

We are here

VIRTUAL 5th NoRCEL Conference How did it all begin...?

29-31 MARCH 2021

LUCAs

ONLINE EVENT

Transitional LUCAs

Prebiotic Chemistry

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www.norcel.net

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VIRTUAL 5th NoRCEL CONFERENCE: ABSTRACTS LIST

Martin Dominik, President, University St Andrews, UK Elias Chatzitheodoridis, CEO, National Technical University of Athens, Greece Sohan Jheeta, Editor-in-Chief at NoRCEL, UK Oleg Kotsyurbenko, CEO, Yugra State University, Russia Rowena Ball, Scientific Officer, Australian National University, Australia Pauli Laine, Secretary, University of Jyväskylä, Finland Ammar Sakaji, Regional Centre for Sp. Sci. Tech. Edu. for Western Asia, Jordan Sávio Torres de Farias, Federal University of Paraíba, Brazil Golden Nyambuya, National University of Science and Technology Zimbabwe Vinod Gupta, CMD Postgraduate College, Bilaspur, India Prospery Simpemba, Copperbelt University, Zambia Rabeea Rasheed, University of Management and Technology, Pakistan Priscilla Muheki, Mbarara Uni of Sci and Tech, Mbarara Uganda Ahya Rezaei, Bou Ali Sina University, Hamedan, Iran Kathy McGrath, Network Administrator, UK

NoRCEL – a distinctive network

Dr Sohan Jheeta, independent research scientist and free thinker, is an avid promoter and supporter of science for everyone..., as he believes that, by and large, an educated society is generally a more stable one. It is for this reason that he founded the Network of Researchers on the Chemical Evolution of Life (NoRCEL https://norcel.net).

He organised the first conference at *The Open University* in Milton Keynes, UK, in 2013 and set it up to run as a biennial event. As the network continues to grow and develop, Dr Jheeta remains as Chairman and has appointed an international committee, with Dr Martin Dominik (University of St Andrews) as President and Professor Elias Chatzitheodoridis (National Technical University of Athens) as Chief Executive Officer.

NoRCEL is growing from strength to strength, thanks to extensive promotion and profile-raising and it is hoped that our conferences and subsequent networking and collaborative efforts will help it gain its rightful place amongst global scientific communities.

Dr Jheeta has formulated a culture which, above all, makes NoRCEL unique.

The uniqueness of NoRCEL

- 1. Live conferences will not run for longer than 3 days;
- 2. Ordinary speakers are allocated 30 mins including Q&A;
- 3. Keynote speakers are allocated 45 mins including Q&A;
- 4. There will be no parallel sessions;
- 5. A maximum of 40 oral presentations per conference;
- 6. Abstracts will be chosen on the basis of the quality of the science and not on the standing of any individual or their affiliations;
- 7. Proactive efforts will be made to encourage and invite scientists who are not necessarily involved in the origin of life (eg cancer specialists, medical virologists, palaeontologists virologist, etc);
- 8. Students will be allowed equal opportunity in terms of selection of presentations; and
- 9. A report of the conference will be generated and subsequently published.

What's on the horizon?

Future spin-offs (as headed by Sohan Jheeta) being proposed include:

- 1. **NoRCEL Blue Earth Project**: this will focus on various ground-breaking environmental issues, such as the crisis of over-population and water shortage, as well as species extinction due to irresponsible human activities etc; and
- 2. **NoRCEL Science Education Institute**: to promulgate and foster innovative educational concepts amongst developing nations.

Sohan Jheeta HND, BSc, MSc, PhD MInstP, MRSC, FRMS, FRSB Website: <u>www.sohanjheeta.com</u> Founder and Chairman of NoRCEL – scientific network Founder and Chairman of Frontiers of Sciences – science in society network E-i-C at <u>www.norcel.net</u>

Conference Time Plan

Please, consider the following:

- **UTC Time:** *Universal Time Coordinated /* Universal Coordinated Time / Zulu Time. It is based on the International Atomic Time (TAI). This is a successor of *Greenwich Mean Time* (GMT), that applies to the 0° (Prime Meridian) longitude. This time is an international reference/standard time and <u>does not change with the change of the seasons</u>.
- We made an effort to estimate your local start time of your talk, and we give it in parentheses under the UTC time of your talk. Please, in any case, especially if you change country, check the indicated local time according to the UTC time. The UTC time should be the time referred to for any activity of this conference. Seasonal changes might affect each time zone or country differently, and these are taking place around the date the conference begins, so please do check.
- You can convert UTC Time to your local time by visiting the website: <u>https://www.timeanddate.com</u>
- There are 30-minute keynote speeches and 20-minute regular talks. Both include 5 minutes of questionss
- During all designated "breaks", we encourage you to participate in informal small-group interactions on the Wonder platform, which will also be used for the "reception". We have created a NoRCEL "room", in which you can walk around and form discussion circles with others (just like in a real room), accessible via https://www.wonder.me/r?id=0a635ec1-d6e1-4f63-a3ce-84d9f9200cfd. Please note that you should use the Chrome or Edge browser on a laptop/desktop device (not mobile or tablet).
- To view updates on the work programme, and links to the updated version of this document (Book of Abstracts) please visit: <u>https://norcel.net/norcel21-programme/</u>
- To view information about the two tools we use to create our e-rooms, that is the ZOOM platform and the WONDER platform, please visit: <u>https://norcel.net/venuenorcel21/</u>
- To look for detailed instructions on how to use ZOOM, please check at: https://norcel.net/zoom instructions/
- Other information about NoRCEL will be visible under <u>https://norcel.net</u> which is the new, under development, website of the network and your resource to everything related to NoRCEL.

DAY 1 Monday, 29th March 2021

REGISTRATION 08:00 - 08:20 UTC

OPENING REMARKS 08:20 — 08:30 UTC: Sohan Jheeta

| Talk Number | Talk UTC Time (Estimated Local Time) | Speaker |
|----------------------|---|---|
| | | Session chair: Sohan Jheeta |
| 1 (30 min) | 08:30 – 09:00 (17:30) | TONY Z JIA Liquid Crystal Peptide/DNA Coacervates and Other Membraneless Compartments in the Context of Prebiotic Molecular Evolution |
| 2 | 09:00 – 09:20 (19:00) | VLADIMIR KOMPANICHENKO Role of periodic stress in the process of life emergence |
| 3 | 09:20 – 09:40 (17:20) | STYLIANOS MAGROGKIKAS LactoPS (Lactobacillus-based Pathogen Sensors): A rapid and cost-effective bacterial-based system for SARS-COV2 testing |
| 4 | 09:40 – 10:00 (11:40) | MICHAEL RUSSELL Life's four billion year journey began with a single step |
| | | |
| | | BREAK (1 hour) 10:00 – 11:00 UTC Time |

| Session chair: Sohan Jheeta | | |
|-----------------------------|---------------------------------|---|
| 5 (30 min) | 11:00 – 11:30 (13:00) | JOSEP M TRIGO-RODRIGUEZ The catalytic properties of chondritic meteorites and their role in the origin of life in Nitrogen- and water-rich environments |
| 6 | 11:30 – 11:50 (14:30) | DORON LANCET Reproducing catalytic micelles as early nanoscopic protocells harboring dynamic lipid aptamers |
| 7 | 11:50 – 12:10 (13:50) | POLINA YAKOVLEVA Prokaryotic communities of East Antarctic oasis soils and their resistance to antibiotics and heavy metals |
| 8 | 12:10 – 12:30 (14:10) | MARTIN FERUS Prebiotic synthesis initiated in formaldehyde and hydrogen cyanide by laser plasma simulating high-velocity impacts |
| | | |
| | | BREAK (1 hour) 12:30 – 13:30 UTC Time |

| Session chair: Martin Dominik | | | |
|---------------------------------------|---------------------------------|---|--|
| 9 | 13:30 – 13:50 (15:30) | NORCEL Update (Martin Dominik) | |
| 10 | 13:50 – 14:10 (14:50) | MARTIN DOMINIK NorCEL GapMap — an unreview of universal biology | |
| 11 | 14:10 – 14:30 (16:10) | GOLDEN GADZIRAYI NYAMBUYA Resolution of the Faint Young Sun Paradox via the Expanding Earth and Radiation Balance Equilibrium Hypothesis | |
| 12 (30 min) | 14:30 – 15:00 (11:30) | SAVIO de TORRES FARIAS Transfer tRNA: The molecular demiurge in the origin of biological systems | |
| BREAK (1 hour) 15:00 – 16:00 UTC Time | | | |
| Session chair: Martin Dominik | | | |

| 13 (30 min) | 16:00 – 16:30 (9:00) | BRUCE DAMER The Hot Spring Hypothesis for the Origin of Life: New Experimental Approaches and Results |
|-----------------------|--------------------------------|--|
| 14 | 16:30 – 16:50 (9:30) | HELEN HANSMA Where was the potassium, [K+]? |
| 15 (20 min) | 16:50 – 17:20 | JORGE VAGO |
| (30 min) | (18:50) | why is Oxia Planum the right landing site for ExoMars 2022? |

| Introduction by Elias Chatzitheodoridis | | |
|---|-----------------------|------------|
| PUBLIC TALK | 18:30 – 19:30 (20:30) | JORGE VAGO |
| Searching for Signs of Life on Mars | | |
| with the ExoMars Rover | | |

DAY 2 Tuesday, 30th March 2021

| Talk | Talk UTC Time | |
|----------------|------------------|---|
| Number | (Estimated Local | Speaker |
| | Time) | |
| | | Session chair: Ahya Rezei |
| | 07:30 - 08:00 | |
| (30 min) | (10:30) | Reliable encoding of information on the genomes of living organisms |
| 2 | 08.00 - 08.20 | SHINJI KAKASAWA Chamical evolutions in membranes formed on the surface of water on the early |
| 2 | (17·00) | Farth |
| | (17.00) | SANDEEP AMETA |
| 3 | 08:20 - 08:40 | Compositional identity and robustness of compartmentalized self-reproducing |
| _ | (13:50) | catalytic RNAs |
| - | | BALANAGULU BUSUPALLI |
| 4 | 08:40 - 09:00 | Asymmetric membrane scission in polymer vesicles induced via osmotic pressure |
| | (14:10) | difference |
| | | |
| | | |
| | | BREAK (1 hour) 09:00 – 19:00 UTC Time |
| | | |
| | | |
| | | Session chair: Pauli Lane |
| 5 | 10:00 - 10:30 | ADDY PROSS |
| (30 min) | (13:00) | Chemistry's New Kinetic Dimension and the Origin of Life |
| 6 | 10:30 - 10:50 | BEPPE BATTAGLIA |
| | (11:30) | Minimal conditions for making a vesicle chemotaxis |
| 7 | 10:50 - 11:10 | |
| | (13:50) | What are the first mutations that began Evolution on the Earth? |
| 8 | (13.10) | CLAUDIO MACCONE Molecular Clock as an Evo-SETLL ognormal Stochastic Process |
| | (15.10) | |
| | | |
| | | BRFAK (1 hour) 11:30 – 12:30 UTC Time |
| | | |
| | | |
| | | Session chair: Vinod Gupta |
| | 12.20 12.50 | OLEG KOTSYURBENKO |
| 9 | 12:30 - 12:50 | The hypothetical microbial community of Venusian clouds can inhabit an |
| | (14.50) | ecological niche with a structure in the form of water foam |
| 10 | 12:50 - 13:10 | DANIELE DONDI |
| | (14:50) | Are the natural amino acids the most stable among their isomers? |
| 11 | 13:10 - 13:30 | SAIBAL MITRA |
| 42 | (15:10) | Urigin of life via a violation of local thermodynamic equilibrium |
| 12 (20 min) | 13:30 - 14:00 | DIKK SCHULZE-MAKUCH Some Ideas about Riediversity of Alien Life on other Planetary Redics |
| | (15:30) | Some rueas about biourversity of Allen Life off other Planetary Boules |
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Virtual 5th NoRCEL Conference

| | | BREAK (1 hour) 14:00 – 15:00 UTC Time | |
|----------|---------------------------------------|---|--|
| | | | |
| | Session chair: Savio de Torres Farias | | |
| 13 | 15:00 - 15:30 | DAVID HOLMES | |
| (30 min) | (08:00) | Biosignature Gases for Life Detection on Exoplanets | |
| 14 | 15:30 - 16:00 | DAVID LILLEY | |
| (30 min) | (16:30) | Glimpsing ancient ribozymes from modern RNA species | |
| 45 | 16:00 - 16:20 | DANIEL BOICE | |
| 15 | (10:00) | Cometary Phosphorus | |

RECEPTION 16:20 – 18:00 UTC Time

| Introduction by Sohan Jheeta | | | |
|---|-----------------------|------------------|--|
| PUBLIC TALK | 18:30 – 19:30 (14:30) | LOWELL GUSTAFSON | |
| The Origins of Life within Big History: | | | |
| Meanings for Humanity | | | |

DAY 3 Wednesday, 31st March 2021

| Talk Number | Talk UTC Time (Estimated Local Time) | Speaker |
|----------------------|---|---|
| | | Session chair: Oleg Kotsyurbenko |
| 1 (30 min) | 11:30 – 12:00 (13:30) | FRANK TRIXLER Natural Nanofluidic Environments as Prebiotic Reaction Vessels: Abiotic RNA formation in temporal nanoconfined water |
| 2 (30 min) | 12:00 – 12:30 (20:00) | KUHAN CHANDRU The possible role of non-biomolecules in the Origins of Life |
| 3 | 12:30 – 12:50 (14:30) | OLIVER HERBORT From clouds to crust - stability of water in the crust and clouds |
| 4 | 12:50 – 13:10 (14:50) | PATRICK BARTH Understanding the role of lightning in the formation of organic molecules on early Earth |
| | | |
| | | BREAK (1 hour) 10:00 – 11:00 UTC Time |
| | | |

| Session chair: Oleg Kotsyurbenko | | | |
|----------------------------------|---------------------------------|---|--|
| 5 | 14:10 - 14:40 | JUNTIAN WU | |
| (30 min) | (16:10) | Exploring replication fidelity in a synthetic self-replication system | |
| 6 (30 min) | 14:40 – 15:10 (19:10) | AHYA REZAEI What we can learn from Remote Sensing in Agriculture as applied to life elsewhere in the Universe | |
| 7 | 15:10 – 15:30 (18:10) | MARGARITA KRIUCHKOVA Soil fungal communities as the objects of astrobiological research | |
| 8 | 15:30 – 15:50 (16:30) | NorCEL GapMap (Martin Dominik) | |
| | (10.30) | | |

BREAK (1 hour) 12:30 – 13:30 UTC Time

| Session chair: Elias Chatzitheodoridis | | | |
|--|---------------------------------|--|--|
| 9 (30 min) | 16:50 – 17:20 (18:50) | MARA LAGUNA-CASTRO Viruses as analogues of first self-replicating molecules in Early Earth and other planets: life adaptation to extreme environmental conditions | |
| 10 | 17:20 – 17:40 (19:20) | ROSANNA del GAUDIO From molecular simplicity to biological complexity: seeking plausible geochemical scenarios and necessary ingredients to kick-start early stages of life on Earth and on Earth-like planets | |
| 11 | 17:40 – 18:00 (10:40) | RAZVAN COJOCARU A Clamping Domain Facilitates Processivity and Promoter Recognition in an RNA | |

| | | Polymerase Ribozyme |
|-----------------------|---------------------------------|--|
| 12 (30 min) | 18:00 – 18:30 (12:00) | GUSTAVO CAETANO-ANOLLES Untangling the evolution of biological systems: Phylogenomics and the evolutionary rise of hierarchy and community structure in biological networks |
| | | |
| | | BREAK (1 hour) 15:00 – 16:00 UTC Time |
| | | |
| | | Session chair: Elias Chatzitheodoridis |
| 13 | 19:00 – 19:20 (12:00) | SAUL VILLAFANE-BARAJAS Role of serpentinite in HCN-polymerization: molecular complexity under alkaline scenarios |
| 14 | 19:20 – 19:50 | NICK NIELSEN |
| (30 min) | (12:20) | Many Branches on the Tree of Life? |
| | | |
| | CLOSE-OUT: Martin D | ominik, Elias Chatzitheodoridis, Sohan Jheeta 19:50 – 20:10 UTC |

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Abstracts

Sandeep AMETA^{*,1}, Manoj KUMAR¹, Dhanush GANDAVADI¹, Prashanth SHANKAR¹, Nayan CHAKRABORTY¹, Shashi THUTUPALLI^{*,1}

Compositional identity and robustness of compartmentalized selfreproducing catalytic RNAs

¹Simons Centre for the Study of Living Machines, National Centre for Biological Sciences, Tata Institute of Fundamental Research (TIFR), 560065-Bangalore, India

Robust and dynamic compartmentalized self-replicating chemistries are an important step in understanding the emergence of life. Here, we demonstrate the encapsulation of a self-reproducing RNA system in coacervate droplets (compartments) where catalytic RNAs are synthesized from the autocatalytic assembly of smaller RNA fragments.

We observe rate enhancement of the self-assembly process in the condense compartment phase. Further, we demonstrate that cross-catalytic autocatalytic networks of RNA self-reproducers can be constructed, establishing a unique chemical compositional identity of the compartment. Not only the compatibility with network formation, but coacervate compartments also provide compositional robustness against perturbation by other RNA catalysts.

Recently, these autocatalytic reaction networks have been shown to possess critical properties required for Darwinian evolution to occur. Combining them with dynamic compartments that are transient in nature, phase-separated systems have the potential to provide temporal and spatial protection to self-reproducing RNAs from other competing catalytic RNAs

Rowena BALL

Anomalous thermal fluctuation distribution favours primordial chemical evolution

Australian National University, Canberra 2601, Australia

In this talk I shall report on open-flow simulations of non-enzymic proto-metabolic systems, where hydrogen peroxide acts both as oxidant and driver of thermal cycling. Results show that a Gaussian perturbed input produces a non-Gaussian output fluctuation distribution around the mean oscillation maximum. This means that, in order to support proto-metabolism, nonenzymic biosynthesis and chemical evolution. stochastic media must sustain non-steady, or dynamical activity that can produce a right-weighted spectrum of thermal fluctuations, which on average

supports high activation energy biosynthetic reactions over low activation energy degradation reactions.

It is likely that such anomalous fluctuation frequency distributions are reflected from transient non-Boltzmann populations of internal quantized modes of the liquid medium. Thus, these results also provide constraints on the types of media in which chemical evolution is likely to occur. Postulates that extraterrestrial life may be found in seas of liquid hydrocarbons, such as on Titan, are limited by the low specific heat of such media. At the other end, the high specific heat of fresh water may preclude it as a medium for chemical evolution. The dissolved salts in seawater and the presence of hydrogen peroxide may bring the specific heat into the conducive "goldilocks" range

<u>Patrick BARTH</u>^{1,2,3}, Eva E. STÜEKEN^{1,2}, Christiane HELLING^{1,3,4}, Paul B. RIMMER^{5,6,7}, Mark W. CLAIRE^{1,2}

Understanding the role of lightning in the formation of organic molecules on early Earth

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⁵ Department of Earth Sciences, University of Cambridge, Downing St, Cambridge CB2 3EQ, UK

⁶ Cavendish Astrophysics, JJ Thomson Ave, Cambridge CB3 0HE, UK

⁷ MRC Laboratory of Molecular Biology, Francis Crick Ave, Cambridge CB2 0QH, UK

In the 1950s, Stanley Miller and Harold Urey proved in their famous experiment that an electric discharge in an abiotic atmosphere of CH_4 , H_2 , NH_3 , and H_2O can lead to the formation of amino acids [1]. Even though the Earth's primordial atmosphere is expected to have been neutral or oxidizing rather than reducing [2], this experiment shows the important role of lightning as an energy source in the formation of prebiotic molecules. Subsequent work has shown that in an N_2 dominated atmosphere, lightning can initiate abiotic nitrogen fixation through the formation of nitrate (NO_3) and nitrite (NO_2) [3].

These forms of nitrogen could not only have facilitated the origin of life but also sustained the early biosphere. So far, however, this hypothesis has been difficult to test with the available rock record, because geochemical fingerprints of this nitrogen source have not been developed. We are carrying out spark discharge experiments in varying atmospheric compositions corresponding to different points in time of Earth's evolution. We study how the production of nitrate and nitrite depends on the O_2/N_2 and CO_2/N_2 -ratio in the gas phase. Furthermore, we investigate the effect of lightning on the isotopic composition of nitrogen in the produced nitrate. We find that the isotopic fractionation between N_2 gas and aqueous nitrate depends on atmospheric composition and on

other parameters of the experiment such as the electric field strength. By comparison to the sedimentary nitrogen isotope record from the Archean Earth our results allow us to assess for the first time to what degree the origin and early evolution of life may have been influenced by lightning chemistry.

Ultimately, it will not be possible to reproduce all parameters of the Archean environment in an experiment. Therefore, computer simulations are necessary to extrapolate the experimental results to full-scale planetary atmospheres. We use the 1D atmospheric photochemistry and diffusion code ARGO coupled to the chemical network STAND2019 [4-6] to simulate the atmospheric chemistry of exoplanets and the Earth. We study the effect of different high-energy processes, such as X-ray and UV radiation, cosmic rays, and stellar energetic particles on the (prebiotic) chemistry of the atmosphere. Currently, we are developing a model to simulate a lightning strike in a planetary atmosphere and plan to benchmark this model with the measurements from our spark experiments.

[1] Miller (1953), Science 117, 528

- [2] Kasting & Catling (2003), Annual Review of Astronomy and Astrophysics 41, 429
- [3] Cavendish (1788), Philosophical Transactions of the Royal Society of London 78, 261

[4] Rimmer & Helling (2016), ApJS 224, 9

[5] Rimmer & Helling (2019), ApJS 245, 20

[6] Rimmer & Rugheimer (2019), Icarus 329, 124

Beppe BATTAGLIA

Minimal conditions for making a vesicle chemotaxis

University College London, UK

The movement of cells and microorganisms in response to chemical gradients (chemotaxis) has played an essential role in the evolution of many biological processes. Cellular navigation works via the holistic assembly of numerous components into machinery that transforms chemical energy into locomotion. Herein we present and discuss the minimal number of elements required for celllike vesicles to be chemotactic. We show that lipid vesicles can propel in response to chemical gradients when only a transmembrane protein and an encapsulated enzyme are incorporated into the vesicle structure. The herein proposed model serves as a proof of concept to show that even the simplest structured cell can experience chemotactic navigation.

Daniel BOICE¹ and Amaury A. de ALMEIDA²

Cometary Phosphorus

¹Scientific Studies & Consulting, San Antonio, TX, USA.

²Dept of Astronomy, University of São Paulo, Brazil.

Phosphorus is a key element in all living organisms but its role in life's origin is not well understood. Molecules bearing phosphorus have been observed in the interstellar medium and other regions of space. They are prevalent in meteorites in small quantities, and have been detected in the dust component in comets 1P/Halley and 81P/Wild 2 and in the gas phase (atomic P and PO) in comet 67P/Churyumov-Gerasimenko by ESA's Rosetta Mission.

A reactive gas dynamics model of cometary comae (SUISEI) has been adapted to study this problem. Results of this first quantitative study of P-bearing molecules in cometary comae show reaction pathways of gas-phase and photolytic chemistry for simple P-bearing molecules likely to be found in comets and important for prebiotic chemistry. The aim is to aid in future searches for this important element in comets and likely phosphorus-bearing, prebiotic species. Since comets may have delivered prebiotic material to the early Earth, this work may shed light on issues of comet formation and understanding prebiotic to biotic evolution of life. Acknowledgments: This work was supported by FAPESP under Grant No. 2015/03176-8 and the National Science Foundation Planetary Astronomy Program Grant No. 0908529.

Bob BRUNER – EXHIBIT

Meteorites and Minerals associated with the Origin of Life

Denver Museum of Nature and Science, Denver, Colorado 80205, USA

Below is the latest version of my exhibit which has been shown at 22 international conferences since 2014. From left to right and top to bottom I will identify each meteorite or mineral and its role in the Origin of Life four billion years ago. This is based on the latest research through January 2021.

- 1. The brown specimen is an enstatite meteorite which could have supplied all of Earth's water (Piani)
- 2. The silver specimen is the Tambo Quemado meteorite which contains schreibersite (phosphorus) Pasek
- 3. The black specimen is the Aquas Zarcas meteorite which contains organic molecules (Glavin)
- 4. The green specimen is tourmaline from Benner's life originated on Mars theory (2013)
- 5. The white specimen is colemanite from Benner's life originated on Mars theory (2013)
- 6. The red specimen is wulfenite from Benner's life originated on Mars theory (2013)
- 7. The large white specimen is chert from Westall's silica gel theory (2017)
- 8. The blue specimen is opaline silica from Deamer's wet-dry cycles pool theory (2016)

- 9. The plastic packet contains clay from Cairns-Smith and Ferris clay scaffold theories (1970's)
- 10. The white specimen is magnesite from Horgan's study of Jezero Crater onMars (notOOL)
- 11. The green specimen is serpentine from Russell's white smoker theory (2000's)
- 12. The brown and white specimen is geyserite from Campbell's hot springs theory (2016)
- 13. The green specimen is olivene from Russell's white smoker theory (2000's)
- 14. The gold specimen is iron pyrite from Wachtershauser's black smoker theory (1988)
- 15. The tiny black specimen is the Black Beauty (NWA 7034) meteorite containing CHNOPS and parts of Mars surface from four billion years ago Agee (2012)
- 16. The red specimen is pumice from Brasier's pumice raft theory (2011)

This exhibit is 16 specimens, reduced from the 23 at the Perseverance website. The five specimens which should be near biosignatures on Mars are chert, serpentine, clay, opaline silica, and magnesite.

Balanagulu BUSUPALLI

Asymmetric membrane scission in polymer vesicles induced via osmotic pressure difference

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Armin Weiss previously postulated that it could be possible to devise certain layered material systems that can grow and divide akin to natural living systems. Prof. Armin Weiss's work on soluble silicate layers though had never been reproduced since, to say frankly, it inspired me to get heavily interested in the origins of life research. And, that inspiration led me towards obtaining a postdoc position in Harvard University's Origins of Life Initiative after my PhD in Physical Chemistry. One of the major scientific questions that confront humanity is whether life exists beyond Earth, which is again a consequence of the most fundamental question: How life originated on the Earth? The overarching goal of my research in my lab is "to achieve artificial life in the lab".

Approaches to achieve the same involve thorough phenomenological studies through soft materials such as polymer and lipid vesicles/membranes and also via inorganic membranes. Experimental physical chemistry knowledge and techniques would be applied in devising experiments to detect and measure physical properties like area stretch/bending moduli etc., in the artificial/synthetic cells and relate such properties to molecular scale lipid/polymer dynamics in these synthetic cells. Advanced spectroscopic and microscopic techniques would be employed. Also, polymersomes based on polybutadiene were employed to study these phenomena. Polybutadiene based amphiphilic block copolymer polymersomes are spherical hollow structures that are soft in nature but tougher/rigid than liposomes. Polymersomes or polymer vesicles are employed in delivery systems and also as chemical reactors at the micro–scale. Recent renewed interests in origin of life research has rendered these polymersomes as the best suitable mimics of the natural cells owing to their mechanical properties dictated by their area stretch moduli and/or bending moduli numbers.

Life is generally characterized by a set of basic physical properties such as self-replication, information transfer, metabolism and evolution. The most interesting feature of life is selfreplication where the parent natural cell divides itself into two daughter natural cells. Though liposomes are widely studied and regarded as suitable analogues to study and replicate several phenomena occurring in natural cells, polymersomes because of their relatively higher rigid character than the liposomes are considered to be much more efficient in realizing the said basic physical properties. In this study, several polymersomes prepared from polybutadiene based diblock copolymers were studied for their self-replication characteristic which is central to mimicking life in the lab (artificial life). Some examples of the polymersomes employed based on polybutadiene are: PB46-b-PEO30, PB33-b-PEO29 etc. Based on the amphiphilic chain lengths and also based on the individual chain lengths of the hydrophilic and hydrophobic constituents of the amphiphiles the time taken for self-replication to occur in these different polymersomes varies leading to some useful insights. Polybutadiene based diblock copolymers were selected as these are relatively softer than their counterparts such as polystyrene based ones but are tougher than liposomes. In conclusion, polybutadiene based polymersomes were shown to be undergoing selfreplication under the influence of osmotic pressure gradients akin to natural cells but much needs to be understood by further experimentation.

Gustavo CAETANO-ANOLLES

Untangling the evolution of biological systems: Phylogenomics and the evolutionary rise of hierarchy and community structure in biological networks

Evolutionary Bioinformatics, Department of Crop Sciences and C.R. Woese Institute for Genomic Biology, University of Illinois, Urbana, Illinois, IL 61801, USA

The evolution of structure in biology is driven by accretion and change. Accretion brings together disparate parts to form bigger wholes. Change provides opportunities for growth and innovation. Networks can describe how parts associate in wholes. Here I review patterns and processes that are responsible for a 'double tale' of evolutionary accretion in the structure of biological networks. Parts are at first weakly linked and associate variously. As they diversify, they compete with each other and are selected for performance. The emerging interactions constrain their structure and associations. This causes parts to self-organize into modules with tight linkage.

In a second phase, variants of the modules evolve and become new parts for a new generative cycle of higher-level organization. Evolutionary genomics and network biology support the 'double tale' of structural module creation and validate an evolutionary principle of maximum abundance that drives the gain and loss of modules. Examples of network evolution at various levels of complexity and different timescales (nanosecond to billions of years) include the emergence of metabolic networks, the rise and diversification of the proteome, and the evolution of the ribosomal RNA scaffold that supports protein biosynthesis. Remarkably, the phylogenomic data-driven double tale of evolutionary accretion was already recounted in P. Strasb. Gr. Inv. 1665-6, a ~2,000-year-old papyrus roll from the ancient city of Panopolis in Upper Egypt archived at the University of Strasbourg National Library.

Kuhan CHANDRU

The possible role of non-biomolecules in the Origins of Life

Space Science Centre (ANGKASA), Institute of Climate Change, Research Complex, Universiti Kebangsaan Selangor, Malaysia

Prebiotic Chemistry is essentially "messy chemistry". Most Origins of Life (OOL) research focuses on known prebiotically available biomolecules to show how biopolymers or self-assembly can happen in a preferred prebiotic setting. While this was useful, there are still many non-biological compounds in prebiotic chemistry that may have aided chemical evolution. Here we show how various non-biological prebiotic compounds can form polymers under mild wet-drying conditions via a simple condensation reaction, ring-opening polymerisation and exchange reactions. We will also present a hypothesis on how non-biological compounds, from a messy chemical system, may have triggered and scaffolded the OoL that went on to become life-as-we-know-it.

Razvan COJOCARU and Peter J. UNRAU

A Clamping Domain Facilitates Processivity and Promoter Recognition in an RNA Polymerase Ribozyme

Department of Molecular Biology and Biochemistry, Simon Fraser University, Burnaby, BC, Canada

The "RNA World" proposes that early in evolution RNA could have served both as the carrier of genetic information and as a catalyst. Later in evolution, these RNA functions were gradually replaced by DNA and enzymatic proteins. Arguably, the greatest limitation to exploring this hypothesis is the lack of a true RNA replicase: a processive, trans-acting RNA dependent RNA polymerase ribozyme capable of mediating general replication of RNA. Derived from the Class I ligase ribozyme, we have selected a processive polymerase ribozyme with an RNA clamp domain that mimics many of the mechanisms of modern protein DNA-dependent polymerases.

The selected ribozyme has the following features: 1. The polymerase clamp domain forms an "open" complex when activated with a sigma-like RNA. 2. This "open" complex then searches for a specific RNA promoter. When found, the sigma-like RNA is displaced from the clamp onto the template, triggering a structural rearrangement to a "closed" complex entrained on the RNA template. 3. The displaced sigma-like RNA now serves as a primer, allowing the clamped polymerase to extend a broad range of templates in a processive fashion. This Clamping

Polymerase (CP) ribozyme was isolated from a high diversity pool using a range of new in vitro selective strategies. The CP ribozyme has two distinct predicted secondary structures that suggest how the polymerase first binds a sigma-like RNA to find a promoter and then in a second step associates with an RNA template via the formation of a topological clamp.

As an additional feature, this polymerase can synthesize part of its own sigma-like RNA when in the "open" form. This allows part of the polymerase sequence to be encoded into the RNA promoter motif, providing a mechanism early in the evolution of life for a molecular sense of 'self' to rapidly evolve. The CP ribozyme demonstrates how the important concepts of promoter recognition, processive polymerization, and self-recognition could have rapidly evolved in a primordial "RNA World".

Bruce DAMER

The Hot Spring Hypothesis for the Origin of Life: New Experimental Approaches and Results

University of California at Santa Cruz, Department of Biomolecular Engineering, Santa Cruz CA, USA

A scenario for an origin of life in a hot spring setting has undergone significant experimental testing over the past decade (Damer and Deamer, 2015, 2020). Laboratory and field studies demonstrated that RNA-like polymers can be synthesized nonenzymatically from their monomers by cycles of hydration and dehydration (Rajamani et al., 2008). Cycling conditions simulate fluctuating fresh water hot spring pools in hydrothermal fields associated with volcanic land masses. Recent investigations of the 3.48Ga Dresser Formation in Western Australia discovered geyserite bedded with well-preserved stromatolites (Djokic et al., 2017), suggesting that some of the earliest evidence for life is consistent with thriving microbial populations in fresh water hot springs on land rather than solely in salty marine conditions.

Computational studies used thermodynamic and kinetic analysis to confirm that phosphodiester bonds can form spontaneously (Ross and Deamer, 2016). The free energy is made available by evaporation that concentrates and polymerizes monomers in thin films on mineral surfaces. The polymers become encapsulated by budding of lipid vesicles during rehydration cycles. The resulting protocells can be subjected to combinatorial selection which promotes the emergence of increasingly functional polymer sets. The collaboration that is investigating the hot spring hypothesis (HSH) has developed a number of new directions and the following proposals will be presented: 1. Membrane-bound polymer sets are models of prebiotic protocells; 2. Aggregates of protocells represent a primitive version of a progenote, defined as a self-assembled niche that supports chemical networks, growth and adaptation; 3. A hierarchy of reaction networks can emerge spontaneously as protocell populations respond to environmental stresses. Each of these proposals carries predictions and can inform future experimental testing.

Rosanna del GAUDIO

From molecular simplicity to biological complexity: seeking plausible geochemical scenarios and necessary ingredients to kick-start early stages of life on Earth and on Earth-like planets

Department of Biology, University of Naples Federico II, Naples, Italy

The origin of life and its possible existence, past or present, on our planet and the likelihood of finding life elsewhere in the Universe are both fascinating and incredibly complex questions that remains enigmatic. They are subjects of great scientific and general interest and one of the main objectives of space research with a lot of ideas and models, diverse competing theories or debates.

Despite knowing approximately when life first appeared on Earth, scientists are still far from answering how it appeared. Today, not only there is no consensus yet on how life might have started on Earth, but also there is not even any agreement on where it started. The hypotheses proposed are:

- life was brought to Earth from outer space by meteorites
- life started around hydrothermal vents on the ocean floor
- life originated in shallow volcanic/sulfuric rock pools
- life first appeared on the clay surfaced ocean shores exposed to tidal wet-dry cycles
- life came into being at sub-freezing temperatures on a snowball Earth

There are also other several competing theories and hypotheses, some even say life might have arisen on Earth more than once, and since it is hard to prove or disprove them no fully accepted exists. Here I'll discuss essential requirement for the first emergence of life on Earth and Earth-like planets reaction might be a primitive form of reaction network supporting abiogenic development of life on Earth or elsewhere in the Universe. The results obtained so far could point a Following the bottom-up approach, utilizing as a model for the emergence and early evolution of life on Earth, the self-organizing M4 material obtained from meteorites and terrestrial rocks and minerals this work puts forward an evolutionary scenario that satisfies the known constraints by proposing that life on Earth emerged, powered by solar radiation, non- enzymatic, photochemical and self-sustaining way towards understanding how Earth kick-started metabolism probably responsible for the emergence of a large pre-biotic pool of molecules from landmass that arose from Archean oceans or Carbonate-rich lakes rather than in the depths near a deep sea hydrothermal vent.

The aim of this work is also to present and discuss results of recent and ongoing wet-lab and in silico-lab experiments supporting the Multiple Root Genesis hypothesis (MuRoGe) already proposed seeking approaches surrounding the mysterious primordial step of life emerging on Earth and on planets around distant stars. This is in addition to the hypothesis that microbial or early forms of life were already present in our solar system at the time of Earth's formation so that panspermia and abiogenesis results not rival theories but two complementary theories.

Martin DOMINIK

The NoRCEL gap map – an unreview of universal biology

University of St Andrews, UK

Scientists can be characterised by being aware of the limitations of human knowledge, and clarity on these serves our progress as we further explore and transcend current boundaries. Unlike a review that discusses what we know, the NoRCEL gap map aims at being a community effort for identifying and discussing what we don't know about universal biology. As an evolving document, it will also serve as a valuable instrument for fostering the NoRCEL community by revealing shared interests and connections across a wide range of diverse expertise, while encouraging thinking beyond disciplinary confines.

Daniele DONDI

Are the natural amino acids the most stable among their isomers?

University of Pavia, Italy

Natural amino acids are fundamental for life's origin. Some of them can be found in meteorites and they can also be easily produced by simple chemical reactions. It is a common assumption that they are the thermodynamically most stable compounds among their isomers. In order to test that, we calculated more than 100'000 isomers. The results will be presented in the talk.

Martin FERUS

Prebiotic synthesis initiated in formaldehyde and hydrogen cyanide by laser plasma simulating high-velocity impacts

Institute of Biophysics of the Czech Academy of Sciences

It is well known that hydrogen cyanide and formamide can universally be considered as key molecules in prebiotic synthesis. Despite the fact that formamide has been detected in interplanetary and interstellar environments, other prebiotic species are far more abundant, including, for example, formaldehyde. We report on a wide exploration of the formaldehyde and hydrogen cyanide reaction network under plasma conditions mimicking an asteroid descent in an Earth-like atmosphere and its impact. Dielectric breakdown using a high-power kJ-class laser system (PALS – Prague Asterix Laser System) along with quantum mechanical, ab initio molecular dynamics, and enhanced sampling simulations have been employed in order to mimic an asteroid impact plasma.

We show that plasma reprocessing of formaldehyde or hydrogen cyanide leads to the formation of several radical and molecular species along with formamide. All the canonical nucleobases, the simplest amino acid (i.e., glycine), and the sugar ribose, have been detected after treatment of formaldehyde and nitrogen gas with dielectric breakdown.

Our results, supported by quantum mechanical and enhanced sampling simulations, show that formaldehyde – by producing inter alia formamide – may have had the role of starting substance in prebiotic synthesis. In contrast, hydrogen cyanide chemistry does not involve synthesis of formamide and represents an independent high energy way for one pot synthesis of all the canonical nucleobases.

Golden GADZIRAYI NYAMBUYA

Resolution of the Faint Young Sun Paradox via the Expanding Earth and Radiation Balance Equilibrium Hypothesis

National University of Science and Technology, Bulawayo, Zimbabwe

We present a plausible solution to the now forty-seven-year-old paleoclimatology riddle of the socalled Faint Young Sun Paradox via the combined hypothesis of the conservation of the state of radiation balance between the Earth and Sun and that of an expanding Earth, where, in the face of a changing (increasing) Solar luminosity, the Earth would maintain steady temperatures by readjusting the height of its atmosphere. That is to say, depending on whether or not the radius of the solid Earth is changing, this re-adjustment of the height of the Earth's atmosphere would mean two things — i.e.: (1) either the height increases — in which event the Earth accretes matter from its immediate surroundings (i.e., the obvious pool formed by the Solar wind) thereby increasing the mass of the Earth's atmosphere, or: (2) the height decreases — in which event the Earth naturally expels matter from its atmosphere, thereby decreasing the effective mass of the Earth.

We demonstrate that if—as the current state of the art ITRF observations seem to indicate, namely that—the Earth's landmass is steadily expanding globally at a paltry rate of $\sim+0.45\pm0.05$ mm yr⁻¹, and, that the Earth's atmosphere is to have a present radial vertical height of about one third of the Earth's radius (\sim 2860km) from the Earth's surface, then, one can (might) with relative ease, explain not only the presence of liquid water on the Earth's surface some $\sim3.20\pm0.70$ Gyr ago during the Archaean eon when the Sun was about 75% of its current luminosity, but also the present radial expansion rate of the Earth. When all is said and done, the Earth system is herein cast as an auto-self-regulating incubator where the auto-self-regulating mechanism is as a result of the Earth's atmosphere responding by automatically re-adjusting its height.

Lowell GUSTAFSON

The Origins of Life within Big History: Meanings for Humanity

Villanova University, Villanova, Pennsylvania, USA

The origins of life present paradoxical meanings for humanity. 1) It is one of the central parts of big history that describes a series of common origins and it is one of the origins that begins a process of enormous diversification. Out of many chemicals comes one cell and then many life forms. 2) The origins of life required bringing together elements and chemicals in enormously complex relationships; this is part of the big history account of increasing complexity. A process of increasing complexity runs from the big bang to the relationships of billions of people within a contemporary digital culture. However, this increasing complexity is by far the exception rather than the rule. Most carbon is not directly part of life forms.

The idea of global, human relationships – of being a citizen of the world – resonates with only some people at best. Given the second law of thermodynamics, we expect increasing disorder; increasing complexity requires increases in availability of energy. Not becoming more complex, or even becoming less complex, is far more common. 3) So far, we have evidence of life originating only once, on Earth, and yet given that the universe is homogenous and isotropic, and we have evidence of thousands of other habitable planets just within our local area of the Milky Way, it must be commonplace throughout the universe. 4) The coming together of sets of relationships produces tenacious life that has persisted for some 3.8 billion years. Yet, some people also perceive how fragile it is, depending on so much for it to continue. Most seem rather unconcerned.

Paradoxical Meanings of Origins of Life Common origins Diversification Complex, sustained relationships More common to remain unrelated Life unique to Earth? A marvel that it happened at all

Expectation of it being commonplace To be expected Tenacity of relationships Fragility of life Initial Discussion of the Themes

In this presentation, I will draw out the paradoxical meaning for humanity from the scientifically verifiable facts about the origin of life. This is part of the effort made by some in big history regarding how to understand our place on Earth and in the universe. The International Big History Association defines big history as "the integrated history of the Cosmos, Earth, Life, and Humanity, using the best available empirical evidence and scholarly methods." The origin of life is one of the key thresholds or transitions that are commonly listed in works on big history, or the scientifically based narrative of the major steps between the big bang and humanity. (e.g. Brown, Chaisson, Christian, Spier). Since the Miller-Urey experiment in 1952, there has been significant advances in understanding how chemical evolution led to and combined membranes, metabolism,

and reproduction in response to the environment. Still, there is not yet consensus on exactly how this occurred some 3.8 billion years ago, much less a replication of the process in a modern laboratory. Big historians who do not hold their degrees in the field of biochemistry look with interest to the accessible work of those who are in that field in order to keep big histories up to date and accurate. I will argue in my presentation that there is a paradoxical meaning in big history for humanity. The first is that it is an account of common origins. The entire known universe began in a single big bang, as far as we know.

On Earth, it appears that all currently existing life forms have descended from a single origin of life; and so far, we have evidence of life only on Earth. Some 3.8 billion years later, a small band of homo sapiens in East Africa seem to have been the common ancestors for all currently living humans. In this regard, we have a scientific basis for our common ground, perhaps even our common good. We often seek an evidence-based reason for unity. On the other hand, after the big bang, there has been such an expansion that our universe perhaps is some 93 billion light years across, although we can only see as far as 13.8 light years from us. Huge numbers of galaxies have long since sped beyond our view. A common big bang goes along with the majority of existence expanding out of view. After the origins of life, an almost infinite variety of life forms developed, many having little to nothing to do with each other. What comfort it is to a antelope having common origins with a snarling lion is unclear. And human cultures have diverged significantly since our ancestors all lived in a small band in Africa; many of them oblivious or hostile to each other. We face evidence of r astounding diversity and ultimate heat death or separation. Exactly how life originated, it involved an incredibly complex series of relationships. The first prokaryote cell was the most complex set of relationships that we know of to the date of its origin in the universe. The theme of increasing complexity is important within big history; we see the development of quarks within protons and neutrons, atomic nuclei with electrons, elements within chemicals, biochemistry to life, increasingly complex life forms, ecosystems and social species, human kinship, villages, cities, nations, empires, and global systems. It is the story of how we got here. Yet, it is incredibly atypical. Vast hydrogen clouds from the big bang exist without any increase in complexity. Vast numbers of prokaryote cells exist today without themselves having become eukaryote cells or any more complex life forms.

Most people seem to exhibit little interest in being "citizens of the world," must less than of the universe. Increasing complexity is highly unlikely, yet here we are. The universe is homogenous and isotropic. Laws of physics work everywhere. We know now that there are great numbers of habitable planets in the local area of the Milky Way. Throughout the universe, there must be untold numbers of planets with the same chemicals and similar enough conditions to have experienced the origin of life. It must be commonplace. But as Enrico Fermi asked, "So where is everybody?" Not only have we found no evidence for intelligent life, we so far have not found evidence for any life beyond Earth at all. If we find evidence for microbial life on Mars from billions of years ago, we will be ecstatic. Is life a marvelous, one-time occurrence on Earth or is the Universe filled with it? If we find evidence of it having existed on Mars, should our response just be, "Well, of course."

In the United States, a major political issue is being "pro=life" or "pro-choice." In big history, it makes little sense to talk about the universe or Earth having been pro-life just because a complex process leading to the origin of life occurred. What we do see is a complex process of chemical evolution that led to life that is impressively tenacious. Life has not only marvellously originated, it has persisted through an oxidation event and now six great periods of extinction. At the same time, we are worried by how fragile life is; how it depends on a huge number of "Goldilocks" conditions to survive. Awareness of the complexity of what was required for life to have originated

– and survived – has led many to greater commitment to protecting it. A paradox is that even more people seem quite uncommitted to any such goal.

Helen HANSMA

Where was the potassium, [K+]?

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All living cells have high intracellular potassium concentrations, [K+]. How and when did this high [K+] appear? There are 2 choices: 1. The prebiotic environment was high in [K+] = "Early K+" 2. The prebiotic environment was not high in [K+], but protocells created a high intracellular [K+], from an environment that was not high in [K+] = "Late K+". There are problems with both options. "Late K+" has the problem of how such an elemental aspect of life could have arisen after other processes in the origins of life had begun. The high intracellular [K+] is now maintained by energetically expensive pumps such as the Na+/K+- ATPase. "Early K+" has the problem: where was the [K+]? It was not in seawater, which has 40x more Na+ than K+.

Two possibilities have been published: in geothermal fields [1], and between the sheets of mica or biotite in micaceous clay [2, 3]. Neither possibility is ideal. The geothermal fields are described as 'vapor-dominated,' and there is not convincing data about the excesses of K+ over Na+ in geothermal fields [1]. Mica has several advantages. Some of these are the following: Mica was present in the Hadean, and mica's anionic mineral sheets are held together by a hexagonal grid of K+ with a periodicity of 0.5 nm, which is also the spacing of phosphate groups in extended single-stranded nucleic acids, DNA and RNA. Most micaceous clay, however, appeared later on Earth. This question, "where was the K+?" is an elephant in the room of research on the origins of life.

[1] Mulkidjanian, A. Y., et al. (2012), Proc Natl Acad Sci U S A 109, E821-830.

- [2] Hansma, H. G. (2010), Journal of Theoretical Biology 266, 175-188.
- [3] Hansma, H. G. (2020), Preprints 2020090409.

Oliver HERBORT^{1,2,3}, Peter WOITKE^{1,2}, Christiane HELLING^{1,2,4}, Aubrey ZERKLE^{1,3}

From clouds to crust - stability of water in the crust and clouds

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One of the fundamental questions for planetary science is what surfaces of other planets similar to the rocky bodies in our Solar System look like. What is the rock structure like? Will there be water? Are there any active atmospheric cycles? How can these different conditions be detected? Does the detection of water vapour or water clouds already prove the existence of water on the surface of the planet? The current space missions and ground-based instruments allow the detection of specific gas species and some cloud compositions in atmospheres of giant exoplanets. With instruments installed in the near future and spacecraft currently being built or planned, these kinds of observations will be available for planets with smaller sizes and an overall rocky composition.

We aim to further understand the connection of the conditions of the upper atmosphere with the conditions on the crust of the planet (temperature, pressure, composition). Our equilibrium chemistry models allow us to investigate the expected crust and near-crust-atmosphere composition. With this, we investigate the conditions under which liquid water is stable at the surface of a planet and not incorporated in hydrated rocks.

Based on this crust - near-crust-atmosphere interaction we build an atmospheric model, which allows us to investigate what kind of clouds are stable and could be present in atmospheres of rocky exoplanets. This allows us to investigate the stability of various different cloud condensates, including water. The pressure level, at which water becomes stable in the atmosphere is dependent on the crust hydration. Independent on whether water is stable at the surface, it becomes stable at lower pressures in the atmosphere.

David HOLMES

Biosignature Gases for Life Detection on Exoplanets

Center for Bioinformatics and Genome Biology, Fundación Ciencia & Vida, Santiago, Chile

With the discovery of thousands of exoplanets, many of which reside within the habitable zone of their respective stars, it is urgent to develop remote techniques, such as biosignature gas detection, to help identify planets with potential for habitability and even to detect possible life on such planets. A biosignature gas is defined as one that is produced by life and accumulates in an atmosphere to detectable levels. Ideally, it should not be produced in significant quantities by abiotic processes and should be out of equilibrium with planetary geochemical processes. It also needs to have a spectroscopic signal that can be readily and uniquely identified by land- or space-

based telescopes. Among many candidate biosignature gases being considered, O2 is regarded as particularly useful with one caveat that will be discussed. Recently, phosphine (PH3) was identified in the clouds of Venus. It was suggested to be a biosignature gas as it was hypothesized to have had a biological rather than an abiotic origin. However, both the validity and interpretation of these results are being hotly debated.

The resulting inventory of the problems and pitfalls of using phosphine for life detection highlights the difficulty of identifying useful biosignature gases. However, the Venus phosphine controversy has called attention to several interesting and important lines of investigation regarding both the biological and abiotic sources of phosphine on Earth. It has reinvigorated discussion of the role of reduced forms of phosphorus (e.g. phosphite) during Earth's geochemical history, including their potential pivotal role in the transition from prebiotic to cell-based biochemistry (origin of life) in the Archean epoch. It has underscored our substantial lack of understanding of the biochemistry and genetics of phosphine production in anaerobic econiches on Earth, exposing major gaps in our knowledge of the biogeochemical cycling of phosphorus, including the under-appreciated involvement of phosphine in the cycle.

Advances in these areas will help define the usefulness of phosphine as a biosignature gas for life detection and will shed light on its potential as an indicator of the geophysical chemistry and history of exoplanets. By combining the detection of different biosignature gases, it may be possible to deduce the level of sophistication that life on a planet has attained, relying on the fact that different signatures signal alternative biochemical processes, e.g. anaerobic versus aerobic metabolisms

Shinji KARASAWA

Chemical evolutions in membranes formed on the surface of water on the early Earth

Professor emeritus, Miyagi National College of Technology, Japan

As the purpose of exploring the origins of life, we reveal the fundamentals of how organisms have evolved so complexly. The primitive Earth was covered with a thick atmosphere containing large amounts of H<2>O and CO<2>. The atmospheric molecules were collided with H<+> of solar wind at a speed of about 500 km/s. Today, the peak of the density of atomic hydrogen is at an altitude of 80 km, which must be supplied by the solar wind. Assuming the amount of H<+> emitted from the Sun is 10<9> kg/sec, and the ratio of the surface area of the sphere radius at the point of Earth's orbit to the cross section of the Earth is 1:2.2x10<9>, the amount of H<+> reaching Earth is 0.45 kg/sec (39.3 tons/day).

Hydrocarbons are produced from carbon ions which were ionized by the collision of solar wind to the primitive atmosphere. If the boiling point of the hydrocarbon is lower than the temperature of the surface, it evaporates and stays in the atmosphere and chemical reactions are continued. If the state of hydrocarbons is liquid, the molecules stay on the surface of the Earth and were accumulated. Hexadecan (C16H34: melting point 18°C boiling point 287°C) and Octadecane (C<18>H<38>: melting point 28-30°C boiling point 317°C) remained on the surface of the Earth and accumulated on the Earth's surface. Hexadecan or Octadecane is the main component of the

cell membranes of every living organism on Earth. The liquid hydrocarbons on the surface of the water are hydrophobic and are arranged on the surface of the water by interaction with hydrogen bonds created in a reticulated form by water molecules to form a membrane of intermolecular bonds.

Molecules in the atmosphere collide with molecules in water, resulting in a chemical reaction of combination of adjacent molecules by the irradiation of the Sun's light. Amino acids with amino and carboxyl group can be synthesized using a part of hydrocarbon molecules on the membrane as an R group. Protein molecules of filamentous molecules synthesized by the membrane can strengthen the structure of the membrane by sewing the membrane. The theory of the origin of life in Aleksandr Ivanovich Oparin (1894-1980) is supported by intermolecular bonds of water [1]. Bubbles surrounded by membrane tissue by intermolecular bonds are repeatedly formed by the mechanism of generating the membrane, and repair, metabolism, or primitive regeneration are carried out. The membrane has evolved by adding new molecules gained through experience to the next generation.

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Vladimir KOMPANICHENKO

Role of periodic stress in the process of life emergence

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In the course of numerous laboratory experiments on prebiotic chemical evolution, various models ("protocells" and more complex "artificial cells") were obtained, consisting of biologically important organic compounds (lipids, polynucleotide and polyamino acid chains, etc.). They are considered as precursors of living cells. However, they do not manifest self-sustaining biochemical processes that could be designated by the term "life". According to the author's approach, availability of prebiotic microsystems in the medium is one of the two main components for the emergence of life.

The second component is the obligatory "pumping" of microsystems by continuous oscillations of physicochemical parameters (including high-frequency diapason), which took place in a hydrothermal medium (Kompanichenko, 2017, 2019). As a response to high-frequency pumping, the induced extremely fast chemical reactions inevitably arise in the microsystems. Their speed can reach 10-10 second that is confirmed experimentally (Eigen, 1971). It was those reactions that contributed into the emergence of fantastically fast biochemical reactions during the emergence of life on the early Earth.

Thus, within the framework of the developed "inversion" approach, the emergence of life occurred through an active (intensified and purposeful) stress-response to the effects of environmental stress-factors, which occurred in the mode of high-frequency fluctuations of physicochemical parameters (temperature, pressure, concentrations of components, etc. etc.). It follows from it that even primary microorganisms and populations could exist in two states: a) passive (anabiotic), if the

"pressure" from the environment (the action of stress-factors) exceeded their ability to effectively counteract; b) active if their response to environmental stressors was enhanced and targeted.

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Soil fungal communities as the objects of astrobiological research

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The modeling of extraterrestrial environments is one of the ways to investigate the possibility of surviving of Earth-like life forms on different objects of the Solar System, for studying the potential ways of microbial adaptation and evolution under extreme conditions. The native microbial communities in extreme Earth environments which are similar in a number of physical and chemical parameters with some of the planets and small bodies of the Solar System can be considered as the objects for astrobiological research. Microorganisms and their communities in such habitats have the widest set of mechanisms for protection from the effects of stress factors.

Fungi are known as the most resistant eukaryotic organisms, pure strains can survive after the exposure to high doses of ionizing radiation up to 117 kGy³. The sustainability of fungal communities in natural substrates like soil to the impact of the extreme factors is higher, but now it is not studied enough.

The aim of this study was to analyze the response of fungal communities of desert soils to the physical impact simulated long-term (1-10 million years) presence in extraterrestrial (Mars and space) conditions.

Samples from the upper humic horizon of grey soil (Negev desert, Israel) and grey-brown soil (Moroccan mountain desert) were the objects of the present research. The samples were irradiated by high doses of gamma-radiation (0,1 and 1 MGy) and accelerated electrons (0,05; 1; 2; 3; 4; 5 MGy) at low temperature (-50°C; -130°C) and pressure (1 Torr; 8-9×10⁻³ Torr) in the climatic

chamber. Some samples were affected only by low temperature and pressure without radiation treatment.

For culturing of fungi the method of soil suspensions inoculation was applied using solid Czapek medium⁴ and alkaline agar¹. Soil suspensions were warmed before inoculation $(52^{\circ}C, 2 \text{ min})^2$. The fungi were cultivated at temperatures 5°C, 25°C, 37°C. The amount of fungal biomass in situ and its morphological structure were evaluated by the method of direct fluorescent microscopy with calcofluor white, ethidium bromide and acridine orange dyes⁴.

The exposure of soil samples to 0,1 MGy gamma-radiation activated fungal communities: the quantity of fungal propagules, biodiversity and fungal biomass increased. The exposure to 1 MGy gamma-radiation led to the elimination of many species. The most resistant species which dominated after the impact of extreme conditions were *Aspergillus fumigatus* and *A. niger*.

The influence of low temperature and pressure had no significant effect on the number of colony forming units (CFU). The impact of accelerated electrons at low temperature and pressure activated the germination of species with small spores but the total biodiversity decreased. Many colonies of yeast were observed after the irradiation with accelerated electrons at a dose of 1 and 2 MGy.

The obtained results testify to the possibility of prolonged survival of eukaryotic natural communities in conditions of Mars regolith, and also in the space environment inside of small bodies.

¹Bilanenko E.N., Georgieva M.L. Micromycetes of saline in South Siberia (Kulunda steppe) // Mycology and Phytopathology. 2005. V. 39. № 4. P. 6-13.

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³Selbmann L. et al. Resistance of an Antarctic cryptoendolithic black fungus to radiation gives new insights of astrobiological relevance // Fungal Biology. 2017. V. 122. № 6. P. 546-554.

⁴The methods of soil microbiology and biochemistry.: Schoolbook/ Edited by D.G. Zvyagintsev. M.: MSU, 1991. 304 p.

<u>M. LAGUNA-CASTRO</u>, M. ARRIBAS, E. LÁZARO

Viruses as analogues of first self-replicating molecules in Early Earth and other planets: life adaptation to extreme environmental conditions

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Viruses, understood as macro-assemblies with replicative capacity, can be really useful to unveil the origins of life in the early Earth and on other planets, as well as to clarify the molecular mechanisms that allows life adaptation to not ideal conditions.

 $Q\beta$ bacteriophage is a very simple RNA virus, which genome encodes three structural proteins and a very special replicase, highly specific and lacking of error correcting activity. This last feature

highly increases the mutation rate of the virus, so $Q\beta$ is able to generate a really large, mutants' rich progeny in each generation. This "mutant cloud" contains a huge amount of different genomes that offer the virus the chance to get quickly adapted to changing environmental conditions, "escaping" through the fitness landscape to a higher, better position according to these new conditions.

In our group, we carry out experimental evolution research using $Q\beta$ phage as an analog of first self-replicating molecules that developed themselves millions of years ago in our young planet. Forcing this phage to undergo extreme selective pressures of astrobiological interest, such as high or low temperature, not ideal pH conditions, low concentration of available hosts or UV radiation, we observe and characterize its response from several approaches.

Amit KAHANA, Doron LANCET

Reproducing catalytic micelles as early nanoscopic protocells harboring dynamic lipid aptamers

Weizmann Institute of Science, Israel

Protocells are often conceived as bilayer-ensheathed life precursors, whose self-reproduction necessitates the earlier emergence of replicating biopolymers with catalytic capacities. We have explored the alternative scenario, whereby nanoscopic lipid micelles with catalytic capabilities were forerunners of biopolymer-containing vesicles.

This postulate gains considerable support from extensive experimental literature on micellar catalysis and on autocatalytic proliferation of micelles. Augmented evidence resides in recent reports on mixed micelles, showing non-equilibrium steady-state homeostasis in a self-reproducing molecular ensemble. All of these life-like attributes reinforce the idea that catalytic micelles, just like ribozymes, are capable of both catalysis and self-copying, hence the term "lipozymes". Such entities could undergo compositional reproduction, driven by endogenous mutually catalytic networks, that propagate compositional information and are capable of primal selection and evolution. One of the recent activities in our laboratory addresses the question of how specific molecular recognition events can emerge on a fluid micellar surface. We discovered widespread reports on what is known as dynamic aptamers, the supramolecular analogs of selection-identified covalent oligomers with recognition functions.

There is substantial published evidence that just as catalytic dyads and triads underlie effective catalysis by protein enzymes with rigid folding, micelles are shown to harbor significant catalysis based on dynamic proximity and disposition of heterogeneous lipid headgroups on a micellar surface. We have also critically assessed the underpinnings of our chemically-rigorous computer-simulated GARD model for collectively autocatalytic sets. We now have a better explanation as to how the model's emergent chemical dynamics indeed predicts and strengthens the abovementioned origin of life implications of the mixed micelles experiments. One key observation in our recent GARD simulations is that molecular networks within micelles behave as dynamic attractors. This means that the transition from random composition to such capable of self-copying can be much faster than previously expected, suggesting rapid chemical prebiotic evolution.

To help fathom the paths for subsequent protocellular complexification en route to LUCA, we extend the GARD model, relying on experimental studies reporting how catalyzed lipid modifications could underlie both micelle to vesicle transition and monomer to biopolymer progression. Such graded progress takes place within a protocellular entity that continuously preserves the capacity for homeostatic reproduction. In other words, while complexity of individual molecules and of the protocell's composition gradually increases, this molecular ensemble preserves the essential property of catalysis-driven effective reproduction under selective pressures. Finally, we point out that unlike biopolymer-harboring vesicular protocells, micellar protocells can withstand high levels of exogenous chemical diversity and extreme environmental conditions, enhancing the realism of planet-scale micellar life emergence.

This could help bridge the gap between life's early initial steps, which may have involved highly resilient lipid assemblies, and the more delicate molecular structure of LUCA. Such argument further substantiates our proposed inference that protocellular evolution could have been seeded by chemically-simple lipid assemblies, which likely predated forms of early life that depended on RNA-based information transfer.

David LILLEY

Glimpsing ancient ribozymes from modern RNA species

CR-UK Nucleic Acid Structure Research Group, MSI/WTB complex, University of Dundee, UK.

It is probable that in the early development of life on this planet RNA would have acted both as a store of genetic information and as a catalyst. RNA has two key properties relevant to the latter. It can act as a chemical catalyst (ribozymes), and it can bind small molecules with great selectivity (riboswitches). A number of ribozymes are known in contemporary cells, accelerating reactions by a million-fold or more. However, these are largely confined to phosphoryl transfer reactions, whereas an RNA based metabolism would have required a much greater chemical diversity of catalysis, including relatively difficult reactions like carbon-carbon bond formation.

By comparison with proteins, RNA occupies a relatively small chemical space, but this could be significantly expanded with the use of coenzymes. Many coenzymes are based on nucleosides and can be traced back to LUCA. A number of these coenzymes are bound by riboswitches including SAM, FMN and TPP. Examination of the structures of a number of these riboswitches suggests how they might be converted to ribozymes, and indeed they could well have evolved from former ribozymes. Perhaps some such activities still exist in modern biology, and we can ask how we might seek such chemically diverse ribozymes.

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Claudio MACCONE

Molecular Clock as an Evo-SETI Lognormal Stochastic Process

Via Renato Martorelli 43 10155 Torino (TO), ITALY

Evo-SETI (Evolution and SETI) Theory is a mathematical model describing the evolution of life on Earth and Exoplanets by virtue of lognormal stochastic processes. These lognormal stochastic processes L(t) are a generalization of the Geometric Brownian Motion (GBM) used in the mathematics of finances (Black-Sholes models) in that, while the GBM mean is always assumed to be an exponential in the time, the mean of our L(t) may be either an exponential (i.e. a GBM again) or a polynomial in the time. In particular, we show that, if the mean of L(t) is just an increasing straight line in the time, then L(t) may be regarded as the stochastic-process generalization of the famous Molecular Clock well-known to biologists since 1962. In this paper we derive the mathematical properties of our "Molecular Clock Stochastic Process" for future use in biology, astrobiology, paleontology, and mores

Stylianos MAGROGKIKAS

LactoPS (Lactobacillus-based Pathogen Sensors): A rapid and costeffective bacterial-based system for SARS-COV2 testing

FALCONBIO PTE. Ltd. 32 Carpenter Street, SGINNOVATE, 059911, SINGAPORE

COVID19 has deteriorated the global economy and has resulted in 2.7 million deaths. Fast and accurate detection of the SARS-COV2 virus has contained the spread of the virus and protected risk groups from asymptomatic people in developed countries. Unlike developed countries, developing countries are unable to scale up the diagnostic quantitative PCR (qPCR) testing — the gold standard in SARS-COV2 detection, because qPCR machines are expensive. Therefore, a non-qPCR diagnostic kit is needed for developing countries.

Our Lactobacilli sense SARS-COV2 proteins and RNA with surface nanobodies and "toehold" RNA switches respectively. Our Lactobacilli compute their response with genetically encoded

"logic gates" and respond by expressing the Purple chromogenic protein. When the Purple chromogenic protein is expressed, our *Lactobacilli* become purple.

Genetically modified *Lactobacilli* can "scale" rapidly. Agar stabs can be used to deliver *Lactobacilli* in a short period of time and only a cost-effective incubator is needed to propagate the bacteria. Finally, our bacteria can be snap-frozen to allow the detection of viral RNA.

Saibal MITRA

Origin of life via a violation of local thermodynamic equilibrium

Independent researcher, Hoedekenskerke, The Netherlands

Most of the existing models of prebiotic chemistry assume local thermodynamic equilibrium (LTE). This means that while the considered system can be very far from thermodynamic equilibrium, the chemical processes at every point proceed under a well defined local temperature and chemical potentials. In this presentation, I argue that a violation of LTE is a necessary condition to get to biology starting from only simple molecules. I will present a model where large random organic molecules are forged under LTE-violating conditions via the percolation process. This involves chemical processes in interstellar ice grains due to UV irradiation and heating events.

Such models have been invoked as mechanisms to get to interesting biomolecules [1, 2, 3]. As shown in [4], a runaway percolation process can yield large random molecules spanning the ~0.1 micrometer size of the grains. Aggregates of such molecules would have been deposited on protoplanets in the early solar system, yielding organic structures containing large numbers of compartments connected via pores. The micro-environment inside these compartments is ideal for prebiotic chemistry: The concentration of organics is large, large polymers are present from the start, the presence of a finite number N of random organic molecules in a compartment will have broken symmetries such as chiral symmetry at a level of ~1/sqrt(N). The first self-replicating systems that can arise under favorable conditions will not have a precisely defined molecular structure.

Information that is reliably copied exists in the form of coarse-grained averages of molecular structures. The Eigen limit for the maximum amount of information that such systems can contain is much larger than for conventional prebiotic systems. The larger information capacity can allow the system to develop mechanisms to improve replication accuracy. The error rate for storing and copying information at smaller scales can then improve, allowing the information capacity to increase. This process invokes evolution via natural selection, but this can stall in simple systems. In the proposed model, due to the different chemistries in the different compartments, the exchange of molecules via pores connecting the compartments can affect the chemistry in each compartment in ways that without the exchanged molecules would have required too many unfavorable mutations.

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Nick NIELSEN

Many Branches on the Tree of Life?

Icarus Interstellar

The origin of life is a major threshold of emergent complexity, but is there is one and only one form of emergent complexity—life as we know it—that springs from this threshold, or might there be other forms of emergent complexity that are the peers of life, but which are not identical to life? The latter conception I call *emergent complexity pluralism*.

Peers to terrestrial life are best understood as descendants from their common ancestor of astrochemical precursors. Emergent complexity thresholds familiar to human beings that have followed after the origins of life on Earth—complex life, consciousness, intelligence, technology, civilization—may all represent opportunities for branching complexities that diverge indefinitely from life as we know it. New concepts may be necessary to understand peer emergent complexity on a cosmological scale, and new sciences may be necessary to study them.

Addy PROSS

Chemistry's New Kinetic Dimension and the Origin of Life

Department of Chemistry, Ben-Gurion University of the Negev, Be'er Sheva, Israel

The origin of life on Earth remains one of the most tantalizing scientific questions of all time. In this talk I will describe recent developments in systems chemistry which throw new light on this question. Recent studies on energy-fueled chemical systems have revealed that within the space of chemical potentiality there exists a largely unexplored kinetic dimension. That dimension contrasts with traditional chemistry which normally operates within the thermodynamic domain. The discovery of this new dimension has opened doors toward the preparation of active materials with biological-like functionality, as well as offering new chemical insights into the origin of life process. Light at the end of the origin of life tunnel? Maybe more than just a glimmer!

R. Pascal and A. Pross, Chemistry's kinetic dimension and the physical basis for life, *J. Systems Chem.* 2019, 7, 1.

Ahya REZAEI

What we can learn from Remote Sensing in Agriculture as applied to life elsewhere in the Universe

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Remote sensing means sensing things from distance. The measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study. Remote sensing occurs at a distance from the object or area of interest. Interestingly, there is no clear distinction about how great this distance should be. The intervening distance could be 1 cm, 1 m, 100 m, or more than 1 million m from the object or area of interest for example in the earth and environmental science especially in Precision Agriculture; Remote sensing and digital image processing techniques can also be used. Agriculture provides for the most basic needs of humankind: food and fiber. The unprecedented availability of high resolution (spatial, spectral, and temporal) satellite images has promoted the use of remote sensing in many precision agriculture applications, including crop monitoring, irrigation management, nutrient application, disease and pest management, and yield prediction. Monitoring crop growth and yield are necessary to understand the crop response to the environment and agronomic practices and develop effective management plans for fieldwork and/or remedies. Leaf Area Index and biomass are two essential indicators of crop health and development. LAI is also used as an input in many crop growth and yield forecasting models. Insitu methods of LAI estimation (physical and optical) are time-consuming and labor-intensive, similar to the destructive field methods used for biomass estimation. Also, these methods do not provide a spatial variability map of crop growth and biomass. Remote sensing data on crop growth (e.g., LAI) and biomass can help obtain valuable information on site-specific properties (e.g., soils, topography), management (e.g., water, nutrient, and other inputs), and various biotic and abiotic stressors (e.g., diseases, weeds, water, and nutrient stress). Similarly, remote sensing data can also be used to map differences in tillage and residue management and their effects on crop growth. Several studies have used hyperspectral images with various machine learning and classification techniques to map tillage and crop residue in agricultural fields. Such information on crop conditions can help to understand and trace plants that grow in difficult conditions on Earth in order to find the strongest plants and try to transfer them to Mars or Moon.

Michael RUSSELL¹ and Laura BARGE²

Life's four-billion-year journey began with a single step

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The first step to life was the formation of an active barrier separating the natural disequilibria on the early Earth between the basic interior and the relatively oxidized exterior [1]. Spontaneously precipitated minerals formed this barrier which allowed harvesting of Eh and pH gradients at a

submarine alkaline hydrothermal vent. Like all motors, life and proto-life had to be "plugged in". The earliest individual reproducers would have been activated by a flow of electrons and protons commensurate with that required of single cells today, i.e., $>10^{6}/sec/cell$ [2,3].

Experimental and theoretical emphasis to date has been given to life's early evolutionary steps, i.e., the synthesis and polymerization of amino and nucleic acids and their supposed assemblies driven by Lippman's notional pyrophosphate squiggle and/or dry/wet cycling [4,5]. But first, organic molecules had to be continuously synthesized from substrates available on the early Earth, and exponentially so. The naturally occurring substrates were H2, ē, CH4, HS–, CO2, H+, HPO4– and NO2– generated "in house", i.e., in the nanoconfined interlayers of the sulfides and oxyhydroxides comprising the barrier acting as a membrane [1,6-16]. One waste product, excess water, is excreted through a precursor to aquaporin, i.e., through the oxyhydroxide galleries, consequent upon contrasting osmolalities of the internally produced water with the ambient ocean water and the hydrothermal solution [17].

There is no so-called "water problem" [6,18,19]. Nor is there a problem with the source of the substrates – the mineralogy of the early Earth cannot be dismissed with the facile line "it is uncertain whether these were available on the prebiotic Earth" [19]. Building life from the bottom-up (how else?), demonstrations of abiotic syntheses at hydrothermal vents are becoming ever more numerous [7-10,12,13,16], perhaps to the point where origin-of-life funding might be more equably distributed.

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This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA, supported by the NASA Astrobiology Institute NNH13ZDA017C Icy Worlds.

Dirk SCHULZE-MAKUCH

Some Ideas about Biodiversity of Alien Life on other Planetary Bodies

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Life on Earth is carbon-based, uses water as a solvent, and photosynthesis and chemosynthesis as a way to obtain energy. However, life on our planet is only a singular example of the only biosphere we know, and alien life could in principle be based on different chemistries, solvents, and energy sources (Schulze-Makuch and Irwin, 2018). The probability that any specific known or unknown type of life will be found on another planetary body will depend to a large extent on the nature and history of that alien world.

Here I provide various examples of possible life on an alien world including that of a superhabitable planet, which may hold more biomass and a higher degree of biodiversity than Earth (Schulze-Makuch et al. 2020). Other examples are a barren planet devoid of surface liquids, an ocean world (rocky planet with an ice-covered global ocean), a frigid world with abundant liquid hydrocarbons, a rogue planet independent of a host star, a tidally locked planet, and a planet with a biosphere thriving in a dense planetary atmosphere (Irwin and Schulze-Makuch, 2020).

Irwin, L.N. and Schulze-Makuch, D. (2020) The astrobiology of alien worlds: known and unknown forms of life. Universe 6(9), 130; <u>https://doi.org/10.3390/universe6090130</u>

Schulze-Makuch, D. Heller, R., and Guinan, E.F. (2020) In search for a planet better than Earth: today's top contenders for a superhabitable planet. Astrobiology, doi: 10.1089/ast.2019.2161

Schulze-Makuch, D. and Irwin, L.N. (2018) 3rd edition, Life in the Universe: Expectations and Constraints. Springer, Berlin, 343 p

Dmitry SKLADNEV

What are the first mutations that began Evolution on the Earth?

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Whatever way (abiotic self-organize, panspermia, etc.) the first prokaryotic cells — Pioneers — appeared on an **initially sterile** Earth, they were the Common Ancestor for all terrestrial living organisms. The author suggests that the moment when did the first cell division occur on our planet it should be chosen as a starting point for considering the issues of Life and Biological Evolution. To indicate this point, I'm offering to use a word made up of Greek roots diplaparche ($\delta i\pi \lambda \alpha \pi \alpha \rho \chi \eta$) as the very first prokaryotic cell doubling.

Only some low-molecular weight **abiotically** synthesized compounds (that were initially present of the Earth in those climatic and geological conditions) could act as growth and energy substrates for Pioneers cells as a source of biological atoms — C, N, S, P, O. During this period the colonization of the Earth's surface by Pioneers (with the appearance of new and newer generations of cells capable of growth and division), "the high-energy" biotically synthesized **terrestrial organics** began to accumulate. Most likely water-soluble new "bioorganics" were distributed quite differently on separate prebiotically organized ecological niches than high-molecular weight biopolymers. Thus, insoluble compounds could form the separate sites of the congestion which have become petroliferous zones. Then slowly but steadily the inhabitants of the Earth have the opportunity to use as growth substrates a variety of already-made terrestrial biogenic compounds, et



al.). All of these high-energy compounds could and did become new terrestrial biogenic sources of carbon and energy for the new generations of microorganisms.

The appearance of biogenic organics on the Earth's surface and in the primary Ocean could serve as a basis for the "trophic specialization of cells" in the preferred use of certain substrates. Today, it is obvious that the emergence of the ability to utilize new biogenic growth substrates is provided by the emergence of new enzymatic activities and transport biosystems of membranes. At the same time, the use of high-energy growth substrates by cells could enhance the growth characteristics of Pioneers. Thus, we can assume that the first mutations that occurred on the Earth contributed to the expansion of the trophic preferred and capabilities of Pioneers. According to modern standards, radical changes in the trophic structure or metabolism of mutant cells can be qualified as the appearance of new biological species that can reasonably be considered the first terrestrial taxones. In general, the biosynthesis of terrestrial organic high-energy substrata has spurred on

the first events of Evolution of prokaryotes on the Earth \sim 3.7 billion years ago.

As for hydrophobic lipids they accumulate in the form of deposits (oil). This means that the detection of lipid compounds enywhere can serve as a reliable marker of Life of a terrestrial type. Furthermore, the study of the chemical composition of these lipid molecules will provide information about the history of biological Evolution on this Space object.

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The hypothetical microbial community of Venusian clouds can inhabit an ecological niche with a structure in the form of water foam

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The sustainability of terrestrial organisms is provided with their incorporation in stable biogeochemical cycles as a community in which close trophic interactions take place. The energy that is generated as a result of the work of such cycles is shared by the members of the community. An important factor for the effective development of such communities is their physical organization, which implies a common space for trophic interactions, in particular, a common water space of sufficient volume.

Currently, there is evidence for extended zones in the cloud layer of Venus, where physicochemical conditions favor the existence of microorganisms of the terrestrial type. If such a hypothetical microbial ecosystem exists, then there must be a sufficient volume of the aquatic environment to support effective and balanced trophic interactions between microorganisms of the community. The authors suggest that such conditions can be realized in a specific foam-like structure of the water layer and propose a hypothesis for the existence of a "Habitable foam of Venusian clouds"

The main statements of the hypothesis are as follows:

- The inhabitant of the cloud layer of Venus is a community of different microorganisms that are in close trophic interactions.
- The physical form of "inhabited" water in the cloud zone with physicochemical conditions suitable for biological organisms is an extended heterophase (solid-gas-liquid) structure, similar to water foam.
- The existence of a common volume of water-gas foam structures facilitates the efficient transfer of substrates and metabolic products, promotes cyclic metabolic processes with gaining bioenergy.
- Such foam structures can be stable along all the Venusian cloud layer assuming the presence of various microbial communities functioning at both elevated (50-80°C) and low (0-20°C) temperatures.
- Stabilization of the water-foam structure occurs due to various surfactants and gaseous compounds, which can, in particular, be produced by microbial cells as well as various inorganic and organic nanoparticles reaching the cloud layer as a result of exchange processes with the planet's surface.
- Inorganic and polymeric organic compounds synthesized on the surface of Venus can make a significant contribution to metabolic microbial processes in the water-foam layer of clouds

and be a part of a global aerogeochemical cycle of elements, in which a hypothetical microbial community can be actively involved.

Thus, we postulate that the physicochemical conditions in the cloud layer of Venus and the aerogeochemical processes including polymerization reactions occurring on the planet's surface can lead to the creation and stabilization of foam-bubble liquid structures. Such ecosystems can be colonized by microorganisms developing as a community with balanced trophic interactions. This microbial system should have enough physical space for driving metabolic cycles to sustain and gain energy.

Vladimir V. SOROKIN, Dmitry A. SKLADNEV

What is Life? The importance of negative controls

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Question: how to distinguish the Life from the dead matter can be called "old as the world". Now we can try to formulate four basic criteria that are sufficient to isolate Living objects from all the rest.

i. Only Life matter contains genetic information that can provide multiple reproduction of themselves from generation to generation (in the presence of growth substrates and suitable conditions).

ii. Only living cells are capable of regulating the biosynthesis of organic compounds and biostructures to maintain homeostasis.

iii. Only living cells can use external sources to replenish the supply of intracellular bioenergy.

iv. Only living cells are programmed to respond to changes in the environment.

The inability to carry out all four listed amounts of biochemical and physiological reactions allows us to consider that the tested "bioobject" is dead. Accordingly, it is possible to construct a logical approval – only the deprivation of the biological object of the signs of Life can confirm its original living state. In other words, a Life detects its signs by the ability to lose them strictly after inactivating such signs in strictly defined biocide ways/methods. This phase transition during the possibility of the experimental murder (transformation of a living biological object into a non-living state as negative control) can be detected using the offered DBNG (Detection Biogenic Nanoparticles (*MeNPs*) Generation/Growth) approach.

with i n a c t I v e objects vis only with living cells Me⁺ \rightarrow Me⁰ \rightarrow \rightarrow Me⁰NCs \rightarrow \rightarrow \rightarrow Me⁰NPs

The new simple and universal nanobiotechnological DBNG approach for the detection of Life is based on registration of biogenic metal nanoparticles *in situ* generated only by living cells Reducing agents for the spinodal decomposition as the first step for synthesis of metallic nanoclusters can be biogenic compounds and biopolymers (sugars, starch, proteins and amino acids, tannic acid et al.). Living cells have even greater reducing activity: metabolically active cells

can rapidly (in minutes) generate metal NPs broad size range 5-150 nm (from metal ions of added salt) due to their ability to constantly "efflux" electron donors and electrons into the reaction medium. Inactive cells, cells with destroyed and non-active biostructures as well organic components of cytoplasm, can reduce cations much weaker and form only nanoclusters (*MeNCs* < 2 nm) as precursors of nanoparticles. In the case of artificial inactivation (biocide treatment) of living objects in the tested sample (that is, in the aliquot of negative control), we do not see the formation of nanoparticles. No MeNPs generation newer was observed in control samples artificially free of cells – as negative control also.

Thereby, the generation of metal nanoparticles (when a source of metal cations is added to the sample) can be considered as an indicator of the presence of living active cells in a reaction mixture. If there is no generation of nanoparticles after processing/inactivation of the sample by methods that kill living cells, this indicates the presence of living microorganisms in the untreated sample.

Savio de TORRES FARIAS

Transfer tRNA: The molecular demiurge in the origin of biological systems

Laboratory of Evolutionary Genetics Paulo Leminski, Department of Molecular Biology, Federal University of Paraiba - Brazil

Although increasing knowledge about biological systems has advanced exponentially in recent decades, it is surprising to realize that the very definition of Life keeps presenting theoretical challenges. Even if several lines of reasoning seek to identify the essence of life phenomenon, most of these thoughts contain fundamental problems in their basic conceptual structure. Most concepts fail to identify necessary and sufficient features to define life.

Here, we analyze the main conceptual framework regarding theoretical aspects supporting life concepts, such as (i) the physical, (ii) the cellular and (iii) the molecular approaches. Based on ontological analysis, we propose that Life should not be positioned under the ontological category of Matter. Yet, life should be better understood under the top-level ontology of "Process". Exercising an epistemological approach, we propose that the essential characteristic pervading each and every living being is the presence of organic codes. Therefore, we explore theories in biosemiotics in order to propose a clear concept of life as a macrocode composed by multiple interrelated coding layers. Therefore, we suggest a clear distinction between the concept of life and living beings, a distinction that is not evident in theoretical terms.

From the proposed concept, we suggest that the evolutionary process is a fundamental characteristic for life's maintenance but not to its definition. The current proposition opens a fertile field of debate in astrobiology, biosemiotics and robotics.

Josep M TRIGO-RODRIGUEZ

The catalytic properties of chondritic meteorites and their role in the origin of life in Nitrogen- and water-rich environments

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Undifferentiated asteroids and comets are composed by primordial materials that were forming part of the protoplanetary disk. Some of the most pristine meteorites are the chondrites, and the carbonaceous ones host fascinating chemistry (Trigo-Rodríguez, 2015; Nittler et al., 2019). Some mineral phases contained in these rocks exhibit unique catalytic properties as we discovered in a series of experiments (Rotelli et al., 2016). I'd like to introduce in this talk the important implications of such properties for the unset of the origin of life on Earth during the early Archean. The Grand Tack Model (Walsh et al. 2011) is used to explain the main features observed in the distribution pattern of planets, and the current distribution of minor bodies in the main belt, among other observational evidence (see e.g. Morbidelli et al., 2012).

In such a scenario, an early period in planetary evolution, in which the final setting of Jupiter and Saturn naturally increased the flux of fragile volatile-rich bodies crossing the terrestrial planets. Direct impacts and close approaches of minor bodies with planets were far more usual at those remote ages, and delivered huge amounts of pristine materials to rocky planets. About 3.8 Gyrs ago the arrival of these bodies to the Earth-Moon binary system excavated big craters, but other fragile bodies carrying organics and water were probably fragmenting during close approaches to planets, and delivering their contents (Trigo-Rodríguez, 2017, 2019).

I have estimated that the early Earth was subjected to a meteoritic flux that could have well been at least 5-6 orders of magnitude the one at present. If that hypothesis is correct, huge amounts of chondritic materials could have reached the surfaces of the Earth, Mars and the rest of the planetary bodies at an annual rate of thousands of billions of metric tons. Was that event delivering essential components the key to promote the origin of life on Earth and perhaps other planetary bodies?

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Frank TRIXLER

Natural Nanofluidic Environments as Prebiotic Reaction Vessels: Abiotic RNA formation in temporal nanoconfined water

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The "water paradox" is a crucial problem in the research on the prebiotic chemical evolution towards the emergence of life: It states that although aqueous environments are essential for life, they impede key chemical reactions such as nucleotide polymerisation. In aiming to overcome this paradox various hypotheses have been proposed, including scenarios based on alternative solvents like formamide, condensing agents like cyanamide, high temperatures (~160°C) or approaches based on wet/dry cycles. However, when appraising the prebiotic plausibility of such scenarios general weaknesses appear. Besides the fact that all known life manages the water paradox without needing such proposed conditions, evolutionary conservatism – the principle that evolution builds on existing pathways – indicates that the same physicochemical effects were probably involved in the abiotic origin of biopolymers as now being tapped by life via complex enzymes.

This talk shows that abiotic temporal nanoconfinements of water can serve as natural reactions vessels for prebiotic RNA formation. Evidence is presented for spontaneous, abiotic polymerisation of nucleotides in water. According to the results the reaction is enabled by the rise of anomalous properties of water when being temporarily confined between nanoscale separated particles of geological ubiquity within aqueous suspensions. These findings can solve the water paradox in such a way that nanofluidic effects in aqueous particle suspensions open up an abiotic route to biopolymerisation and polymer stabilisation under chemical and thermodynamic conditions which also exist within the intracellular environment of living cells. The fact that polymerase enzymes also form temporal nanoconfined water clusters inside their active site implies that the same physico-chemical effects are tapped for nucleotide condensation in water both by biochemical pathways and the reported abiotic route.

This indicates that our model is consistent with evolutionary conservatism stretching back to the era of prebiotic chemical evolution. The consistency is further supported by the fact that water is not trapped by nanoconfinements within the polymerase core but can exchange with the surrounding intracellular fluid – a situation which is also prevalent in nanofluidic environments within aqueous particle suspensions. Our experimental finding that under the reported conditions an amino acid catalyses the abiotic polymerisation of nucleotides may give a hint to a nanofluidic origin of cooperation between amino acids and nucleotides evolving to the interdependent synthesis of proteins and nucleic acids in living cells. Abiotic RNA polymerisation in temporal nanoconfined water does not depend on highly specific mineralogical and geological environments: Now as then in the prebiotic world, watery suspensions of micro- and nanoparticles are virtually ubiquitous – they exist, for example, in the form of sediments with pore water, hydrothermal vent fluids containing precipitated inorganic and polyaromatic particles or dispersed aggregates inside water-filled cracks in the crust of the earth and possibly of icy moons such as Enceladus.

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Tamir TULLER

Reliable encoding of information on the genomes of living organisms

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Genetic materials encode a large proportion of the information that determines an organism's phenotypes (e.g. gene expression and encoded proteins).

The mechanisms by which genetic information determines phenotypes differ between modern cellular organisms, viruses, and ancient pre-cellular life, although they are analogous and have many similarities. This information, however, is challenging to decipher because it is encoded in a non-modular manner, where parts of the genetic material often code for multiple functions.

In this talk, I will review our approaches for modelling and engineering this information based on state-of-the-art algorithms, including our novel pipeline for encoding additional (orthogonal) information on the genomes of living organisms. The aim of this pipeline is to be able to introduce additional information to the genetic material without substantially affecting the original information and the organism's fitness.

This work has wide-ranging biotechnological applications and also provides remarkable lessons about the characteristics of genetic information and its evolution.

<u>Jorge L. VAGO¹, E. Sefton-Nash¹,</u> the RSOWG³, the ExoMars Science Working Team, and the ExoMars Project Team

Why is Oxia Planum the right landing site for ExoMars 2022?

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ExoMars 2022 was conceived, from the very beginning, to answer one question: Was there ever life on Mars? All project design decisions have focused and continue to centre on the achievement of this one scientific objective. This is particularly the case for the Rosalind Franklin rover. Putting

the science team in the best possible position to search for physical and chemical biosignatures has led to:

- 1. The need to have a 2-m depth drill;
- 2. The choice of payload instruments (including the trade-offs we had to make).
- 3. The science potential and age of the landing site.
- 4. The surface exploration strategy: which targets, how much travelling, and way the instruments will be used together to test hypotheses.

This presentation will summarize how and why this came about and what, based on what we know about Oxia Planum today, we expect to be able to study.



Rosalind Franklin rover deploying its solar panels (ESA/Mlabspace).

Saúl A. VILLAFAÑE-BARAJAS¹, María COLÍN-GARCÍA², Marta RUIZ BERMEJO³, Pedro RAYO PIZARROSO³, Santos GALVEZ-MARTINEZ³, Eva MATEO-MARTI³

Role of serpentinite in HCN-polymerization: molecular complexity under alkaline scenarios

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Hydrogen cyanide, HCN, is a fundamental molecule in chemical evolution and prebiotic chemistry experiments. Several researches have shown that "HCN-derived polymers" release an important amount of different organic molecules after hydrolysis treatments. In addition, some novel

researches have been focused in the study of the role of mineral surfaces along the hydrolysis and/or polymerization of cyanide species but until now, the effect of mineral surfaces is no clear.

The role of minerals along chemical evolution processes is crucial, because they undoubtedly interacted with the organic molecules during early Earth by different process. In this way, we simulated the probable interactions among HCN and serpentinite under simple alkaline hydrothermal conditions. Thus, herein it is studied the effect of serpentinite during the thermolysis of HCN at basic conditions (i.e., HCN(l) 0.15 M, 50 h, 100 °C, pH > 10). The HCN-derived thermal polymer and supernatant formed after treatment were analyzed by several and complementary analytical techniques.

The results obtained suggest that: I) the mineral surfaces could act as mediators in the mechanisms of organic molecule production such as, the polymerization of HCN; II) the thermal and physicochemical properties of the HCN polymer produced are affected by the presence of the mineral surface; and III) serpentinite seems to inhibit the formation of bioorganic molecules comparing with the control experiment (without mineral).

Juntian WU

Exploring replication fidelity in a synthetic self-replication system

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Self-replication is widely considered to be an essential element of the origin of life and Darwinian evolution. Replication fidelity, which is the degree of replication exactness, plays a crucial role in evolution. Replication with high but not perfect fidelity maintains the genetic information passed from generation to generation and enables the emergence of mutations to adapt to a change of environment. A vast number of studies on non-enzymatic DNA/RNA polymerization investigated the role fidelity played early on when the first genetic systems became established. Chemical synthetic replication systems are a promising approach to the de novo synthesis of life and to alternative biochemistries.

Our group has constructed a synthetic self-replicating system by using a dynamic combinatorial chemistry (DCC) approach. A typical DCC library starts from peptide substituted dithiol benzene building blocks that spontaneously form a series of large macrocycles which can participate in thiol-disulfide exchange to change their ring size and composition. Macrocycles with a specific ring size tend to self-assemble by stacking and form amyloid-like fibers which can catalyze the formation of more macrocycles with the same ring size, resulting in the elongation of the fiber. Upon stirring, long fibers will break into two which promotes exponential self-replication.

Moreover, we have reported a mixed building blocks system, containing two structurally closely related building blocks, F and S. The only difference between these building blocks is that one amino acid is changed from phenylalanine to serine. In this system, one set of F-rich hexameric replicators and one set of S-rich hexameric replicators can arise and the first emerged F-rich set is the ancestor of the second S-rich set. Herein, our recent progress on exploring replication fidelity in our synthetic multi-replicators system will be presented. In the F and S system a series of

hexameric replicators can form, with different ratios of building blocks. When a library is seeded with pre-formed replicators, either composed entirely of F building block (F6) or of a mixture of the two building blocks, the majority of the replicators observed are F-rich hexamers centered at F5S1 or F4S2.

Using data-fitting and parameter estimation, the kinetic constants representing the building blocks interaction energies are obtained. We found that the F6 and S6 replicator have the highest and lowest replication fidelity, respectively. The theoretical building block fidelity for F building block is just a little lower than the average building block fidelity in a ribozyme. In this work, we obtained the replication fidelity and mutation rate of a synthetic self-replicator system via the combination of experiment and modeling. The values of replication fidelity inform on the evolvability of the system and could give us more insights about how to construct and investigate synthetic systems with different evolvability and properties like error thresholds. Furthermore, this work also paves the way towards the study of Darwinian evolution, the origin of life and the de novo synthesis of life.

Polina YAKOVLEVA

Prokaryotic communities of East Antarctic oasis soils and their resistance to antibiotics and heavy metals

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Antarctic soils have traditionally attracted the attention of scientists around the world, not only from the point of view of studying the existence and evolution of life in such extreme habitats, but also due to the fact that such objects are considered as models for astrobiological extrapolations. Despite the continuing interest of researchers in the study of life in Antarctica, many aspects of the functioning of microbial communities in the extreme climatic conditions of this continent remain poorly understood. It has previously been shown that Antarctic soil bacteria are resistant to certain antibiotics and a number of heavy metals. The study of bacterial communities with natural resistance to antibiotics and heavy metals is currently an urgent task, since it can provide answers to a number of questions related to the patterns of distribution of resistance genes.

The aim of the work was to count the number of live and culturable heterothrophic bacteria from the microbial communities of the most ancient Antarctic soils from the Larsemann Hills, Bunger Hills and Thala Hills oases of East Antarctica, as well as to determine the resistance to heavy metals and antibiotics of bacterial strains isolated from these soils. It was shown that in all the main parameters (the total number of bacteria, the content of viable heterotrophic bacteria and nanoforms, the profile distribution of the number of microorganisms), the studied soils were similar to the previously studied soils from Antarctic oases. In 63 isolated strains, resistance to heavy metals was more common than resistance to antibiotics, but in all the samples studied, strains resistant to one or more antibiotics and heavy metals compared to gram-positive ones. The greatest number of strains was resistant to chromium, which can be explained by the increased content of chromium in the soils, which was inherited from the bedrocks – granites and gneisses.

Liquid Crystal Peptide/DNA Coacervates and Other Membraneless Compartments in the Context of Prebiotic Molecular Evolution

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Liquid Crystal Peptide/DNA Coacervates in the Context of Prebiotic Molecular Evolution Tony Z. Jia and Tommaso P. Fraccia Liquid–liquid phase separation (LLPS) phenomena are ubiquitous in biological systems, as various cellular LLPS structures control important biological processes.

Due to their ease of in vitro assembly into membraneless compartments and their presence within modern cells, LLPS systems have been postulated to be one potential form that the first cells on Earth took on. Recently, liquid crystal (LC)-coacervate droplets assembled from aqueous solutions of short double-stranded DNA (s-dsDNA) and poly-L-lysine (PLL) have been reported. Such LC-coacervates conjugate the advantages of an associative LLPS with the relevant long-range ordering and fluidity properties typical of LC, which reflect and propagate the physico-chemical properties of their molecular constituents. Here, we investigate the structure, assembly, and function of DNA LC-coacervates in the context of prebiotic molecular evolution and the emergence of functional protocells on early Earth.

We observe through polarization microscopy that LC-coacervate systems can be dynamically assembled and disassembled based on prebiotically available environmental factors including temperature, salinity, and dehydration/rehydration cycles. Based on these observations, we discuss how LC-coacervates can in principle provide selective pressures effecting and sustaining chemical evolution within partially ordered compartments. Finally, we speculate about the potential for LC-coacervates to perform various biologically relevant properties, such as segregation and concentration of biomolecules, catalysis, and scaffolding, potentially providing additional structural complexity, such as linearization of nucleic acids and peptides within the LC ordered matrix, that could have promoted more efficient polymerization.

While there are still a number of remaining open questions regarding coacervates, as protocell models, including how modern biologies acquired such membraneless organelles, further elucidation of the structure and function of different LLPS systems in the context of origins of life and prebiotic chemistry could provide new insights for understanding new pathways of molecular evolution possibly leading to the emergence of the first cells on Earth.