The Creation of the World – According to Science

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How was the world created? People have asked this ever since they could ask anything, and answers have come from all sides: from religion, tradition, philosophy, mysticism….and science. While this does not seem like a problem amenable to scientific measurement, it has led scientists to come up with fascinating ideas and observations: the Big Bang, the concept of inflation, the fact that most of the world is made up of dark matter and dark energy which we cannot perceive, and more.

Of course scientists cannot claim to know the definitive truth. But we can approach the question from a scientific viewpoint and see what we find out. How do we do that? First, we look to the data. Thanks to modern technology, we have much more information than did people of previous ages who asked the same question. Then we can use scientific methods and techniques to analyze the data, organize them in a coherent way and try and extract an answer. This process and its main findings will be described in the lecture.

The Ghosts in the (Primitive) Soup: A Review of Some of the Debates that Shaped Early Discussions on the Origin and Nature of Life

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The heterotrophic origin of life proposed by Oparin and Haldane in the 1920's was part of a Darwinian framework that assumed that living organisms were the historical outcome of a gradual transformation of lifeless matter. This idea was strongly opposed by the geneticist H. J. Muller, who argued that single genes or DNA molecules represented primordial living systems. Their debates represent not only contrasting views of the nature of life itself, but also major ideological discussions that reached a surprising intensity in the years following the 1953 Miller experiment, which demonstrated the ease with which organic compounds could be synthesized under putative primitive conditions. During the years following the Miller experiment, attempts to understand the origin of life were shaped scientifically by the development of molecular biology and, in socio-political terms, by the atmosphere created by Cold War tensions.

Metabolist Versus Geneticist Views: Consequences for the Interpretation of the Tree of Life

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Traditionally, there have been two opposite currents with regard to the definition of life and the hypotheses advanced to explain the origin of life. One is metabolism-centered and favors self-sustained auto-organizational, energy-based processes emerging first, while the other is gene-centered and favors the development of genetic, information-based systems first. I contend that, though disguised, these opposite views (metabolism versus genetics or energy/function versus information) are pervasive in biology and affect the ways biologists view evolution and interpret the tree of life. Two active and controversial debates in modern biology illustrate this. The first affects the concept of the tree of life at different degrees (does it exist or not?, is it a tree of genes or of organisms?, is it a tree or network?) and the nature of the last common ancestor (community of genes versus organism). This is a complex issue that affects also the levels at which selection is supposed to occur (gene versus organism-level). Geneticist views tend to favor network-like trees of genes and, the most extreme, even deny the true existence of a tree of life, the level of selection being fundamentally the gene. They consider that the last common ancestor corresponded to a community of genes scattered in a population of cells freely exchanging genetic material. More metabolist views consider the organism as the basic unit of selection and accept the existence of a true tree of life representing organismal evolution that may be reconstructed based on (selected) gene phylogeny. For them, the last common ancestor was a single organism living in a community of organisms. The second debate affected by this dichotomic perception relates to the place of viruses in biology, whether they are alive or not and whether they can be incorporated to the tree of life as a fourth domain. Whereas the epistemological discussion about whether they are alive or not and whether some virus-like forms replicators precede the first cells is a matter of debate that can be understood within the metabolism-versus-genes dialectic, the claim that viruses form a fourth domain in the tree of life can be solidly refuted by proper molecular phylogenetic analyses and needs to be removed from this debate.

Extending Darwinian Theory to the Origin of Life

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Abstract: Though Darwinian theory dramatically revolutionized biological understanding, its strictly biological focus has resulted in a widening conceptual gulf between the biological and physical sciences.[1] In this talk we will describe our attempt to reformulate Darwinian theory in physicochemical terms so it can accommodate both animate and inanimate systems, thereby helping to bridge this scientific divide. The extended formulation is based on the recently proposed concept of *dynamic kinetic stability* and data from the newly emerging area of systems chemistry. The analysis leads us to conclude that *abiogenesis* and *evolution*, rather than manifesting *two* discrete stages in the emergence of complex life, actually constitute *one* single physicochemical process. Implications of the general theory to the origin of life problem, to understanding the global characteristics of living systems, and possible links relating Darwinian theory and the Second Law of Thermodynamics will be discussed.[2,3]

1. C.R. Woese, *Microbiol. Mol. Biol. Rev.* **2004**, *68*, 173-186.

2. A. Pross, *Chem. Eur. J.* **2009**, *15*, 8374-8383.
3. N. Wagner and A. Pross, *Entropy* **2011**, *13*, 518-527.

The Ancient Collaboration Between the Mitochondria and the Nucleus: The Basis for Eukaryotic Life and Speciation?

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Genetic variation in many life forms exhibit signatures of both random and non-random evolutionary processes. It is the interplay between genes and environment that underlies the differential response of organisms to continuously changing environments, disease susceptibility differences among people and even the emergence of new species. This environment-gene cross talk is further complicated by the functional and genetic interactions between genes from different genomes, and the DNA sequence changes at different paces in evolutionary time scales. Although varied levels of gene-gene-environment interplay underlie the operation of many cellular activities, there is a unique organelle, harboured within all animal cells, that compete all others both at the level of genetic variability between individuals, within individual cells, as well as in the number of genetic interactions required for its operation. Such is the mitochondria.

Mitochondrial bioenergetics plays a key role in multiple basic cellular processes, such as energy production, nucleotide biosynthesis, and iron metabolism. It is an essential system for animals' life and death (apoptosis) and it is required for embryo development. This, in conjunction with its being subjected to adaptive processes in multiple species and its gene products being involved in the formation of reproductive barriers in animals, raises the possibility that mitochondrial bioenergetics could be a candidate genetic mechanism of speciation. We discuss the possible involvement of this unique system, encoded by two genomes (the mitochondrial and nuclear genomes), that differ by an order of magnitude in their mutation rates in processes leading to speciation events.

Lessons from the Archaeology of Human Evolution

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Drawing lessons from the archaeological remains of human evolution is considered by many as a needed endeavor for understanding the behavioral foundation of us modern humans. This ambitious undertaking is conducted from various viewpoints. Scholars search the past in order to trace the origins of languages, the evolution of cognition, the material cultural remains, and mundane subjects such as the social and economic steps that brought us to share today's globalized civilization. Not less important are the investigations of the evolution of the human body, and the head in particular. Examining the different approaches to the documented past may lead us to recognize the limitations of the records, the fictional narratives, and the contradicting interpretations. We therefore need to ask ourselves at least two questions - "do we really need to know what happened during 2.6 million years of human evolution?" and "why foragers became farmers some 12,000 years ago and changed for ever the face of the planet?"

Looking back through the prehistoric concrete evidence from *Homo habilis* to *Homo sapiens sapiens*, we have to admit that the descriptions and/or analyses of those rapidly accumulating data sets posit major challenges even for the fully versed researcher. Hence, the minimalist, straightforward approach is to rely on the study of the best-preserved documents, namely, the stone tools. However, discoveries of objects shaped from other raw materials in different locations during different times, provide additional insights. A few examples are in place. The wooden spears from Schöningen dated to ca. 400,000 years ago, the bone tools older than 50,000 years in Africa or the antlers and ivory objects from Eurasia that are younger than this date, are intriguing finds to interpret beyond their mere description. Their interpretations as technological markers during the course of social evolution could be simple but it is not the only one. Let us take for example the abundance of beads and pendants in Western Europe during what we call the Upper Paleolithic period (ca. 40-11,000 years ago), or the large number of caves in the Franco-Cantabrian region that served as arenas for painting and sculpting of animal figures. Why are these phenomena essentially regional and not common in other regions where similar raw materials and caves were available for the prehistoric artisans?

We may end this brief survey with what is often regarded as the ‘simultaneous appearance of agricultural systems’ that established the foundations for our current social and political structures, agro-pastoral economies, and different religions. Did the innovative shift in subsistence systems by particular groups of hunter-gatherers some 12/11,500 years ago, known as the Neolithic revolution, occurred simultaneously? Only from an overall encompassing view of the entire human evolution as a continuous story of success, writers may see it as a global ‘event’ while disregarding the actual dates when farming systems were established in various regions. Thus, sweeping generalizations mask the particular history of regional populations.

Currently archaeologists try to uncover the remains of the past with the aid of scientific techniques and reach better understandings of field and laboratory eye-observations. The remains of intentional fires, microscopic residues of food on tools and human teeth, are aggressively sought. Others propose a deeper understanding by drawing lessons from behavioral traits that are studied in modern societies. They commonly assume that they are the outcome of a long (or short) social evolution in the course of environmental adaptations. Among these are intra and inter-group violence, brain modules, and changes in cognitive capacities, cooperation, altruism, the role of “free riders”, kin and group selection, to mention just a few. In addition, current genetic research including scanty information of ancient DNA, suggests that the image of global populations in human evolution was more complex than the records of the human fossils. In sum, several of these intriguing questions and their implications for our society will be examined in the course of my presentation.

The Recent Evolution of the Question "What is Life?"

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The question of life has not received equal attention from biologists during the whole XXth century. At the end of the 1960s, the question partially disappeared from the writings of biologists. The question had been solved by the progresses accomplished in molecular biology, by the discovery of the genetic information present in all organisms.

Forty years later, the question has reemerged, in part from the evidence that knowledge of genetic information is not sufficient to understand « What is life ? ». Nevertheless, the question has changed. Most biologists are of the opinion that the basic principles of life have been discovered. What remains to be explained is the complex path which led to the emergence of the first organisms. The question of life has become a historical question.

In addition, the question of life is now clearly distinguished from the question of the emergence of cognitive abilities and consciousness.

Muller on Life

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Herman J. Muller was arguably the most avid reductionist materialist biologist at the beginning of the twentieth century. His turn to the study of Mendelian genetics reflects his desire to reduce life to rational material terms. Yet, his insight that the essence of life is its complex, purpose oriented, organization was difficult to think of without the notion of design. Early on Muller concluded that conceiving of *genes* as autonomous entities that, "besides the ordinary proteins, carbohydrates, lipoids, and extractives, of their several types, … play a fundamental role in determining the nature of all cell substances, cell structures, and cell activities" might provide the resolution to his dilemma. The logical conclusion of his deliberations was that "all other material in the organism is made subsidiary to the genetic material, and the origin of life is identified with the origin of this material by chance chemical combination."

Even in 1955, when "recent evidence indicates that the gene consists of the substance known as *nucleic acid*, in the form of a much coiled chain, or double chain, composed of a great number (thousands) of links," he stressed that these entities have the property of *autonomous self replication*, in principle independent of the services of the cells, such as cell enzymes.

> It may be concluded that the essence of life is not protoplasm or its operations, …Life's essence lies in the capability of undergoing such evolution, and this capability is inherent in the gene, by virtue of its property of duplicating its variations.

The Origin of Life and the Problem of Defining the Organism

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Molecular biology frequently claims that the properties of life can be reduced to molecular properties and therefore to the laws of chemistry and physics. However, most common theories announcing successful reduction are based on a misconception of the nature of molecular biology. Indeed, a thorough understanding of life at the molecular level provides the most stringent arguments for the autonomy of biology. This does not imply that the basic laws working in the organisms transcend physics and chemistry. Using new models of reductive explanations I will defend the idea that the only way of linking the realm of physics and chemistry to that of biology is by reconstructing the origin of life. This, however, requires a definition of the minimal properties of a living system. Different attempts to provide such definitions will be discussed.

Origin of Life: Conceptual Considerations

Ulrich Charpa

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'Origin of life' is a folk expression which covers many biological as well as literary and religious issues. It is a part of a common practice of considering origins as explanatory factors (in contrast to motives or simultaneous causes). I will focus on the following topics:

- the thematic scope of origin-questions
- the relationships between these questions
- the thematic position of 'origin of life'
- the two main options to reconstructing this concept logically
- the methodological aspects of this concept (with special references to Hutton, Whewell and others)

Additionally, it will be shown that religion/science clashes with regard to evolutionist origin-explanations are based on confounding the two logical reconstructions and neglecting the methodological character of the concept 'origin of life'.

Spontaneous Generation in Medieval Jewish Philosophy and Theology

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The idea of life forms emerging from inanimate matter – spontaneous generation – was widely accepted until the 19th century. Several medieval Jewish scholars acknowledged this scientific theory in their philosophical and religious contemplations. Quite interestingly, it served to reinforce diverse, or even opposite, theological conclusions. One approach excludes spontaneously-generated living beings from the biblical account of creation. It has also been argued that these species were not among the animals saved on Noah's ark during the flood. Underlying this view is the understanding that organisms which generate spontaneously evolve continuously in nature, and therefore there is no need for divine intervention in their coming-to-be, or survival during disastrous events. A naturalistic position as such makes use of spontaneous generation in reducing the miraculous dimension of reality. Others were of the opinion that spontaneous generation is one of the extraordinary marvels exhibited in this world. Creating life in the most vile materials such as putrid fruits or decaying animal flesh, demonstrates the glory and omnipotence of God. Accordingly, this interpretation considered spontaneous generation to accentuate the divine in nature. Each of the two conflicting conceptions will be examined in light of the intellectual environment which influenced the individuals who expressed these notions.

Origin of Life: The FAT Story.

Omer Markovitch and Doron Lancet

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The fundamental question of how life came to be has drawn attention throughout history and in particular over the past decades. What led to the appearance of the first protocell in prebiotic Earth is an intriguing question. A metabolism-first approach for the origin of life entails that as early as replicating entities have emerged, they must have constituted relatively complex molecular networks, arising via spontaneous accretion of early assemblies of simpler organic molecules. In this scenario, faithful assembly reproduction directly stems from specific network attributes. The graded autocatalytic replication domain (GARD) quantitative model for life’s origin provides support for this scenario by allowing one to better understand the crucial network properties of the implicated molecular assemblies.

GARD describes the homeostatic growth and evolution of an assembly composed of a repertoire of N_G simple molecules, e.g. lipids, and suggests a possible pathway to the formation of a minimal protocell. The talk will briefly present GARD in the context of metabolism-centered approaches towards the origin of life, and describe some of our recent research, namely selection in GARD and how a balanced degree of self-catalysis and mutual-catalysis is required to best facilitate evolution.