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The Origin of Life: Preliminary Considerations on Necessary and (Possibly) Sufficient Conditions

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The principal thesis of this paper is that it is possible to construct a hierarchical system, via the prescription for hierarchical continuation, which exhibits the necessary conditions for the emergence of life. The sufficiency of these conditions is shown to be highly plausible on the basis of the deducibility of certain formal considerations in biological control theory from the formal decision process whereby a life-dynamics is generated.

1. Introduction

The problem of the nature of life is substantially the problem of its origin. Traditionally, the emphasis on an essentially systematic approach is dictated by the overwhelming complexity of living systems, as we know them today, as well as by the plausible assumption that life is one possible branch of material evolution and that, for reasons of "continuity" in such evolution, the early forms of life were divested of those functional and structural complications which are, in it way very often undecidable, not intrinsically fundamental to life itself.

This point of' view is to be compared (perhaps contrastually) to what we might call the definitional-deductive approach. The latter usually suffers from the difficulty of extracting a set of fundamental features from a body of data which is redundant, possibly only in an essentially unknown way. This same criticism applies equally to the many unsubstantiated claims of reductionist theories (as well as to their non-reductionist counterparts). The mere fact that two distinct hierarchial systems, which exhibit a common origin (level), happen to share some aspects of, say, their dynamics at some level, does not necessarily mean that one is explainable in terms of the other, but simply that there do exist specific relations between them (Rashevsky, 1969; Bianchi & Hamann, 1969a).

Our objective here is to begin an investigation of the formal and experiential symbolic structure of the two postulated branches of the hierarchical evolution of matter. The details of a model for such an organization will be presented in a subsequent paper.+ Here we will show how the historical and definitional-deductive approaches can be naturally fitted together in a hierarchical theory within which the occurrence of a branching point can be exhibited deductively once the presence of certain necessary and (possibly) sufficient conditions which we explicate herein is experientially realized. Thus life emerges in-.and-as-imaged-by a hierarchically structured and continuable system which is essentially closed in the sense that it contains physical persistent representations of certain decision processes together with certain constraining relations as required therein.

2. Relationalism: A Relevant Summary

In any discourse on life and its origins it is possible only presumptively to separate out the philosophical foundations on which the living inquirer establishes the discourse itself. Hence we will begin with a brief statement of such existential and formal presumptions as they appear in Relationalism.++ Relational philosophy is presumptively founded upon the experiential notion of Relational System, which man is and within which he is Subsumed, which he Images in another form of the same, and which he acts upon by a Decision process which is itself relational. Subsumed by these presupposed notions are the concepts of "formal system" and "formal decision system", symbolized as

$$S \overset{R}{\leftrightarrow} S' \text{ (or SRS') and } S \underset{D}{\overset{R}{\leftrightarrow}} S',$$

respectively. Within a presupposed decision system, all theories are defined and formed as specific subsumptive [hierarchical (Bianchi & Hamann, 1969a,b)] decision structures, e.g. of the form

$$\left(\ldots\left(S \underset{D}{\overset{R}{\leftrightarrow}} S'\right) \underset{D'}{\overset{R'}{\leftrightarrow}} S'' \left(\underset{D''}{\overset{R''}{\leftrightarrow}} S'''\right)\ldots\right)$$

Also subsumed by these presumptions are the notions of "order" and, in inseparable relation, "disorder". It is principally in terms of order-disorder relations that experience is in fact imaged by man in formal systems.

If by a prior decision we are given the system variables and relations thereon, but with no given (initial) values, the minimal structure of a "(specifically spatial-temporal) 'real' subsumptive decision system" includes the following five classes of relations in each level in the hierarchy:

(1) Order relations
- (a) Deterministic kinematics
- (b) Deterministic dynamics

(2) Initial order decision relations

(3) Disorder relations
- (a) Probabilistic kinematics
  - (i) Subsystemic probabilities
  - (ii) Systemic probabilities
- (b) Probabilistic dynamics
  - (i) Subsystemic probabilities
  - (ii) Systemic probabilities

(4) Initial disorder (probabilistic) decision relations: Choose those subsystemic probabilities which maximize tile systemic probability subject to all given relational constraints.

(5) Action (relation-to-the-"real").

\+ J. R. Hamann "The Origin of Life: A Hierarchical Model", being a Section in the following.

++ J. R. Hamann, *Relational Systems: Introduction.* Monograph, under revision for publication via the Internet.

3. Preliminary Sketch of Necessary and (Possibly) Sufficient Conditions for the Evolutionary Origin of Life

In the process of' material evolution, the following systemic relations must emerge in specific form for matter to manifest itself as living. It should be observed that these conditions represent direct specializations of the previously specified philosophical presumptions, a characteristic feature of Relationalism. This underscores the rather obvious fact that the fundamental experiential and theoretical questions concerning life are inextricably interwoven with the foundations of philosophy at the level of the living inquirer.

(A) IMAGE CARRIER

Of central importance to the emergence of life is the evolution of a system whose relation to other systems is that of a carrier of an image of the interaction between the carrier and the other systems. This is also recognizable as the concept of *record* (Pattee, 1970a, b).Via the interaction of a system with the carrier the image can be "read out" to alter the relational structure of the system. A feature of the image of essential import is its persistence, relative to that of the actions which gave rise to it and to that of the interactions the carrier will undergo with other systems. Moreover, it has to be noted that the carrier may hold more than one image, thus leading to various possible relational impressions on an interacting system.

(B) FORMAL DECISION SYSTEM

In order for a system to effectively use the image carrier, it is necessary that there evolve a decision system ("pair-relational" or "decisional" dynamics). In the formal representation of such, all decision rules must be expressible without arbitrariness (i.e. without recourse to a metalanguage) in the system. This decision process is also termed selection, classification, recognition, choice, etc., in other work.

(C) HEIRARCHY

Finally, representing the evolution of matter hierarchically, specialized hierarchical relations of' the image carrier and decision system must emerge to effect the branching into the non-living and living hierarchies. These are the following:

Bidirectional hierarchy

Definition: A hierarchy (which, by definition, is *directional* from the lowest level throughout the sequence) is said to be *bidirectional* if the relations at one level alter those at a preceding level.

Definition: If the bidirectional hierarchical relations refer to a temporal system, the latter is said to exhibit *hierarchical control* (Pattee, 1970a,b) or to be a hierarchical control system.

Hierarchical continuability

The last relation essential to the representation of the evolutionary branching of matter is that of *hierarchical* continuability. The meaning of this concept will be made clear in the following section.

4. A Formal Realization of Hierarchical Continuability

In a hierarchical theory, given any level consisting of deterministic and probabilistic sub-levels (including, of course, the respective symbolic-to-real relations), a formal realization of hierarchical continuability is achievable in the following way. The next-level systemic components are determined in terms of dynamically (deterministically or probabilistically) stable aggregates of the components in the given level. Construct the corresponding next-level system variables as functions (e.g. expected value functions) on the system variables in the given level. The associated next-level kinematics are either determined by the same in the given level (reductionistic theory), or by experiential extension (emergent theory). Basic to the completion of the next-level remains the adjunction of the dynamics. It is our contention here, that, given an existent image carrier, our formal representation of the (necessary) intra-level decision system can also be taken as a formal realization of the hierarchical continuability process. Hence, we apply the maximum systemic probability decision relation (see footnote, section 2; Kikuchi, 1960, 1966; Hamann, 1968; Hamann & Bianchi, 1969) of the given levels, together with experientially relevant additional relations, as a variational procedure for generating the next-level deterministic dynamics.

5. Non-living and Living Hierarchies Compared

On the basis of the procedure for hierarchy continuation we here sketch roughly a possible representation of the evolutionary branching of matter into living and non-living hierarchies. For the latter, we choose the well known sequence: classical (Newtonian or Hamiltonian) mechanics (CM)→classical statistical mechanics (SM) and classical thermomechanics (TM) (thermostatics and thermodynamics). Here CM and SM will be regarded as sublevels of the subsystemic level, classical particle mechanics. TM will be considered as the next-level. What we intend to do is to sketch a second hierarchy which begins with the same particle mechanics at the subsystemic level but which proceeds to a next-level which is principally an *ordered extension* of the preceding order-disorder levels. A detailed model of this hierarchy will be presented in a subsequent paper (see footnote, section 1).

(A) CM-SM-TM HIERARCHY

The details of the structure of this hierarchy have been summarized in previous work (Bianchi & Hamann, 1969a) and will not be repeated here.

(B) CM-SM-LM HIERARCHY

Starting with the same subsystemic level (CM-SM) we now want to construct a next level representing the tentative completion of an evolutionary chain exhibiting the properties outlined above as being necessary and (possibly) sufficient for the origin of the minimal living system. LM represents this "life mechanics", to be described prescriptively as follows:

Image carriers

We consider tile system as divisible into (at least) two classes of components (at least) one of which contains subsystems with the properties of image carriers. An image, e.g., might be considered as carried via *average properties* (expectation values) on the carrier systems.

Formal decision system

As opposed to the process of employing the *maximum systemic probability principle* only as a method of generating prior subsystemic probabilities, given certain expectation value constraints (see footnote, section 2; also Jaynes, 1957a,b) we here recognize it as a *natural decision (variational) process for constructing a systemic dynamics* (see footnote, section 2; Kikuchi, 1960, 1966; Hamann, 1968; Hamann & Bianchi, 1969), specifically a life-dynamics (LD). The difference between this hierarchy and that including TM, which can be similarly constructed and hence exhibits a similar evolutionary chain, resides in the role of the expectation value constraints. In the LD they are formally considered to enter physically via *internal* image carriers.

Hierarchy

Hierarchical control has appeared as a "natural" property of our system, as follows. The average properties of the carriers, through a next-level dynamics generated by the above-described variational process, *constrain the subsystemic probabilistic dynamics* (of the given level).

Hierarchical continuability also appears "naturally" as indicated above, and, in fact, represents a feature essential to the divergence in the chain of material evolution. The living branch exhibits an increased tendency-to-order (order-disorder→order) relative to the non-living branch. This process emerges in our model due to the persisting images which, when continued hierarchically, as a relation on the decisional dynamics, generate a next order level. This is in contradistinction to the non-living branch (CM-SM-TM) in which there is no hierarchical continuation of relation, explicitly because of an absence of the effect of persisting images in a decisional dynamics; hence, there is no evolution of order.

6. Discussion and Conclusions

It is the principal point of this paper that it is possible to construct a hierarchical system, via the prescription for hierarchy continuation, which exhibits the necessary conditions for the evolutionary origin of life. Moreover, the experientially "observed" branching into living and non-living chains appears as a deductive consequence within our theory when these conditions obtain. This possibility depends upon the existence of a formal decision system in which the decision rules are formally representable *in* the system and which depends upon a physical (subsystemic) carrier of constraining (expected value) relations (information) required in the decision process. If either (or both) of these last two conditions does not obtain the system is not hierarchically continuable and life cannot emerge. It was also noted that the specific difference between TM and LM is that in the former the decision process is completed only via extrasystemic (external) relations.

The preceding claim was concerned only with the specific conditions as being necessary for the origin of life. In order to demonstrate their sufficiency, it must be shown: (1) that there exists a physical image carrier, e.g. of expected value constraints, in each level in the hierarchy preceding the last; (2) that the classes of life processes (metabolism and reproduction) are deductive consequences of the LM. With respect to the second of these sufficiency requirements, there now exists adequate work to make plausible this condition. In a subsequent paper (see footnote, section 1) on a specific model we will examine this point in more detail. Let it suffice here to point out that the formal considerations underlying biological control theory (Milsum, 1966; Wilson, 1964) and biological design (Wilson, 1966) are deducible as consequences of the above-mentioned formal decision process whereby a life-dynamics is generated.

Concerning the first sufficiency requirement, its proof, in part, will eventually rest upon the development of a relevant formalism for stochastic stability theory. Without such it is analytically unreal at present to prove the sufficiency of the conditions, even though certain computer generated stability "theorems" may increase their plausibility (Higgins, 1967, Kauffman, 1969). Efforts related to the development of stochastic stability theory are less than a decade old (Kushner, 1967; Shear, 1967, 1968) and to our knowledge, have not yet been directly applied to the problem of evolutionary hierarchies. This formulation of a basic problem in the development of a theory of the origin of life characterizes formally the problem of deducing stable expected stochastic subsystems in any order-disorder level.

Finally, we call attention to the fact that any theory presupposes a prior decision system. Our present problem, in part, is to formally represent the natural emergence of such within the hierarchy. This is achieved via the dual relational form of the maximum systemic probability principle, in one instance as a purely formal decision system and in the second as a formal image of a physical decision process.

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