.1)$$

which together with number, $N_s d\Omega$, of particles scattered into $d\Omega$ per unit time being

$$\sigma_{\Omega} d\Omega = N_s d\Omega = \frac{d\Omega}{\tau_{\text{corr}}} = \frac{kT}{\hbar} d\Omega \quad (2.4.2)$$

Hence one gets for the total cross section

$$\sigma_{\text{tot}} = \int \sigma_{\Omega} d\Omega = \int \frac{N_s}{N_{\text{inc}}} d\Omega \quad (2.4.3)$$

leading to the simple relation between

$$\frac{n}{4\pi} = \frac{kT}{\hbar} \tau_{\text{rel}} = \frac{\tau_{\text{rel}}}{\tau_{\text{corr}}} \quad (2.4.4)$$

Establishing a correlated cluster of harmonic oscillators with the energies $\epsilon_l = \hbar\tau_l^{-1}$ with the (smallest) energy difference between the equidistant harmonic oscillator levels being $\hbar\tau_{\text{rel}}^{-1}$

displaying a spectrum from the zero-point energy to $\hbar\tau_{\text{corr}}^{-1}$. The quantized oscillators are in a sense reminiscent of Planck's law. Straightforward examination of the situation reveals

$$\tau_{\text{rel}} = (l-1)\tau_l = \tau_2 = \frac{n\tau_{\text{corr}}}{4\pi}; \quad l = 2, 3 \dots n \quad (2.4.5)$$

From Eqs.(2.3.4), (2.3.5) and (2.4.5) one gets

$$\beta\epsilon_l = \frac{2\pi(l-1)}{n} \quad (2.4.6)$$

which inserted into Eq.(2.3.4) gives, $\Gamma_T = e^{-\beta\mathcal{L}_B}\varrho$

$$\Gamma_T = \varrho_T = \lambda_L \sum_{k,l=1}^n |h_k\rangle e^{i\frac{\pi}{n}(k+l-2)} \langle h_l| + \lambda_S \sum_{k,l=1}^n |h_k\rangle e^{i\frac{\pi}{n}(k+l-2)} (\delta_{kl} - \frac{1}{n}) \langle h_l| \quad (2.4.7)$$

The result (2.4.7) reveals its importance via the transformation $\mathbf{B}^{-1}$. Introducing the new basis $|\mathbf{h}\rangle\mathbf{B}^{-1} = |\mathbf{f}\rangle$ one obtains

$$\Gamma_T = \varrho_T = \lambda_L J^{(n-1)} + \lambda_S J \quad (2.4.8)$$

with J being the nilpotent operator defined by $J^{(n)} = 0$; $J^{(n-1)} \neq 0$ imparting the quantum transitions

$$J = \sum_{k=1}^{n-1} |f_k\rangle \langle f_{k+1}| \quad (2.4.9)$$

In passing one notes that the matrix representation of the shift operator J is an n -dimensional matrix with one's above the diagonal and the remaining elements equal to zero. In general any matrix representation of a degenerate eigenvalue partitions into blocks of various dimensions. The largest dimension occurring defines the Segrè characteristic of the degeneracy.

The result will be of crucial importance, see more below, since it implies that $\Gamma^{(N)} = |\Psi(g^{N/2})\rangle\langle\Psi(g^{N/2})|$, after reduction, analytic continuation and thermalization corresponds to $\Gamma_T^N = |\Psi(f^{N/2})\rangle\langle\Psi(f^{*N/2})|$, $f = f_1$ and with $\Psi(f^{N/2})$ and $\Psi(f^{*N/2})$ orthogonal to each other⁴. We will use this result commensurate with two primary aspects, (i) *to develop relevant building blocks for complex enough biological systems* and (ii) *to use the properties of the transformation $\mathbf{B}$ in (2.2.7) as a semantic code for communication between entities on the molecular level*.

Retracing one may recognize that once “communication” is established between molecules and cells this might naturally be extended to higher order levels of semiotic exchanges. The

⁴ The proof of this statement will be shown elsewhere.

order of organization, Eqs.(2.4.7-9), will here be referred to as a Correlated Dissipative Structure, CDS, which, as will see in the next section, will be an essential ingredient of the Correlated Dissipative Ensemble, CDE.

2.5 The Correlated Dissipative Ensemble and its Time Evolution

We have derived from Eqs.(2.2.2-5) a thermalization procedure, that through the boundary condition, Eq.(2.4.6), converted the density matrix by describing the molecular state distribution as transitions between the apt states of the system. This distribution is suitable for representing entities like cells and cellular networks. Note that the quantization condition above relates the temperature, the relevant time scales and the size of the correlated open system. The choice of zero energy level in the system (cell) is commensurate with the zero trace property of matrices like Γ_T . In order to maintain a “living state” characterized by (a) its dissipative coupling to the environment, (b) its metabolic processes, (c) the genetic function and (d) homeostasis for appropriate spatio-temporal regulation, one must describe the biochemical pathways by which the cell obtains energy. The *sine qua non* is not catabolism or the breakdown of molecules to generate energy, but the anabolic synthesis of what the cell needs. As will be shown below, the CDS of the previous section imparts microscopic self-organization and serves as a proxy of the Helmholtz free energy including the functional emergence of quantum-thermal correlations.

To facilitate our aim to consider a higher order dynamics, we will utilize the CDS as base units for a specific Liouville formulation to be detailed below. Although it may seem a misnomer to call the result an ensemble, it will be shown that the higher order structure in terms of established resonance components indeed leads to a Poisson distribution of these elements defining physical communication channels between e.g. cells. In particular for the central nervous system, CNS, in the presence of a special type of cells, called neurons, the dynamics is characterized by short time scale oscillations, building up pulses of light carriers (electrons), spikes that correlate the basic dissipative systems (here cells/neurons) and providing an irreducible coupling-communication between them.

There are several ways to prove the reduction processes (i) $\Gamma^{(N)} \rightarrow \Gamma^{(2)}$, (ii) $\Gamma^{(2)} \rightarrow \Gamma_T$ and finally (iii) $\Gamma^{(N)} \rightarrow \Gamma_T^N$. The step (i), linked to Yang’s celebrated concept of ODLRO, [29], was independently derived by Sasaki [30] and further employed by Coleman [31] in his extreme state formulation of a wavefunction representable $\Gamma^{(2)}$. Sasaki’s derivation concerns his studies of a system of fermions or bosons composed of two subsystems and the so-called Sasaki formula [30, 61], which is based on a counting argument involving the properties of the symmetric group. A simple statistical derivation was published e.g. in [9, 20, 36, 62]. Step (ii) did, in addition to the aforementioned citations, originate in the proceedings of the Resonance Workshop; held at Lertorpet in 1987, see e.g. [63] and particularly [64]. Finally the step three consists of defining an essentially the same $\Gamma^{(N)}$ based on f instead of g and continued analytically to $\Gamma_T^N = |\Psi(f^{N/2})\rangle\langle\Psi(f^{*N/2})|$.

Although the reductions above appear complicated the result is easily combined into a higher order Liouville structure, continuing the model build-up from molecular aggregates in

the cell organization to the actual cell, that we will call a Correlated Dissipative Ensemble. Defining a “cell basis” or quantum dot-like Jordan block units, cf. Eqs.(2.4.8-9), with n and N large

$$\varrho^i = C^i = \frac{1}{\sqrt{1+q^2}} \left\{ q |f_1^i\rangle \langle f_n^i| + \frac{1}{\sqrt{(n-1)}} \sum_{k=1}^{n-1} |f_k^i\rangle \langle f_{k+1}^i| \right\} \quad (2.5.1)$$

$$\text{Tr}\{\varrho\varrho^\dagger\} = 1; \quad q = \frac{p}{1-p}; \quad p = N/2n \quad (2.5.2)$$

each base entity, ϱ^i , $i = 1, 2, \dots, m$, building a basis $\mathbf{H}$. This entails the build-up of a higher order Liouville super operator structure based on the propagator/generator $\mathcal{P}$, see below, where in analogy with $\mathbf{h}, \mathbf{g}, \mathbf{f}$ of section 2.4, the corresponding base entities (here cells) $\mathbf{H}, \mathbf{G}, \mathbf{F}$, subject to the same fundamental transformation $\mathbf{B}$ (where the dimension m in principle different from n but, as will be seen below, related to the one in (2.2.4), and with $\omega = e^{i\pi/m}$ as in analogy with the previous structure.

Since a degeneracy generally consists of several Jordan blocks of various orders, we will describe the propagator, as it generates the time evolution for any member of the ensemble, corresponding to the Segrè characteristic m , irreducibly coupled via J , see below, obtaining, *mutatis mutandis*, with $I = \sum_{k=1}^m |F_k\rangle \langle F_k|$

$$\mathcal{P} = (\omega_0 \tau - i)I + J \quad (2.5.3)$$

$$J = \sum_{k=1}^{m-1} |F_k\rangle \langle F_{k+1}| \quad (2.5.4)$$

with ω_0 the thermal frequency, $\tau = \tau_{\text{rel}}$, the average lifetime of the cell, and τ_{corr} the fast timescale, here essentially equal to the thermal molecular motion. Note the analogy between Eq.(2.5.3), pertaining to cellular entities and the thermalization derived from Eqs.(2.3.3-4). The Liouville configuration imparts, as already said, the thermal frequency ω_0 and the correlation time $\tau_{\text{corr}} = \hbar/kT$ from environmental interactions. Hence the build-up of (2.5.3) is straightforward, save the non-conventional appearance of the operator J . In principle one can build a symmetric geminal power of “cell” functions, based on an “appropriate” bosonic degree of freedom, and then apply the Sasaki formula to obtain a result analogous to Eqs.(2.2.5-7). For simplicity we will study the consequences of the incorporation of a representative irreducible correlations instigated by J in Eq.(2.5.3).

Describing the generator $\mathcal{P}$ in dimensionless units, we obtain the cellular Q -value as

$$Q = \omega_0 \tau \quad (2.5.6)$$

cf. its use in regard to quality aspects of oscillators or resonators. Here one may determine Q as follows. From Eqs.(2.4.4-5) one finds, with $\tau = \tau_{\text{rel}}$, that

$$\frac{n}{4\pi} = \frac{kT}{\hbar} \tau_{\text{rel}} = \omega_0 \tau_{\text{rel}} = \frac{\tau_{\text{rel}}}{\tau_{\text{corr}}} = Q \quad (2.5.7)$$

and since we have defined $\tau = \tau_{\text{rel}}$ as the average timescale for the cell C_i , we can integrate over the solid angle $d\Omega$ and obtain the result

$$\int Q d\Omega = n \quad (2.5.8)$$

The fundamental result, (2.5.8) imparts important information, since the cell's Q -value signifies not only the dimension n of the *intracellular dynamics*, but it also conveyed a possible interrelation between the latter and the *intercellular correlations* implied by the m -dimensional transformation $\mathbf{B}$. Due to the factorizing nature of $\mathbf{B}$, i.e. the ensuing cyclic properties of its column vectors, the Q -value, n , of the cell basically entreats a semantic encoding/decoding inclusion, depending on the value of m , that protects simultaneously all the levels from the molecular- the super-molecular- to the cellular levels and possibly beyond.

We are now in position to define the causal propagator $\mathcal{G}(t)$ and the resolvent $\mathcal{G}_R(z)$ defined by

$$\mathcal{G}(t) = e^{-i\mathcal{P}\frac{t}{\tau}}; \quad \mathcal{G}_R(\omega) = (\omega\tau I - \mathcal{P})^{-1} \quad (2.5.9)$$

yielding directly by inserting the Liouvillian, Eq.(2.5.3),

$$e^{-i\mathcal{P}\frac{t}{\tau}} = e^{-i\omega_0 t} e^{-\frac{t}{\tau}} \sum_{k=0}^{m-1} \left(\frac{-it}{\tau}\right)^k \frac{1}{k!} J^k \quad (2.5.10)$$

$$(\omega\tau I - \mathcal{P})^{-1} = \sum_{k=1}^m [(\omega - \omega_0)\tau + i]^{-k} J^{(k-1)} \quad (2.5.11)$$

From $F_k(t) = e^{-i\omega_0 t} e^{-\frac{t}{\tau}} F_k(0)$ one finds for the r^{th} power of t (note that only F_1 is an eigenfunction of $\mathcal{P}$ while the remaining F_k 's complete the root manifold)

$$N(t) \propto |\langle F_1 | J^r | F_{r+1} \rangle| \left(\frac{t}{\tau}\right)^r \frac{1}{r!} e^{-\frac{t}{\tau}} = \left(\frac{t}{\tau}\right)^r \frac{1}{r!} e^{-\frac{t}{\tau}} \quad (2.5.12)$$

with the definition

$$J^r = \sum_{k=1}^{m-r} |F_k\rangle \langle F_{k+r}| \quad (2.5.13)$$

For the highest power $m - 1$ one gets

$$dN(t) = t^{m-2} \left(m - 1 - \frac{t}{\tau} \right) N(t) dt \quad (2.5.14)$$

which imparts a modified microscopic law of evolution

$$dN(t) > 0; t < (m - 1)\tau \quad (2.5.15)$$

In passing we note that Eqs.(2.5.14-15) imparts a higher-level timescale $\tau_{\text{com}} = (m - 1)\tau_{\text{rel}}$. In other words it modifies the boundary conditions Eqs.(2.4.5-6), with $\tau_{\text{corr}} \rightarrow \tau_{\text{rel}}$ and $\tau_{\text{rel}} \rightarrow \tau_{\text{com}}$. It is remarkable that the communication bearing transformation $\mathbf{B}$ authorizes “messages” between the molecular-DNA-RNA-gene level and the hierarchical organization of cellular function and order. Actually the possibilities of a communication protocol is simply given by the cyclic properties of the columns of $\mathbf{B}$, see Eq.(2.2.7) displaying $\sqrt{12} \mathbf{B}$ as a diagram, where the dimensions of the cyclic vectors of $\mathbf{B}$ are given in the appropriate entry. We will not display the first column vector of one-dimensional units “1”, and therefore we will only have 11 columns, see Ref. [20] for more details

$$\begin{array}{ccccccc} & & & & 2 & & \\ & & & & 2 & 3 & 4 \\ & & 4 & 3 & 2 & 2 & 3 & 4 & 6 & 12 \\ 12 & 6 & 4 & 3 & 12 & 2 & 12 & 3 & 4 & 6 & 12 \\ & 6 & 4 & 3 & 2 & 2 & 3 & 4 & 6 & 12 \\ & & 4 & 3 & 2 & 2 & 3 & 4 & 6 & 12 \\ & & & & 2 & & & & & & \\ & & & & 2 & & & & & & \end{array} \quad (2.5.16)$$

observing also the manifest column symmetry of the graph. Space will not allow a more detailed discussion of the various possibilities to interpret the consequences of the present paradigm of evolution with specific reference to its teleonomic character, see e.g. Mayr [3,4].

The present CDE representation has an interesting overlap with Trehub’s retinoid model, devised for visual perceptions [65], with a straightforward parity argument based on the CDE, for the perplexing image switching of Necker’s famous cube illusion [8]. The retinoid system involves neurons, especially a class called the autapse, i.e. neurons with synapses connected onto itself. Since neurons “communicate” via spike trains, one might exploit the metaphor of a “Call Centre”, seeing the communication as a number of “phone calls” between the cells during a given time, t , being multiples of their characteristic time $\tau = \tau_{\text{rel}}$. Therefore the probability that k “calls” are transferred during a given time interval, with each “telephone call” occurring with a known average (intensity) parameter $\lambda_l = (l - 1)\tau_{\text{rel}}/\tau_{\text{rel}} = (l - 1)$; $l = 2, 3, \dots m$, i.e. with a definite distribution for each value of l , is simply given by

$$P_{\lambda_l}(k) = \frac{(l - 1)^k}{k!} e^{-(l-1)} \quad (2.5.17)$$

with the mean equal to the variance $\lambda = l - 1$. The number of calls during $\mathcal{T}_{l-1} = (l - 1)\tau_{\text{rel}}$ is at maximum for $l = m$. If counting $l = 0$ as an event the “society of neurons” comprises,

during $\mathcal{T}_{m-1}$, with a probability according to (2.5.17), every cell shares m communications distributed over m possible “sites” in the organism. Hence the length, m , of a message is directly matched with the variance and the mean (a well-known property of the Poisson distribution).

In summary, each cell is characterized by a Correlated Dissipative Ensemble, CDE, which, through the factorized canonical vectors of the associated transformation $\mathbf{B}$ incorporate nested encodings, as programmed in the process of evolution. Communication runs over several orders of time scales, from the genetic code to more complex semiotics, e.g. the plan for the accumulation of proteins, stored in the genetic alphabet and further conditioned via resonant mechanisms to cellular interactions depending e.g. on the cell’s quality value.

4. Conclusion

4.1 Consciousness as an Irreducible Process

In this account we have so far guided our formulation to cells in general and neurons in particular, cf. the neural network of the Retinoid System. However, the present representation of a neural communication network is neither Boolean, Bayesian, decision making- or any other classical version. It is neither strictly a quantum network, cf. quantum computational schemes lacking self-referentiability. Since the nodes are self-referential and communicative they should be called a Gödelian network [8,9,20,36]. Obviously a cellular environment, with precise “responsibilities”, must assist the neurons, as the latter will be functioning in analogy with the example of Poisson distributed telecommunications, i.e. a “Call Centre”. One such crucially supporting network is the astroglial “Master Hub” as advocated by Fernandes de Lima and Pereira [66]. Further contraptions are related to the astrocyte role of releasing neurotransmitters in the synaptic cleft, and how this is coupled to and dependent on calcium ion propagation.

In order to promote consciousness as a general and complete concept one needs to undertake the whole activity from (i) perception, (ii) awareness, (iii) cognition, and (iv) feelings and also emotions as an irreducible process of the mind, yet being characterized by fundamental time scales. It is evident that the “protracted communication hypothesis” originates already in the initial stage, i.e. about 3-7 ms, of the sensory neocortex-reorganised background due to the impact of e.g. a conditioned stimuli, CS [66]. The next stage that concerns awareness, cf. Libet’s conscious awareness delay up to several hundred ms, nevertheless retrospectively creates a subjective back track. Hence the conscious mental experience cannot survive without the brain processes that give rise to it. It seems that the steps (i) perception, (ii) awareness can be separated according to specific time scales, i.e. (i) 5-10 ms, (ii) 200-500 ms, while (iii) cognition is fundamentally irreducible as regards the time scales of (i) and (ii).

Somehow the consciousness of the SELF develops its projected images over several hundreds of ms, but on “the lower level” this distinction is irreducible. In terms of the various tasks of the different key actors one might discern:

- (a) *the stochastic background* for tonic firing without presynaptic input (inverse stochastic resonance), i.e. the neurons and the astrocytes are accessible for any activity produced by an external stimulus – external in the sense of outside the neuronal and astroglial networks.
- (b) *the phasic firing* occurring after a neuron is activated due to presynaptic activity (due to e.g. the astrocytes) and its acquiring motion, giving rise to a so-called stochastic resonance, on top of any background (tonic) activity a neuron may have.
- (c) *the local field potential varies as a result of synaptic activity* and reflects the sum of action potentials from neurons within a few hundred μm , while the slower ionic movements contribute over a few mm.
- (d) *the synaptic activity* consisting of (mainly) spatially distributed Poisson statistics which permits semantic encoding-decoding communication (the astroglial *Master Hub*)
- (e) *the spike trains* exhibit (mainly) temporally distributed Poissonian statistics, which conveys encoding decoding communication. (the neuronal *Call Center*).
- (f) these spike records reflect *the astroglial input*, consisting of high-frequency fluctuations in the potential difference, and being filtered out, leaving only slower fluctuations.
- (g) *the low-pass filtering* due to complex electrical properties of extracellular space being associated with subjective feelings.

The points (a-e) “take care” of the steps (i-iii), while (f-g) relate to (iv) and possibly to a longer two-second duration [67]. Nevertheless (a-g) are irreducible in the sense that without any of the six reported steps above a conscious feeling may not be “created”. The point (g) should be commensurate with the explanation of the so-called SMTT (Seeing More Than There is) experiments [68]. Note that the Call-Centre analogy of the Gödelian neurological network does not document which neurons are recorded, which may be commensurate with the “dark matter problem in neuroscience” [69].

A crucial supporting neuron-astrocyte mechanism refers to the increase of cytosolic calcium ions, i.e. the regulation of the intracellular calcium flux contributing to the effect of calcium-dependent synaptic change. More than 20 years ago [53], we investigated the (still) unresolved problem of excess mobility of hydrogen (and hydroxyl) ions in aqueous solutions with K^+ and Na^+ ions (and Cl^- for the hydroxyl ion) as background. The model, based on coherent dissipative dynamics, more or less identical to the concepts above, led to predictions that actually confirmed and predicted contemporary NMR spin-echo experiments [70,71].

However, the molecular dynamics community, heavily committed to the classical Grotthuss model, did not appreciate the mechanism. Still, the temperature dependence, as revealed by high precision conductivity data, displayed the increase in the logarithm of the quotient between excess conductivities of hydrogen – and hydroxyl ions as a function of temperature in stark contrast to classical models. The mechanism suggests that hydrogen (and hydroxyl)

ions might easily provide the gradient and be indirectly responsible for the mechanism of transporting Ca^{2+} ions, through aqua-porins or receptors like Ryanodine [72], since the hydrogen ion or proton can hardly move through these channels. Thus one might consider taking the pH dependence on the cytoplasmic matrix into account in the regulation of positive ion mobility in the cytosol.

It is obvious that the main part of the chemical processes that guard the evolution of a CES that is part of a life form is, even if belonging to a human brain, primarily unconscious. However, in the latter instance, the physical processes evoking awareness and thus being central to consciousness, nevertheless constitutes an irreducible phenomenon even if the authentic code processing can be partitioned into tangible temporal steps.

4.2 Regulation by an Evolved Program

Intelligence is a highly controversial term and as a result we will only use it in its most trivial sense, i.e. in the meaning to pick out or understand something, but also to discern, distinguish, differentiate and recognize. Following Mayr [3,4], one might essentially use *telos*, purpose or goal, in two different contexts. On one hand referring to physical laws, like gravity or the second law of thermodynamics, as governing teleomatic processes, and on the other a programmed activity, restricted to action or behaviour owing its goal-directedness to the influence of an evolved program, as governing teleonomic actions during evolution, thereby lifting prevailing teleological thinking to a higher conceptual level. Mayr's final concern [4] relate to insufficiencies in the laws of nature, a resolution that would entrench any definition of a *bona fide* science of biology. Aided by these remarks and clarifications, including the presently highlighted progress in chemistry and physics, we will return to Rosenberg's statement, Rosenberg [18], cited in the introductory remarks.

It is obvious that the quote refers to a minimalistic amount of physical laws in order to outline a clear and unmistakable physical stance accounting for the origin of life and its subsequent evolution. Omitting primeval physical processes like nucleosynthesis, where atomic nuclei were formed in stars and then ejected to form, in the case of earth, the solar nebula from which planets form via gravitational growth, traditional narratives focus on the so-called primordial soup of the early earth. This representation did catch affirmative support due to the famous Miller-Urey experiments [73] and Miller [74] in which the prebiotic atmosphere of the earth, as believed to reflect the true environment, was carefully simulated, showed that these conditions synthesized an abundance of organic compounds including several amino acids. Later experiments, Oró [75], established the prebiotic synthesis of the nucleobase adenine.

Thus it appears that the second law of thermodynamics seems to support [18], as it is commensurate with long-established chemical experiments. The critical statement of Nagel [12], the carefully administered confrontation by Deacon [12] and the more opinionated claims by Fodor and Piatelli-Palmarini [14], do not, however, agree with Rosenberg, as neither would Mayr in his conceptual stance. Chemical reactions produce large molecules but do not provide adaptation, where the latter usually refers to the functions of a higher-level target aiming at the access of the potential benefits inherently predicting their activities. In

fact the intrinsic, but indirect, causal nature of exaptations, cf. Lewontin and Gould's Spandrels of San Marco [19], could also fall into the present category. Hence, the crucial question is whether we have "at home" all the laws of nature needed to understand how evolution does indeed "produce us".

It is well known, that quantum theory and Einstein relativity are not yet considered to be satisfactory joined, notwithstanding a consistent description of some precise key properties of gravitational laws have been recently stated, see Refs [9,20]. Furthermore the current formulation faces the incidence of well-known inconsistencies and conundrums, plaguing physicalism, transcending from the microscopic- to the macroscopic level, see e.g. Primas [43]. Neo-Darwinistic principles, i.e. natural selection and the genetic code depend on causal forces and teleonomic laws or in other words causality is needed to instigate adaptation. Hence, neither causality, despite their absence on the fundamental microscopic level, nor progression that rely on semantically encoded processes, can be ruled out by physical law. Indiscriminately banning intentionality, or rather ententionality [12], one risks "throwing out the baby and keeping the bath water".

The persistent development, as envisioned by Rosenberg [18], viz. *emergence of copies of itself out of the atoms floating around in thermodynamic noise, templating, catalysing or otherwise producing copies of itself*, mimics Darwin's belief in gradualism. Evidently, as the laws of chemistry stipulates, larger and larger assemblies of molecular and macro-molecular structures evolve for plausible biological processes – and after some 500 million years iteration of the same process will produce more and more adaptation all in concert with the second law. This conclusion is based on a trusting acceptance of the causality related term adaptation, and the subsequent statement in [18] that only processes related to the 2nd law is permitted by physics. The conviction might be inappropriate as this specific scenario does fall between the chairs of micro-macro correlates. For instance, it is natural to characterize the law of causality as a fundamental rule on the macroscopic level, while cause and effect seem to vanish in the microscopic arena. Besides, one cannot rigorously derive the second law of thermodynamics, from statistical physics, without subjectively include a loss of information, see e.g. Ref. [44]. Thus the thesis, as stated earlier that everything is physical, is not complete, Mayr [4], necessitating a consistent verification of physics beyond the domain of time-reversible and non-causal classical and quantum physics.

An extension of the picture given in [18] is consequently unavoidable in order to strictly take account of concepts like adaptability and the origin of the genetic code. Recapitulating Mayr [4], the physicalist ideas are not sufficient to probe biology with its roots in concepts rather than physical laws. In this setting belongs the criticism of gene-centered Neo-Darwinism by Jablonka and Lamb [11], directed at a more specific interpretation of evolution. For recent debates on open questions in the philosophy of biology, see Ayala and Arp [76].

To account for the disparity, discussed above, one must be able to find an extension that incorporates some form of teleonomy. As our main purpose implicates a formulation of a CES, from the microscopic- to the macroscopic level, any solution of the controversial statements and criticisms of Darwinism must be taken seriously starting with a re-evaluation of modern quantum chemistry and chemical physics as developed over the last 50-60 years. The field has, as already stated, attracted considerable attention owing to general

developments of theoretical methodologies and significant advances in computer technologies [77]. Theoretical chemical physics comprise many different branches where the significance of the presence of so-called unstable states in the continuous spectra [33,34,35] has led to a rigorous expansion of quantum mechanics to include irreversible quantum dynamics, including both nuclear and electronic motions beyond the Born-Oppenheimer picture [55].

The rigour and the maturity of the field has already led to the coinage of Non-Hermitian Quantum Mechanics [35] opening up new vistas for exploration, see particularly section 2 above. A substantial portion of novel developments has guided extensions to fundamental areas, like non-equilibrium quantum statistics, original interpretations of the quantum-classical enigma, the inter-level formulation of subdynamics, and the subsequent derivation of CDS, the Correlated Dissipative Structure, and CDE, the Correlated Dissipative Ensemble, providing base units for microscopic self-organization. The intrinsic (Gödelian) self-referential property of the correlated ensemble [9], supports transformations that exhibit nested encodings and communication protocols through Poisson-distributed channels. Molecular aggregations like genes and cells recognize their position in the hierarchy of biological organisms via instructions through quality Q -values. Hence “communication” takes place between molecular constituents, starting from the nucleus of the undifferentiated stem cell to somatic cells, and also in connection with heritable variations in the lineage of germ cells, as well as in higher-level objects for embedded messages. In principle this includes epigenetic inheritance systems [11]. Function, adaptation and natural selection follow through encoding, storage and retrieval of teleonomic processes in the neural system, the support systems and the spinal cord or to be brief in the brain. In other words the law of self-reference leads to constraints through an evolved program containing the blue print for the appropriate structure, confined, restricted and teleonomically regulated.

It should be obvious for the reader that, with the objectives met, and with the validity of a natural teleonomic law at hand, a minor addition to the Rosenberg quote [18], offers a legitimate physicalist response to the problems of incorporating Darwinism under the laws of physics. With such a law, as mathematically formulated above, nature is provided with an intrinsic property, and hence, with this appendage Nagel’s major objection concerning the vanishing likelihood, that life forms comes spontaneously into existence, should be adequately answered.

5. Afterword

We have here extended the notion of “communication” to provide syntax for semantic purposes, extracted in physically well-defined information channels, to express function, information, reception, submission, transmission, regulation and adaptation. For this purpose, we have reformulated thermodynamics to comprise merged quantum-thermal correlations, which explicitly show the important roles of temperature and biological time scales in complex enough biological systems. This development not only points the way towards microscopic self-organization, but it also imparts non-equilibrium thermodynamics with a teleonomic origin. These advances are possible in a properly defined non-Hermitian

framework, allowing more general, symmetry-violating solutions to the wide-ranging Liouville master equations and related thermalization procedures.

Communication and functional understanding start already at the spatial intra-cell level, where fortified encodings or programs, linked to the undifferentiated stem cell, are downloaded, initiated and opened with the proper “copyright license”. Once molecular communication is realized and developed between cells and cellular aggregates, amongst protein segments and protein domains and in 3D arrangements of the multiple folding of multi-subunit protein complexes, Czaba et al., [78], it continues to map concepts, perceptions, and possibly thoughts on the neurological level, metaphorically represented as a “Call Center”. Cellular recognition via teleonomically controlled Q -values provide boundary conditions for the material build-up of biological structures from a CES with coordinated duties and responsibilities in the organism all the way to the spinal cord and the brain.

The Poisson process is stochastic, lacking intrinsic memory, giving rise to something non-intrinsic of teleonomic implication. Consequently, synchronized neural spike trains in the nervous system, the “Call Center”, obeying Poisson statistics, where classes of distributions with various λ -values, grants the necessary channel for semantic communication. Decoding–encoding is based on simple arithmetic and provides an original “language” for syntax and semantics. The process amplifies through the nervous system, with constraints due to the synthesis of proteins in synaptic transmissions, and continues through the ladders and ultimately to the perceptions of the mind.

It is a natural step to anticipate the semantic process to transcend appropriate regions of the cortex and view higher–level perceptions, “codes of codes” as protracted CDS’s. These extensions suggest a more precise and complete gene-based definition of the “social gene” coined the *meme* by Dawkins [10]. Cultural evolution has recently been discussed by Deutsch [42], where he concludes that knowledge changes the structure of the Universe. A complex meme should instigate both micro- and macro-evolution, and possibly extend to and beyond the social arena. In particular, it ascertains general aspects of communication from the spatio-temporal molecular and cellular level of a CES through higher-order levels, e.g. the social, the ecological, and even the cosmological rank. Evolution thus comprises also the non-material world, including mathematics, linguistics, fine arts, music, science, etc. By combining the superoperator algebra defined in Eq. (2.2.4) and Eq. (2.3.2), it is easy to see the connection with the recent work of Schmeikal on geometric Clifford algebra of space-time, establishing novel relations between logic and geometry [79]. Note that context-dependence of genetic information pushing semantic information in prebiotic matter has recently been reviewed by Küppers [80].

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