THE SYNTHESIS OF PRIMITIVE 'LIVING' FORMS: DEFINITIONS, GOALS, STRATEGIES AND EVOLUTION SYNTHESIZERS

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Abstract. The arbitrariness of the definition of life is discussed in relation to both the archaic biological entities that preceded cells during the Molecular Evolution era, and the hypothetical, primitive, 'living' entities that presumably can be synthesized in the laboratory. Several experimental approaches to the synthesis, detection, and characterization of 'living' entities are discussed. The experimental approaches considered for the synthesis are the constructionist strategy, the whole-environment strategy, and the modular strategy, which is a combination of the first two. The whole-environment strategy is discussed in more detail and the establishment of an Evolution Synthesizer, based on this strategy, is proposed and rationalized. The guidelines for the detection and characterization of populations and processes of 'living' entities include chemical and physical analyses, but are based mainly on the reproductive characterization of these entities. It is expected that the higher the evolutionary level of the 'living' entities, the longer and more difficult it will be to synthesize them, but the easier it will be to detect them.

1. Introduction

A definition of 'life' reflects not only one's perspective into the subject matter, but also certain implications inherent in this definition. The heart of the present discussion is the synthesis of primitive forms of life, and this implies immediately a practical experimental strategy. Therefore, the definition should preferably be a physical one, given in terms of measurable properties. A succinct physical definition that is general enough to serve here as a starting point, was recently rephrased by Kuppers (1983) in terms of the properties necessary for a system to be considered alive, namely:

(a) metabolism;
(b) self-reproduction;
(c) mutability.

In spite of being somewhat arbitrary, like every other definition of life (see Rholfing, 1984), this one may serve as a common denominator for 'all living things' (Kuppers, 1983). At the same time, it may be used as a point of departure for the discussion of the transition zone between non-living and living entities, as is shown below.

The present work is based on the assumption that even the oldest known living cells (see Schopf, 1983) were very advanced and complex compared with earlier and more primitive forms that can still be considered as living entities. Moreover, it is assumed that the fundamental attributes of life may be discerned already in those forms, which were presumably rather well organized biopolymeric assemblies, long before living cells as we know them came into being.

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The goals of the present work are:
(a) To re-examine the fundamental characteristics of the presumed assemblies of biopolymers that preceded living cells.
(b) To discuss experimental strategies for a future attempt to synthesize primitive entities that may be considered 'alive'.
(c) To discuss the experimental approaches for the detection of these 'living' entities.

2. Discussion

2.1. RELEVANCE AND IMPLICATIONS OF THE PHYSICAL DEFINITION OF LIFE TO THE MOLECULAR EVOLUTION ERA

The first question that should be asked has to do with the very definition of life, namely: Is the above definition applicable to those presumed primitive systems that constitute a transition between non-living and living entities? And, if indeed this definition is adopted, because of considerations of generality and/or convenience, what are the implications that refer specifically to those primitive systems, and to our ability to synthesize living entities and detect them? Let us first examine the above three properties of contemporary living cells and discuss their applicability to the Molecular Evolution era.

2.1.1. Metabolism

Metabolism is an attribute of an open system where exchange of matter and energy between living entities and their environment takes place. Since the above definition refers to all known living forms, space limitation (see also Baltcheffsky and Jurka, 1984), or a boundary between the living form and its environment, is implied. In living cells, this means a cell membrane. It is implied also for primitive assemblies of biopolymers, which may have undergone various reactions in the total or partial absence of compartmentalization mechanisms.

Among the different schools of thought in origin of life studies, the feature of compartmentalization by means of a kind of a membrane at an early stage of the evolution is a common denominator for various models. Examples are Oparin’s coacervates (Oparin, 1957), Fox’s protocells (Fox and Dose, 1977), marigranules (Yanagawa and Egani, 1978), and surfactant aggregates (Fendler et al., 1975). An inorganic zoning method by means of mineral particles, i.e. clays, has been suggested by Cairns-Smith (1966), and later by White (1980) and Kuhn and Wazer (1981) to name only a few. Still another method of compartmentalization was suggested by Woese (1980), where the boundary of the evolving domain is the surface of an aqueous droplet hovering in the primordial Earth’s atmosphere.

In addition to serving as a means to prevent assemblies of biomolecules from dissipating into their environment, compartmentalization mechanisms may be considered as physico-chemical regulators carrying out and adjusting exchange of materials and energy between these assemblies and their environment. Thus, their