NoRCEL

Network of Researchers on the Chemical Emergence of Life

Emergence ▸▸ Evolution ▸▸ Extinction

NoRCEL VII

ONLINE CONFERENCE

OCT 30 th-NOV 1st, 2024

YOU DON'T MAKE LIFE FROM (JUST) CARBON...
REACTIVE OXYGEN SPECIES

NoRCEL Inaugurated 2013
NoRCEL is an organisational member of the Royal Society of Biology

Introduction

The Network of Researchers on the Chemical Emergence of Life (NoRCEL) is an interdisciplinary *collaborative* network focussed on understanding the emergence and evolution of life from a chemical perspective. Founded by Sohan Jheeta, NoRCEL's primary aim is to bring together scientists from various disciplines to investigate one of the most fundamental questions in science: how life began. We have now evolved into a truly global network of scientists, researchers, students and lay people coming together to work to investigate and fathom some of the most multi-faceted aspects of—and elusive challenges facing the scientific world. This has led to our more recent missions into exploring global issues, as with our *Blue Earth project* (BEP), as well as developing educational tools in our endeavour to enable wider access to the field of astroscience, especially in the Global South. The latter innovative initiative is encompassed in the form of *AstroScience Exploration Network* (ASEN).

To extend the essence of NoRCEL globally please now find as follows: it is true that there are many laboratories specifically researching into the question of the emergence of life on Earth; this type of research is generally carried out by astrobiologists. However, equally, there is an extensive amount of research, not necessarily directly involved in answering the posed question, which may well be able to contribute something to the total sum of our knowledge pertaining to the emergence of life. It is from this position that NoRCEL has been established, with the aim of kick-starting a debate amongst those practitioners who are directly involved in the theoretical aspects and experimental studies pertaining to the origin of life and those scientists who traditionally work in other fields (e.g., medical virology, phylogenetics, cancer research, etc.) This pooling of a wide array of knowledge may thus contribute to and accelerate the understanding of the emergence of life on Earth.

Therefore, we encourage an eclectic range of practitioners to join the network and come together at our meetings in order to air, share and debate their ideas under one roof. It is our fervent desire that our regular conferences, reports and published papers will assist in expediting a better understanding of the emergence of life on the Earth.

NoRCEL's spotlight in 2024 will again be examining the processes by which life emerged on the Earth. Since there are more than twenty hypotheses in literature which claim the way forward for the emergence of life, we are inviting proponents from all across the astrobiology and origin of life (OoL) communities to join us to discuss and promulgate their theories and findings. Here are just a few of the suppositions to consider: archaea, bacteria or viruses first; metabolism or genetics (RNA world) first; peptides, lipids or minerals/clays first. We also take a look at reactive oxygen species (ROS) and investigate the ways that these may also have played a pivotal role in the emergence of life—you don't make life from (just) carbon chemistry.

#	All TIMES SHOWN ARE FOR THE UNITED KINGDOM ON THE DAY (GMT) Everyone—please check the corresponding time in your location on the day, so that you are synchronised with the UK time	
	Start of Day 1: Wednesday 30th October, 2024	
	12:30—13:00	Arrival
	13:00—13:05	Opening Kathy (5min)
	13:05—13:25	Sohan Jheeta (20min)
	13:25—13:35	Matin Dominik (10min)
		Chair 1: Elias Chatzitheodoridis
1	13:35—13:45	**Shinji Karasawa** (Emeritus Professor) Sendai National College of Technology, Miyagi, Japan *Short video: A comprehensive and inclusive understanding on the origin of life Protein replication by interaction of helical structures between different chirality*
2	13:45—14:15	**Prasanta S. Bandyopadhyay**, Gordon Brittan, Jr., Yves Idzerda and Laila Moeller Department of History & Philosophy and Department of Physics Montana State University, Bozeman, MT 59715, USA *Emergences of Life and Consciousness: What Does Simpson's Paradox Reveal?*
3	14:15—14:45	**Ramona Khanum**[1], Nirmell Sathiyasilan[1], Mahenderan Sithamparam[1], Navaniswaran Tharumen[1], and Kuhan Chandru[1,2,3] [1]Space Science Center (ANGKASA), Institute of Climate Change, National University of Malaysia, Selangor, 43600 Malaysia [2]Polymer Research Center (PORCE), Faculty of Science and Technology, National University of Malaysia, Selangor, 43600 Malaysia [3]Institute of Physical Chemistry, CENIDE, University of Duisburg-Essen, 45141 Essen, Germany *What If LUCA Was A (Bio)film Before a Single-cell?*
4	14:45—15:15	**Romeu Cardoso Guimarães**[1] and Sávio Torres de Farias[2] [1]Lab. Biodiversity and Mol Evo, Dept Genetics, Eco & Evo, ICB Federal University, Brazil [2]Lab. Evolutionary Genetics - Paulo Leminski, Dept Mol Bio, Federal Univ. Paraíba, Brazil *Formation of the Genetic Anticode, the RNP and DNP Realms*
5	15:15—15:45	**Marco V. José** Theoretical Biology Group, Instituto de Investigaciones Biomédicas, Universidad Nacional Autónoma de México *The Quaternion group of symmetries of the Genetic code*
6	15:45—16:15	**Aaron Engelhart** University of Minnesota Dept of Genetics, Cell Biology, and Development, Minneapolis, USA

		Nucleic acid electron transfer and halogenation chemistry on Earth, Mars, and elsewhere
	16:15—17:15	BREAK (60 min)
		Chair 2: Miryam Palacios Pérez
7	17:15—17:45	**Alan Hidalgo Aranda** National Autonomous University of Mexico / Nuclear Sciences Institute (ICN) /Conahcyt *Uracil stability in extreme conditions*
8	17:45—18:15	**Ana Karoline da Nóbrega Nunes-Alves** Evolutionary Genetics Lab, Universidade Federal da Paraíba, Brazil *From RNA to DNA: The Evolution of Reverse Transcriptases*
9	18:15—18:45	**José Emilio Ramírez Piña** Dr. Luis José Delaye Arredondo, Research Center and Advanced Studies of Instituto Politecnico Nacional CINVESTAV, Genetic Engineering Department, Mexico City, Mexico *Unravelling LUCA's growth traits*
10	18:45—19:15	**Terry Kee** Department of Chemistry, University of Leeds, UK *Life as Process*
11	19:15—19:45	**Saibal Mitra** NoRCEL, Leeds, UK *Origin of life via a liquid neural network*
		End of Day 1
		Start of Day 2: Thursday 31st October, 2024
		Chair 3: Oleg Kotsyurbenko
12	13:00—13:30	**Chukunoye Enunuwe Ochonogor** Professor Extraordinaire, Tshwane University of Technology, Pretoria, South Africa *Influence of Chemistry of Reactive Oxygen Species on Animal and Plant lives*
13	13:30—14:00	**Daniel S. Helman** Visiting Assistant Professor, Department of Environmental Studies, Wofford College, Spartanburg, South Carolina, USA *Ice on Early Earth as a Source of Energy for Redox Reactions: Ice Strain, Electricity and Protometabolism*
14	14:00—14:30	**Bejero Sandoval Sinuhe**[1,2], Heredia Barbero Alejandro[2,3] [1]College of Geography. FFyL UNAM, Mexico [2]Nuclear Science Institute. ICN UNAM, Mexico [3]International Team Member of NoRCEL, Leeds, UK *Vaalbara's Legacy in the Ancient Earth: Geographical Continental Evolution and the Prebiotic Chemistry*
15	14:30—15:00	**Dave LePoire**

		Systems Scientist, Environmental Science Division, Argonne National Laboratory, USA *The Possible Roles of Ionizing Radiation in Forming the ROS Environment of Early Life*
16	15:00—15:30	**Krishnendu Ghosh** Department of Pathology, Carver College of Medicine, University of Iowa, Iowa City, IA, USA *Reactive Oxygen Species (ROS) as a potential speculative curator of emergence of life: an ode to enlightenment through neoplastic cells*
17	15:30—16:00	[1]**Gustavo Caetano-Anollés**, [1]Fizza Mughal, [1]M. Fayez Aziz, Kelsey Caetano-Anollés[2] [1] Department of Crop Sciences and C.R. Woese Institute for Genomic Biology, University at Illinois at Urbana-Champaign, Urbana, IL 61801, [2] Callout Biotech, Albuquerque, NM 87112, USA *A phylogenomic data-driven analysis of the birth of structural domains and intrinsic disorder in protein evolution*
18	16:00—16:30	**Anel Sanjuán-Castellanos**[1,2], **Eduardo Fonseca-González**[1,3], A. Paredes-Arriaga[1], A. Negrón-Mendoza[1] and A. Heredia-Barbero[1]* Affiliations—see the abstract *Computer Simulation of the Stability of Hydrated Electron: An Insight in the Structural Stability for Prebiotic Chemistry Studies*
	16:30—17:30	**BREAK (60 min)**
		Chair 4: Sávio Torres de Farias
19	17:30—18:00	**Frank Trixler** [1,2,3] [1] Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München (LMU), Munich, Germany [2] RiesCraterMuseum, Bavarian State Collections, Nördlingen, Germany [3] Center for NanoScience (CeNS), LMU München, Germany *Prebiotic formation of large RNA strands with sequence complexity enabled by interstitial water in a nanogeological model environment*
20	18:00—18:30	**David S. Holmes**, [1]Eva Vergara and [2]Jorge Valdes [1]Fundacion Cienca &Vida, San Sebastian University and [2]Andres Bello University, Santiago, Chile *Unravelling Oxygen's Origins and its Implications for ROS and Astrobiology*
21	18:30—19:00	**Rosa Alejandra Reyes Quinones** Universidad Nacional de Colombia *Bottom-up Models: An Integrative Synthesis*
22	19:00—19:30	**Kuhan Chandru**[1,2,3] [1]Space Science Center (ANGKASA), Institute of Climate Change, National University of Malaysia, Selangor, 43650 Malaysia [2]Polymer Research Center (PORCE), Faculty of Science and Technology, National University of Malaysia, Selangor, 43600 Malaysia [3]Ins., of Physical Chem., CENIDE, Uni. of Duisburg-Essen, Germany *A Contingency-Driven Non-Biocentric Approach to Astrobiology*

23	19:30—20:00	**Frankline Besonge Bokanda** University of Bologna Italy *Astrobiological potential of the Silcretes of the Makgadikgadi pan (Botswana): Implication for the search of life on Mars*
Start of Day 3: Friday 1st November, 2024		
		Chair 5: Alejandro Heredia Barbero
24	13:00—13:30	**Tamir Tuller** Tel Aviv University *Engineering RNA viruses based on the modulation of local RNA structures*
25	13:30—14:00	**Vladimir N. Kompanichenko**[1,2] [1]Institute for Complex Analysis of Regional Problems RAS, Birobidzhan, Russia. [2]Network of Researchers on Chemical Evolution of Life, Leeds, UK *Four stages of the metabolism emergence stimulated by high-frequency oscillations in hydrothermal environment*
26	14:00—14:30	**Judit E. Šponer** Institute of Biophysics, Czech Academy of Sciences, Brno, Czech Republic *Crystallization as Circe-effect in prebiotic polymerization processes*
27	14:30—15:00	**Svatopluk Civiš** J. Heyrovský Institute of Physical Chemistry Czech Academy of Sciences, Prague, Czechia *Stellar wind contribution to origin and transport of water on the surface of oxygen-containing minerals*
28	15:00—15:30	**Hitesh. G. Changela**[1,2] & the Czech Hayabusa-2 Consortium [1]SETI Institute, California, USA [2]Dept of Earth & Planetary Sciences, University of New Mexico, USA *The Evolution of Organic Material on Carbonaceous Asteroids*
	15:30—16:30	**BREAK**
		Chair 6: Deepnil Ray
29	16:30—17:00	**Josep M. Trigo-Rodríguez** Spanish National Research Council, Bellaterra, Barcelona, Spain *Catalytic reactions promoted by meteorite reactive minerals under the presence of water in the early Earth: pathway towards organic complexity*
30	17:00—17:30	**Sathesh Raj V Periasamey** and Paola Manini University of Naples Federico II, Italy *Design of Synthetic Insoluble Organic Matter (IOM) Samples via a Systems Chemistry Approach: Towards Disentangling Spectroscopic Features of Planetary Soils and Meteorites*
31	17:30—18:00	**Uri Malamud**

		Technion Israel Institute of Technology *The importance of comet nuclei size and the potential for internal liquid flow*
32	18:00—18:30	E. Mieli, A. M. F. Valli and **Claudio Maccone** Affiliations—see the abstract *Astrobiology: resolution of the statistical Drake equation by Maccone's lognormal method in 50 steps*
33	18:30—19:00	**Rosanna del Gaudio** Department of Biology, University of Naples Federico II, Italy *Did minerals surfaces and meteorite components act as prebiotic catalysts for chemical evolution increasing molecular complexity toward the origin of life?*
	19:20	**End of Day 3 and Close of Conference—Sohan Jheeta**

ABSTRACTS

DAY 1: Wednesday 30th October, 2024

A comprehensive and inclusive understanding on the origin of life
Protein replication by interaction of helical structures between different chirality

Shinji Karasawa
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Abstract

The life quickly reacts for change of surroundings compared with the other matter. Every constituent of the creature adapts for change of its neighboring. The first activity of creature was organized by harmonized with the surroundings. Since each molecule of liquid water is harmonized with of its surroundings, the environment of the first creature must be the liquid water. The liquid water consists of multiple clusters at each instant because molecules in a liquid water linked each other by hydrogen bonds. The linked distorted tetrahedrons tends to form a helical structure like α-quartz that has chirality. So, the instantaneous cluster may form spiral structure by distorted tetrahedrons of water molecules. There is the fact that most of creature possessing with constituents of helical structure with chirality. The protein replication is formed by the interaction of helical structures between different chirality [1],[2]

References

1. Karasawa. S, "Evolution of protein synthesis and that of intelligence", https://youtu.be/IG26T15SLLM
2. Karasawa. S, "Origin and evolution of metabolism", https://youtu.be/P8SikZCZm_U

Emergences of Life and Consciousness: What Does Simpson's Paradox Reveal?

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Abstract

Simpson's Paradox is the reversal of the direction of the data when data are pooled together. It has two versions: the static, and the dynamic versions. The static version represents a 2 x 2 contingency table with a reversal where data are fixed. The dynamical version makes room for the appearance and disappearance of a reversal due

to the impact of new data. David Chalmers contends that there are two types of emergences: weak and strong. By "weak emergence," he means that the emergent behaviors, i.e. higher-level properties that are surprising and novel, are deducible from low-level properties. Additionally, a causal narrative can explain the "weak emergence" of higher-level properties from lower-level ones. Contrastingly, in "strong emergence" higher-level properties are *not* deducible, in principle, from the lower-level properties. He argues further that there is no possibility of any causal narrative connecting higher-level properties to their lower-level ones. The only instance of strong emergence, according to Chalmers, is the emergence of consciousness. We will use two types of Simpson's paradox to the emergence issues, from life to consciousness. In our conference paper, we will show how. We show that the static version of the paradox instantiates weak emergence where a causal narrative can be provided. The debate over the emergence of life where we will address both Metabolism First Theory and the RNA World Theory, instantiates a dynamic version of the paradox regarding how life could emerge. A causal narrative regarding how molecules interact in chemical reactions is yet unknown. However, it makes room for its possibility in the future without committing to it. This shows that the emergence of life given the current state of our knowledge, cannot be subsumed under a case of weak emergence. However, the narrative about its emergence is different from consciousness which involves a first-person subjective experience. Hence, life emergence is different from consciousness which is strongly emergent. Therefore, neither the emergence of life is a case of weak emergence nor is it a case of strong emergence. The primary goal of this paper is to discover a middling concept of 'emergence' that better fits the case of life than what we have characterized as 'weak' and 'strong' emergence."

This work is partially supported by the National Science Foundations under grant DMR# 1906383

What If LUCA Was A (Bio)film Before a Single-cell?

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Abstract

The basic unit of biology is the cell; however, this definition does not necessarily apply to the origins of life, where Last Universal Common Ancestor (LUCA) marks the beginning of biological life. Here, we propose the possibility that LUCA was a biofilm-like entity, serving as the starting point where life and non-life molecules interacted within a tight and rigid environment. We will first highlight key features of biofilms and compare them with aspects of prebiotic chemistry, particularly those that form gel-like structures. This comparison suggests that LUCA may have been an early biofilm, which eventually gave rise to progenotes, one of which became LUCA.

Formation of the genetic anticode, the RNP and DNP realms

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Abstract

The Self-Referential Model for the formation of the genetic encoding and decoding system proposes a start and structure based on pairing of (proto)tRNAs through the (proto)anticodons. The two (proto)tRNAs are held together [as ‘dimers’] in a manner that mimics the functional couple of tRNAs in ribosomes. At origins, the peptides produced bind back to the producer (proto)tRNAs forming an aggregate (proto)RNP that is stabilized and engages in natural (non-Darwinian, at the beginning) evolutionary cycles, ending up in formation of the gene-protein correspondences, including the three components of the encoding system: enzymes aminoacyl-

tRNA synthetases, specific tRNA kinds and the amino acid biosynthesis pathways (AaPw), whose end products are the meanings of the anticodons. The resulting chronology of encoding indicated the succession from simple to complex initial substrates of the AaPw: (1) pterin-dependent C1-substrates [Gly, Ser), (2) pterin-independent C1-substrates (Ala, Asp, Asn), (3) complex substrates, of three kinds ([3] pyruvate derivatives leading to gluconeogenesis and the Pentose-P Pw, starting with Phe; [4] pyruvate duplications leading to Leu; [5] fusion of Acetyl-CoA and oxaloacetate leading to the Citrate Cycle whose component αketoglutarate generates Glu and its derivatives Lys, Arg and Pro). This set of 11 Aa corresponds to the early set of encodings, whose anticodons are of the BRR : BYY (Homogenous) kinds of pairs and whose Aa are typical of the RNA-binding protein motifs. The late set of nine Aa have Mixed type anticodons (BRY : BYR) and DNP type Aa. Step (1) Gly is at the core of purines, Step (2) Asp at the core of pyrimidines, and Step [3a] contains precursors to the backbones of the NA polymers. This is taken to indicate that early steps of encoding might not have been driven by RNA structures residing in the (proto)tRNA 'dimers'. The 'RNA world' hypothesis is still in debt with respect to this burden of proof. We propose that the early supporting materials, besides the obvious mineral surfaces, might have been e. g., the rippled sheets of oligo(poly)-Gly, possibly serving also the role of backbone for types of PNA (peptide nucleic acid), decorated progressively with purines (step 1), then pyrimidines (step 2), finally yielding to the sugar-phosphate backbone (step 3).

The Quaternion group of symmetries of the Genetic co

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Abstract

The table of the genetic code can be arranged in 4 columns: RNY, YNY, YNR and RNR (R stands for purines and Y for pyrimidines, N any of them). In previous works we have demonstrated that each column of the table can be represented in a 4-dimensional hypercube. We have also shown that starting from the RNY hypercube, or any hypercube, the remaining 3 hypercubes can be obtained by transversion in the first or third nucleobase. The whole genetic code can be represented in a 6-dimensional hypercube where each triplet is represented as numbers of zeros and ones.

The complex plane C is equivalent to the real plane R^2. Likewise, C^2 is equivalent to R^4. Hence, the hypercubes live in the complex space of $C^{2.}$. In this space, Sir William Rowan Hamilton defined in the XIX century the quaternion numbers. Hamilton discovered the fundamental formula for quaternion multiplication: $i^2 = j^2 = k^2 = ijk = -1,$ where $1, i, j, k$ are the unitary vectors $1 = (1,0,0,0), i = (0,1,0,0), j = (0,0,1,0), k = (0,0,0,1).$ Herein, a matrix representation of the Hamilton quaternion group, by 4x4 square matrixes with entries equal to -1, 0 or 1, is defined. It is proved that this group, denoted as $(Q_M, \circ)$, is a group of rotational symmetries of the 4-dimensional hypercube $\square_2^4$, that is, a subgroup of the special orthogonal group $SO_4(\square_2)$. There are 48 symmetries in each hypercube. The latter is an amazing result, impossible to conceive in Hamilton's time, when the genetic code was unknown. Until now this type of symmetry was unsuspected. These symmetries are not hidden, they can be seen in plain sight. We can now establish that the genetic code is composed by 4 Quantum binary Turing machines.

Nucleic acid electron transfer and halogenation chemistry on Earth, Mars, and elsewhere

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Abstract

The existence of ribozymes has led many to investigate an "RNA world" in which RNA performed additional catalytic functions before coded protein synthesis emerged. Many ribozymes exist that can perform phosphoryl transfer reactions, but comparatively fewer exist that can perform other reactions. We have recently investigated the functional capacity of RNA in the presence of a unique class of oxidized species: oxychlorine anions. These

ions are abundant on Mars, exist in a few dry environments on Earth, and could exist on other dry and oxidizing worlds. These compounds are toxic to most known life and denaturing to many biopolymers, but oxychlorine brines could be an important source of liquid water in some environments. We have found oxychlorine anions allow function of ribozymes and, additionally, enable new functions for ribozymes. In one such example, we have observed that chlorite, one oxychlorine anion, can enable an important oxidation reaction for synthetic chemistry - it can allow a ribozyme to chlorinate organic substrates, such as the dye phenol red. We have also observed that the mild denaturation of RNA by perchlorate allows for a primitive regulatory behavior that could function in prebiotic systems. This demonstrates a new class of redox and synthetic reactions for ribozymes.

RNAs we have examined generally retain function in perchlorate brines, but fewer tested proteins do so. Numerous forms of RNA-based metabolism on Earth have been posited as relics of a past RNA world, despite protein having supplanted RNA as the principal functional biopolymer in known biochemical systems. We suggest the unique biopolymer folding environment provided by oxychlorine brines in oxidized worlds could enable new chemistry, as well as provide selection pressure to favor further forms of RNA-based functional behaviors in oxychlorine-rich environments.

References

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2. Hoog, TG; Pawlak, MR; Bachan, BF; Engelhart, AE. (2022). Biochemistry and Biophysics Reports. 30:101238.
3. Hoog, TG; Pawlak, MR; Aufdembrink, LM; Bachan, BF; Galles, MB; Bense, NB; Adamala, KP; Engelhart, AE. (2022) ChemBioChem. 23(9):e202200090.

Uracil stability in extreme conditions

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Abstract

Uracil is one of the four nitrogenous bases that make up the RNA molecule and is fundamental to life. From an evolutionary perspective, its stability is crucial to understanding how molecules like DNA and RNA could have prevailed under the extreme conditions of early Earth or in interstellar space, where there is a significant amount of ionizing energy. To study the chemistry of primitive Earth or interstellar space, there are two approaches: replicating the extreme conditions in the laboratory or simulating them using computer programs. In this work, we used density functional theory to study the stability of uracil in the presence of the hydroxyl radical and hydrogen radical, which is formed by the interaction of radiation with water molecules. Specifically, this study focused on hydrogen abstraction reactions, radical adduct formation, and the effect of the presence of a clay (kaolinite) and its Watson-Crick pair (adenine).

From RNA to DNA: The Evolution of Reverse Transcriptases

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Abstract

It is currently a consensus in the scientific community that RNA was the first informational molecule, later replaced by DNA mainly in cellular lineages. In this evolutionary process, it was necessary for classes of proteins to emerge that could transfer the information contained and established in an RNA-dominated world to DNA molecules. In this context, a very important class of molecules is the RNA dependent DNA polymerase (RDDP), as the emergence of this class was essential for the appearance of the first DNA molecules in maturing biological systems. We obtained 74 RNA-dependent DNA polymerases sequences from the Refseq database, and aligned them using the MAFFT algorithm. The best evolutionary model was WAG+F+R6. The phylogenetic

tree was constructed using the Maximum Likelihood method. Ancestral sequences were obtained using the MEGA7 algorithm. For the reconstruction of ancestral sequences, three cut-off points were used: complete deletion, 95%, and 90%. Five ancestral sequences were obtained: one for the complete deletion cut-off, two for 95%, and two for 90%. The ancestral sequences were structurally modeled using the I-TASSER algorithm. 39 RNA-dependent RNA-polymerases and 10 RNA-dependent DNA polymerases were downloaded from the Protein Data Bank (PDB). For comparison purposes, we aligned all proteins against each other, using TM-align. The resulting RMSDs, a measure of the average distance between the atoms of the superimposed molecules, were inserted into a distance matrix The distance matrix was then inserted into Trex-online to obtain a distance tree. Data obtained from the reconstruction of ancestral RDDP sequences, as well as their structural modeling, suggest that these molecules may have originated from modifications in ancestral RDRP molecules, thus showing continuity in their evolutionary histories. Other data also suggest that DNA polymerases may have originated from ancestral RDDP, connecting the history of the RNA to DNA transition within the evolutionary history of nucleic acid polymerases. The dataset for this large group of proteins allows us to construct a comprehensive picture of the events that may have occurred in the early stages of biological systems.

Unravelling LUCA's growth traits

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Abstract

The Last Universal Common Ancestor (LUCA) lived approximately 4.2 billion years ago. LUCA likely possessed a considerable diversity of molecular mechanisms and metabolic traits, including translation machinery, RNA synthesis, ribosomal RNA, ribosomal proteins, proteins involved in DNA repair, aminoacyl-tRNA ligases, and enzymes associated with metabolic pathways such as gluconeogenesis, nucleotide metabolism, ATP synthase, and acetyl-CoA production. Other inferred traits suggest that LUCA may have been autotrophic, had approximately 2,500 genes, and a genome size of about 2.5 Mb, resembling modern prokaryotes. While much is inferred about LUCA's molecular and metabolic characteristics, one aspect that has not been explored is whether LUCA exhibited a copiotrophic (organisms with short generation times) or oligotrophic (organisms with long generation times) growth strategy. The objective of this work is to infer whether LUCA had an oligotrophic or copiotrophic growth strategy by using ancestral character reconstruction of certain genomic features and minimum generation times. We estimated traits associated with growth strategy, such as genome size, GC content, number of genes, number of paralogues, and codon bias, from 213 species of prokaryotes and archaea, using available data from NCBI. We also used experimental data on minimum generation times to perform ancestral character reconstruction. The novelty and relevance of this approach lie in its potential to uncover previously unexplored traits of LUCA, which may provide insights into its ecology and contribute to our understanding of the early evolution of growth strategies.

Life as Process

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Abstract

Various models of the concept we call life have been proposed and debated in the literature; all of them based on implicit (sometime explicit) boundary conditions (BC's) or constraints. We contend that it is in no small part due to these constraints that problems in integrating the models persist. In this piece, we offer a critical reconsideration of three such boundary conditions, each a commonly held implicit proposition about life: (i) that life is an inherent property of an object or system, (ii) that life is de facto a biological phenomenon and (iii) that the division between "life and-non life" is binary in nature and things are either classified as one or the other.

We discuss here how these propositions are human-imposed boundary conditions which have no independent evidence of validiy and that when dispensed with, a completely different picture of livingness emerges. What emerges is a philosophical picture of livingness not as a “state of being” possessed by some system, but rather as processes of interaction which results in a manifestation or change in the state of that system. Livingness may therefore ultimately be viewed as the integration of all recursive processes of interactive change present within a certain set of defined boundary conditions, be they structural, mechanistic or conceptual.

When viewed through the (loosely bounded) lens of process rather than state of being, the concept of life may be allowed to shift subtly from being one in which “complexity of outcome is considered the result of complexity of system interactions” to one where “complexity of outcome is the logical consequence of simple algorithmic expression”.

Origin of life via a liquid neural network

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Abstract

A formal description of the origin of life from basic chemical building blocks would specify a powerful machine learning algorithm. The machine learning aspect of the commonly considered theories on the origin of life is limited to genetic algorithms implemented by natural selection of simple replicating systems. Such machine learning systems are, however, far less powerful compared to artificial neural networks. This then suggests the possibility that life arose out of a prebiotic system that implemented a machine learning algorithm based on an artificial neural network.

While conventional artificial neural networks work in a very unnatural way and therefore cannot be implemented by a prebiotic chemical system, the recently developed liquid neural networks [1] do have a plausible prebiotic chemical implementation. In this talk I will briefly discuss liquid neural networks and then consider the implementation of such a system by a prebiotic system that resides in a microenvironment that is partitioned in a large number of compartments between which a limited exchange of chemical compounds is possible.

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DAY 2: Thursday 31st October, 2024

Influence of Chemistry of Reactive Oxygen Species on Animal and Plant lives

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Abstract

The chemical characteristic nature of and envisioned natural relationship of reactive oxygen species (ROS) with living organisms beg for continued studies and further understanding. A common knowledge is that ROS is a free radical or chemical molecule that contains oxygen and is able to react with other molecules within a plant, animal or fungal cell. In other words, Reactive Oxygen Species are unstable chemical molecules bearing oxygen in them. They usually formed from diatomic oxygen (O 2), water (H2O), and hydrogen peroxide (H2O2). Examples of ROS are hydroperoxide (O2H), superoxide (O2-), hydroxyl radical (OH.), and singlet oxygen (1O2) or (O=O) which is a non-radical. This paper attempts to review the influence of the chemistry of Reactive Oxygen Species on animal and plant lives as a contribution to understanding the comparative effects of the highly reactive radicals on living organisms.

Ice on Early Earth as a Source Of Energy for Redox Reactions: Ice Strain, Electricity and Protometabolism

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Abstract

Electrical charge drives redox reactions, and the history of their utility is preserved in shared metabolic pathways in living cells. Ice probably covered the Earth at the time prior to and during life's emergence, i.e. during "Snowball Earth". Tidal forces were much stronger then as the early moon's orbit was about 20 times closer to the surface of the Earth. Large ice sheets would have been subject to cyclical strain from tidal forces, and strained ice can provide electrical energy. Results are presented from recent experiments using water ice with various added salts to understand the energy availability for redox reactions and protometabolic processes. The talk will share results related to different processes that produce electricity in ice, plus different salt combinations and their implications for redox reactions and abiogenesis, as well as geologic settings consistent with an icy worlds hypothesis of abiogenesis on Earth.

Vaalbara's Legacy in the Ancient Earth: Geographical Continental Evolution and the Prebiotic Chemistry

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Abstract

Vaalbara, one of Earth 's earliest supercontinents, formed between 3.8 and 2.8 billion years ago during the Archean Eon. Composing ancient cratons such as the Kaapvaal Craton in South Africa and the Pilbara Craton in Western Australia, Vaalbara existence is supported by geological and paleomagnetic evidence, suggesting these cratons were once united. Over time, plate tectonics fragmented Vaalbara, leading to the dispersal of these cratons and contributing to the formation of subsequent continents.

We propose that the continental evolution starting with Vaalbara played a critical role in the oxidation of water in tectonically active regions. Mechanical stress within rocks generated reactive oxygen species (ROS), including hydrogen peroxide (H_2O_2) and free radicals. These processes, alongside the adsorption and polymerization of amino acids on mineral surfaces, may have facilitated the prebiotic synthesis of essential biomolecules, such as proteins and ancient genetic molecules (RNA).

These phenomena not only altered Earth's surface chemistry but may also have been pivotal in the evolution of early life forms. The generation of ROS in these primitive environments could have created a chemical landscape conducive to anaerobic life and the development of complex biological systems. Integrating these insights within an interdisciplinary framework is essential, bridging prebiotic chemistry and biological evolution.

Acknowledgments

AHB thank to the project UNAM-DGAPA-PAPIIT IN205522 for the financial support

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The Possible Roles of Ionizing Radiation in Forming the ROS Environment of Early Life

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Abstract

Reactive Oxygen Species (ROS) require two components: oxygen and energy. Recent discoveries of non-biotic oxygen generation at the ocean floor near metallic nodules illustrate how oxygen might be derived, but the fundamental understanding of its generation through electrolysis remains unclear. Oxygen can also be produced through radiolysis, which involves ionizing radiation, often alpha particles. While the current ocean floor environment is not highly radioactive, early Earth had much more radioactivity, including the fissile uranium isotope U-235. These factors suggest that the activity from uranium isotopes was about six times higher than today and the overall radioactivity might have been a couple orders of magnitude larger than it is today.

Radioactivity in volcanic rocks can be significant, contributing energy to split water through radiolysis or generate electric potentials, such as alphavoltaic cells, which might drive electrolysis. Radiolysis is familiar to those working with radiation treatments for cancer, as oxidative stress is a common cellular response to radiation exposure. This radiation-generated oxygen is not produced through a low-energy process like electrolysis but ionization instead leads to the creation of radical oxygen species. Even today some microbial communities might obtain energy through the radiolysis of water into molecular oxygen and hydrogen.

However, radiation from uranium primarily involves alpha emitters, which do not travel far (they can be stopped by a piece of paper). In the hydrothermal vent environment, the thickness of the rock and the pore spaces are quite small, allowing a relatively large fraction of alpha emissions to enter the pore spaces where water and potential carbon-containing molecules might reside. Besides alpha emissions, there would be an increase in Radium-226 progeny, which also generate more penetrating gamma radiation.

The relative amounts of energy from these radiations are estimated for hydrothermal vents, along with potential concentrations of ROS from radiolysis. Nick Lane has developed a hypothesis for the emergence of life in such systems. Life may have benefited from early ionizing radiation. The growth of life in a radiation environment is supported by the ubiquitous processes for repairing radiation damage, which are still being investigated. The possibility that LUCA had radiation damage repair mechanisms suggests that radiation was fundamental to the development of life in such an environment, which can be linked to generation of ROS.

Reactive Oxygen Species (ROS) as a potential speculative curator of emergence of life: an ode to enlightenment through neoplastic cells

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Abstract

Reactive Oxygen Species (ROS) referred to a group of small molecules of oxidizing, nitrating, halogenating and thiol-reactive species produced in bio-systems, which is by virtue of their both radical and nonradical moieties, considered to be one of the diabolically tethered molecular groups. In early Earth condition, the high level of ROS, generated by numbers of mechanisms, from hydrolysis of minerals of igneous rocks to generation of CH4/CO2 from hydrothermal volcanic vents, played a pivotal role in the shaping of environment as well and creating a stress-oriented bio-evolutionary drive to govern early proto-cells to urge for enzyme mediated antioxidant system to cope up with extreme reducing condition. High-concentration ROS are extremely toxic to living organisms, but in specialized conditions, ROS act as key modifier of cellular and biochemical signaling cascade. Unlike the normal cellular dynamics where excess ROS burden is taking care of by an array of antioxidant system, the neoplastic cells, having an elevated level of high ROS production and subsequent oxidative stress in the tumor microenvironment (TME), usually understood to move onto prolific apoptotic drive. Surprisingly, along with the upregulation of various disarrayed transcription factors and oncoproteins, studies suggest of unusual upregulation of certain factors like Thioredoxin reductase-1 (TR-1), a class of selenoprotein that usually functions in the thioredoxin antioxidant system, caters malignancy in tumors diminishing ROS oriented oxidative stress burden. Interestingly, few class variants of TR could be found in certain bacteria protecting bacterial cells from oxidative stress. Thus in this current context, the author proposes the idea of considering neoplastic cell as a model to understand the emergence of primitive cellular entities on early Earth condition taking high level of ROS as the stress striker and acting into Darwinian mode of evolution for the Last Universal Common Ancestor (LUCA) to Last Eukaryotic Common Ancestor (LECA) transformation

A phylogenomic data-driven analysis of the birth of structural domains and intrinsic disorder in protein evolution

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Abstract

Protein loops and structural domains are building blocks of molecular structure. They hold evolutionary memory and are largely responsible for the many functions and processes that drive the living world. Here we briefly review two decades of phylogenomic data-driven research focusing on the emergence and evolution of these elemental architects of protein structure. Phylogenetic trees of domains reconstructed from the proteomes of organisms belonging to all three superkingdoms and viruses were used to build chronologies describing the origin of each domain and its embedded loops at different levels of structural abstraction. These timelines consistently recovered six distinct evolutionary phases and a most parsimonious evolutionary progression of cellular life. They also traced the birth of domain structures from loops, which allowed to model their growth *ab initio* with AlphaFold2. Accretion decreased the disorder of the growing molecules, suggesting disorder is molecular size-dependent. A phylogenomic survey of disorder revealed that loops and domains evolved differently. Loops were highly disordered, disorder increased early in evolution, and ordered and moderate disordered structures were derived. Gradual replacement of loops with α-helix and β-strand bracing structures over time paved the way for the dominance of more disordered loop types. In contrast, ancient domains were ordered, with disorder evolving as a benefit acquired later in evolution. These evolutionary patterns explain negative correlations between disorder and sequence length of loops and domains. Our findings provide a deep evolutionary view of the link between structure, disorder, flexibility, and function.

Computer Simulation of the Stability of Hydrated Electron: An Insight in the Structural Stability for Prebiotic Chemistry Studies

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Abstract

The dynamics and different behavior of the hydrated electron were described historically and in physico-chemistry. Its structure is the subject of an active debate. In prebiotic chemistry and molecular evolution, it is a relevant chemical species since it activates with electrons in the physico-chemical environment, acting as a reducing agent. Most of the molecular evolution conditions might have occurred in confined spaces such as mineral interstices at the nanoscale, which makes the structural nature of the hydrated electron relevant. Although we cannot know exactly the conditions of the primitive Earth, several investigations have pointed to high UV and interstellar radiation (gamma rays), making feasible the presence of radical species such as the hydrated electron. On primitive Earth, these reactive oxygen species were important factors in chemical evolution towards forming amino acids. The oxygen-reactive species must be common in our entire universe and associated with ionizing radiation. On our planet, such species are found as silicates (silicate surfaces can be considered as oxygen-rich surfaces) or in the form of assembled molecules of water. The size of the hydrated electron and the correlation to its thermal stability are relevant to understanding its role in interacting with amino acids and mineral surfaces towards increasing the complexation of organic compounds, which can lead to polymerization and the formation of possible catalytic oligomers. Besides the relevance of this active species in ancient Earth, it can be important in astrobiology studies nowadays. In this work, we simulate the stability of the hydrated electron depending on the number of water molecules and intermolecular distances. From our preliminary results in geometry optimizations obtaining potential energies and dipole moments in the mm+ force field and PM3 semi-empirical method, different optimal energies and sizes were obtained. For mm+, with 7 water molecules, -12 kcal/mol, and 0.8 Debyes dipole moment, and for the PM3 method with 10 water molecules, -2017 kcal/mol, and 3.7 Debyes dipole moment, suggesting critical values of relevance in the hydrated electron's performance in specific volumes. More simulations are in process in our group to correlate the stability of this assembly of water molecules, resembling a nanoscale confined electron plasma, to physicochemical reactivity in mineral ancient environments.

Acknowledgments

AHB Thanks to UNAM-DGAPA-PAPIIT IN205522

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Prebiotic formation of large RNA strands with sequence complexity enabled by interstitial water in a nanogeological model environment

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Abstract

One of the key goals of prebiotic chemistry is the abiotic production of biopolymers. However, the synthesis of biopolymers such as RNA is inhibited by water for thermodynamic reasons – a problem known in prebiotic chemistry as the "water paradox". To circumvent this problem, special conditions such as dry-wet cycles, high temperatures, the addition of condensing agents or the replacement of water by other solvents have been used to achieve RNA synthesis. However, such workarounds are far removed from the physiological conditions of living cells, so the disadvantages in terms of prebiotic plausibility become apparent when considering a key principle of evolution: evolutionary conservatism. This principle refers to the observation that evolutionary innovations always build on existing pathways. Taking this principle into account, prebiotic plausible hypotheses of chemical evolution and abiotic biopolymerisation should be based on conditions that are compatible with, or close to, the physicochemical conditions in living cells.

Here I present experimental results demonstrating the spontaneous, abiotic emergence of RNA strands with sequence complexity, dynamic stability and lengths up to 4000 nt and more, running entirely in an aqueous environment under physiological conditions [1]. Several lines of evidence for this emergence are presented based on fluorometric analyses, PCR, gel electrophoresis and nanopore sequencing. The synthesis is achieved by exploiting non-classical properties of water that arise between micro- and nanoparticles in dense aqueous suspensions. From a geological perspective, dense aqueous particle suspensions are ubiquitous settings that represent nanogeochemical environments with vicinal and nanoscale interstitial water. Such environments can be discussed as inorganic analogs to the intracellular environment of living cells, which is highly crowded with suspended organic nanoparticles (proteins), with nanoscale interstitial water between and within these particles occur. Given this similarity, our inorganic RNA synthesis approach is consistent with the conservative nature of evolution in overcoming the water paradox, and can thus be considered a prebiotically plausible pathway in the transition from geochemistry to biochemistry during chemical evolution.

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Unravelling Oxygen's Origins and its Implications for ROS and Astrobiology

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Abstract

This presentation discusses the availability of oxygen for biological processes prior to the Great Oxygenation Event (GOE) and its profound significance for understanding the evolution of mechanisms to mitigate reactive oxygen species (ROS) toxicity. Examining the sources of free oxygen preceding the GOE, we explore the intricate interplay between ROS dynamics, iron oxidation processes, and the emergence of oxygenic photosynthesis. These insights not only shed light on the evolutionary responses of early life forms to varying oxygen levels but also carry implications for astrobiology. Understanding ROS dynamics is crucial for astrobiologists as it provides insights into potential strategies employed by extraterrestrial life to cope with oxidative stress in diverse environments. Furthermore, the study of ROS is particularly relevant for elucidating the evolution of acidophilic microorganisms, which inhabit extreme environments on Earth and may serve as analogues for life on other planets.

Bottom-up Models: An Integrative Synthesis

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Abstract

Any model of the emergence of life requires a thorough understanding of the evolutionary processes that precede biology, both as a phenomenon and as a discipline. Biological processes can be studied as chemical reactions occurring at a molecular level, which are, in turn, governed by physical properties (1). As such, living systems are not only possible but also subject to the organizational patterns of the universe.

These functional connections provide insight into the behaviour of living matter and energy from an evolutionary perspective. This bottom-up approach to life's emergence is grounded in precursor physicochemical processes and provides a framework for answering the essential questions of what is the emergence of life by focusing on how it began. It also sets abiogenic processes beyond the constraints of specific chemical compositions.

This work reviews transversal phenomena such as thermodynamics and complexification systems to elaborate a model for the emergence of life in terms of properties. It considers the transition from the abiotic to the biotic world by examining the prebiotic and "protobiotic" phases and their implications for living organisms' metabolic, informational, and compartmental properties. The processes of complexification and entropy dissipation are framed within the RAF (Reflexively Autocatalytic Food-generated networks) theory and other CAF systems, such as GARD (Graded Autocatalysis Replication Domain), which correlate self-sustaining and autopoietic systems through reaction networks, given their emerging possibilities from various chemical substrates (2).

However, despite the effort to dissociate this model from the classical CHOPNS composition, this proposal remains linked to a geocentric hypothesis for the emergence of life. This is because the interactions between minerals and a liquid solvent at hot springs and hydrothermal vents—through interfaces, gradients, and fluxes (3)—appear unrivalled when supporting autocatalytic foundations. Therefore, this "model of models" may provide valuable insights for future space missions to rocky bodies, such as the icy moons of gas giants in our solar system.

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A Contingency-Driven Non-Biocentric Approach to Astrobiology

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Abstract

Astrobiology involves deciphering the origins of life using prebiotic chemistry and leveraging this knowledge to search for life beyond Earth. To date, most studies have been heavily biocentric, focusing on biomolecules as the essential building blocks of life, both terrestrial and extra-terrestrial. However, this approach has not yet yielded definitive results, highlighting the need for more innovative methods. Therefore, we propose a non-biocentric model viewed through the lens of contingency.

In this work, we incorporate contingency with alternative prebiotic molecules (while still using carbon

compounds) and diverse environmental conditions that might give rise to life on and off Earth. Our aim is to expand the search for extra-terrestrial life beyond traditional biocentric paradigms.

Astrobiological potential of the Silcretes of the Makgadikgadi pan (Botswana): Implication for the search of life on Mars

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Abstract

The Makgadikgadi Basin of central Botswana hosts one of the largest salt lakes (pans) system on Earth. These pans are characterized by strong evaporation rate, high salinity and pH and high UV radiation. For this reason, they are considered “extreme environments” and analogues to playa environments on Mars. Playa environments on Mars, such as Meridiani Planum, present layered sedimentary deposits and hydrated minerals and opaline silica. These Martian deposits, for their direct link with liquid water, became targets for ongoing and future astrobiological missions. Silcretes of the Makgadikgadi pans contain a significant amount of hydrated silica. This has made them very useful to test both theories of past aqueous environments and potential for life on Mars.

Here the focus is on the role of microbial organisms (e.g. extremophiles) in the precipitation of minerals within the silcretes. Silcretes in the pans, has opal as primary cement. Most of the silcretes are quartzarenites and/or quarzitic breccias cemented by a complex paragenesis of quartz and calcite. Lithoclasts of flint, sand-sized quartz grains and ostracods are cemented by microcrystalline quartz (brown opal) and pore-filling spatic (coarse crystals) quartz cement. The fractures and larger pore space are filled by spherulitic chalcedony: fibrous microcrystalline quartz with botryoidal habit and characteristic wavy-extinction. SEM-EDX analysis revealed the presence of putative microbial fossils such as microspherules and filaments; but Raman spectroscopy didn’t reveal any organic compound from the silica cements cementing the silcretes

These silcretes are formed through direct precipitation of silica from groundwater within the pan system. The complex paragenesis reflects fluctuation in the pH and water chemistry. The data sets in this work suggests that early precipitation of silica may not be directly linked to the presence of communities of extremophiles, e.g. cyanobacteria. Microorganisms were passively involved in the formation of the silcretes. Playa and/or evaporitic environments that once hosted water and rocks (silcretes) containing hydrated minerals (e.g. opaline silica) could have provided a niche to microbial life. It is therefore suggested that the Makgadikgadi Pan Silcretes represent a viable analogue for the study of Mars past habitability.

DAY 3: Friday 1st November, 2024

Engineering RNA viruses based on the modulation of local RNA structures

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Abstract

RNA viruses may teach us about the RNA world and the origine of life as they encode complex functions in their RNA structures. In my talk, I will present a multidisciplinary pipeline for re-designing RNA viruses for various objectives such as vaccination and cancer therapy. In addition, I will report some of the products generated by the pipeline. The pipeline is based, among others, on the modulation of local mRNA structures in the viruses based on computational models.

Four stages of the metabolism emergence stimulated by high-frequency oscillations in hydrothermal environment

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Abstract

One of approaches the metabolism emergence in prebiotic microsystems is proposed within the framework of thermodynamic inversion concept (TI concept) [1]. The two key provisions of the concept are the following: 1) a tendency to concentration of free energy and information, observed during the biosphere evolution developed during the period of living systems origin, when in prebiotic microsystems there appeared surplus free energy and information (in relation to entropy) due to thermodynamic transformation (inversion); 2) the transition from nonliving to primary living systems took place in an oscillatory mode, through periodic strengthening and weakening of the emerging life processes. Primary populations of the simplest microorganisms were formed under fluctuating conditions of an ascending hydrothermal flow in the near-surface areas of the Earth crust. The oscillatory nature of vital activity in populations of microorganisms and its dependence on the environmental conditions, traced through the entire evolution of the biosphere, gives us an opportunity to reconstruct the formation stages of metabolism at the start of evolutionary processes. Vital activity fluctuations in modern populations of microorganisms are represented in their ability of transition to a passive anabiotic state under adverse conditions, with a return to active existence upon the onset of favorable conditions. The stages of microbial populations transition from active existence to suspended animation and back are universal, and they have been well studied experimentally. The TI approach substantiates the thesis that the succession of processes microbial populations undergo while getting out from suspended animation, in general inherits the succession of processes that took place during the organic microsystems initial transition to primary forms of life [2,3]. Based on this approach, the metabolism formation in the initial prebiotic microsystems occurred during four stages.

- *The first stage*: self-assembly of prebiotic microsystems. Initial organic (prebiotic) microsystems involved in the process of formation of primary life forms were multicomponent. They had a lipid membrane, probably with incorporated amino acids. According to the TI concept, self-assembly of microsystems proceeded in an oscillatory mode. ATP and sugars were probably absent at this because of a high temperature in the medium (>100ºC).
- *The second stage: formation of protocells.* There appeared a weak energy-giving process of respiration in the microsystems, which facilitated concentrating free energy in them. Acceleration of the movement of lipids in membrane structures, associated with an increase in their fluidity. Appearance of supra-entropic information (the contribution of information became prevalent over the contribution of informational entropy), related with the ability of the forming protocells for active (intensified) response to oscillating conditions in the environment.
- *The third stage: formation of living subcells.* During this stage, ions of K+ and Na+ entered into the evolving subcells. Watering of the cytoplasm and loss of thermal stability enhanced. Simultaneously with the increase in the energy function of the membrane, the level of reactive oxygen species much increased, for the neutralization of which a non-enzymatic antioxidant system of the subcell formed. At the same time, the foundation of the primary structure of the protein-synthesizing apparatus of the subcell took place, but the matrix synthesis of protein macromolecules was still absent.
- *The fourth stage (growth): emergence of primary living cells (progenotes).* During this stage, the formation of the growth cell cycle took place, which led to the appearance of the first living vegetative cells, as constituent elements of the primary populations. The acid-base reactions of phosphates associated with the transfer of protons began to dominate in energy conversion processes and led to the widespread use of ADP and ATP. At this time, the genetic apparatus of the cell began to form as its informational basis. The targeted synthesis of enzymatic proteins that followed ensured active cell metabolism.

So, the proposed scheme of the metabolism emergence one briefly summarize as follows: Stage 1 - unlife; Stages 2 and 3 - protolife; Stages 4 – life (as we know it).

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Crystallization as Circe-effect in prebiotic polymerization processes

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Abstract

Crystallization serves as an effective method for gathering molecules into a highly organized solid structure. Our previous research[1, 2] suggests that this process may also have a crucial role in the prebiotic formation of the earliest oligonucleotide sequences, because in the absence of enzymes and templates it could stabilize nucleotide monomers in reactive configurations. In the first part of my presentation, I will demonstrate how crystallization can facilitate the sequestration and polymerization of cyclic nucleotides from an acidic prebiotic brine that contains all four standard nucleobases found in RNA.[3] In the second part, I will show that an acidic prebiotic pool containing phosphate can support the co-crystallization of amino acids with phosphoric acid. The crystalline salts formed through this process enable a polymerization chemistry that occurs under significantly milder conditions compared to any prior studies of phosphoric acid-catalyzed polymerization reactions.[4,5,6] Additionally, we will explore the effectiveness of polymerization processes in crystalline salts created by amino acids in conjunction with other strong inorganic acids, referencing available crystallographic data from the literature.

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Stellar wind contribution to origin and transport of water on the surface of oxygen-containing minerals

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Abstract

Liquid water covers more than 70% of the Earth's surface and likely more water is present in the Earth's interior. Contrary to the Earth's surface, where hydrogen is mainly present as H2O molecules, "water" in Earth's interior corresponds to hydrogen incorporated in minerals, magmas, and fluids. The origin of water and volatile compounds on Earth and other planets is a hotly debated topic in planetary science, with many dynamic models suggesting that the majority of Earth's water and volatile elements were added later from an external source. The volatile source is believed to have shared a common parent population with carbonaceous chondrite

meteorites, which contain up to 10 wt.% H2O. Recent studies suggest that also enstatite chondrites may contain significant amounts of water.

The stellar wind irradiation of rocky oxygen containing minerals results in a reaction between H ions and silicate minerals to produce water and OH, which could explain the presence of water in the regoliths of airless worlds such as the Moon, as well as the water abundances in asteroids. Here we used the method of High-resolution Infrared Fourier Transform spectroscopy and temperature programmed desorption with mass detection to understand the mechanism of water formation on the surfaces of oxygen-bearing minerals.

We tested 14 different mineral and natural samples and observed the formation of water on their surfaces upon exposure to H+ or D+ irradiation. The adsorbed water remains on the surface at pressure as low as 10−9 mbar (TPD experiment) and temperatures as high as 600 K, which suggests a possible transfer long distances and timescales in the Universe.

Based on our relatively simple and time-limited experiments, we obtained the lower bound amount of water which can be formed on the studied minerals. Even then, the minerals can adsorb between 0.09 and 0.7 % of water. To explain the presence of one ocean equivalent of water on Earth, this process would require 1019−1020 kg of delivered mass, which is somewhat comparable to the 1020 kg of material delivered during the Late heavy bombardment.

The Evolution of Organic Material on Carbonaceous Asteroids

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Abstract

Recent asteroid sample return missions went on among the longest round trips in space exploration, returning to Earth the highest amounts of extraterrestrial material from any previously unsampled planetary bodies. The *Hayabusa-2* mission [1] was first in carbonaceous asteroid sample return on its ~ 4.5 billion km journey, retrieving ~5 g of sub mm- to cm- sized fragments of Asteroid 162173 Ryugu (Ryugu hereon in). Two sites were sampled by touch-and-go (TAG) on the equator of Ryugu, the first from regolith and the second at crater material ejected at lower depths by a ballistic. Samples from both TAG sites on the equator of Ryugu are of the most hydrated and organic-rich carbonaceous chondrite (CC) composition – CI (Ivuna type). Hydrothermal alteration pervades them, lacking any distinct primary components from the solar nebular, and consisting mainly of water derived, secondary minerals including phyllosilicate, (Fe, Ni) sulphides, Fe-oxides, carbonates and phosphates. CI chondrites are however among the least abundant CC group in Earth's meteorite record. That said, Ryugu's CI composition does not seem unique to this asteroid. More recently in September 2023, the *OSIRIS REx* [2] spacecraft returned samples from Asteroid 101955 Bennu (Bennu hereon in). Hundreds of grams were curated from the sample return capsule (the aim of the mission was 50 g) from a region north of Bennu by TAG. Preliminary results show Bennu to be dark CI material very similar to Ryugu.

Samples of Ryugu and Bennu provide the first insight into early Solar System prebiotic evolution from known planetary bodies. The major phase in them is phyllosilicate - interlayered saponite and serpentine. This phyllosilicate surrounds micron to submicron macromolecular organic particles known as insoluble organic matter. We have been coordinating focused ion beam-scanning electron microscopy tomography with scanning transmission X-ray microscopy and transmission electron microscopy on Hayabusa-2 samples to characterise the morphology, functional chemistry and distribution of organic material (OM) *in situ*. We find that a wider-spread diffuse organic component is preserved within the phyllosilicate, more aliphatic-, carboxylic-rich, and aromatic-poor than the organic particles. This diffuse OM is likely a mixture of acid insoluble and water/organic soluble molecules. Carboxyl/aromatic ratios in the diffuse organic matter of Ryugu are characteristic of CI and the most altered CCs, indicating the role of aqueous alteration in its formation. Some organic particles additionally formed to completely surround phyllosilicate itself, meaning that the soluble organic bearing diffuse organic matter is contained within some of the macromolecular organic particles by aqueous alteration on Ryugu. This means that the action water and organics from the early Solar System led to the formation of micron-sized polymeric organic objects encapsulating biologically relevant molecules in phyllosilicate that were delivered more frequently to early Earth, and less so today [3].

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Catalytic reactions promoted by meteorite reactive minerals under the presence of water in the early Earth: pathway towards organic complexity

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Abstract

We have demonstrated the role of some accretionary minerals, particularly sulphides and metal grains, hosted by chondritic meteorites in the catalysis of complex organics under the presence of water and formamide [1-2]. The delivery of water and organics from undifferentiated chondrites gains strength as these primordial meteorites can also contain the clues to promote organic complexity, not only on Earth, but just on planetary bodies subjected to strong fluxes of chondritic materials.

This talk explains our current knowledge on this matter, presents a scenario where the delivery of chondritic materials to the Earth is quantified and suggests future laboratory work. I also describe the progress made recently in some parallel areas of research, including the adsorption of neutral and charged sulphur-bearing species on the surface of silicate grains, common in protoplanetary disks [4]. Some S-containing organic molecules have being envisioned of key interest, and discovered in Ryugu [5].

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Design of Synthetic Insoluble Organic Matter (IOM) Samples via a Systems Chemistry Approach: Towards Disentangling Spectroscopic Features of Planetary Soils and Meteorites

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Abstract

The search for evidence of past or present life on other planetary bodies, such as Mars, remains a focal point of astrobiological research (Frances Westall et al., 2015). A promising avenue for investigation lies in studying insoluble organic matter (IOM) found in primitive meteorites, offering potential insights into the emergence of life in extraterrestrial environments (Marco d'Ischia et al., 2021). Carbonaceous chondrites, a type of primitive meteorite, contain a significant amount of IOM, around 70% (C.M.O'D. Alexander et al., 2017), in addition to soluble organic matter (SOM). Comprising a complex mixture of organic compounds resistant to chemical degradation, IOM may retain crucial information about its origin. The presence of IOM-like compounds on Mars could suggest similar processes of organic matter formation and preservation, potentially furnishing evidence for the emergence of life. However, distinguishing between the abiotic and biotic origins of IOM-like compounds presents a challenge, as they can arise from both biological and non-biological processes (Victor Abrahamsson & Isik Kanik, 2022). Assessing biogenicity requires consideration of factors such as distribution, abundance, molecular composition, and association with potential biosignatures. This research aims to address

the challenge of distinguishing between abiotic and biotic origins of IOM-like compounds by investigating the synthetic production of IOM and its implications as a biosignature for the emergence of life. The experimental focus is on synthesizing IOM samples with diverse compositions using a systems chemistry approach. This approach involves controlling and manipulating chemical reactions and conditions to replicate natural processes that could lead to the formation of IOM-like compounds. The synthesized samples will undergo thorough characterization using various spectroscopic techniques, including infrared spectroscopy, Raman spectroscopy, and mass spectrometry. These techniques will provide detailed insights into the molecular structure and composition of the synthetic IOM samples. Subsequently, the collected spectroscopic data will be analyzed to identify potential biosignatures associated with the synthetic IOM. This analysis includes comparing the spectroscopic features of the synthetic samples with those of known biological and non-biological origins, as well as assessing their relevance in extraterrestrial contexts. The primary goal is to use this information to search for and interpret similar spectroscopic features on celestial bodies, such as Mars, to infer the presence of organic compounds and potentially the emergence of life.

The importance of comet nuclei size and the potential for internal liquid flow

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Abstract

In a recent study (Malamud et al., 2022) we found that for cometary nuclei with a pebble structure, an extremely low thermal conductivity can give rise to enhanced radiogenic heating, in turn leading to higher temperatures within the nucleus than previously considered. For sufficiently large comets, this can even lead to water melting, leading to the instantaneous collapse of the pebble structure, inducing subsequent serpentinization chemical reactions which act as an additional internal heat source, and may potentially generate complex organic molecules that could be important for life. We predict that any form of differentiation in the comet nucleus is primarily a function of its size, and that the degree of differentiation (of hypervolatiles) even before melting temperatures are reached, correlates with size. In more recent work (Robinson et al., 2024) we created a database of comet observations at different wavelengths to look for correlation between comet nucleus sizes and their composition. We found for the first time that such a correlation exists, with high statistical significance, for carbon monoxide, lending support to the hypothesis that comets are not pristine relics of the Solar system

Astrobiology: resolution of the statistical Drake equation by Maccone's lognormal method in 50 steps

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Abstract

The authors use the mathematical tool of Maccone's lognormal distribution to further factor the Drake equation, which calculates the number of advanced civilizations in the galaxy, from the seven original levels of the Drake equation to 49 levels of overall analysis. The Maccone approach, in fact, supported by the central limit theorem, becomes more reliable the more levels are introduced. The resulting study necessarily draws upon an array of disciplines ranging from astronomy, chemistry and geology to biology, palaeontology and futurology. The final result calculates the number of planetary systems suitable for life in its various stages of development: those which have probably hosted life in the past and those which still host it at its various evolutionary levels. The final evolutionary level is the so-called galactic civilization (often called ETC, or extraterrestrial civilizations). The number of resulting galactic civilizations is divided between static civilizations, which do not move around the galaxy and whose Kardašëv rating is still low (<1.4), of which we find three examples (we ourselves plus, perhaps, two others), and potentially dynamic civilizations, which move around the galaxy and have a sufficiently high Kardašëv rating (≥1.4), of which we find 2000

Did minerals surfaces and meteorite components act as prebiotic catalysts for chemical evolution increasing molecular complexity toward the origin of life?

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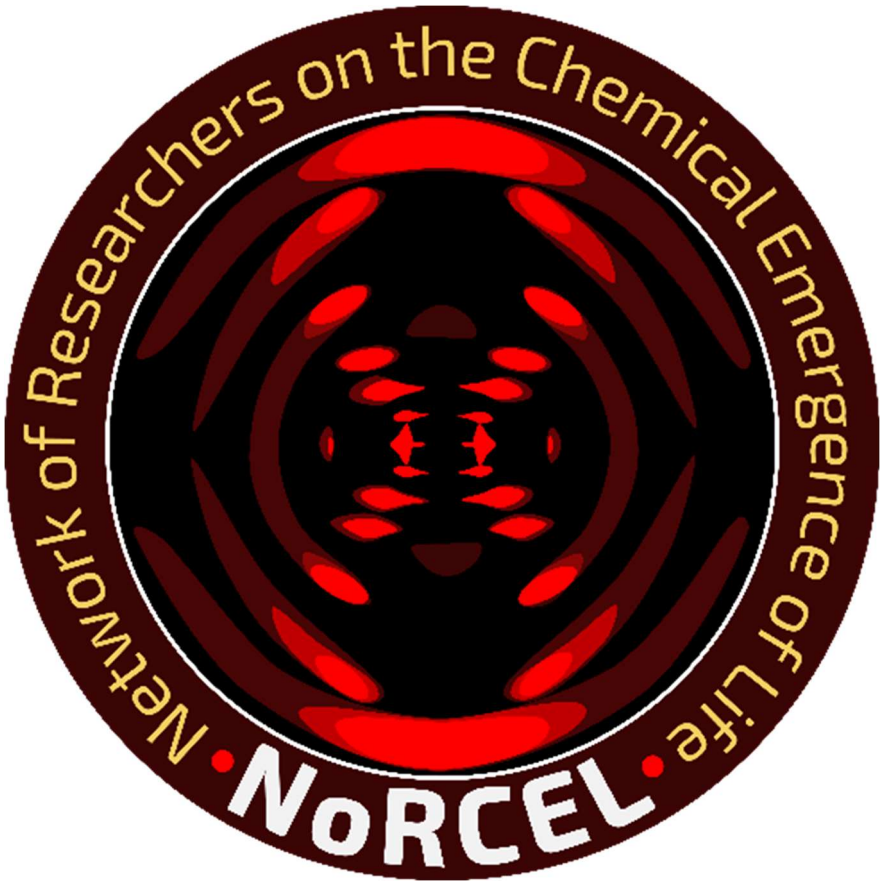
Abstract

It has already been known that both meteorite fragments and terrestrial minerals displayed iron catalyze inorganic and organic reactions leading to production of metalorganic entities (M4 material) which are able to perform catalytic activities typical of the contemporary life forms. While these properties indicate that these might be examples of prebiotic catalysts, complexity of their structures, chemical composition, the production of pigments with the light absorbing properties similar to carotenoids opening up possibilities that they might represent a kind of nonconventional form of pre-terrestrial life.