Orig Life Evol Biosph (2012) 42:379–383
DOI 10.1007/s11084-012-9298-x

CONFERENCE REPORT

# Open Questions on the Origin of Life (OQOL)

**Derek Raine · Pier Luigi Luisi**

Received: 12 September 2012 / Accepted: 18 September 2012 /
Published online: 12 October 2012


The papers in this collection record the talks given at the conference on "Open Questions on the Origin of Life" held in Leicester in May 2012. This was the third such meeting in a series inspired by Professor Luisi with the agenda to discuss open problems and new approaches. The format of the papers presented here broadly keeps to that of the conference, with the extended abstracts of the talks followed by comments from other delegates, which capture just some of the lively discussions.

Prior to the meeting the community is asked to submit questions for each of the conference sessions which are then chosen by ballot. In fact, the main characteristic of this kind of meeting is to collect those questions in the field of the origin of life which are not yet answered. Thus, while most of the conventional science meetings emphasize the new achievements, and ignore the points of ignorance, our meeting dwells precisely on the" dark side", more in particular on the reasons why certain questions remain unsolved, and occasionally even ignored in the scientific discussion—and we try to understand why this is so, possibly looking for ways to come out of the impasse.

This is not the place to summarise the individual questions or contributions but some of what seemed to us to be key themes did emerge. The largest group of contributions were identified by their authors as concerning the transition from chemistry to biology, perhaps because this can be interpreted as simply another way of posing the origin-of-life question in general terms, which is not quite the intention of these meetings. But one specific issue is whether we need new conceptual

Reports of the Third International Conference held in Leicester, May 2012.

D. Raine (✉)
Department of Physics and astronomy, Centre for Interdisciplinary Science, University of Leicester,
Leicester LE1 7RH, UK
e-mail: jdr@le.ac.uk

P. L. Luisi
Dipartimento di Biologia, Università degli Studi di Roma Tre, Viale Marconi 446, 00146 Roma, Italy
e-mail: luisi@mat.ethz.ch

frameworks to address this, or if the established frameworks of chemical kinetics and Darwinian evolution can be made to join up. Darwinian evolution is not confined to a biological substratum, but works as a general framework (for example in the use of genetic algorithms in engineering). Clearly, however, Darwinian evolution does not take us from molecules to organisms in a single step, but through a hierarchy of emergence. The origin-of-life problem asks for the articulation of the series of phase changes in between. Which one of these changes is THE origin of life seems to us to be of less interest. The real problem is the difficulty of constructing the missing phases, and, in particular, what evidence would demonstrate that we had succeeded. Presumably the only way to find out is to start at both ends: from molecular chemistry (both theoretical – witness the discussion on multi-copies - and experimental) and genetic analysis (for example, the evidence that metal complexes give clues to the location of the first life), pushing both as far as possible in the hope that they meet.

While the RNA world adherents were represented, alternative or complementary approaches were more in evidence, particularly in relation to vesicle formation (prebiotic chemistry) and evolution, particularly encapsulation. Perhaps here too we have to push each approach as far as possible in the hope that they too will meet at a future conference.

In the view of one of our delegates (RW) one of the main problems that the recent meeting highlighted is the general lack of a standard, technical vocabulary which could be used by origin-of-life researchers. For example, some of us used terms like self-assembly and self-organization as synonymous, while others used these same terms to describe quite different processes. Many researchers use terms such as self-replication and self-reproduction interchangeably, whereas some of us look for fine differences between them, applying the first term to sequences of genetic information and the second to larger physical assemblies like cells or vesicles. In this recent meeting, in one of the first talks, the term "self-maintenance" was used synonymously with "self-production" and in one of the last talks the same terms where used to differentiate between life (possessing both of those qualities) and other dissipative structures (possessing only the first one).

Clearly, if we use the same words but mean different things we cannot know whether our disagreements are real or just misunderstandings. Many other terms came up during our discussions: steady state, kinetic trap, energy flow, Darwinian evolution. All of these have precise meanings in other fields, but sometimes they possess different meanings in different fields. When we import them to our field we should be sure that we mean the same thing: our discussions seemed to show that often we do not. Also when we abandon terms for others coined by ourselves we should be able to explain such a choice rationally, which again requires that we start from a common understanding of those terms.

Several young scientists present at the meeting experienced for the first time this climate of discussion and the recognition that we do not have all answers yet: and they responded with enthusiasm. Another unique characteristic of the meeting is the attempt to integrate contributions on the philosophy of science, an important consideration if we wish to understand the basis of our research. We would like to conclude by saying that this kind of meeting, where the formal sessions are largely given over to debate about those things which are not understood and, more particularly why, represents a very honest contribution to the field, and this is an initiative that should be continued…

**Acknowledgements** The Conference organisers acknowledge financial support from the Centre for Interdisciplinary Science at the University of Leicester.

## THE QUESTIONS

### Universality

What properties of life are universal?

**The Premise:**

At one extreme, there are researchers who contemplate life not based on carbon (e.g. silicon) who consider solvents for life alternative to water (e.g. formamide) and entertain a possibility of life without boundary structures (e.g. a 'living ocean' on Europa). At the other extreme, a number of scientists claim that the severe constrains on life imposed by physics and chemistry enforce DNA as the necessary genetic polymer and the universality of energy transduction systems and core metabolism. The purpose of considering this question is to flesh out the scientific arguments for and against the universality of different properties of life, and perhaps to reach a consensus on the likely commonality between all forms of life. This question is highly topical in view of the rapidly increasing number of recent discoveries of extra-solar planets and the quest for finding habitable ones among them.

### Emergence

How does biology emerge from chemistry?

**The Premise:**

The transformation of inanimate matter to complex life is traditionally divided into two stages. The first, abiogenesis, involves the conversion of non-living material to simplest life, and the second, the biological phase, is the stage on which Darwinian evolution began to operate. A key issue with regard the problem of the origin of life is to shed light on the physicochemical relationship between these two stages. Processes are normally characterized by driving forces and mechanisms so the question of the origin of life will be greatly clarified if both abiogenesis and biological evolution can be characterized in this way.

### Evolution

Is prebiotic evolution Darwinian?

**The Premise:**

There is no doubt that present-day life is highly open-ended. For example, a small bacterium with genome size of about 500,000 bases has essentially infinite number of possible states. This allowed for life to evolve finding solutions to a variety of problems, giving rise to the high diversity of present-day life, e.g. the number of viable strains, subspecies and individual variants of the aforementioned bacterium. In contrast, closed systems, exhibiting only relatively few possible states, have a much more limited capacity to undergo evolution. What is the relationship between the openness of a system and its evolvability? Is there an optimal 'openness' in this respect, and how could one effectively utilize this insight in computational and experimental models?

### Chemistry

Do we understand enough about prebiotic chemistry to formulate meaningful hypotheses about the origin of life?

**The Premise:**

Since Miller's 1953 demonstration of the synthesis of amino acids from reduced gases using an electric discharge, there has been a continual focus in origins of life research to find novel 'prebiotic' ways of making the molecules of modern biochemistry, including lipids, amino acids, nucleotides and their polymers. Despite almost 60 years of research, many obstacles remain. One possible reason is that the first replicating systems did not use similar compounds in their biochemistry. Indeed, amino acids are actually a rather small percentage of the total number of compounds formed in an electric discharge; more than 95 per cent of the products of such experiments remain unidentified. In carbonaceous chondrites, which are often presented as evidence that the 'molecules of life' are ubiquitous in the cosmos, compounds found in modern biochemistry again make up a vanishingly small fraction (<<1%) of the total small molecule organic inventory. Given that we know so little about the available compound types, is a direct reconstruction of a modern cell from such components the best way, or even a reasonable way to approach the problem of the origin of life? If not, what would we like or need to know to be able to approach this problem more productively?

**Where did life begin?**

**The Premise:**

Evolution described by the Darwinian theory may be depicted as a phylogenetic tree and a postulated root representing the last common ancestor and its precursors. It is sometimes believed that solving the question of the Origins of Life will need to bring information about the lapse of time separating the Origin from the last common ancestor in the postulated root. Scenarios have been proposed based on possible environments assumed on the early Earth (Ocean, vents…). Alternatively, physicochemical principles can be used to reach conclusion about how self-organisation proceeds and chemistry can be helpful in bringing to light the related processes.

**LIST OF PAPERS**

**Universality: What properties of life are universal?**

Michele Lucantoni & Pier Luigi Luisi, *On the universality of the living: A few epistemological notes*

Leonardo Bich & Luisa Damiano, *Life Autonomy and Cognition: An Organizational Approach to the Definition of the Universal Properties of Life*

A. Pohorille & L. R. Pratt, *Is Water the Universal Solvent for Life*?

**Evidence: What would convince us that we have answered the question "How did life begin?"**

Salvatore Chessari & Per Luigi Luisi, *On Evidence: The lack of evidence for prebiotic macromolecular synthesis*

Tereza Pereira de Souza, Pasquale Stano, Frank Steiniger, Erica D'Aguanno, Emiliano Altamura, Alfred Fahr, Pier Luigi Luisi, *Encapsulation of ferritin, ribosomes, and ribo-peptidic complexes inside liposomes: insights into the origin of metabolism*

**Emergence: How does biology emerge from chemistry?**

Andrew Pohorille, *Processes that Drove the Transition from Chemistry to Biology: Concepts and Evidence*

Addy Pross, *How does biology emerge from chemistry*?

Rafal Wieczorek, *On Prebiotic Ecology, Supramolecular Selection and Autopoiesis*

Paul G Higgs & Meng Wu, *The Importance of Stochastic Transitions for the Origin of Life*

Daria V. Dibrova, Michail Y. Chudetsky, Michael Y. Galperin, Eugene V. Koonin, Armen Y. Mulkidjanian, *The role of energy in the emergence of biology from chemistry*

**Evolution: Is prebiotic evolution Darwinian?**

Omer Markovitch, Daniel Sorek, Leong Ting Lui, Doron Lancet & Natalio Krasnogor, *Is there an optimal level of open-endedness in prebiotic evolution*?

Leonardo Bich & Luisa Damiano, *On the emergence of biology from chemistry: a discontinuist perspective from the point of view of stability and regulation*

Saša Svetina, *Cellular life could have emerged from properties of vesicles*

Vic Norris, Corinne Loutelier-Bourhis & Alain Thierry, *How did metabolism and genetic replication get married*?

**Chemistry: Do we understand enough about prebiotic chemistry to formulate meaningful hypotheses about the origin of life?**

Yoichi Nakatani, Nigel Ribeiro, Stéphane Streiff, Laurent Désaubry & Guy Ourisson, *Search for the most primitive membranes: some remaining problems*

Z. P. Zagórski & E.M. Kornacka, *Ionizing radiation: Friend or foe of the origins of life*?

**Where did life begin?**

Armen Y. Mulkidjanian, Andrew Yu. Bychkov, Daria V. Dibrova, Michael Y. Galperin & Eugene V. Koonin, *Open questions on the origin of life at anoxic geothermal fields*