In Search of Quantum Information Biology

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Abstract

Life is neither reducible to ordinary physics nor it is independent of physics. Life is subject to a new discovered fundamental physical property that distinguishes life from nonlife. Thus life (genome) is a quantum information fractal field (QIFF) which generates, in addition to electromagnetic vibrations, self-sustained bio-information oscillations through successive generations. Bio-information is a measure of developmental functional complexity, has the dimensions of energy and information. The bio-information oscillations are represented by a generalized Schrodinger type of system that is nonlinear, non-conservative and irreversible, i.e., periodic functional bio-information attractor, also called the life-organizing principle. The life-organizing principle is a minor attractor when describing cellular dynamics and a major attractor when describing multi-cellular organism dynamics. A cell type is an example of a minor attractor which belongs to a basin of a major attractor. Ontogeny and phylogeny are processes that generate and organize minor attractors into a nested hierarchy of cell, tissue, organ, organ-system and organism. In consequence a QIFF is a nested hierarchy of bio-information attractors toward which a bio-system develops or evolves. The QIFF equations admit limiting transition to linear reversible quantum mechanics.

Keywords — Bio-information attractor; field equations; limiting transition; ontogenesis; phylogenesis; quantum information fractal field.

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I. INTRODUCTION

Quantum mechanics provides the basis for the shapes and sizes of biological molecules and their chemical affinities. Quantum mechanics also accounts for the strengths of

molecular bonds that hold the machinery of life together and permit metabolism[1]. However, quantum mechanics describes the evolution of delocalized objects, i.e. objects subject to the wave function. Such objects, under certain conditions, may exhibit coherence which is the collective cooperation of a large number of particles in a single quantum state. In this regard living systems are macroscopic localized decoherent objects which operate beyond the realm of quantum mechanics. Davies P is concerned with whether there are nontrivial quantum phenomena relevant for biology. By nontrivial is meant the presence of long-ranged, long-lived, or multiparticle quantum coherences, the explicit use of quantum entanglement, . . etc. He emphasized "If quantum mechanics is to play a non-trivial role in bio-systems, then some way to sustain quantum coherence at least for biochemically, if not biologically, significant time scales must be found. Without this crucial step, quantum biology is dead"[1] . Currently photosynthesis, the process of vision, the sense of smell, or the magnetic orientation of migrant birds is considered nontrivial quantum phenomena relevant for biology. These phenomena, even if regarded as nontrivial, raise the question of whether they justify reduction of biology to ordinary physics, or whether they reflect the ability of biological organization to harness physical phenomena.

Moreover, Van Regenmortel asserts that it becomes clearer that the specificity of a complex biological activity does not arise from the specificity of the individual molecules that are involved.[2] In fact, the important developments in coherence quantum electrodynamics (CQED) came with the contention that condensed matter and living matter cannot be reduced only to their molecular components, but they can be reduced, to the molecules oscillating in tune with an electromagnetic field[3-4]. However, by the same token, we may argue that, the organism, as a whole, may not be reduced to its constituent coherence sub-domains. Particularly if we assume, following the CQED model, that the organism as a whole is an outcome of the collective dynamics of its constituent coherence sub-domains at a certain matter information density and appropriate thermodynamic conditions.

Giuliani A, proposed that networks is a privileged way to develop mesoscopic level approaches in systems biology. In his view the notion of graph resides in its multilevel character allowing for a natural "middle-out" causation making largely obsolete the traditional opposition between "top-down" and "bottom-up" styles of reasoning, so fulfilling the foundation dream of systems science of a direct link between systems analysis and the underlying physical reality.[5] Tom L, and Borries D, argue in favor of a framework for postreductionist protein biochemistry, if biochemistry is to venture out from its reductionist roots. Thus a new framework is needed for understanding the complexity posed by the high concentrations and high surface-area-to-volume ratios encountered in biological systems. They emphasize that colloidal and surface chemistry provides great insights into how to approach such systems using fundamental thermodynamics, non-equilibrium thermodynamics, statistical thermodynamics and kinetics.[6]

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In their article "No entailing laws, but enablement in the evolution of the Biosphere", Longo G, Montévil M and Kauffman S stated that the aim of their article is to demonstrate that the mode of understanding in physics since Newton, namely differential equations, initial and boundary conditions, then integration which constitutes deduction, which in turn constitutes "entailment", fails fundamentally for the evolution of life. They argue no law in the physical sense entails the evolution of life.[7]

This is why from the beginning the founders of quantum mechanics were skeptical about the adequacy of quantum mechanics to explain life phenomenon. Bohr had the view that the distinction between living and non-living systems was fundamental, and a manifestation of his principle of complementarity.[8] However, it was not clear at that time what characterizes such living and non-living systems' complementarity. Answering the question: Is life based on the laws of physics? Schrödinger says "What I wish to make clear in this last chapter is, in short, that from all we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics. And that not on the ground that there is any new 'force' or what not, directing the behavior of the single atoms within a living organism, but because the construction is different from anything we have yet tested in the physical laboratory." He further emphasized "We must be prepared to find a new type of physical law prevailing in it". And to the question whether the new law could be non-physical or super physical? He answered "No. I do not think that. For the new principle that is involved is a genuinely physical one: it is, in my opinion, nothing else than the principle of quantum theory over again" Schrodinger[9].

In 1949, Delbruck, inspired by Bohr, expressed a view that is similar to that of Schrodinger: "Just as we find features of the atom, its stability, for instance, which are not reducible to mechanics, we may find features of the living cell which are not reducible to atomic physics, but whose appearance stands in a complementary relationship to those of atomic physics."[10] Pattee asserts that if living matter is exactly the same as nonliving matter with respect to description by physical laws, then this does not answer the obvious question of why living matter is so conspicuously different from nonliving matter.[11]

To overcome this dilemma Elsheikh proposes that a living system's genome represents a new type of quantum information fractal field (QIFF), that is different and beyond ordinary physical fields.[12] A QIFF is a nested hierarchy of bio-information attractors toward which a biosystem develops or evolves. This field notion becomes clearer as we proceed. However, it is evident that a biosystem (organism or ecosystem) needs badly the notion of field, because a field is an attractor, and an attractor by definition is a set of states toward which a system is attracted. For example let us assume for the sake of argument that an organism can be represented by a periodic functional attractor, meaning that it preserves the organism dynamics through successive generations. Also assume that each of the organism's subsystems, i.e., cell, tissue, organ, organ-system can be represented by sub-periodic functional attractors that belong to the basin of the organism's attractor. Then under this hypothesis some of the basic properties of a biosystem or organism can be derived, these are:

- Holism, i.e., downward causation.
- Connectivity, i.e., constructive interference of subsystems and cooperation.
- Self-organization, i.e., growth and development.
- Directionality, i.e., increase of bio-complexity.
- Dynamic equilibrium or stability.

If the notion of field is so rich to this extent why scientists do not capitalize on it? The answer is because the notion of field in ordinary physics has diametrically opposite properties to what mentioned above. An ordinary physics field, being conservative field, is subject to weak stability and upward causation. Moreover, it is a system of energy and the energy concept is not sufficient to contain the dynamical essence of living systems, because a living system is both a system of energy and an information processor. If so, then how can I justify my proposed QIFF hypothesis?

To justify it Elsheikh[12-13] proposed a paradigm shift which broadens the ontological foundation of contemporary physical theory. The broadening necessitates the following:

- Broadening the concept of information.
- Extension of quantum field
- Revealing life fractal nature.
- Extension of action principle

Information:

Elsheikh[12-13] distinguishes between genome physical information which is a measure of genome static physical complexity in bytes[14], and genome's bio-information a measure of genome's bio-complexity which is developmental and functional, and has the dimensions of energy and information. In this new perspective the genome's bio-information (v(t)) is about the phenotype, since the genome's bio-information is meaningless without producing a phenotype. The bio-information increases before adulthood, has a maximum when the organism is fully grown, decreases afterward, and becomes zero when the organism dies. For example, considering a unicellular organism that divides for successive generations, the bio-information becomes a periodic function of time. Thus it represents the bio-information oscillations generated by the genome through successive generations. Elsheikh claims that the bio-information oscillations represent a new discovered fundamental physical property which distinguishes life from non-life. The new property broadens the concept of matter and sets a new generalized complementarity according to which a material system does not possess simultaneously matter-waves and bio-information oscillations descriptions.

Quantum Field:

A field whether classical or quantum is defined as a function over space and time. This definition is not sufficient to contain

the dynamical essence of living systems. Because a living system dynamics or functionality depend on its bio-information or bio-complexity rather than on the space coordinates it occupies. So we define the genome quantum information fractal field (QIFF) as a function over bio-information and time, L(v,t). Such field generates, in addition to weak EM waves, self-sustained bio-information oscillations for successive generations. This means the genome is the material substrate of a quantum information fractal field.

To substantiate this notion of QIFF we draw attention to the fact that in quantum field theory each particle is embedded or associated with a field, so matter and fields are inseparable[15]. For example the material electron is not the field; rather it is a localized vibration in an electron field. In this perspective the electron field is a carrier or source of the material electron. Likewise, but in a reverse manner, similar to a magnetic or electrostatic field, the material genome being an information storage, processor and replicator, is the carrier or source of the genome field, which is a field of bio-information. A field of bio-information exists if a certain value of bio-information is defined at each point of a bio-information space. The notion of bio-information space is developed below, it is also shown that bio-information is quantized and fractal hence come the notion of QIFF. The QIFF provides physical basis for the abstract and sometimes metaphysical proposed morphogenetic fields [16,17-18] .

Life Fractal Nature:

Fractals model complex physical processes and dynamical systems. The underlying principle is that a simple process that goes through infinitely much iteration becomes a very complex process [19]. Kurakin ascertains the ubiquitous nature of fractality in biological hierarchy, whereby certain organizational structures and processes are scale invariant and occur over again and over again on all scales of the biological hierarchy, at the molecular level, cellular, organism, population and higher-order levels of biological organization. Based on his self-organizing fractal theory (SOFT), Kurakin proposes the existence of universal principles governing self-organizational dynamics in a scale invariant manner.[20] Moreover, Dan Winter - a pioneer on golden ratio in physics- asserts that golden ratio fractality is a condition of recursive constructive interference. In his view golden ratio fractality is the only geometry that allows wave patterns to add and multiply recursively constructively, thus produces optimum charge distribution and coherence. He coined the term quantum fractal field to designate the state of perfected charge distribution and coherence characteristic of the DNA.[21]

Least Action Principle:

In physics, the principle of least action, or more accurately the principle of stationary action is a variation principle when applied to the action of a mechanical system, can be used to obtain the equation of motion for that system. According to the least action principle a particle moves along the path for which the action is minimum; this means the spontaneous motion of the particle is to minimize action. Now is it possible to extend the action principle to incorporate the case of maximum action? [22]. In general, a maximum or most action principle must allow a system to follow spontaneously a path of maximum action. Thus spontaneous self-organization becomes possible, because under such circumstances the maximum action principle maximizes the rate of change of action, e.g., embryogenesis and morphogenesis, whereas under the least action principle the rate of change of action is less or equals zero.

Based on this paradigm shift, a biosystem has a physics that is beyond ordinary physics; has bio-information that is beyond physical information; has a quantum field that is beyond ordinary quantum fields; has an action principle that is beyond the least action principle. We call such new physics of biosystems quantum information biology.

II. METHODS

Quantum Information Fractal Field Hypothesis (QIFFH):
Definition 1:

A genome or genome pool is a quantum information fractal field, QIFF.

Postulates:

(i)- The QIFF (genome) generates, in addition to weak EM waves, self-sustained bio-information oscillations through successive generations

(ii)- The bio-information oscillations contain the dynamical essence of the living system.

(iii)- The bio-information sustains the living state.

Definition 2:

Bio-information, I(t); which is the information stored in DNA and proteins, is developmental functional complexity, within a specific environmental context, where (t) is the time measured from the moment of initial growth.

Definition 3:

Vitality, v (t), is defined as the genome capacity to generate developmental functional complexity, i.e., the capacity to generate phenotype.

Thus, capitalizing on the third postulate, it is possible to recognize the fundamental biological variables. The postulate emphasizes that bio- information sustains the living state, by which we mean:

a) Maintaining the system's survival.
b) Maintaining the system's self-propagation.

By maintaining the system survival, we mean the utilization of a certain matter-energy growth function to exhibit the basic properties of life, during a certain period of time. We usually call such period a lifespan, A, or life expectancy. Accordingly, we confine the fundamental bio- information variables to:

X – Matter-energy growth function, E(t), i.e., total matter-energy metabolized by the system, measured in calories.

Y – Life expectancy, ℓ . (ℓ = A- t), where A is the lifespan, measured in minutes, hours, days, or years in accordance with the organism.

Z – Self-propagation, or natality rate, N(t).

The effects of all other aspects of biological information, in addition to the effects of environmental conditions are to be interpreted as a perturbation or a modification of these

variables, [E, ℓ , N]. Note that [E, ℓ , N] are average values for a given organism of a given species.

Having specified and quantified the bio-information fundamental variables, we proceed to attempt to quantify vitality in terms of these variables:

$\therefore$ I(t) = I [E(t), ℓ (t), N(t)] (1)

Where I(t) is the bio-information assigned to a growing organism.

If there is no explicit natality, N(t), dependence we let,

v(t) = I [E(t), ℓ (t)]

Considering the simple plausible assumption,

i - v(t) $\propto$ E(t) , ii - v(t) $\propto$ ℓ^a

Where $a = \dfrac{\dot{E}(\alpha)\ell(\alpha)}{E(\alpha)}$, (2)

is a parameter which depends on the species and assumed to relax the dependence on ℓ [13]. α is the time when the organism is fully grown, i.e., having maximum bio-complexity. It follows from i and ii,

v(t) = bE(t) ℓ^a (3)

Where, b is proportionality constant which has information units. It might be a good idea to suggest that the proportionality constant, b, represents the given species genome's physical information measured in bits or bytes.

It follows, then, that the phenotypic expression of bio-information characterizes the physical nature of vitality. Being a function of the phenotypic fundamental variables, vitality measures the system capacity to generate bio-information. For simplicity, we limit our considerations to energy metabolism, where:

$$E(t) = \int_0^t M(x)dx \ , \qquad (4)$$

Where x is a dummy variable and M(t) is the metabolic rate, usually given by:

M(t) = $cW^r(t)$, c and r (= ¾), are constants and W(t) is the organism's body mass, Kleiber [23]. Thus, Elsheikh proved mathematically and empirically the following vitality properties[13].

i) $\dot{v}(0) > 0$

ii) $\dot{v}(\alpha) = 0$ (5)

iii) $\ddot{v}(\alpha) < 0$

iv) v(A) = 0

Consequently, in this model, there exists a vitality function v(t) that satisfies the following condition:

It increases before adulthood, reaches a maximum at adulthood, decreases afterwards and becomes zero when the organism dies.

It follows to compare or measure the bio-complexity or bio-information of different species, using equation (3), we get:

$$v_s(\alpha) = A^{-a}v(\alpha) = bA^{-a}E(\alpha)\ell^a(\alpha)$$

` (6)

Where $v_s(\alpha)$ is lifespan specific vitality the unit of which is bytes x calories. Consequently the organism's bio-information or bio-complexity has information as well as energy dimensions.

The vitality model may be usefully employed to discuss vitality for successive generations. We shall essentially be concerned with unicellular organisms, particularly those which reproduce by binary fission. For such systems, we suggest the following equation:

$$v_g = v(t+mA) = v(t) \qquad (7)$$

where m = 1, 2, 3 ,.. , is the number of cell divisions or generations. Equation (7) defines vitality as a periodic function of time, i.e. it represents vitality oscillations, or equally acceptable, the bio-information oscillations generated by the genome as a self-replicating quantum information fractal field. Consequently, the genome's bio-information measured in calories x bytes, oscillates in the time-vitality (t-v) space, also called bio-information space, during successive generations. This model is equally applicable to multi-cellular organisms which reveal an overlap of generations, i.e., overlap of bio-information oscillations.

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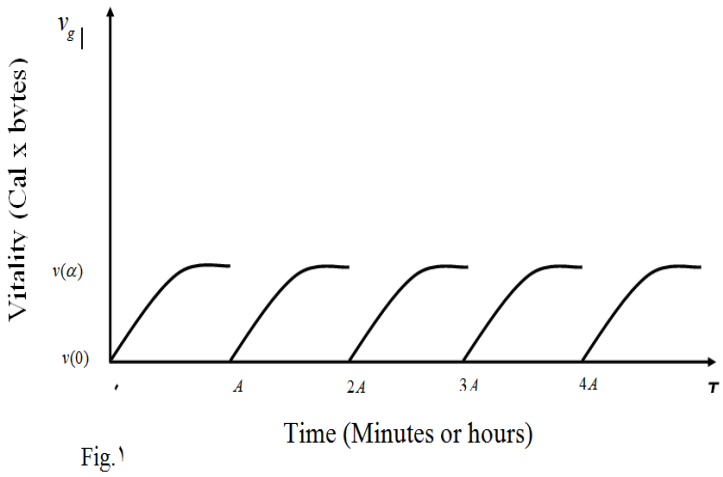

Fig.1

Fig.1: Hypothetical representation of bio-information oscillations of a unicellular organism for successive generations. The lifespan, A, (here cell cycle time) is the period of oscillations.[13]

The following definitions will be useful in our subsequent considerations.

Instantaneous total vitality:

$$V(t) = \int_0^t v(x)\,dx \qquad (8)$$

Where x is a dummy variable.

Total vitality, $V(A) = \int_0^A v(t)dt$ (9)

It is clear that the genome total bio-information is composed of two components: the capacity to grow and develop and the capacity to proliferate. We represent the former by vitality function, v(t), and correlate the latter to a natality density function, f(N(t)). We assume, for simplicity, that these two components of genome total bio-information are linearly additive. Based on this assumption and conservation of total bio-information an empirically falsifiable equation of logistic nature can be derived. It follows the genome's total bio -information, T(A), from (3) is given by:

T(A=

$$\int_0^A I[v(t),N(t)]dt = \int_0^A v(t)dt + \int_0^A f(N(t))dt = V(A) + F(N(A))$$

(10)

where N(t) = (dP/dt)/P is natality rate; P is population size; f(N(t)) is natality density function; V(A) is total vitality; F(N(A)) is total natality density function.

The Life- Organizing Principle

Based on the first and second postulates of QIFFH, the life state of an organism, L, called the life-organizing principle LOP [1-24] being an attribute of QIFF, must satisfy the following conditions:

i- L = L(v, t)

ii- L is a Schrödinger's type of system.

iii- L is a periodic functional attractor.

We shall therefore assume the simple following form:

$$L = L_0 e^{i\Phi/G} \quad (11)$$

where L_o is the amplitude, G is a constant to be found and has the dimension of Planck's constant. To satisfy the above mentioned conditions, we limit our considerations to the concrete example in which Φ is given by:

$$\Phi(t) = \int_0^t E(1-\frac{x}{A})^a dx \quad (12)$$

This completes the definition of L. Where x is a dummy variable.

$$\Phi(t) = b^{-1}A^{-a}V(t) = b^{-1}A^{-a}\int_o^t v(x)dx$$

$$\therefore L = L_o \exp.\frac{i}{bA^a G}\int_o^t v(x)dx$$

$$\therefore L = L_o \exp.\frac{i}{k}\int_o^t v(x)dx \quad (13)$$

$$k = b A^a G \quad (14)$$

$$\therefore \quad \ddot{L} - \frac{\dot{v}}{v}\dot{L} + \frac{v^2}{k^2}L = 0 \quad (15)$$

Elsheikh shows that equation (15) represents a non-linear, non-conservative and irreversible system, which describes self-sustained oscillations[12-13]. Furthermore, it has been proved that equation (15), being a generalized Lienard's system, admits limit cycle. Stable limit cycle solutions usually characterize structural stability, a property of high significance to bio-systems [25,26-27]. We call the life-organizing principle that describes muticellular organism dynamics a major attractor, while that which describes cellular dynamics a minor attractor. A cell type is an example of a minor attractor which belongs to the basin of a major attractor.

III. RESULTS

Result1.1 - Field Equations:

In addition to the life-organizing principle, we also call periodic bioinformation attractor:

- $\ddot{L} - \frac{\dot{v}}{v}\dot{L} + \frac{v^2}{k^2}L = 0$

We can derive the following laws:

- **First Law of Self-Organization**

To account for the spontaneous growth, development and functional activity of living systems, the living system must maintain a path of maximum action. Under such circumstances the genome capacity to generate developmental functional complexity (vitality) must be correlated to the rate of change of action to match the path. Thus we try to demonstrate that the phase of the genome's bio-information oscillations, which has action units, is the path of maximum action we are looking for. So, let us start from equation (12):

$$\Phi(t) = \int_0^t E(x)(1-\frac{x}{A})^a dx = A^{-a}\int_0^t E(x)(A-x)^a dx \quad (16)$$

From equation (3):

$$\Phi(t) = b^{-1}A^{-a}\int_0^t v(x)dx = K\int_0^t v(x)dx \quad (17)$$

Where x is a dummy variable and

$$K = b^{-1}A^{-a} \quad (18)$$

We propose equation (17) to be the biological integral of maximum action, which is a time dependent integral. The integral being time dependent, this very much simplifies finding the trajectory or equation of motion, v (t), without resorting to variational methods.

Given equation (17):

$$\therefore\ \dot{\Phi}(t) = K v(t) \qquad (19)$$

Equation (19) shows that the rate of change of action is proportional to vitality which is the genome capacity to generate developmental functional complexity. We call (19) the first law of self-organization. Using (6), (18) and (19) the bio-complexity for different species is given by:

$$v_s(\alpha) = A^{-a} v(\alpha) = A^{-a}\frac{\dot{\Phi}(\alpha)}{K} = \dot{\Phi}(\alpha) b$$

It is important to note that the findings of Tu B, and McKnight S, concerning yeast metabolic cycle (YMC) substantiate the first law of self-organization. They find during continuous culture growth, budding yeast exhibit robust metabolic cycles as measured by oxygen consumption. They also find that genes that encode proteins having functions that are associated with energy and metabolism tend to be expressed with exceptionally precise and robust periodicity, suggesting that these cycles are intrinsically metabolic. "Remarkably, more than half of yeast genes (~57%) are expressed periodically as a precise function of the YMC", Tu et al[28].

Moreover, Nikolai S, David B and Amy C, have also accomplished the same result, whereby they assert that most gene annotated to the cell division cycle are transcribed in concert with metabolism. As I said these results substantiate the first law of self-organization because they correlate metabolism (the rate of change of action) to gene expression which is a function of bio-information or vitality[29].

- **Second Law of Self-Organization**

This law demonstrates that total vitality which is the area under vitality curve is quantized and bifurcates in accordance with Fibonacci numbers (I, 2, 3, 5, 8, 13…..) [12,30-31]. The derived quantization relation may provide plausible theoretical basis for punctuated equilibrium [32]. Thus given (8) and (13) we get:

$$L(t) = L_0 e^{\frac{iV(t)}{k}} = C\cos\frac{V(t)}{k} + B\sin\frac{V(t)}{k} \qquad (20)$$

Setting the boundary conditions:

At t = 0 biotic- irreversibility (represented by the age of the organism) is zero, so V (0) = 0, we let L (0) = 0

At t = A the system is dead and v(A) = 0, we let L(A) = 0

$$\therefore\ 0 \le t \le A \qquad (21)$$

This means the life of an organism is bounded i.e. closed within the interval (21), thus the organism has no life before birth and has no life after death.

From (20) and the boundary conditions and (21) and (14), we get:

$$C = 0,\quad \frac{V(A)}{k} = n\pi,\ n = 1,2,..$$

$$V(A) = n\pi k = n\pi bGA^a \qquad (22)$$

$$= \frac{n\pi bG}{f^a} \qquad (23)$$

Note the lifespan, A, is at the same time the period of oscillations. Equation (23) is the second law of self-organization; it is a quantum information fractal law of evolution and development. It is a power law, a Pareto [33] type of law, which indicates that total vitality varies directly with Fibonacci numbers and genome physical information and inversely with the frequency of bio-information oscillations [12]. It is interesting that Bak and Paczuski [34] have also proposed a power law to account for punctuated equilibrium [32]. However, based on (23) the motif of bifurcations occurs in accordance with Fibonacci numbers. In consequence, (23) generates tree-like structures ontogenetically as well as phylogenetically. Such result can be empirically underpinned by development ontology tree [35] and the tree of life [36].

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- **Law of Conservation of Total Bio-Information**

From equation (10) the genome total bio-information is given by:

$$T(A) = \int_0^A v(t)dt + \int_0^A f(N(t))dt = V(A) + F(N(A))$$

Now assume for successive generations under certain perturbations the genome's total bio-information is conserved, i.e.,

$$T = U(t) + Z(N(t)) = \text{constant} \qquad (24)$$

U(t) is the population mean total vitality at time t during successive generations, and Z(N(t)) is total natality density function at time t during successive generations. Elsheikh [12-13] shows that equation (24) can be employed to derive logistic equations for the growth and development of organisms and populations:

$$\therefore\ \frac{dp}{dt} = p\left(c - \int_0^t \frac{\dot{U}\,dx}{Z'_N}\right) \qquad (25)$$

Result1.2- Macro-Evolution

Evolution (mutation, selection. .) is a process through which the life organizing principle undertakes negative damping, that leads to the increase or maximization of total vitality which is the area under the vitality curve, in accordance with:

$$V(A) = \frac{n\pi bG}{f^a}$$

Elsheikh 12 clarifies that although mutational changes are random, beneficial mutations, for which the life-organizing principle undertakes negative damping, are beneficial because

they generate or consolidate a total vitality quantum stationary functional state. Consequently, natural selection by selecting total vitality as goal or fitness function selects the path of maximum action and shortest evolutionary time. Whereby, total vitality is the product of genome physical information, lifespan and organism's total action. This is why identifying a direction for evolution progress had always been problematic as researchers used to pick up a single component of total vitality as a measure of evolutionary progress.

The realization that phylogenetic evolution (macro-evolution) is driven by a power law distribution (the second law) may shed some light on the Cambrian explosion. Accordingly, 80% of the initial time of phylogenetic evolution contributes 20% of total vitality increase, whereas the 20% of the succeeding time contributes 80% of total vitality increase, which may account for the Cambrian explosion. Now, since the Cambrian explosion started approximately 0.6 billion years ago, it means that life originated approximately 3 billion years ago. Jorgensen[37], using eco-exergy density which can be correlated to total vitality, demonstrates empirically that macro-evolution takes a path that can be represented by a power law such as the second law of self-organization.

Result1.3- Ontogenetic Development

Living systems have two fundamental discrete bio-information quantum units, i.e., cell and organism, as there is no such thing as a fraction of a cell or a fraction of an organism. A bio-information quantum unit is the smallest bio-information carrier within a certain developmental or evolutionary domain. The cell quantum unit develops (specializes) ontogenetically, through cellular differentiation. Thus cellular differentiation is a process through which the life-organizing principle (or stem cell bio-information attractor) undertakes negative damping, which leads to the increase of total vitality and the eventual decrease of bio-information oscillations frequency in accordance with the second law of self-organization. But what do we mean by saying the stem cell bio-information attractor undertakes negative damping?

To answer this question we follow Furusawa C, Kaneko K [38] .They argue that development involves an increase in the number of cells communicating via intracellular signaling, a property essential for maintaining distinct cell types and their homeostasis. They found that stem cells generally show temporal oscillations in their gene expressions at the single-cell level. In such cases, with the increase in cell number, state differences between cells are amplified by cell-cell communication such that the sensitivity to a signal increases. Some cells at a certain phase of oscillations escape their original attractor in response to a signal and fall into the trough of a different attractor, whereas other cells of different phases remain with the original attractor. Thus, they conclude that gene expression oscillations are necessary for stemness, whereas the loss of stemness is characterized by a loss of oscillatory dynamics. Based on this finding we assume that there is a correlation between the frequency of bio-information oscillations and the frequency of the temporal oscillations in stem cell gene expressions. In other words stem cells initially (cleavage phase) having high frequency of bio-information oscillations is associated with high frequency of temporal oscillations in gene expressions. This is why with increase in cell number the intracellular signals can easily be amplified, which causes the stem bio-information attractor to undertake what we call negative damping. However, after cellular differentiation occurs the frequency of bio-information oscillations decreases according to the second law, in which case intracellular signaling decreases.

In consequence the developed (or specialized) quantum unit is structured along a path of maximum action in accordance with the first law of self-organization to generate higher total vitality nested hierarchy of quantum stationary functional states, these are: tissues, organs, organ-systems, and ultimately an organism. In addition to the abovementioned operations of the first, second law, and the bio-information attractor which identifies the different quantum stationary functional states, the law of conservation of total bio-information operates within and across all attractors' basins. In particular conservation of total bio-information being local and global consolidates organism functional stability. It can monitor any disturbance locally and globally simultaneously, thus it facilitates efficient cooperative response.

$$T = U(t) + Z(N(t)) = \text{constant}$$

$$\therefore \quad \frac{dp}{dt} = p\left(c - \int_0^t \frac{\dot{U}\,dx}{Z'_N}\right)$$

Here p is the number of cells, so conservation of total bio-information also determines the maximum number of cells involved in any quantum stationary functional state, i.e., determines the maximum bio-information attractor size.

Result2.1-

A multicellular organism's nested hierarchy of bio-information attractors is fractal, and organized a long a path of maximum action.

Proof:

Let v(t) represents the mean vitality of specialized cell for a given multi-cellular organism, then we get:

Tissue vitality = x v(t) , where x is the number of tissue's different specialized cells, i.e., different cell types.

Consider the following table:

System	Mean-Vitality	Bio-Information Attractor
Specialized cell	v(t)	$L = L(v, t)$
Tissue	$v_1(t) = xv(t)$	$L = L(v_1, t)$

Organ	$v_2(t) = v(t)\sum_{i=1}^{n} x_i = y\, v(t)$	$L = L(v_2,t)$
Organ-System	$v_3(t) = v(t)\sum_{j=1}^{n} y_j = z\, v(t)$	$L = L(v_3,t)$
Organism	$v_4(t) = v(t)\sum_{k=1}^{n} z_k = w\, v(t)$	$L = L(v_4,t)$

where x, y, z, w, $\in \mathbb{N}$, and x < y < z < w are the numbers of different cell types in tissues, organs, organ-systems, and organism. Note: $v(t)\sum_{i=1}^{n} x_i$, is the summation of an organ's vitality of different tissues, i = 1, 2, 3,… n, is the number of different tissues. Similarly, j = 1, 2, ..,n, is the number of different organs, …,etc.

Therefore, it is clear that the organism's nested hierarchy of bio-information attracters is scale invariant, i.e., v(t) is invariant, and therefore fractal. It is also clear $v < v_1 < v_2 < v_3 < v_4$, so the bio-information attractors are organized a long a path of maximum action.

Result1.4- Quantum Information Fractal Field Characteristics:

- Existence of genome or genome pool.
- Field equations are applicable.
- An evolved (or specialized) bio-information quantum unit, organized along a path of maximum action.
- Nested hierarchy of bio-information attractors.
- QIFF equations admit limiting transition to quantum mechanics.

Definition-4 :

A QIFF is a nested hierarchy of bio-information attractors toward which a bio-system develops or evolves.

Definition-5:

Bio-information space is the time-vitality space (t-v-space) where bio-information attractors propagate and nest.

RESULT1.5- LIMITING TRANSITION TO QUANTUM MECHANICS

Why there is upward causation within the physico-chemical hierarchy? This is because, based on Planck's law (energy equals Planck's constant times frequency), levels having higher frequency have greater energy and strong force. So levels having lower frequency and weak force are reduced to those having stronger force, which usually belong to the lower level of the physico-chemical hierarchy. Thus there is upward causation. Now, this situation is reversed with regard to the biological hierarchy. Because, based on the second law of self-organization, levels having greater total vitality have lower frequency. In consequence levels having higher frequency, including the physico-chemical hierarchy which is a subset of the biological hierarchy, are reduced to the upper level of greater total vitality. This is why minor attractors belong to a basin of a major attractor. Therefore, there is downward causation. If this hypothesis is correct, then it is plausible to derive the basic laws of quantum mechanics as special case from the laws of QIFFH. For this sake we begin by introducing the following assumptions:

Assumption (A):

Biotic irreversibility is the fundamental attribute for the transition from inanimate to animate systems.

Assumption (B):

The time t - the age of organism - measured from the moment of initial growth is at the same time a measure of biotic irreversibility.

Note, in this case the time t has two meanings, it is a measure of the organism's age as well as a measure of the organism's bio-irreversibility. For example, when the organism dies at age t= A, its bio-irreversibility t = 0.

Since the time t is a measure of bio-irreversibility, then the main idea is to eliminate the bio-irreversibility from the equations of QIFFH, by taking the limit as t goes to zero in order to obtain the corresponding inanimate laws belonging to the lower level of the physical hierarchy. For this purpose let the vitality of a dead system be given by v(0), which means the system's bio-irreversibility t = 0. We assume for such dead or inanimate system the total matter-energy content E(0) is constant, i.e., subject to the law of conservation of matter-energy. In other words the difference between the living and non-living is that for the former $\dot{v}(0) > 0$ and for the latter $\dot{v}(0) = 0$

Result 2.2-

The life-organizing principle admits limiting transition to Schrodinger equation.

Proof:

Let $t \to 0 \Rightarrow L \to \Psi$, and $G \to \hbar$, under limiting transition, then we get:

Given: $L = L_0 e^{\frac{i}{k}\int v(t)dt}$

$$\therefore \lim_{t\to o} \frac{d}{dt}(ikL) = \lim_{t\to 0} \frac{d}{dt}\left[ikL_0 e^{\frac{i}{k}\int v(t)dt}\right]$$

Using (14) we get:

$$\therefore \quad i\hbar b A^a \frac{d\Psi}{dt} = -v(o)\Psi = -bE(0)A^a\Psi$$

$$\therefore\ i\hbar\frac{d\Psi}{dt} = -E(0)\Psi = -\hat{H}\Psi \qquad (26)$$

Having been able to specify the system's Hamiltonian, $\hat{H}$, one may identify the corresponding Schrödinger's equation.

Result 2.3-

Total vitality admits limiting transition to the law of conservation of total energy.

We first prove that total vitality is constant under constant environmental conditions:

$$V(A) = \int_0^A v(t)dt = constant$$

Proof:

Given: $V(t) = \int_0^t v(x)dx$

$$\therefore \dot{V}(t) = v(t)$$

$$\therefore \dot{V}(A) = v(A) = 0$$

$$\therefore V(A) = \text{constant},$$

under constant environmental conditions. This is why a species preserves its kind through successive generations.

Now let us consider the limiting transition:

$$\therefore \lim_{t\to 0} \frac{d}{dt}V(A) = \lim_{t\to 0} \frac{d}{dt}\int_0^A v(t)dt = \lim_{t\to 0} \frac{d}{dt} const. = 0$$

$$\therefore \lim_{t\to 0} \int_0^A dv = 0 \Rightarrow \lim_{t\to 0}[v(A) - v(t)] = const.$$

$$\therefore -E(0)bA^a = const. \Rightarrow E(0) = const. \quad (27),$$

Thus conservation of total vitality yields in the limiting case the law of conservation of matter-energy.

Result2.4-

The second law of self-organization admits limiting transition to Planck's law.

For simplicity let us assume the exponent a is approximately constant along a given phylogenetic lineage, we get:

$$V[A(t)] = \int_0^{A(t)} v(x,t)dx = \frac{n\pi bG}{f^a} = n\pi bGA^a(t)$$

$$\therefore \lim_{t\to 0} \frac{dV}{dt} = \lim_{t\to 0} \left[\int_0^{A(t)} dv\,(x,t)\frac{dx}{dt} + v(A,t)\frac{dA}{dt}\right] = n\pi bG \lim_{t\to 0} \frac{d}{dt} A^a(t)$$

we let $\frac{dA(t)}{dt} = const. = 1$, where A(t) $\propto$ t . Also note b is basically inanimate property, measured in bits.

$$\therefore \lim_{t\to 0} [bE(t)(A(t)-t)^a - bE(t)(0-t)^a + bE(t)(A(t)-t)^a] = n\pi bGa \lim_{t\to 0} A^{a-1}(t)$$

$$\therefore 2E(0)A^a(0) = n\pi GaA^{a-1}(0)$$

$$\therefore E(0) = \frac{n\pi aG}{2A(0)} = \frac{1}{2}n\pi aGf(0)$$

If $t \to 0 \Rightarrow \frac{1}{2}\pi aG \to h,$ then we get Planck's law:

$$E(0) = nhf(0) \quad (28)$$

It follows quantization of total vitality yields in the limiting case energy quantization.

Result2.5-

The maximum action principle admits limiting transition to the stationary action principle.

Proof:

A dead organism's total matter-energy content E(0) being subject to the law of conservation of energy, we let:

$\therefore$ E(0) = constant

Given:

$$\Phi(t) = K\int_0^t v(x)dx$$

$$\therefore \dot{\Phi}(t) = Kv(t)$$

$$\therefore \lim_{t\to 0} \dot{\Phi}(t) = \lim_{t\to 0} Kv(t) = KbE(0)A^a = \frac{bA^aE(0)}{bA^a} = E(0) \quad (29)$$

Let $\lim_{t\to 0} \dot{\Phi}(t) = \frac{dS}{dt}$

$$\therefore \frac{dS}{dt} = E(0) \Rightarrow S = \int E(0)dt \quad (30)$$

Equation (30) defines the principle of least or stationary action for a conservative system.

It is interesting that the laws of the proposed QIFFH, in the limiting case, leave the basic laws of linear reversible quantum physics invariant. This supports Elsasser's [39] view that any substantial conceptual innovation occurring in the passage from theoretical physics to theoretical biology must be such that it leaves laws of quantum mechanics invariant.

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IV. Discussion

I consider the following four questions for discussion in order to shed some light on certain important ideas**:**

1) How could the bioinformation be a periodic function of time? What is responsible for determining the periodicity without referring to the very bioinformation?

Bioinformation is defined as genome capacity to generate developmental functional complexity. This capacity propagates through successive generations due to cell division in case of

unicellular organisms and reproduction in case of multi-cellular organisms. Within each generation an organism grows, i.e., increases in developmental functional complexity, has a maximum growth at adulthood and then gradually declines. So for successive generations we get cycles of growth and decline. These cycles are represented by a vitality function which measures developmental functional complexity in terms of energy and information. We call such cycles or periodicity bio-information oscillations. It follows the genome capacity for self-replication generation after generation is responsible for determining these bioinformation oscillations.

2) How could we define bio-information and bio-complexity without referring to materials in space and in time?

Evidently, since bioinformation or biocomplexity has the dimensions of matter-energy and information they refer to materials in space and in time. However, when I said the QIFF is a function over bioinformation and time rather than a function over space and time, I did mean that the spontaneous self-organizing dynamics of the material system which is the bio-system is an attribute of its biocomplexity or bio-information, i.e., it is independent of the space coordinates it occupies. In consequence if the QIFF equations are independent of space coordinates, how can we account for this result? The result suggests that a bio-system is subject to two types of dynamics. Ordinary dynamics according to which a bio-system, governed by ordinary physical laws, is both embedded in space and moves through space. And fundamental dynamics according to which a bio-system moves (develops or evolves) through time independent of space coordinates. For example, within the same three dimensional space -Earth- life has evolved from molecules to men during the last three and half billion years. It is plausible to suggest this movement (evolution) occurs in bioinformation space or time–vitality space (t-v-space) where bioinformation oscillations propagate and nest. Particularly in such space, based on the QIFF equations, bio-information is conserved, quantized and fractal. In general, it seems appropriate to suggest that life belongs to a 5-dimensional space; bioinformation is the fifth dimension. This, probably, explains why life has always been problematic from the perspective of ordinary physics.

3) Is it possible to define the so-called biological fractality without referring to space?

What do we mean by biological fractality? We mean when we zoom in the organism, we find organ-systems. When we zoom in organ-systems we find organs. When we zoom in organs we find tissues. When we zoom in tissues we find cells. So the cell as bioinformation quantum unit is the building unit for this hierarchical organization, i.e., the hierarchy is scale invariant with respect to the cell. In each scale the cell genome contains the whole and the whole contains the cell. In consequence it is more appropriate to define biological fractality with reference to the proposed bioinformation space, whereby a nested hierarchy of bio-information attractors represents cell, tissue, organ, organ-system and organism in scale invariant manner (Result 2.1).

4) How can we justify a maximum action principle in biology without offending the least action principle well accepted in physics? Is there no connection between physics and biology?

Physical laws have domains of validity, beyond the limits of a given domain a law does not hold. However, sometimes when we transcend the limits of this domain we encounter a more general law which encompasses the initial law as special case. This happens when we transcend the limits of classical mechanics to encounter relativity and quantum mechanics, also happens when transcending the limits of thermodynamics of closed systems to develop the thermodynamics of open systems. It follows the least action principle also has domain of validity. It is valid when the spontaneous rate of change of action of a phenomenon under consideration is less or equal to zero. So what do we do when we encounter a phenomenon for which the spontaneous rate of change of action is greater than zero, e.g., organism growth and development? As scientists we must stick to the empirical evidence. Therefore the connection between biology and physics is that the least action principle is a special case of a more general principle (Result 2.5) that is the maximum action principle which accounts for organism growth and development.

V. Conclusions

What is quantum information biology (QIB)?

QIB is the study of biosystems as spontaneous selforganizing dynamical systems. Suffice to say the quantum information fractal field, being a nested hierarchy of bioinformation attractors, facilitates downward causation a basic attribute of spontaneous selforganizing dynamics. QIB bridges the gap between physics and biology and proposes a unified theory of life according to which both phylogeny and ontogeny can be studied on the basis of QIFF equations. The philosophical impacts of QIB on issues concerning the nature of reality, relationship of biology to human sciences, reductionism-anti-reductionism, and so forth are unmistakable. In this perspective biology becomes the central driving science in the universe, since its laws contain the laws of ordinary physics as special case and its space contains the ordinary 4-dimensional physical space as a subspace. What are the basic steps to develop such a revolutionary vision? Four steps are necessary:

First: We propose a paradigm shift that broadens the concepts of information, life fractal nature, quantum field, bioinformation space and least-action principle.

Second: Based on the paradigm shift, we identify what physically distinguishes life from nonlife (i.e., the genome's capacity to generate bioinformation oscillations through successive generations).

Third: Based on the bioinformation oscillations, we formulate the life-organizing principle, which is a generalized Schrödinger type of system with vitality, a measure of bio-information, as path variable.

Fourth: Based on the life-organizing principle, we derive the first and second laws of selforganization, which explain biological evolution and development.

The life-organizing principle, first and second laws of selforganization and conservation of bioinformation represent the QIFF's equations which admit limiting transition to

quantum mechanics. Thus we report the following important empirically falsifiable predictions:

- An organism's rate of change of action is directly proportional to the increase of its bio-information.
- An organism bio-complexity is a product of its maximum rate of change of action (measured in calories) and its non-redundant functional genome size, genome physical information, (measured in bytes). So we can compare the bio-complexity of different species.
- Total vitality, being a product of the organism's total action, genome physical information and lifespan, facilitates a conclusive evolution goal function or fitness function.
  .
- Macro-evolution is a punctuationistic transition from a lower major attractor (life-organizing principle) to an upper major attractor. The transition is governed by the second law of selforganization.
- Simulation of development ontology tree as well as the tree of life using the second law of self-organization.

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