The Hamiltonian of Life: an Anticipatory Operator of Evolution

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Abstract: A rule determining sequences of conservative Poincaré sections of a topological space in which Life is embedded is proposed. A hamiltonian of living organisms and ecosystems should include: (i) kinetic components as the manifold of metabolic interactions, activity and anticipatory behavior leading to homeostatic and evolutionary adaptation; (ii) potential components as the selection of expressed characters from DNA existing structures, and the construction of new genomic components by evolutionary processes. Both are connected to the set of environmental forces, and a distribution of hamiltonians of interacting organisms is proposed. Corollaries derive the conditions of occurence of evolution and identify boundaries to biological engineering within the Planet and the solar system as conservative embedding systems.

Key words: Biohamiltonians; Convolution; Life conservation; Spacetime rule.

1 Introduction

Rosen pointed that "Since organisms themselves are composed with matter, the properties of matter influence the behavior of organisms" [20] while he noted that such biological system as any given enzyme represents a system which "has no hamiltonian, no Schrödinger equation, no wave function, etc." [21]. Since then, hamiltonian equations have been derived for some peculiar properties of proteins and other components of life. The present study addresses the problem for the living phenomenon in its whole, which implies some preliminaries.

1.1 External Influences in Classical Concepts

A potential energy W_P or E_{Pot} is the product of a scalar μ (characteristic of components of mass of an object) by a distance of functions $d[\varsigma(x_i),\varsigma(x_j)]$ of its positions, where ς maps a causality factor applying on μ. Thus, components outside the system are involved. The kinetic energy W_K or E_{kin} is a function of some expression of the mass M of a system ($M=\cup m_i$) and of the square of the velocities $(v_i)^2$ of its components, in newtonian, relativistic and related forms. The theorem of the kinetic energy again involves causality and interaction of external with internal forces.

Let E_{kin} and E_{Pot} be the kinetic and potential energies of a system. The hamiltonian is defined for a conservative system as $H = E_{kin} + E_{Pot}$ while the lagrangian is $\mathcal{L} = E_{kin} - E_{Pot}$. The kinetic component is usually reflected by $mv^2/2$ for masses m composing the system, while the potential component is dependent on contextual forces able to act on

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the system's structure. Given a potential U, scalar and vectorial expressions of the associated force or energy are currently represented by $E = U.Q$ where Q is the charge of the system related to U, and $\mathrm{vect}(F) = - \mathrm{vect}(\mathrm{Grad})(U)$.

As far as these points are assessed, the classical Hamilton relations state that, given X a coordinate of position, t a coordinate of time, p the momentum and m the mass of the system: $dX_i/dt = \partial H/\partial p_i$ and $\partial p_i/\partial t = \partial H/\partial X_i$. The Lagrange relation equivalently states that $d(\partial \mathcal{L}/\partial X^{\bullet}_i)/dt - \partial \mathcal{L}/\partial X_i = 0$, with $p = (m.X^{\bullet}_i)$.

However, while no physical system is totally invariant (particles have limited lifespan, orbitals have varying energies, etc.), a living system cannot be considered as isolated from its environment, and conservativity conditions must be revisited.

The action in the sense of Maupertuis is the summation of p over a space interval while in the sense of Hamilton-Jacobi, it is the summation of the Lagrangian over a time interval. In the sense of Planck, action is the summation of an energy over a time interval or per frequency intervals. The least action principle states that a small change in the motion of a system would let the Hamilton-Jacobi action unchanged.

1.2 Advances in Wave Function Interpretation

In classical quantum mechanics, the wave function (ψ) is determined by the frequency (ν) and by the de Broglie wavelength ($\lambda_{\mathrm{de\ Br.}}$) of a particle [14]. So far, no physical interpretation was possible for (ψ) as the root of a probability of localization. However, recently the wave function of a macroscopic object has been described in terms of specific deformations of space [14], [15]. This approach provides a physical meaning to the de Broglie and Compton wavelengths as well as to the frequency of the system, and the corresponding formalism has been shown to reach a classical form. Let $\{\pi\}$ be a set of vector parameters describing all of the mass components of the corpuscular system and $\bar{c}_{\pi}$ a limit in the transmission velocity of space deformations; then, $\pi^{\bullet\bullet} - \bar{c}^2_{\pi}.\nabla\pi = 0$ [14]. Wave function components of one particle can thus be extended to those of an entire organism and to all massive objects. Therefore, a deterministic wave function $\psi(X,t)$ becomes conceptually accessible to macroscopic objects.

Both E_{kin} and E_{Pot} are dependent on components of X, and t is an indexation of a ordered sequence of topological configurations, as seen below. Then the expression of Hamiltonian and Lagrangian operators can be envisioned for a complex system like a living organism. The present works preliminary explores the general features of these operators and some implications for conservativity through interactions and evolution.

2 Conservation in Spacetime Sequence

Previous works [2], [4] have described spacetime as a ordered sequence $\{S_i\}_{i \in N}$ of Poincaré 3-D closed sections of a topological 4-space $(X,\perp)$. This imposes that general topological properties ($\mathcal{T}$) of the space of any section are conserved in the next one. This condition provides a "reference frame" for the *Analysis Situs* of objects in these sections. Motion appears when a point belonging to a subset in one section is mapped into a corresponding point in another subset in the next section. One among all laws of selection of S_{i+1} from any S_i determines our observable universe and all other concepts are embedded in it.

Proposition 2.1. A law of selection of a space section S_{i+1}, given a section S_i is the following:

$$(\perp_o) = \begin{cases} \text{(i) conservation of topologies: } \forall i,\ \mathcal{T}(S_{i+1}) = \mathcal{T}(S_i) \\ \text{(ii) } S_{i+1} \neq \emptyset;\ S_{i+1} \neq S_i \\ \text{(iii) } \{S_i \mid (S_i \cap S_{i+1}) = \max(S_i \cap S_{i+k})_{\forall k \geq 1}\} \end{cases} \quad (1)$$

Conjecture 2.1. This rule implies the least action principle and predicts the occurence of geodesic trajectories.

In effect, the distance between two successive positions from one to the next topologically closed section $d(x_i, x_{i+1}) = ds$ will be minimal. The sum of such distances over a trajectory will thus coincide with a geodesic.

Conjecture 2.2. Relation (1) could be consistent with the rule holding on our observable spacetime. A full demonstration of the proposition is in progress.

3 Peculiarities of Living Systems

3.1 Evolutionary Interactions

Life has emerged from the reproduction and evolutionary diversification of primitive organisms (see [3], for review). There exists a short-to-medium term continuum between an individual and its progeny, and a long term continuum between all phyla and their common ancestors.

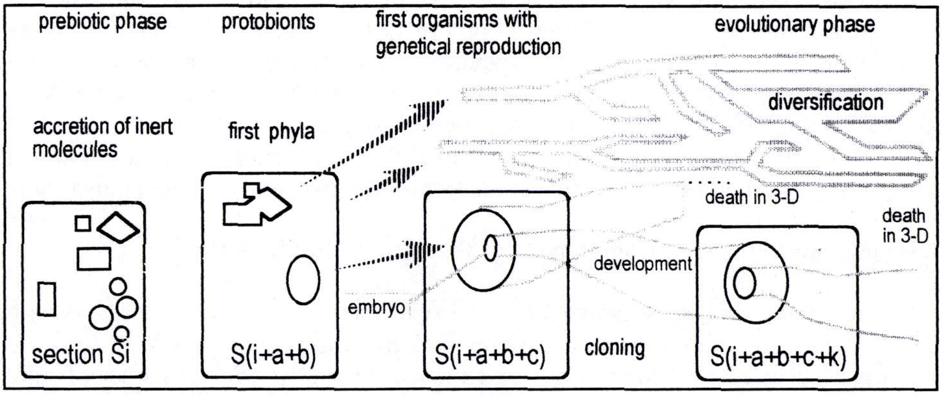

Figure 1: The continuum of life from prebiotic forms. Dotted lines schematically denote the trace in 4-D embedding space of the sequence of 3-D sections constituting the observable spacetime, where objects are closed, thus interactive.

Proposition 3.1.1. A living organism is separated neither from its ancestors nor from its progeny. (i) Ancestors have provided initial equipments that have allowed its evolution into a form eventually adapted to local conditions in time and space. (ii) progeny is able to directly interact with the energetic status of the genitor, and reciprocally.

Therefore, a living system must be considered through its continuity (Fig.1), and connected hamiltonians must be defined over individuals, clones and phyla.

The complementary in the 4-space of physical objects is open and cannot be considered as physically existing. Thus wave functions are physically pertinent only in 3-D sections while they remain defined over the entire structures.

Proposition 3.1.2. Ecosystems represent 3-D traces of interactive collections of phyla with their environmental habitat and resources: this involves a specific type of hamiltonian. Due to their interconnections, the components of a ecosystem should be considered as members of a global entity, like atoms are members of a molecular entity.

Proof. (i) In a molecule, some atoms are more reactive than others during contact with other molecules. Some atoms may appear as nearly inert, and may be considered having more a structural than a interactive role, while others are highly reactive and determine the chemical properties of the molecule. However, even structural components play a key role during some types of interaction such as ligand binding to receptors.

(ii) Similarly, in a ecosystem, some components are more structurally than actively involved in the global activity of the system. However, their role is emphasized by the fitting of active species to their characteristics, like a substrate site fits to the characteristics of the substrate within an enzymic macromolecule.

Remark 3.1. Conservation of living systems lies on that of the embedding planet.

Proposition 3.1.3. The hamiltonian of a ecosystem at time (t) is not independent from its hamiltonian at time (t+k).

Proof. (i) The interval between a closed subspace in (S_i) and its mapped image in (S_{i+1})belongs to the complementary in the embedding 4-manifold of closed 3-D spaces: therefore it is open and cannot contribute to observable physical processes. (ii) Topological substructures are not modified within a open space interval. Therefore, wave function properties of the progeny and of farther species along continued phyla are not independent from those of the genitors. (iii) The viability of the evolutionary progeny of an organism is dependent on its fitting to further characteristics of habitat and resources, which.involves anticipatory mental imaging.

Therefore, future states of the entire system are not independent from the state of the initial genitor and conservative entities oscillate between organisms and the medium.

3.2 Kinetic and Potential Components of Biological Hamiltonians

Kinetic components must include the totality of factors enumerated in section 1.1 as $\{\cup(m_i.v_i)^2\}$which are involved in motion and its causality factors connected with internal, external forces, connections and interactions. Call {WK} the set of kinetic components. Then, let indices (ε, μ, m, M) denote respectively the submicro scale (the scale of corpuscles), the molecular scale, the meso-scale (organ functioning) and the macroscale (whole body motion). Components of relation (2) are listed in Table 1.

$$WK = \cup_{\varepsilon,\mu,,m,M} \{WK_\varepsilon, WK_\mu, WK_m, WK_M) \qquad (2)$$

Table 1: The various members constituting the sets {WK} of components of the kinetic energy of a living system.

Scale	Symbol	Members
Corpuscular	WK_{ε}	corpuscular translation, vibration and rotation (i.e. temperature)
Molecular	WK_{μ}	intracellular molecular transfers for metabolic pathways, identification and detoxification of foreign compounds, immunity, enzymic induction, etc.
Meso (organs and tissues)	WK_m	blood flow, intestinal peristaltism and transit, cardiac rhythm, pulmonary rhythm, biliary and renal excretion, etc.
Macro (entire organisms)	WK_M	whole body motion in connection with food search and catch, shelter construction, search for partners, fight with or flight from ennemies, social activities, game, and specifically for human, all administrative constraints from political and economical world

Remarks 3.2.1. (i) All these actions are measurable.

(ii) The above members are entirely dependent on the supply of resources from the embedding ecosystem [8].

(iii) All living organisms are involved in the flow of species and resource exchanges which characterize the hamiltonian of the whole ecosystem as a conservative supersystem. Thus the following:

Corollary 3.2.1. The hamiltonian of a living organism depends on that of its embedding ecosystem. Furthermore, since the Earth global ecosystem receives part of its energy from the sun, not independently from the other planets, that the solar system is dependent on its galaxy, and so on, up to the very origins of the construction of the total universe, strictly speaking, the bio-hamiltonian is a component of the Universe hamiltonian as the most conservative supersystem.

Corollary 3.2.2. An individual living system is not isolated. However it can be considered as a conservative system through the flow of input and output of energy in its various forms. In general terms, one will write: A (input) ≈ B (output) over a short time interval, with for instance:

$$A = \{\text{input of radiations, } O_2,\ H_2O,\ \text{nutrients}\}$$

$$B = \{\text{output of } CO_2,\ H_2O,\ \text{waste compounds}\} \qquad (3)$$

All of the above components are connected by mutual influence, and their interactions are schematically illustrated by Figure 2. The fate of longer time intervals will be examined below.

The potential component WP contains all factors that involve forces able to act on, and interact with, the considered system. However, these forces manifest themselves at various periods of time and some may interact only with a future configuration of a given organism. Following definitions in section 1, components will include $\mu\, d[\varsigma(x_i),\varsigma(x_j)]$ in which (μ) represents the parameter connected with the equivalent of mass (or some mathematical "weight") of the involved objects and $[\varsigma(x_i),\varsigma(x_j)]$ the configurations whose distance stands for the corresponding potentials.

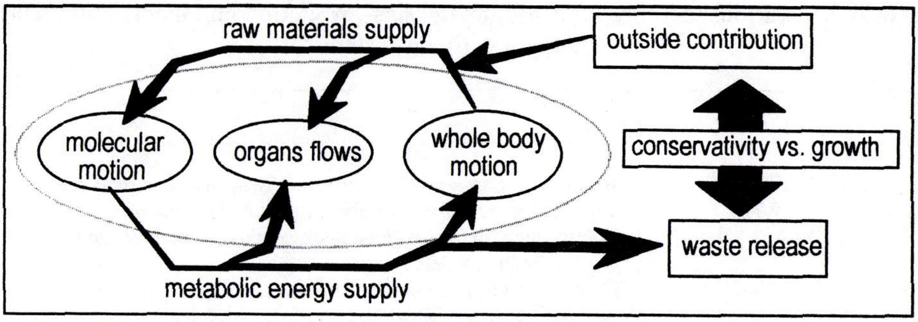

Figure 2: Interactions between members of the kinetic component of the bio-hamiltonian. Conservativity is provided by outside/inside flows equivalency.

In relation (4), WP1 has the same indexation as for WK, and in WP2, G denotes total genomic potentialities. Subcomponents are detailed in Table 2.

$$WP = \begin{cases} WP1 = \cup_{\varepsilon,\mu,,m,M} \{WP_{\varepsilon}, WP_{\mu}, WP_{m}, WP_{M}\} \\ WP2 = \cup_{G,\, G1,\, G2} \{WP_{G}{=}(WP_{G1}, WP_{G2})\} \end{cases} \tag{4}$$

Table 2: an evaluation of members of first kind and second kind subcomponents of the potential energy of living organisms, at various scales

Scale	Symbol	Members
First kind potential factors (WP1)		
Corpuscular	WP_{ε}	atomic and molecular cohesion
Molecular	WP_{μ}	homeostatic potential as keeping of the organism's integrity of energy reserves: glycogen, glycerides, etc.
meso	WP_{m}	homeostatic potential for organs, arms, legs, fingers; potential of resistance against blood flow, and other motion by friction, gravity, etc, along with food storage, etc.
macro	WP_{M}	potential founded on brain mental image-directed intentions
Second kind potential factors (WP2)		
expression level	WP_{G1}	potential of gene expression by selection among existing genes and alleles
evolutionary level	WP_{G2}	potential of gene evolution from introns and repetitive sequences, towards the acquisition of new genes for somatic confrontation with changed environmental forces

Remark 3.2.2. Here also, components WP1 are interactive and depend on each other as for WK (Fig. 1). Furthermore, component (WP2) is dependent on WP1 and on WK.

4 Anticipatory Features and Evolutionary Clauses

Proposition 4.1. The subhamiltonian $H_M = (WK_M \cup WP_M)$ is provided with anticipatory properties.
Proof. Let for example a situation of threat be perceived: first the individual evaluates the various possible endpoints: this doing, he forms mental images anticipating over a future situation. Then he adjusts his action on a decision depending on these anticipatory speculations. Further, he will eventually readjust his action to an intermediate reevaluation of the endpoint. This case exactly describes an hyperincursive property, in the sense of Dubois (1998) [10] of the hamiltonian, at both kinetic and potential levels .

The connection of the potential to the kinetic components of the cellular hamiltonians is subjected to a condition which can be stated as follows.
Theorem 4.1. The evolution of organisms involves a force defined by a potential variation under a clause of continuity which implies a correlation between the stability of DNA and the functionality of coded proteins.
Proof. Let $G=\{E,\perp_F\}$ be the space of the cellular genome: $E=\{E_{ex}, E_{intr}, E_{alt}\}$.for respective sets of exons, introns and altered material (from mutations, clastogenicity, etc.). Let $S=\{F,\perp_m\}$ be the space of protein structures of the living organism, with $F=\{F_m, \emptyset, F_{alt}\}$ for functional, empty and altered forms as the range of E from a mapping f of E into F: $f \in (\perp_F)$. For any gene succession x1, x2 $\in$ E, with xi=x(ti), there corresponds f(x1), f(x2) $\in$ F. When distance d(x1,x2) is lower than an integer n (n is a number of aminoacid residues changes), there exists an integer e (e is a number of elementary biochemical operations, like a number of mols of substrate transformed by time unit) such that d(f(x1), f(x2)) is lower than e. This provides f with continuity.

Now, suppose there exists some x3 $\in$ E such that $f(x3) \in F_{alt}$. One always have in E for any n some p such that min dist(x1,x3)$\leq$n implies min dist(x1,x3) $\leq$ p. In the functional range of F, one has min dist(f(x1),f(x3)) > min dist(f(x1),f(x2)).

In effect: take for dist(A,B) the topological distance $\Delta(A,B) = C_{A \cup B}(A \cap B)$, with C denoting the complementary operation. Then, dist(F_{ex}, x2)=$C_{F_{ex}}(x2) \subset F_{ex}$. In contrast dist($F_{ex}$, x3)=$C_{F_{ex}}(x3) = x3 \cup F_{ex}$. Therefore dist($F_{ex}$, x2) $\subset$ dist(F_{ex}, x3). Finally, for any p there exists some e such that:
min dist(x1,x3) $\leq$ p $\Rightarrow$ min dist(f(x1),f(x3)) > e. Similarly max dist(f(x1),f(x3)) > diam(F_{ex}) while for any n there still exists some p such that max dist(x1,x3)$\leq$n implies max dist(x1,x3) $\leq$ p. Thus continuity would not be respected and F could be filled with structures devoid of functionality.

Accordingly, cellular functionality is provided iff stable DNA codes for functional proteins. QED
Remark 4.1. Function $f_{|ex} : E_{ex} \mapsto F_m$ is a restriction of f into F_m.

5 About Distribution of Individual Hamiltonians

The relationships between the hamiltonians of individual systems within the global ecosystem are distributed in time and space. How hamiltonians of individual components of a system are composed into the hamiltonian of the complete system deserves special attention. In effect, this point determines the way through which the organization of the full system can reach its optimum, by analysis of extrema of the various forms of action. Here, the interaction can be conservative, not its members.

Definitions 5.1.1. Denote by $X=\{A,B,Q\}$ the set of species, habitat and resources, respectively. The global ecosystem is a space of magmas [4] $E=\{(X), (\Phi)\}$, where (Φ) is a functional. Call $(\circ)$ and $(\perp)$ two kinds of mappings connecting hamiltonians $H(x_i)$ and $H(x_j)$ for any two members of (X) and $(T^{\perp})$ the family of mappings from $(\perp)$ to some $(\circ)$. Call (φ) the specific kind of relationship which maps two components $H(x_i)$ and $H(x_j)$ contained in $H\{(x_i), (x_j)\}$. Let $H[(x_i) \cup (x_j)] \mapsto \varphi[H(x_i), H(x_j)]$ be a function (approximated as $H(x_i) \cup H(x_j)$ in Sections 6.1 and 6.4). Note that $dH(x_i)\neq 0$, $dH(x_j)\neq 0$ during interaction, with $dH(x_i, x_j)\approx 0$ for $\varphi(x_i,x_j)\subseteq\{x_i,x_j\}\subseteq(X)\subseteq(E)\subseteq($ etc.).

Repartition functions will be denoted by F and distribution functions by f.

Theorem 5.1.2. Hamiltonians of individual components of a invariant pair in a system with higher order of complexity are mapped by non-linear convolution-like functions.

Proof. For continued variables, let $H(z) = \varphi(H(x_i), H(x_j))$. Then [22]:

$$F(H(z) = \int_{\varphi(H(x_i),H(x_j)) \subseteq H\{x_i,x_j\}\ )} f(H(x_i), H(x_j))dHx_i.dHx_j \tag{5a}$$

while for discrete variables one would have the following distribution of probabilities P:

$$P(\varphi(H(x_i), H(x_j))) = \bigcup_{k\in\emptyset}^{k\in(X)} P\{(\varphi(H(x_i)=k) \cap (\varphi(H(x_j))=\mathbf{C}_X\,\varphi(H(x_i)))\} \tag{5b}$$

where $\mathbf{C}_A(B)$ denotes the complementary of B in A, also denoted by A\B.

Reducing relations (5a,b) to the particular case where one would simply write: $\varphi(H(x_i), H(z))=(H(x_i) + H(x_j))$ would give for a discrete variable:

$$P(H(x_i) + H(x_j)) = \sum_{k=0}^{Hz} \{P(Hx_i=k) \cap (Hx_j=Hz-k)\} \tag{6a}$$

and for a continuous variable the repartition function:

$$F(Hz_i)=\int_{-\infty}^{+\infty} f(Hx_i).F(Hz-Hx_i)dHx_i \tag{6b}$$

that is also the distribution, with commutativity between Hx_i and Hx_j:

$$f(Hz_i)=\int_{-\infty}^{+\infty} f(Hx_i).f(Hz-Hx_i)dHx_i \tag{6c}$$

which denotes the convolution $f(Hx_i)*f(Hx_j)$.

This allows an extension of the general case of the functional (Φ). In effect: let i and j be indexed on Card(X), k be indexed on a spatial distribution within any of Poincaré sections (S_α) of the ordered sequence $\{S\}_n$, and L be indexed on the sequence ($n \in L$). Then, the mappings of (Φ) are involved in the following two expressions :

$$\begin{cases} ((Hx_i) \perp^L (Hx_j))_{L+t} = T_L^{\perp} ((Hx_i) \circ^L (Hx_j))_L & (7a) \\ ((Hx_i) \perp^k (Hx_j))_{k+p} = T_k^{\perp} ((Hx_i) \circ^k (Hx_j))_k & (7b) \end{cases}$$

that is, by gathering (7a) and (7b) into one single form:

$$((Hx_i) \perp^{(L*k)} (Hx_j))_{(L+t)*(K+p)} = T_{L*k}^{\perp} ((Hx_i) \circ^{(L*k)} (Hx_j))_{(L*k)} \qquad (8)$$

which denotes a nonlinear generalized convolution in the sense of Bolivar-Toledo et al. (1985) [1]. (QED)

A simplified form of this general formalism will be tentatively proposed in Section 6.4. Now, some preliminary consideration should be added about the area of validity of these functionals, that is on the boundaries of the system.

Definitions 5.2.1. We will call "canonic functions" the conditions for the functionality of ecosystems which apply to all members as equivalence relations or in a commutative way (which includes the Abelian groups for all binary relations operating with relevant kinds of mappings). Examples are the founding conditions [5] of continuity, complementarity and mutualism.

We will call "specific functions" those which connect interspecific relations as order relations. An example is the relation "feeding on" in predator-to-prey relations.

Proposition 5.3.2. The domain of the convolution of hamiltonian functions [equation (8)] belongs to the set of canonical functions, and its range belongs to the complete system of canonical plus specific functions.

How specific functions are involved will be matter of further developments. All these results provide a perspective for further exploration of relationships connecting hamiltonian components of the hamiltonian of a system within a invariant globality.

6 Some Biological Implications

6.1 Contribution of the Intellectual Component

Call H_a the hamiltonian of the individual part of a living organism A, and H_E that of the Earth (E). Interactions (A,E) include the input of energy and matter from E to A, say x_e, and the output from A of non-used components (w) to E. The difference ($x_e \backslash w$) actually represents the part of H_E transfered to H_a. Hence, w stands for a xenobiotic component to A:

$$H_a \cap H_E = C_{xe}(w) \qquad (9)$$

Denote by $\mathcal{D}$ a device, an invention or a discovery whose knowledge is able to produce some available amount of energy: $E_{\mathcal{D}}$. Let A be a teacher and B his pupil. The transfer of $E_{\mathcal{D}}$ from A to B involves a weak amount of energy (E_δ), namely some biochemical energy for brain connections, speaking and/or writing on the blackboard, and writing on a paper. In contrast, the knowledge associated with $E_{\mathcal{D}}$ may allow B to save a comparatively much greater amount of energy $F(E_{\mathcal{D}})$. Suppose that in turn B brings back some help to A thanks to the same knowledge, with or without the incorporation of a weak supplement (E'_δ). Then, the hamiltonians of A and B become:

$(H_a)_1 = (H_a)_o \cup H(E_\delta \cup E_{\mathcal{D}})$ as from Definitions 5.1.1 (10a)

$(H_b)_1 = (H_b)_o \cup H(E'_\delta \cup E_\delta \cup E_{\mathcal{D}})$ (10b)

This can be illustrated by the following examples. A teacher explains to his pupil the principle of Archimedes' lever: Thereafter the student's potential capability of producing work is considerably increased, while the intersection of the teacher's and the pupil's hamiltonians is reduced to a weak amount of kinetic energy. Skilled worker honeybees teach young adults how to find the shorter way to a nectar source: this saves a long flight and a huge energy amount that would have been needed otherwise to the young, to search for the nectar without guiding information. Birds teach their progeny a correct song: this implies less energy than training them for flight, but without this singing capability, the progeny may not be able to mate and its potential component for further adaptation is reduced to about zero.

6.2 Role of the Extra-Cellular Matrix in Pluricellular Organisms

In a single cell molecules are moving, binding, and transforming into one another. The hamiltonian of an enzymic system is composed of the kinetic energy of the enzyme and of the substrate, and the potential energy of their interaction. The hamiltonian of the cell contains the hamiltonians of the components contained in this cell in addition to the global kinetic component of the cell, for instance when it is moving, like a blood cell.

Now, the cells composing tissues and organs are connected together and maintained in proper position thanks to the extracellular matrix (ECM) , a network of proteoglycan polymers and structural glycoproteins, which surrounds these organs and tissues [17]. However, the energy demand of the ECM must be lower than that of the functional cells, otherwise vital functions could not be fueled with the needed energy. This is the case for adhesion molecules at synaptic junction [25], with consequences at intellectual level, or for scavenging properties facilitating the removal of xenobiotic components [12].

The major components of the hamiltonian of complete systems (full organs gathered in apparatus) include the hamiltonians of contained subparts.

6.3 Ecosystem Hamiltonian and Ecological Constraints

Proposition 6.3.1. The trace of the macroscopic wave function of a ecosystem in the sequence $\{S_i\}$ of Poincaré sections stands for the historical of the ecosystem.

In effect, the state and fate of an ecosystem are determined by the nonlinear sequence of its former states, i.e. its "historic" [16]. This means that at this stage, causality factors are not confined in one initial state. Instead, they are determined by a complete dynamical trajectory which essentially represents the trace of the global wave function of the system in the embedding 4-space.

Proposition 6.3.2. Interspecific competition alters the potential component of the hamiltonian of a complex system.

Proof. Former works have demonstrated that the topological properties of ecosystems impose that their evolution towards optimum states is founded on continuity, complementarity of species with regard to utilization of habitat and resources, and on mutualism [5]. This predicts that ecological competition may result in a degradation of the hamiltonian of an ecosystem. Here, the potential component (WP1), involving the interactions resulting in hatching, food search, etc. may be adversely altered and in turn affect (WP2). This has just been experimentally verified in a mesocosm containing frogs in presence of toxicants and submitted to interspecific competition [7].

Proposition 6.3.3. Evolution must orient species to an increased level of adaptability to environmental changes, thus to sustained increase of diversity.

Proof. Consider the manifold of phyla ($Y= \{E, \perp_Y\}$) with (E) denoting all living species, and that of niches ($V=\{(B,R), \perp_V\}$, in which we include habitat (B) and resources (R). The optimalization of the global ecosystem functioning imposes that evolution should drive to a bijective state of a sequence of mappings $\{\Omega\}$:

$$\text{Convergence } \{\Omega\} = (\Omega_{\text{Optimum}}) \colon \max\{B,R\} \mapsto \max\{E\} \qquad (11)$$

In effect: (i) Biotopes and resources are subjected to geophysical variation which occur over both short and long periods (like a meteor impact, a fire, a tornado, versus a glaciation and other vast climatic changes). These changes are contra-adaptative with respect to living populations. Therefore, biology has to readapt. Since a rapid and sufficiently lasting change may kill a specie, an absolute condition is that that species develop a genetical preadaptation to future changes of their ecosystem's structures, so that some strains can survive dramatic events and start new phyla [5]. This imposes an anticipatory condition. Suppose that a phylum (Ea) evolves into a lesser adaptable strain (Ea‡). Then, following the next change in the ecosystem structure, there will exist biotopes (B*) to which species of (Ea‡) will not be adapted. This introduces a discontinuity, which has been shown to switch the ecosystem's evolution to a degenerative phase.

(ii) Biological evolution continuously produces new species, and since living species contribute to changing the ecosystems structures, then the adaptability of biological phyla should grow exponentially in such a way that the potential component of the hamiltonian of living species keeps bijectively mapped with the hamiltonian of the milieu which provides these hamiltonians with the resources needed to switch their potential part to the kinetic forms: in effects, only the kinetic component allows a specie to actually get the resources available in their niches and warrant the further evolutionary adaptation of the phylum.

Alternate injections and surjections should finally overlap to a final bijective state.

This proposition fulfils the same type of continuity as above and appears as a corollary of Theorem 4.1. Its implications support recent conjectures about the evolvability of evolution [13], [18] and observations about evolutionary factors enhancing genomic variation in E. Coli [24].

6.4 About Biological Engineering

Proposition 6.4.1. Ecosystem components must have hamiltonian properties that order themselves in the sense of the laws leading to optimization, namely continuity, complementarity and mutualism, otherwise they degenerate and may disappear. Thus the hamiltonian of an ecosystem components is at least partly determined by the rules governing the organization of the evolution of the whole. On the other hand, the embedding ecosystem provides each individual, clone and phylum with the resources needed for sustaining the metabolic turnover supporting their existence and evolution.

Proposition 6.4.2. Conservativity of the embedding system imposes that engineering for a change to the hamiltonian state of a initially balanced situation results in a counterpart at the expenses of some components of the system.

Proof. Let A be an organism, with $\{WKx, WPx\}$ the hamiltonian component concerning its mass production (cellular growth), and $\{WKy, WPy\}$ the component associated with its immune function (resistance to adverse factors and detoxification). Call $H_{x,y}$ the part of H_a corresponding with this set of functions. This quantity if fixed by the interactions with the ecosystem, within the limits of the hamiltonian of Earth (H_E), which is fueled essentially by a determined flow of radiation and gravity. In first analysis, one can write:

$H_{x,y} = (WKx \cup WPx) \cup (WKy \cup WPy)$ from Definitions 5.1.1, i.e. also:

$$H_{x,y} = (WKx \cup WKy) \cup (WPx \cup WPy) \qquad (12)$$

Each term is constant over a short time interval (dt) and function of H_E over a longer interval, that is: $H_{x,y}(t) = f(H_E(t))$. Let us examine these two possibilities.

(i) In the first case, one has $H_{x,y} \approx C$, a constant. Therefore, if specie A is engineered for increase of mass production by $\Delta(H_x)$, then its components will be rearranged by an equivalent quantity:

$$\begin{aligned} H^{e}_{x,y} &= (WK^{e}x \cup WP^{e}x) \cup (WK^{e}y \cup WP^{e}y) \approx H_{x,y} \\ &= (WKx \cup WPx \cup \Delta(H_x)) \cup (WK^{e}y \cup WP^{e}y) \qquad (13) \end{aligned}$$

that is, upon an energetic equivalence $\Delta(H_x) \equiv \Theta(H_y)$:

$(WK^{e}_{y} \cup WP^{e}y) = (WKy \cup (WPy \setminus \Theta(H_y))$, i.e. (sign \ denoting complementarity):

$$H^{e}_{y} = H_y \setminus \Theta(H_y) \qquad (14)$$

The symmetric process can be written for an engineering to resistance. In these two cases, one improvement for mass or resistance is got at the expense of resistance or mass. Let now the case of an engineering for both production and resistance, by factor $\Delta(H_{x,y})$. Then, similarly, the result will be obtained in counterpart of a change $\Delta(H_E)$ occuring in (H_E), that is at the expense of other components, that is either species, or habitat or resources.

(ii). Over (t), the part of resistance after engineering is: $H^{e}_{y}(t) = H_y(t) \setminus \Delta(H_x)$ following (14), that is: $H^{e}_{y}(t) = fH_{Ey} \setminus \Delta(H_x)$, where fH_{Ey} denotes the contribution in equivalent of resistance factors provided by the Earth, and $\Delta(H_x)$ still the gain in productivity.

The resistance factor (H_y) is a function of both production (through biochemical pathways) and resistance (through molecular specificities), and $\Delta(H_x)$ is gotten from the planetyary ecosystem to which the specie belongs. Let $\Delta(H'_x)$ be the portion drawn from the Earth's surrounding resources and $f(H_{Exy}(t))$ the contribution of the Earth. Then:

$$H_y = f(H_{Exy}(t)) \setminus \Delta(H'_x) \qquad (15)$$

so that the resistance component after engineering ($H^{e}_{y}(t)$ can be expressed as follows:

$$(H^{e}_{y}(t) = \left| \begin{array}{l} \text{assuming } H_y(t) \text{ is constant} \\ f(H_{Exy}(t)) \setminus \Theta(H_y) \quad \text{or:} \\ f(H_{Ex}(t)) \setminus \Delta(H'_x) \end{array} \right. \qquad (16)$$

where $\Theta(H_y)$ is the equivalent in resistance of $\Delta(H_x)$.

These relations suggest that either the resistance of the terrestrian ecosystem or the services it can provide would be proportionally reduced. Lastly, suppose that $H_{Exy}(t)$ can be made constant by some way: then, the corresponding component would be drawn from the radiation and gravity of the solar system, and so on up to higher scales.

This counterpart is usually ignored in the present form of externalized economy, but it emerges in terms of damage to the global life-support system, energy consumption, waste accumulation, disease progression, and increased pressure of alternative pests resulting in increased pressure of pollution, though in alternative forms.

7 Discussion and Conclusions

The above considerations first allow to come back to the still unsolved question of the identification of the nature and specificity of life. Obviously, the presence or absence of a brain is not a criterion, since unicellulars are living, nor is the faculty of reproduction since for instance a senior scientist is still living and able to enrich the potential part of the hamiltonian of human societies, though he is no longer reproducing himself in the genetic sense. Let us review the two cases.

In organisms with brain, the living system is able to construct mental images with anticipative properties. It can thus confront a new situation with its panoply of images, and finally take a decision. The latter therefore stands as an intermediate parameter playing an essential part between the intention (a member of potential component, sometimes founded on abstract mental images) and the action (a member of the kinetic component). Furthermore, decision is adaptative in a sense that cannot be predicted through any algorithmic logics. For instance, it can be neutral or even suicidal. The latter case sometimes corresponds to a fitting of brain receptors to a increasingly stressful situation, and therefore, this is also a particular - though fatal - case of an adaptation. In all of these situation, the mood of the concerned organism (determined by cortex to amygdala interactive analysis of perceptions) in connected to a form of adaptation: but its peculiarity is that the determinism eventually imposed by the emotional component escapes formal predictibility. Such elements as abstract mental imaging, emotional factor in decision taking meet with a definition of life proposed long ago by Pirie, namely that a living organism should be “sometimes doing something”. Incidentally, Since the emotional factor is constructed on perceptive mental images, it involves the potential component of the hamiltonian and thus also the evolutionary factor. Then it can be proposed that the Darwin hypothesis about the relation of emotional expression and evolution gets some logical support, without need for introducing factor chance as a motor of evolution. Interestingly, recent experimental data in cardiopulmonary physiology have been interpreted in a related sense [19].

In organisms without a brain, the psychological component is apparently absent from the potential member of the hamiltonian. This means that the ability of taking of a decision in conformity with, or against the sense of, adaptativity to the environment will be missing. However: (i) two other adaptative components are maintained. One is the genetical fitting, which still is able to prepare a reservoir of diversity in which adaptation to future situation will possibly subsist, though unconsciously to the concerned organism. The other is the molecular component which is potentially prepared to allow enzymes and receptors to regulate extreme situations by cooperative interactions, feedback processes, biphasic responses and other biochemically structural processes. (ii) sensory or sensory-like organs are present in lower organisms (e.g. ciliates). This suggests the possibility that they can produce feedback loops with some similarity of effect with those of mental imaging in higher animals [6].

Alternative structures in lower organisms might thus meet with the fixed point condition which is fulfilled in brain by convergence of sequences of neuronal configurations, and provide decision-based autonomy. Taken together, these elements provide some rationale for a further identification to the threshold between life and the so-called inert world. Preadaptation to unexpected situations is a common feature, while consciousness of this fitting is what differentiates higher forms of life from advanced computer devices. Thus the frontier remains rather fuzzy, especially if one considers that computers have been created by humans like a new phylum. This has been well emphasized by researches about a possible fusion of human and computer complementarities in an anticipatory searchlight approach [11]. Thus, identifying the possibility of an equivalent of consciousness of perceptions in living organisms without brain would be the next challenge before the question can reach an answer.

The objectives of the present work were limited to a preliminary exploration of the conditions for assessment of the hamiltonian of complete biological systems through conservativity features. Several points emerged from this study. (i) Life must be considered through its continuum, which connects individual organisms to their progeny and to their genitors, through various numbers of generations, and clones to their corresponding phyla. (ii) The bio-hamiltonian possesses anticipatory properties. (iii) Part of the bio-hamiltonian is drawn by operator functions which convert potential components into kinetic forms. (iv) The contribution of bio-hamiltonian features to the understanding of biological evolution clarifies the nature of its driving force, namely an adjustment to external conditions: sequence $\{g(ti)_{i\in I}\}$ is embedded in $\{Sj\}_{j\in J}$ such that $I\subset J$ and $i<j$. This imposes a correlative stability of the genome and of its expressed functional structures, which denotes a nonrandom evolutionary process, where the environment hamiltonian is embedding the specific hamiltonian component of the concerned living organism. (v) Intellectual components stand as integral parts of the bio-hamiltonian: the hamiltonian of Archimedes having the idea of the lever is equivalent with that of the system composed of Archimedes before the idea, plus the hamiltonians of the lever and of the point of appui. (vi) the concept of bio-hamiltonian may shed some light on the question of identification of the threshold, if any, between living and nonliving systems: higher forms of life could be characterized by a less deterministic way of decision making, based on the capacity of anticipatory abstract mental imaging by the brain or by systems playing a similar part in brainless organisms. In lower forms the capability of facing new situations is more tightly connected to the genomic variability as an anticipatory component. These features meet with the

characteristics of living systems pointed out by Schwarz (2001) [23], in terms of history and teleonomic organization.

Relation (8) opens the possibility of calculation of minima of action applying to a complex system. As it stands, this formalism emphasizes the absence of predominance of a component over any other, which raises an alternative way for the former demonstration of the conditions of continuity, complementarity and mutualism which characterize the evolution of an ecosystem towards optimum states [5]. All terms of the bio-hamiltonian are calculable, including the potential terms as net gain or loss of ecosystem's resources versus waste release and fate. Since the kinetic term is dependent on the potential term, a characteristic of a bio-lagrangian is that it could be essentially negative. An application of this point can be found in the problems raised by the externalization of industrial activities [8]: when industries do not take into account the consequences of their activities at all levels of interaction with the rest of the planetary ecosystems in the cost of their productions, then nearly insolvable problems appear after a period of apparent profits. Evolution is inseparable from the planetary ecosystem hamiltonian, so that expectations from artificial selection technologies are strictly bounded. Furthermore, commonly used concepts, like "undesirable species", or "species with priority in the use of the planetary resources" must be revisited.

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