Under the auspices of the
Hellenic Space Agency (HSA)

National Technical
University of Athens

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4th NoR HGT & LUCA Conference

MOLECULES to MICROBES

RNA DNA

4-5-6 NOVEMBER 2018

National Technical University of Athens
Conference Hall of the Eugenides Foundation

Contact:

Elias Chatzitheodoridis • eliasch@metal.ntua.gr

Sohan Jheeta • sohan@sohanjheeta.com

Network of Researchers on Horizontal Gene Transfer & Last Universal Common Ancestor

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European Astrobiology Network Association

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Foreword from the Chairman

Our network has taken the meeting outside the UK for the first time this year and we would like to thank Elias Chatzitheodoridis of the *National Technical University of Athens*, who has been instrumental in organising the meeting at the *Eugenides Foundation* in Athens. Also, this year saw the quality and number of abstracts submitted increase; this is in line the with the network's ethos; the idea being that network should be growing organically and not fall into the trap of being a one hit wonder or becoming stagnant. To aid in this endeavour we will continue to implement the following elements of our meetings:

- Standard 30 min talks - including Q & A;
- Keynote speakers are given 45 min including Q & A;
- Abstract booklets;
- Longer term aims of the Network: to attract top 50 abstracts worldwide; and
- Remaining abstracts will be given poster sessions.

In the age of sound bites and with the impact of technology these little paper booklets could be seen as a rare indulgence – you may have already lost the feel for "fingering through" an abstract and flipping one page to the next and back again. Memory sticks, on the other hand, are the product of drive efficiency, ease and profit: they don't necessarily give one any feelgood factor, so, we'll stick with the abstract booklets permanently.

The previous three meetings had some prominent speakers taking part such as: Peter Gogarten, *University of Connecticut*, Addy Pross, *Ben Gurion University* and Patrick Forterre, the *Pasteur Institute*, to mention but few. This year is no different in that we are in graced by Rowena Ball, *National University of Australia*, George Cambourakis, *National Technical University of Athens*, Doron Lancet, *Weizmann Institute of Science* and Tamir Tuller, the *Tel Aviv University* as well as having the meeting opened by a delegate from the *Hellenic (Greek) Space Agency*; and Georgios Anastassakis, Vice Dean of the *School of Mining and Metallurgical Engineering* at *National Technical University of Athens*.

With the changing fortunes of time, NoR HGT & LUCA may also be transforming slightly. By the time of our 2020 meeting we are thinking of changing our name to the much more memorable "Chem2Life Network" (abbreviated to C2L Network). Our research has revealed that, over time, the name NoR HGT & LUCA is predominantly associated with biology rather than with any other relevant scientific arena. Therefore, we propose that our next meeting in 2020 should be held under the title "C2L Network" and that it will take place at the University of St Andrews, Scotland, thanks to Martin Dominik. **We would welcome your feedback on the proposed name change**.

On to further horizons, we are currently in discussions with the Russia Astrobiology Council via Oleg Kotsyurbenko of Yugra State University, Russia, with the possibility of hosting a joint meeting in Moscow at some stage. So, the future for our Network looks bright…

Sohan Jheeta
MinstP, MRSC, FRSB, FRMS, FRAS

Guest Editorship

I have been invited to take up a Guest Editorship on the MDPI's Journal: **Sci**. The good news is that there will not be any charges for publication in the special issue of the Sci Journal. I will forward the relevant details regarding the submission of papers, as and when they become available. On my last three Guest Editorships the number of good quality papers has been on the rise, and so let's do it again.

To this endeavour I seek your help so as to make the *Chem2Life Network* go from strength to strength; we can all pull together and stand up and be counted - big thanks in advance.

Organising Committee

Prof Elias Chatzitheodoridis
National Technical U. of Athens
eliasch@metal.ntua.gr

Prof Sohan Jheeta
Independent Researcher, NoR HGT & LUCA, UK
sohan@sohanjheeta.com

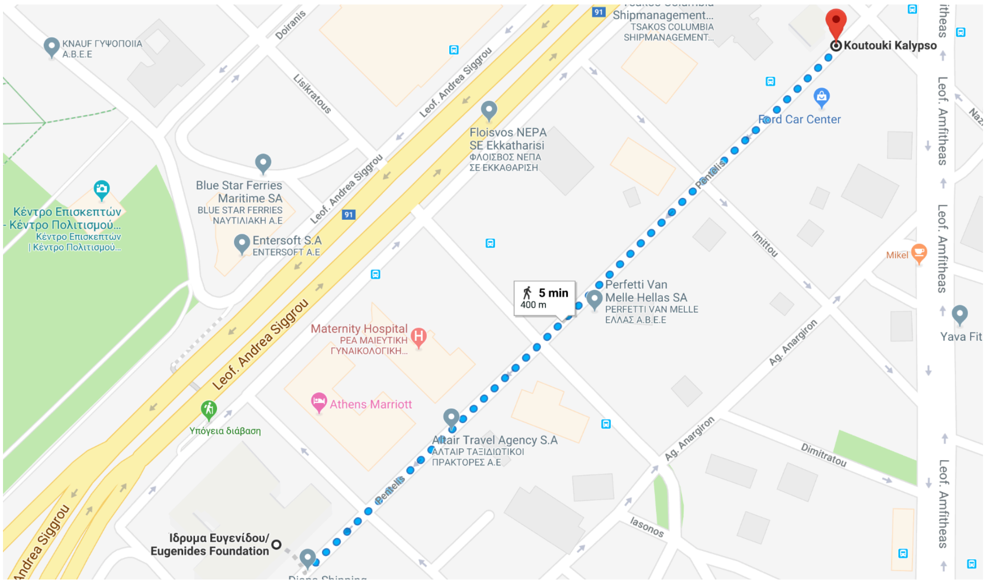
Dr (Reader) Martin Dominik
University of St Andrews, UK
md35@st-andrews.ac.uk

Prof John F Allen
University College London, UK
j.f.allen@ucl.ac.uk

Prof Nigel J Mason
The Open University, UK
Nigel.Mason@open.ac.uk

Conference dinner

This will be at **20.00 (pm)** on **Monday 5th November 2018** at the traditional Greek restaurant, **Κουτούκι Kalypso** (Koutouki Kalypso), Pentelis 41, Paleo Faliro 175 64, Greece, which is located only 400 metres from the conference venue (walking distance).



Conference photo

The weather in Athens will be hopefully still nice and sunny, so we aim to do this at **9:40 am** on **Monday 5th November**. If in the unlikely event it does start raining, then we will reschedule for during another one of the breaks.

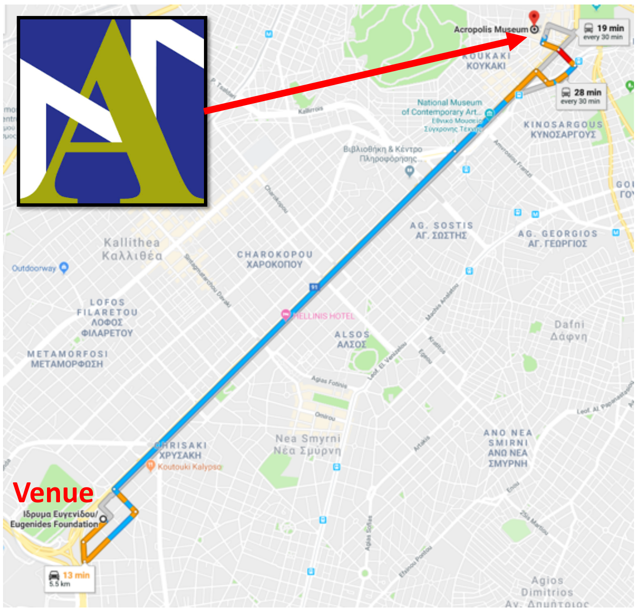
An excursion to the Acropolis museum

We have organised a complimentary excursion with a professional guide for you to the **Acropolis Museum** for **Wednesday 7th November** (About 5 km from the venue, towards the city centre of Athens). The detailed arrangements for the visit will be announced during the meeting.

The Acropolis Museum (in Greek written as Μουσείο Ακρόπολης, Mouseio Akropolis) is an archaeological museum including in its collection the findings of the archaeological site around the Acropolis area of Athens. These artifacts are from the Greek Bronze Age to the Roman and Byzantine Greece. It also lies over the ruins of the Roman and early Byzantine Athens.

The museum was founded in 2003. It has been opened to the public six about years later. It now contains nearly 4,000 archaeological exhibits which are displayed over an area of 14,000 square metres. The first museum was actually on the Acropolis rock itself, and was operational since 1874. The collection of artifacts has been however enriched significantly due to successive excavations and the old building could not host the full collection.

The museum is located next to the south-eastern slope of the Acropolis hill, on the ancient road that led up to the "sacred rock" in classical times. It is only 280 meters (310 yd), away from the Parthenon, and about 400 meters (440 yd) walking distance from it. The museum is the largest modern building in the ancient siteof Acropolis. Easy access from the main entrance on Dionysiou Areopagitou Street, which is directly adjacent to the Akropoli metro station (the red line of the Athens Metro).



The Sohan Jheeta Travel Award for NoR HGT & LUCA

This year, the awards have been donated to **Zoe Meziere**, a student from Paris and a postdoc, **Asif Iqubal** from IIT, India.

This award will continue to be made available for all future NoR HGT & LUCA conferences.

Acknowledgements

Sir John Mason Academic Trust

JMAT

Sir John Mason Academic Trust

fostering academic collaborations in atomic and molecular physics

The **Sir John Mason Academic Trust** is a trust to foster academic collaboration in atomic and molecular physics.

Eugenides Foundation

The NoR HGT & LUCA Conference Organising Committee recognizes the kindness of the *Eugenides Foundation* for the generous provision of the venue and for making this meeting possible.

ΙΔΡΥΜΑ ΕΥΓΕΝΙΔΟΥ 1954
EUGENIDES FOUNDATION
PUBLIC BENEFIT FOUNDATION
HONORED WITH THE GOLD MEDAL OF THE ATHENS ACADEMY

The Eugenides Foundation was established in 1956 as a non-profit-making legal entity in private law. Its purpose was to implement the wishes expressed in the last testament of the late Eugenios Eugenides, a benefactor of the Greek nation.

Registered and based in Athens, its founding charter states that its objective is to contribute to the education of young Greeks in science and technology.

The Foundation is administered by a board of three members, one of whom is always the serving Chancellor of the National Technical University of Athens. In recognition of its multi-faceted contribution to Greek society the Foundation was awarded the Gold Medal of the Athens Academy in December 1965.

Hellenic Space Agency

The NoR HGT & LUCA Conference is taking place under the auspices of the *Hellenic Space Agency* (HSA):

http://www.hellenicspaceagency.gov.gr/en/home

The Organising Committee would like to thank the *Hellenic Space Agency* for its participation.

The Hellenic Space Agency with the distinctive title "H.S.A. S.A." is a legal entity of private law and was established in 2018 with the intention to configure Greece's strategy proposal in the space field as well as to devise a dynamic plan of action for the country's space strategy.

Commercial sponsors

SEMELI Wines

The Organising Committee also would like to thank *Semeli Estate Wines* (https://www.semeliwines.gr) for their kind provision of the wine that will be provided to the participants during the ice breaker reception of the Sunday evening.

Two wine varieties will be served, the dry red wine "Semeli Nemea Reserve 2015" and the dry white wine "Semeli Mantinia Nassiakos 2017". Both are special reserves of the Semeli Estate which is located in the historical Nemea area of Peloponnese.

List of Speakers

1. **Ameta, Sandeep**
   ESPCI Paris, France
sandeep.ameta@espci.fr and sandeep.espci@yahoo.com

2. **Ball, Rowena**
   Australian National University
   rowena.ball@anu.edu.au

3. **Battaglia, Guiseppe**
   Department of Chemistry, University College London, UK
   g.battaglia@ucl.ac.uk

4. **Cambourakis, George**
   National Technical University of Athens, Greece
   gcamb@cs.ntua.gr

5. **Capova, Klara Anna**
   Durham University, UK
   k.a.capova@durham.ac.uk

6. **Chatzitheodoridis, Elias**
   National Technical University of Athens, Greece
   eliasch@metal.ntua.gr

7. **Christian, Sherri Memorial**
   University of Newfoundland, Canada
   sherri.christian@mun.ca

8. **del Gaudio, Rosanna**
   University of Naples Federico II, Italy
   rosanna.delgaudio@unina.it

9. **Dominik, Martin**
   University of St Andrews, Scotland, UK
   md35@st-andrews.ac.uk

10. **Ellery, Alex**
    Carleton University, Ottawa, Canada
    alexellery@cunet.carleton.ca

11. **Fox, Stefan**
    University of Hohenheim, Institute of Chemistry, Department of Bioinorganic Chemistry, Stuttgart, Germany
    stefan.fox@uni-hohenheim.de

12. **Georgiou, Christos D**
    University of Patras, Greece
    c.georgiou@upatras.gr

13. **Grunska, Nolan**
    Texas State University, USA

ngrunska@aol.com

14. **Hansma, Helen Greenwood**
University of California at Santa Barbara, Santa Barbara, USA
helen.hansma@gmail.com

15. **Iqubal, Mohammad Asif**
Indian Institute of Technology Roorkee, India
asifiqubal.88@gmail.com

16. **Jheeta, Sohan**
Independent Research Scientist, NoR HGT & LCUA, Leeds, UK
sohan@sohanjheeta.com

17. **Kompanichenko, Vladimir N.**
Institute for Complex Analysis, Russian Academy of Science (FEB), Birobidzhan, Russia
kompanv@yandex.ru

18. **Kotsyurbenko, Oleg**
Yugra State University, Russia
kotsor@mail.ru

19. **Koumandou, Vassiliki Lila**
Agricultural University of Athens, Greece
Koumandou@aua.gr

20. **Kovacevic, Andjelka**
University of Belgrade, Belgrade, Serbia
andjelka@matf.bg.ac.rs

21. **Laine, Pauli E**
University of Jyväskylä, Finland
pauli.e.laine@student.jyu.fi

22. **Lancet, Doron**
Department of Molecular Genetics, Weizmann Institute of Science, Rehovot, Israel
doron.lancet@weizmann.ac.il

23. **Lang, Andrew**
Memorial University of Newfoundland, Canada
aslang@mun.ca

24. **Maccone, Claudio**
Istituto Nazionale di Astrofisica (INAF), Italy
clmaccon@libero.it and claudio.maccone@iaamail.org

25. **Mitra, Saibal**
Independent Researcher
smitra00@gmail.com

26. **Papasakellariou, Konstantinos**
Agricultural University of Athens, Greece
(Koumandou@aua.gr)

27. **Tuller, Tamir**

Tel Aviv University
tamirtul@post.tau.ac.il

28. Uyama, Taichi
The University of Tokyo
t.uyama@astron.s.u-tokyo.ac.jp

29. Westall, Frances
CNRS-Centre de Biophysique Moléculaire, Orléans, France
Frances.WESTALL@cnrs.fr

Schedule Day 1
Sunday 4th November

13:30 – 14:30	Arrival of Attendees

Chair: **Sohan Jheeta**
Theme: **Space – the final frontiers**

14:30 – 15:15 **Keynote speech** **(45 min)** Page 17	**George Cambourakis** *National Technical University of Athens, Greece* **Life entropy symmetry**
15:15 – 15:45 **(30 min)** Page 17	**Taichi Uyama** *The University of Tokyo* **Direct Imaging Search for Exoplanets around Young Stellar Objects abstract**
15:45 – 16:15 **(30 min)** Page 18	**Pauli E Laine** *University of Jyväskylä, Finland* **Life as inflationary expanding phenomena**

16:15 – 16:45	Coffee break (30 min)

Chair: Elias Chatzitheodoridis
Theme: astrobiology inference

16:45 – 17:15 **(30 min)** Page 18	**Klara Anna Capova** *Durham University, UK* **Astrobiology Outreach and Dissemination: the new communication channels for an innovative science**
17:15 – 17:45 **(30 min)** Page 19	**Rosanna del Gaudio** *University of Naples Federico II, Italy* **In quest of a conceptual framework for the transition from Non-Living to Living Matter on the early Earth: evidence supporting MuGeRo hypothesis**

17:45 – 19:30	Welcome get together / ice breaker

19:30 - Close of day 1

Schedule Day 2
Monday 5th November

08:00 – 08:30	Arrival and registration
08:30 – 08:40 Opening	**Elias Chatzitheodoridis** **Start of Day**
08:40 – 09:00 **(20 min)** Opening	**Christodoulos Protopapas** *President of the Hellenic Space Agency* **Welcome speech**
09:00 – 09:20 **(20 min)** Opening	**Welcome speeches and conference information.**
09:20 – 09:30 **(10 min)** Opening	**Georgios Anastassakis, Vice Dean of the School of Metallurgy at National Technical University of Athens** *National Technical University of Athens* **Welcome speech**
09:30 – 09:40 **(10 min)** Opening	**Sohan Jheeta** **The Network**
09:40-09:45	Group Photo (5 min)

Chair: **Martin Dominik**
Theme: **life models**

09:45 – 10:30 **Keynote speech** **(45 min)** Page 21	**Rowena Ball** *Australian National University, Canberra, Australia* **HP sauce on everything: Multiple roles of hydrogen peroxide in mediating the origin of life**
10:30 – 11:00	Coffee break (30 min)
11:00 – 11:30 **(30 min)** Page 22	**Frances Westall** *CNRS-Centre de Biophysique Moléculaire, Orléans, France* **A hydrothermal sedimentary origin of life?**
11:30 – 12:00 **(30 min)** Page 23	**Sandeep Ameta** *ESPCI Paris, France* **Network of autocatalytic RNA in the origin of life: Pre-Darwinian evolutionary dynamics**
12:00 – 12:30 **(30 min)** Page 24	**Nolan Grunska** *Texas State University, USA* **Are Scientific Models of Life Testable? A Lesson from Simpson's Paradox**
12:30 – 13:00 **(30 min)** Page 24	**Christos D Georgiou** *University of Patras, Greece* **Biosignatures for the search of extraterrestrial life on Mars, Europa, and Enceladus**
13:00 – 14:00	Lunch (60min)

Chair: **Sohan Jheeta**
Theme: **Vesicles**

14:00 – 14:45 **Keynote speech** **(45 min)** Page 25	**Doron Lancet** *Weizmann Institute of Science, Rehovot, Israel* **Compositional lipid catalytic networks as the earliest evolving replicators**
14:45 – 15:15 **(30 min)** Page 26	**Vladimir N. Kompanichenko** *Institute for Complex Analysis, Russian Academy of Science (FEB), Birobidzhan 679016, Russia* **Arising of the Functional Sequences and Their Horizontal Transfer at the Moment of the Origin of Life**
15:15 – 15:45 **(30 min)** Page 27	**Helen Greenwood Hansma** *University of California at Santa Barbara, Santa Barbara, USA* **Biotite is a better mica for the origins of life**
15:45 – 16:15 **(30 min)** Page 28	**Guiseppe Battaglia** *UCL, London, UK* **The minimal chemotactic vesicle**
16:15 – 16:45	**Coffee break (30 min)**

Chair: **Tamir Tuller**
Theme: **Bio-signals**

16:45 – 17:15 **(30 min)** Page 29	**Stefan Fox** *University of Hohenheim, Stuttgart, Germany* **Searching for Signs of Extraterrestrial Life**
17:15 – 17:45 **(30 min)** Page 30	**Martin Dominik** *University of St Andrews, Scotland, UK* **Life in the Universe – and beyond**
17:45 – 18:15 **(30 min)** Page 30	**Elias Chatzitheodoridis** *National Technical University of Athens, Greece* **Detecting the signatures of life: state-of-the-art instruments and methods**
18:15 – 18:45 **(30 min)** Page 31	**Claudio Maccone** *Istituto Nazionale di Astrofisica (INAF), Italy* **Energy of ontogenesis according to Evo-SETI theory**

Close of day 2
Relax, socialise and get ready for the conference dinner

20:00	**Drinks and Conference dinner** **Koutouki Kalypso, 500 meters from venue**

Schedule Day 3
Tuesday 6th November

Chair: **Elias Chatzitheodoridis**
Theme: **Insight into the origin of life**

08:30 – 09:15 **Keynote speech** **(45 min)** Page 32	**Sohan Jheeta** *Independent Research Scientist, NoR HGT & LUCA, UK* **Life: Probable chemistry rather than improbable one**
09.15 – 09:45 **(30 min)** Page 33	**Oleg Kotsyurbenko** *Yugra State University, Russia* **Methanogenic microbial community as a biological system: insights into origin of life**
09:45 – 10:15 **(30 min)** Page 33	**Vassiliki Lila Koumandou** *Agricultural University of Athens, Greece* **Evolution of bioenergetic diversity across the prokaryotes, and within the human gut microbiome**
10:15 – 10:45 **(30 min)** Page 35	**Konstantinos Papasakellariou** *Agricultural University of Athens, Greece* **A high throughput computational approach for fractionation of RNA species from whole transcriptomes, in terms of their biochemical identity**
10:45 – 11:15	**Coffee break (30 min)**

Chair: **Stefan Fox**
Theme: **Transfers of materials**

11:15 – 11:45 **(30 min)** Page 35	**Sherri Christian** *Memorial University of Newfoundland, Canada* **Extracellular vesicles enable sophisticated cell-cell communication**
11:45 – 12:15 **(30 min)** Page 36	**Andrew Lang** *Memorial University of Newfoundland, Canada* **Gene transfer agents: catching phage and putting them to work**
12:15 – 13:30	**Lunch (75 min)**

Chair: **Martin Dominik**
Theme: **Molecular chemistry**

13:30 – 14:15 **Keynote speech** **(45 min)** Page 36	**Tamir Tuller** *TAU, Israel* **Deciphering and designing relations between the genetic material and the fitness of cells and viruses via computational synthetic biology**
14:15 – 14:45 **(30 min)** Page 37	**Andjelka Kovacevic** *University of Belgrade, Belgrade, Serbia* **Exoplanets Atmospheres Mass Loss: The importance of Supermassive Black Holes Radiation**

14:45 – 15:15 **(30 min)** Page 37	**Saibal Mitra** *Independent Researcher* **Percolation clusters of organics in interstellar ice grains as the incubators of life**
15:15 – 15:45 **(30 min)** Page 38	**Mohammad Asif Iqubal** *Indian Institute of Technology Roorkee, India* **Facile One Pot Synthesis of Nucleic Acid Bases by Divalent Metal Ion Doped Iron Oxide Nanoparticles from a Single Carbon Atom Precursor Molecule Formamide: A Prebiotic Chemistry Approach**
15:45 – 16:15	**Sohan Jheeta: Close of Day summary and future meetings**

Close of Day 3

Abstracts Day 1

DAY 1

14:30 - 15:15

Life entropy symmetry

George Cambourakis
National Technical University of Athens, Greece
gcamb@cs.ntua.gr

Parmenides, Greek pre-Socratic philosopher from Elea in Magna Graecia, who flourished before 500 BC, teaches that an entity exists if it has boundaries. The boundary of an entity, living or not, can have at most three intermingling sub-boundaries. An entity having a material sub-boundary has also an energetic one and an ITformational. A very interesting category of entities is those having only ITformational boundary. ITformation is the most primitive "substance" and the precursor of what we think as information. ITformation is the main ingredient of Laws (physical or not). All laws come from the two super-laws, namely (a) Self-preservation (law of no Change) and (b) Communication (law of Change). Symmetry is a manifestation of the *law of no change*. Flux is a manifestation of the *Change law*. Conservation laws are consequences of symmetry. Time is the local derivative of Change. Entropy is a local measure of symmetry. Flux of ITformation (Shannon information) is a complex physical measure, which correlates with order and entropy. Symmetry breaking (decrease in entropy) produces order. Intramolecular configurations, which are at a dynamic equilibrium between transition states, store *configurational* entropies, which take a distinct part in the *free energy* of the transition process. Life starts as a symmetry breaking process and the emergence of homochirality. This is certainly true in biology, as symmetry breaking along well-defined axes is intimately linked to functional diversification on every scale, from molecular assemblies, to subcellular structures, to cell types themselves, tissue architecture, and embryonic body axes.

DAY 1

15:15 - 15:45

Direct Imaging Search for Exoplanets around Young Stellar Objects

Taichi Uyama
The University of Tokyo
t.uyama@astron.s.u-tokyo.ac.jp

From the first detection of exoplanet in 1995, thousands of exoplanets have been reported. Interestingly physical and orbital parameters of most reported exoplanets are much different from those of planets in the solar system. I'm working on direct imaging method and main target is young stellar object (YSO). They are basically younger than 10 Myr and often have protoplanetary disks where

planets are being formed. Previously planet formation theory has been constructed from solar system, which should be updated to understand planet formation synthetically. In this talk I will explain what we have been obtaining from direct imaging explorations and touch on future prospects.

Day 1

15:45 - 16:15

Life as inflationary expanding phenomena

Pauli E Laine

University of Jyväskylä, Finland

pauli.e.laine@student.jyu.fi

Origin of life is one of the greatest mysteries. We don't yet know if life is something that emerges always in right conditions or whether life on Earth is unique phenomena in observable Universe or even in a collection of universes in an infinite and eternal multiverse. I argue here that life has an analogue in modern cosmology: life is something that emerges from micro-scale physiochemical landscape, and if successful, undergoes inflationary expansion, just as the Universe expanded from a quantum fluctuation. I will further argue, that this analogue will actually increases the possibility of extraterrestrial life.

Day 1

16:45 - 17:15

Astrobiology Outreach and Dissemination: the new communication channels for an innovative science

Klara Anna Capova

Durham University, UK

k.a.capova@durham.ac.uk

The multidisciplinary field of astrobiology provides an excellent example of the international cooperation among a large number of disciplines. Yet, at the same time, it poses a challenge of how to effectively communicate and disseminate such a wide and innovative field of knowledge to audiences outside the astrobiology community. In general, scientists today are often expected to take a proactive role in this endeavour and assist the society in understanding the basic concepts of their respective fields as well as the recent discoveries.

The need to communicate science information applies also to the promotion of a 'good' science as a reaction to often misleading media or popular stories. In the context of the new technologies, also new channels of communicating scientific knowledge are being explored, such as advanced visualisation techniques, interactive exhibits, virtual reality and other.

Astrobiology, as a science that deals with the profound questions ‘who are we’ and ‘where do we come from’, in fact, deals with topics of high social interest and far-reaching sociocultural implications. Those are also questions that have significant public appeal.

The presentation will firstly highlight the astrobiological research of public interest that have a potential for science popularisation in general. Secondly, it will show how new channels of knowledge communication and science dissemination can become an opportunity for scientists to reach out to other educators, policy advisors and public alike. At last, during the presentation, some concrete examples of recent outreach projects related to astrobiology dissemination will be showcased.

Day 1

17:15 - 17:45

In quest of a conceptual framework for the transition from Non-Living to Living Matter on the early Earth: evidence supporting MuGeRo hypothesis

Rosanna del Gaudio

University of Naples Federico II, Italy

rosanna.delgaudio@unina.it

The story of life’s origins is one of the deep, intriguing and unsolved mysteries of Science. How, when and where life arose on the toxic and inhospitable environment of our planet billions of years ago remain debated questions. The puzzle boils down to bridging the gaps between chemical, geological and biological processes. Even though we know how some molecules behave and also have knowledge of how cells “work” we still don’t understand how a mixture of lifeless molecules could have given rise to the first living cells.

In the field of the origin of life, one of the proposed theories suggests that relevant organic compounds were delivered on to the surface by comets and meteorites. These molecules led to the formation of peptides (metabolism first) which preceded the emergence of oligonucleotides.

Other scientists have proposed that ready-made microorganisms may have been transported to the surface of the Earth by meteorites (1, 2, 3). With several other hypotheses in play, the challenge is to replicate the conditions that allowed life to emerge. One such theory suggests that life could have emerged on Earth from inanimate matter via minerals/rocks-organic interface processes (4).

I developed a new approach (5) to stimulate the energetic processes that may have led to the emergence of proto-metabolic pathway on Earth or earth-like planet. Current status of laboratory experiments in hydrogel environments utilizing the self-organizing M4 material (patent) obtained from meteorites and terrestrial rocks and minerals as a model for the emergence and early evolution of life on Earth, will be presented and discussed.

My findings are in line with some recent papers showing that minerals containing iron and nickel would have been common on the early Earth (5) and those reported by other authors (6, 7) also give support to the previously proposed MuGeRo hypothesis (8).

In conclusion, in quest of a framework for the emergence and evolution of early Earth, my proposal is that abiotic, photo-geochemical reactions could have given rise to a variety of independent biogenic events getting to a plurality of an Initial Darwinian Ancestor (IDA) form of life (9) and the origin of life on Earth represents only one pathway among many along which life emerged.

In conclusion, my questions are: "Do all microbes and organisms living on Earth share a common ancestor? Did life on Earth begin more than once? Can we exclude that alien microbes or invertebrate species subject to similar environmental conditions can gradually converge and mask evidence of independent biogenic events and appear similar to life forms of the current tree of life?"

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Abstracts Day 2

Day 2

09:45-10:30

HP sauce on everything: Multiple roles of hydrogen peroxide in mediating the origin of life

Rowena Ball
Australian National University
rowena.ball@anu.edu.au

The HP crucible hypothesis holds that life began in a localised environment that was perfused with a flow of hydrogen peroxide from a sustained external source, which powered and mediated molecular evolution and the protocellular RNA world. The story of the relationship between hydrogen peroxide and life is complex and ongoing, and fraught with misapprehensions. Living cells make and break hydrogen peroxide, and, after a long period when it was reviled as a toxic cell vandal and saboteur of gene transcription fidelity, evidence is mounting that its relationship with living organisms is intimate and vital. This relationship is usually assumed to have begun with the evolution around 2.3 billion years ago of oxygen-evolving photosynthesis. Yet hydrogen peroxide was present on Earth before photosynthetic cells appeared, and primitive anaerobes must have come to some arrangement with it. And what of its role with respect to proto-cellular life, the putative RNA world?

In this talk I shall consolidate and review recent evidence for multiple roles played by hydrogen peroxide in the evolution of the first living systems: i) it provides a periodic power source as the hydrogen peroxide/thiosulfate (THP) redox oscillator, ii) it may act as an agent of molecular change and evolution and mediator of homochirality, iii) the THP oscillator, subject to Brownian input perturbations, produces a weighted distribution of output thermal fluctuations that favours polymerisation and chemical diversification over chemical degradation and simplification. The HP crucible hypothesis can shed light on the hero and villain roles of hydrogen peroxide in cell function, and on the singularity of life: of necessity, life evolved early an armory of catalases, the continuing and all-pervasive presence of which prevents hydrogen peroxide from accumulating anywhere in sufficient quantities to host a second origin. The HP crucible hypothesis is radical but based on well-known chemistry and physics, it is eminently testable in the laboratory, and many of our simulations provide recipes for such experiments.

Day 2

11:00-11:30

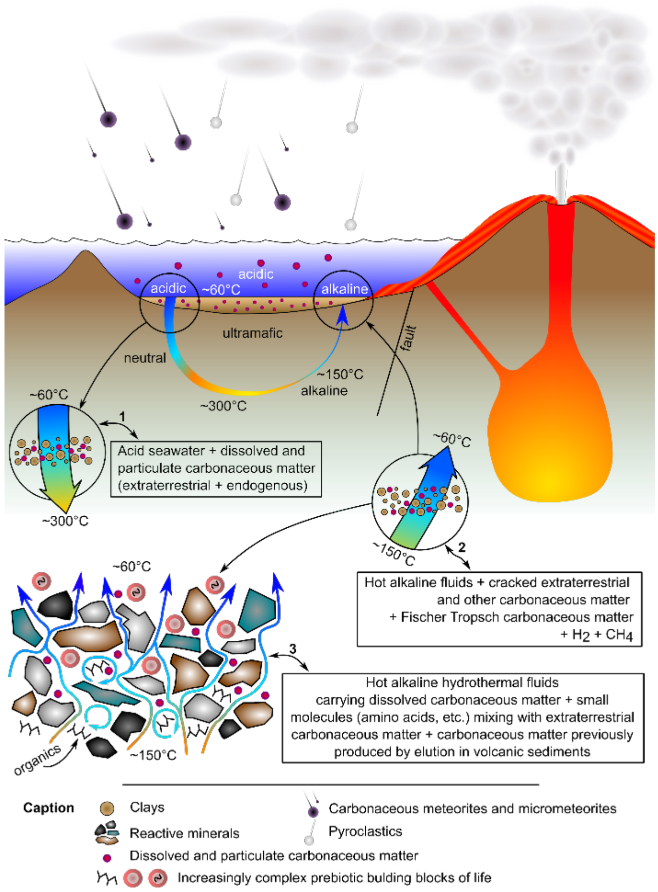
A hydrothermal sedimentary origin of life?

Frances Westall*, K. Hickman-Lewis, N. Hinman, P. Gautret, K.A. Campbell, J.G. Bréhéret, F. Foucher, A. Hubert, S. Sorieul, A.V. Dass, T.P. Kee, T. Georgelin, A. Brack

CNRS-Centre de Biophysique Moléculaire, Orléans, France

Frances.WESTALL@cnrs.fr

Many locations have been proposed for the origin of life ranging from hydrothermal vents and pumice rafts, through volcanic-hosted splash pools to continental springs and rivers, each with respective advantages and certain disadvantages. However, there is another, hitherto unrecognized environment that, on the Hadean Earth (4.5-4.0 Ga), would have been more important than any other in terms of spatial and temporal scale: the sedimentary layer between oceanic crust and seawater.



Using as an example sediments from the 3.5-3.33 Ga Barberton Greenstone Belt, South Africa, analogous at least on a local scale to those of the Hadean Eon, we document constant permeation of the porous, carbonaceous and reactive sedimentary layer by hydrothermal fluids emanating from the crust. This partially UV-protected, subaqueous sedimentary environment is characterised by physical and chemical gradients, including ionic concentrations, pH, temperature, water activity etc. It represented a widespread system of miniature chemical reactors in which the production and complexification of prebiotic molecules could have led to the origin of life.

This kind of scenario for the origin of life is valid for any extraterrestrial body hosting hydrothermal water interacting with (hot) rocks and where there is a supply of prebiotic molecules.

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Day 2

11:30-12:00

Network of autocatalytic RNA in the origin of life: Pre-Darwinian evolutionary dynamics

Sandeep Ameta

ESPCI Paris, France

sandeep.ameta@espci.fr *and* ***sandeep.espci@yahoo.com***

Life as we know today is extremely unlikely to have originated with all the required properties at once on the prebiotic Earth, and origin of life must have been a gradual process starting from elementary interactions between molecules. Among various origin of life scenarios, 'RNA world hypothesis' is the most experimentally tested. It is based on the fact that RNA molecules can store information as well as catalyze reactions, tasks which are performed by DNA and protein in the contemporary cells. Yet there is insufficient evidence for the appearance of first template-based RNA replicase in such RNA world scenario. Alternatively, collectively autocatalytic sets (CAS) where, in an ensemble, molecules can replicate each other could have preceded the template-based replication era. While CAS have been extensively studied theoretically and even few scenarios of their emergence have been proposed, empirical studies to test such are largely lacking. Thus, there is a strong need for understanding the pre-Darwinian dynamics through which CAS could have evolved and propagated on the prebiotic Earth. In my postdoctoral research, we have empirically investigated RNA-based CAS by combining droplet-based microfluidics and single droplet-level sequencing. Using RNA fragments from the group I intron ribozyme of Azoarcus bacterium we constructed a big and diverse library of CAS in small droplets and analyzed the composition of each CAS at an unprecedented resolution. The results highlight that the fraction of a ribozyme within a network can be very well predicted by the incoming connections. Using compositional neighborhoods of these networks, the effect of change of a node 'perturbation' is also analyzed. We observed that such changes can shuffle the rankings of nodes in the network and, in general, well-connected networks are more resistant against such perturbations than sparsely connection ones. Understanding such dynamics will guide us to design selection strategies, test scenarios where robust RNA networks are favored and demonstrate Darwinian evolution using CAS.

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Day 2

12:00-12:30

Are Scientific Models of Life Testable? A Lesson from Simpson's Paradox

Nolan Grunska*, Prasanta S. Bandyopadhyay, Mark C. Greenwood

**Texas State University, USA*

ngrunska@aol.com

In this paper, we discuss two competing theories about the emergence of life on earth: Metabolism First Theory (MFT) and RNA World Theory (RWT). MFT postulates energy utilizing chemical reactions to have generated primordial organic life. In contrast, RWT holds that self-replicating RNA forms the basis of life by storing both genetic information and catalyzing the chemical reactions in primitive cells. One central debate between them consists in objecting to one another that chemical reactions invoked by the other is inefficient. We call this the "inefficiency objection" to the emergence of life theories, which, if true, precludes the emergence of life. Given that life did indeed emerge, the inefficiency objection needs to be explained away.

Borrowing an insight from Simpson's paradox (SP) we argue that even though bio-chemical reactions for producing life could be locally inefficient in each cell, they could be globally efficient - a reversal characteristic of SP. This shows that the inefficiency objection need not pose a problem for emergence of life theories.

Day 2

12:30-13:00

Biosignatures for the search of extrasterrestrial life on Mars, Europa, and Enceladus

Christos D Georgiou

University of Patras, Greece

c.georgiou@upatras.gr

Current space probes are designed/employed to detect extinct/extant life on Mars, Enceladus, and Europa, using terrestrial amino acids and nucleobases as biosignatures, although these are also produced by abiotic chemical reactions. The following universal functional properties of life are proposed as more reliable alternatives:

A. Patterns of certain amphiphilic hydrocarbon lengths, larger from those found in meteorites: The first lipid vesicles to house life were unstable because they were assembled from the available abiotic hydrocarbon derivatives, having short chain length (4C to 9C). Subsequently, life increased the hydrocarbon chain-length patterns (16C to 24C) of its membranes, to enhance their stability, fluidity, and permeability for optimum adaptation to temperature, pH and salinity. Lipid hydrocarbon biomarkers are chemically stable, easily fractionated, and identifiable by well-established techniques (e.g. GC-MS).

B. Patterns of organic molecules that are universally associated with biological functions, catalytic and structural: Biochemical catalysis, especially hydrolysis, must be a primarily function of all water-based life. Biochemical reactions are immensely accelerated by organic catalytic groups within membranous compartments in order to be sustained against substrate/product dilution. Hydrolytic activity of extraterrestrial organics, in particular, can be identified/measured as biomarker of extraterrestrial life by existing ultrasensitive fluorescent assays, which use certain artificial hydrolytic substrates (e.g. umbelliferone, 6-methoxynaphthaldehyde). Catalytic groups of extraterrestrial life are likely to be structurally similar to certain terminal groups in the side-chains of amino acids, especially those possessing very high catalytic propensity (i.e. they are found at high percentages in the active centers of most enzymes). Such catalytic groups are imidazole (in His), thiol (in Cys), guanidinium (in Arg), and amide (in Asn, Gln). These groups and their amino acids are potential biomarkers because they are not found in meteorites. In contrast, the meteoritic abiogenic amino acids (Asp, Glu, Lys, Ser, Thr, Gly, Leu, Pro, Ile, Ala, Val) possess very little catalytic propensity. As biomarkers, can also serve those pattern distributions of certain biogenic amino acids, which correspond to their participation patterns (in enzymes of terrestrial life) as hydrolytic catalytic triads and dyads, together with certain abiogenic amino acids; these are His (in the triads Ser-His-Glu, Ser-His-Asp, and Thr-His-His), Tyr (in Asp-Tyr-Lys), and Cys (in the dyads Cys-Ser, and Cys-Thr). Distributions of certain abiogenic amino acids can also serve as biomarkers as long as they correspond to their participation patterns (in terrestrial life's enzymes) as catalytic triads (Thr-Lys-Asp and Lys-Glu-Lys) they appear in enzymes of terrestrial life. Thus, life must have invented amino acids with high catalytic propensity in order to overcome, and be complemented by, the low catalytic propensity of the abiogenically synthesized amino acids. Certain distribution patterns of the abiogenic amino acids and of the biogenic ones with low catalytic propensity (e.g. Phe, Met), can serve as biomarkers on the basis of their functional propensities related to protein 3D-structure. These are: (1) Amino acids with high propensity to form α-helical intra-membrane peptide domains, because these can serve as, (i) primitive transporters in protocell membrane bilayers, and (ii) catalysts of simple biochemical reactions. (2) Amino acids with high propensity for participation in the 3D-structure of terrestrial, and possibly of extraterrestrial, extremophile proteins; thermophile, psychrophile and halophiles. The catalytic/structural functional propensities of organic matter offer a new perspective in the search of extraterrestrial life, and they unify past terrestrial amino acid-based approaches; let alone, they can be identified by existing methodologies.

Day 2

14:00-14:45

Compositional lipid catalytic networks as the earliest evolving replicators

Doron Lancet

Department of Molecular Genetics, Weizmann Institute of Science, Rehovot, Israel

doron.lancet@weizmann.ac.il

We advocate a dissident view, whereby spontaneously accreting assemblages of heterogeneous amphiphiles were the first replicators. This is substantiated via rigorous chemical kinetics simulations within the Graded Autocatalysis Replication Domain (GARD) model, based on the notion that the accumulation and transfer of compositional information predated sequence-based informational biopolymers. We show the emergence of privileged non-equilibrium GARD assemblies ("composomes"). These constitute mutually catalytic networks, portraying cell-like homeostatic growth. With occasional fission, GARD assemblies manifest compositional reproduction. GARD evolution is demonstrated in computer simulations showing composome selection within a sparse fitness evolutionary landscape, in response to environmental changes. These observations refute claims that GARD assemblies (or other mutually catalytic networks in the metabolism-first scenario) cannot evolve. Composomes represent both a genotype and selectable phenotype, being likely forerunners for later entities in which the two were separated. Detailed simulation analyses show that the attractor-like transitions from random assemblies to self-organized composomes involve negative entropy change, establishing GARD composomes as dissipative systems, hallmarks of life. Finally, we draft a new GARD model version, metabolic GARD (M-GARD), in which lipid covalent modifications are controlled by non-enzymatic lipid catalysts, themselves compositionally replicated. With the expected immense acceleration of molecular dynamics, M-GARD could soon quantitatively depict elaborate GARD protocells, with orchestrated replication of both bilayer and lumenal content. Such simulated M-GARD vesicles would constitute a rigorously described instance of a primeval protocell, as supported by a first published experimental instance of lipid-based M-GARD. Analyzing composome emergence in a whole-planet context leads us to estimate that such simple evolving structures may have emerged very early after planet Earth last cooled down 4 billion year ago. It thus may have taken all of 500 million years to transit from reproducing M-GARD lipid assemblies to life's last universal common ancestor (LUCA), as the latter are likely seen in the consensual unicellular fossils of 3.5 billion years ago.

Day 2

14:45-15:15

Arising of the Functional Sequences and Their Horizontal Transfer at the Moment of the Origin of Life

Vladimir N. Kompanichenko

Institute for Complex Analysis, Russian Academy of Science (FEB), Birobidzhan, Russia

kompanv@yandex.ru

There are key points of the presentation based on the author's inversion concept of the origin of life (Kompanichenko 2017). A key step in the origin of life consists in the *thermodynamic inversion* that radically changed macro-state of a prebiotic microsystem. At the inversion moment, the total contribution of free energy and information into the transformed microsystem became prevalent over the total contribution of entropy. The appeared excessive "over-entropy" free energy and information, which are not suppressed by entropy, launched proper biological processes in the initial forms of life (called "probionts"). With the inversion, the primary functional sequences formed through the highest internal tension and counteraction with random sequences (Figure 1).

- Emergence of initial life forms occurred under nonequilibrium conditions in hydrothermal systems, where incessant oscillations of physic-chemical parameters forced the prebiotic microsystems to respond to them through continuous recombination. Regular external oscillations initiated formation of repetitive fragments in the macromolecules, while irregular fluctuations led to sudden disjunctions in the sequences; the complex combination of regular and irregular fluctuations of pressure and temperature has been actually detected in hydrothermal systems in Kamchatka.

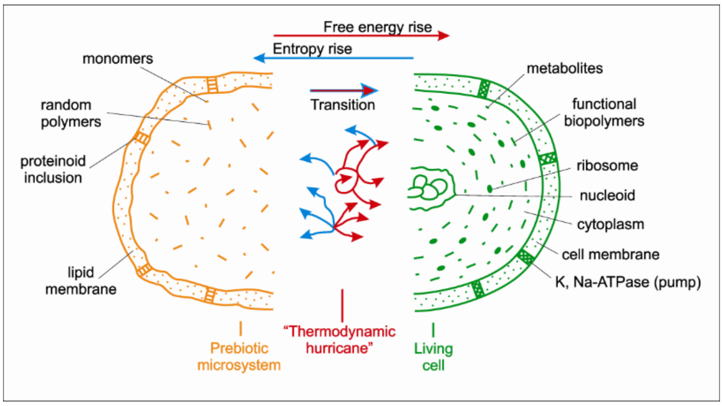

Figure 1 Schematic transition of an oscillating prebiotic microsystem into primary living unit (cell) in course of thermodynamic inversion. Left: prebiotic microsystem (half) composed of random polymers, monomers, and simple molecules. Center: the violent transition into the living state during overcoming of the negentropy barrier (through "thermodynamic hurricane"); conditional directions of the proto-biochemical processes with rise of free energy (red) and entropy (blue). Right: the simplest prokaryotic cell (half) with the main cellular structures: nucleoid (ring DNA), ribosomes, and cell membrane

- Emergence of initial life forms occurred under nonequilibrium conditions in hydrothermal systems, where incessant oscillations of physic-chemical parameters forced the prebiotic microsystems to respond to them through continuous recombination. Regular external oscillations-initiated formation of repetitive fragments in the macromolecules, while irregular fluctuations led to sudden disjunctions in the sequences; the complex combination of regular and irregular fluctuations of pressure and temperature has been actually detected in hydrothermal systems in Kamchatka.

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Day 2

15:15-15:45

Biotite is a better mica for the origins of life

Helen Greenwood Hansma

University of California at Santa Barbara, Santa Barbara, USA

helen.hansma@gmail.com

Life might have started between the sheets of mica, powered by the mechanical energy of moving mica sheets (1). Mica is an ancient mineral – ancient enough to have been the place where life started. The spaces between mica sheets could have been the ancient precursors of cells, sheltering and concentrating, and phase-separating the earliest biomolecules, before cells were covered with membranes. Mica also forms hydrogen bonds [H-bonds] with biological molecules (2), which is exciting, because H-bonds are ubiquitous in biomolecules. Recent research (3) shows that the dielectric constant of water is tiny in the first 2-3 water layers above a surface, because these water molecules lack the rotational freedom of bulk water. Bulk water has a dielectric constant of ca. 80, vs ca. 2 for the confined water layers above a surface. Surface water molecules therefore provide almost no screening of charges, which means that charged or polar organic molecules on a mica surface will interact strongly with mica's surface charges. Muscovite mica has been envisioned as the site where life originated, but biotite mica has advantages for life's origins that Muscovite mica lacks (5). Biotite is a common mica, a black mica, rich in both iron and magnesium (Mg). Being high in iron (Fe), biotite is capable of redox reactions, which were essential for life's origins. The iron is predominately Fe(II), which reduces organic molecules, producing the molecules of higher energy that were needed for living cells. Mg is a major inorganic divalent cation in living systems. Biotite is the most conductive mica, because iron (Fe) conducts the electrons. The electric current increases exponentially with the iron content of the micas (2). The electrical conductivity and redox chemistry of biotite mica both increase the advantages of mica as a site for life's origins.

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Day 2

15:45-16:15

The minimal chemotactic vesicle

Giuseppe Battaglia

Department of Chemistry, University College London, UK

g.battaglia@ucl.ac.uk

Directed locomotion or taxis is possibly one of the most important evolutionary milestones, as it has enabled many living organisms to outperform their nonmotile competitors. In particular, chemotaxis (that is, the movement of organisms either toward or away from specific chemicals) is possibly the most common strategy adopted by many unicellular organisms to gather nutrients, escape toxins, and help coordinate collective behaviours such as the formation of colonies and biofilms. Chemotaxis is conserved and exploited by multicellular systems for tissue development, immune responses, or cancer metastasis. It enables long-range interactions that extend over length scales that are several orders of magnitude larger than the motile system itself.

Chemotaxis is one of the most characteristic manifestation of out-of-equilibrium physics and in modern living systems involves complex machineries as well as cooperative signalling and sensing. Here I will show however that chemotaxis can be observed in both lipid and synthetic vesicles and its emergence is conditional to chemical gradient and asymmetry in the vesicle membrane. I will discuss the mechanistic of minimal chemotaxis, its collective nature and how this can be exploited to improve drug delivery. Most importantly I will show that complex behaviours topically observable in living systems can be replicated by simple supramolecular arrangements comprising few species.

Day 2

16:45-17:15

Searching for Signs of Extraterrestrial Life

Stefan Fox

University of Hohenheim, Institute of Chemistry, Department of Bioinorganic Chemistry, Stuttgart, Germany

stefan.fox@uni-hohenheim.de

If the assumption is true that life, at least unicellular life, is not limited to the Earth and could be common in the Universe, searching for signs of extraterrestrial organisms should be worthwhile. The search for extant or extinct life on other planets and moons requires adequate life indicators and suitable detection techniques. Chemical biosignatures, such as those arising from biomolecules, biologically altered minerals and fractionation of stable isotope ratios, are among the most useful life indicators. Apart from the technical challenges, misinterpretations that are caused, for example, by false positives can have grave consequences in that such results will demonstrate the presence of extra-terrestrial life on an exoplanet when clearly there isn't any.

A common issue in space missions is terrestrial contaminations, which are technically unavoidable at best of times. They can be erroneously interpreted as signatures of extra-terrestrial life as with as with the false positives above. Other false positives may occur when organic molecules are produced abiotically in nature, for example, porphyrins are considered to be of biological origin, but in fact there are at least two other known ways for them to be made abiotically thus resulting in potential false positive outcomes. Some biosignatures can be more reliable than others (Fox and Strasdeit 2017). Among them are (*i*) polymers that are homochiral and have a defined length and sequence, (*ii*) enantiopure compounds and (*iii*) the existence of only a subset of molecules when a continuous range of molecules would be produced via abiotic synthesis; proteinogenic amino acids are an example for such a subset. During the search for life via space missions in our Solar System; observational and radio-spectroscopes observation of exoplanets further afield, it is particularly important to keep in mind the possibility of misleading results being part and parcel of such observations. Therefore, it is essential to devise strategies for the detection and interpretation of potential biosignatures.

One reason for searching of extra-terrestrial organisms is that knowledge about independently developed life would allow a deeper understanding of the terrestrial life and its origin.

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Day 2

17:15-17:45

Life in the Universe – and beyond

Martin Dominik
University of St Andrews, Scotland, UK
md35@st-andrews.ac.uk

Planet Earth is the only place in the whole Universe known to us to harbour life. However, if we believe in the laws of Nature being universal, why should we be special? In the quest for finding out whether biology extends beyond home, do we have appropriate concepts and a sound plan?

Day 2

17:45-18:15

Detecting the signatures of life: state-of-the-art instruments and methods

Elias Chatzitheodoridis
National Technical University of Athens, Greece
eliasch@metal.ntua.gr

The search for the origins of life is an intriguing area of research and experimentation. It requires that we search for those organic molecules that have been synthesised in nature by inorganic processes and which have been the building blocks for the first living entities. It also requires that we mimic different processes that nature possibly has used to synthesise life, *i.e.*, primary organic molecules, minerals, geochemical environments, and physicochemical conditions.

To date, over 190 complex organic molecules (*e.g.*, methanol, formaldehyde and formamide) are common in the interstellar medium [1], and over 90 such molecules have been identified in meteorites [2] including amino acids, nitrogenous bases, and polycyclic aromatic hydrocarbons (PAHs). Such molecules have been used by life in certain patterns, and when life ceases, some of these chemical patterns remain; such patterns are termed biosignatures, and they are identifiable. To enable us to do this, we require *state-of-the-art* instruments as well as sophisticated processing and data interpretation methods.

This work focusses on high mass resolution spectrometry techniques, such as Time of Flight (ToF) mass spectrometry or dynamic mass spectrometry, either based on ion sources using sputtering methods, or on laser desorption methods using high energy pulsed lasers. We will provide a description of the instruments together with a methodological way on interpreting complicated mass spectra and identifying patterns that could constitute signatures of life. We will give examples from terrestrial samples, but also on extra-terrestrial ones, such as Martian meteorites and measurements from the comet 67P/Churyumov–Gerasimenko acquired with the COSIMA instrument onboard the ESA's ROSETTA spacecraft [3].

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Day 2

18:15-18:45

Energy of ontogenesis according to Evo-SETI theory

Claudio Maccone

Istituto Nazionale di Astrofisica (INAF), Italy

clmaccon@libero.it and claudio.maccone@iaamail.org

Energy of ontogenensis is the total energy (measured in Joules) that a newly-born baby (whether human or belonging to other living forms) needs to receive in the period of time between birth and puberty, In other words, the ontogenesis energy is the energy required by all living forms to acquire their genetic load until they are ready to reproduce. In mathematical form, this energy is the integral between birth and puberty of the “logpar” power curve (measured in Watts) that this author recently brought to light in two papers (Refs. [1] and [2]) dealing with his much more general mathematical model of life called “Evo-SETI Theory”. In this paper we publish for the first time several new results about the energy of ontogenesis:

1) The equation yielding the energy of ontogenesis may be expressed by reducing it to the error function typically used in probability theory;
2) The third derivative of the logpar power curve with respect to the time enables us to find approximated expressions for the time when the baby need for energy is highest (point of maximum curvature of the logpar in between birth and puberty) and, after puberty, when the adult takes the decisions that will guide his whole future lifetime (“intellectual maturity”); and
3) A comparison between the energy of ontogenesis and the subsequent energy that the living organism will need for the rest of his life is also possible in terms of the mathematics outlined in this paper.

In conclusion, our invention of the logpar power curve representing the lifetime of a living organism provides a profound mathematical tool not only for our Evo-SETI mathematical description of Life, but now also Ontogenesis.

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Abstracts Day 3

Day 3

08:30-09:15

Life: a probable chemistry rather than an improbable one

Sohan Jheeta

Independent Research Scientist, NoR HGT & LCUA, Leeds, UK

sohan@sohanjheeta.com

All living entities consist of a cell with a boundary called the cell membrane, so all life's reactions occur within this "sack". Nothing new so far, but the cell is packed full of reaction by-products (eg CO_2) and newly made peptides, as well as activated reactants eg 20 different types of charged and neutral amino acids and nucleotides. Also "clogging" up the cells are endoplasmic reticula, lysosomes, vacuoles, DNA, RNAs, plasmids, mitochondria, centrioles, Golgi apparatus, starch granules, protein active sites and electrolytes, as well as amphoteric and triglyceride molecules.

In order for a cell to survive peptides and other substrates have to travel to wherever else in the cell that they are needed eg transmembrane proteinous sites. This means that they have to negotiate many obstacles in order to reach their targets; not any easy task because they will careering about blindly, knocking into one another and the rest of the cell's contents and also being attacked by various radicals and proteolytic enzymes; their "safe" passage may also be blocked by other larger molecules and nano-machines (e.g. mitochondria) and not forgetting that water molecules, being bi-polar, will be a major barrier too. Then ultimately upon their eventual arrival at the place of destiny, the active site on the recipient enzyme may be facing the wrong way; the right orientation of both molecules has to be synchronised before any discernible intended activity can take place. Overcoming this level of chaos and difficulty would seem to be highly improbable as a cell appears to be a disordered environment rather than a cosy organised place, does it not?

However, despite all this, cells still manage to carry on with the business of living, performing appropriately necessary reactions and replication, often on a nanoscale. The result being that the reactions which occur in cells can be referred to as *probable chemistry*, noting that such reactions were present during the very early chemical evolution of life. Such reactions have remained unaltered since before the very first emergence of a preLUCA.

So, what is probable chemistry? It is chemistry which occurs in three stages (a) self-organisation of molecules; self-assembly of nanoparticles and instructed chemistry. All these facets eventually led to the emergence of life, which in essence is super-hypercomplex chemistry.

Day 3

09:15-09:45

Methanogenic microbial community as a biological system: insights into origin of life

Oleg Kotsyurbenko

Yugra State University, Russia

kotsor@mail.ru

Methanogenic microbial community is a complex tropically connected biological system. It composes of different microbial groups degrading organic matter step by step and sharing energy available from various metabolic processes. The occurrence of these processes is driven by thermodynamic laws. Methanogens are the terminal microbial group of the community that depends on substrates provided by other microorganisms in the trophic chain and in turn regulates microbial processes by feedback. Evolutionary, methanogenesis seem to be one of the most archaic ways to get energy for organisms on Earth so that methanogens are considered to be one of the ancient living forms.

The system analysis applied to methanogenic microbial community gives insights into main principles of the development of living forms. According to G.A. Zavarzin, the system analysis of life as a phenomenon includes following basic premises: 1. the hierachic construction "element-system" is the basis of biological interactions; 2. the life phenomenon starts from a micro (organism), systems of a lower level being lost life intrinsic properties; 3. an organism can only exist as a part of the community. The system interactions can be the important precondition for the origin of life.

Methane is recognized to be the important biomarker in the concept of searching for life in the universe. Cosmic bodies in Solar System where methane was detected and subsurface water reservoirs are presumed are potential habitats for methanogenic microorganisms. Panspermia hypothesis could explain the distribution of living forms in space. Methanogenic microbial community from the Negev desert soil could be a model biological system for the astrobiological experiment testing the hypothesis of panspermia including return space missions. The community should be enclosed in soil being a matrix that is suggested to protect microorganisms and increase their survival.

Day 3

09:45-10:15

Evolution of bioenergetic diversity across the prokaryotes, and within the human gut microbiome

Vassiliki Lila Koumandou

Agricultural University of Athens, Greece

Koumandou@aua.gr

Prokaryotes are characterized by an amazing metabolic diversity, which allows them to persist in diverse and often extreme habitats. Apart from oxygenic photosynthesis and oxidative phosphorylation, well-studied processes from chloroplasts and mitochondria of plants and animals, prokaryotes utilize various chemo- or lithotrophic modes, such as anoxygenic photosynthesis, iron oxidation and reduction, sulfate reduction, and methanogenesis. Most bioenergetics pathways have a similar general structure, with an electron transport chain composed of protein complexes acting as electron donors and acceptors, as well as a central cytochrome complex, mobile electron carriers, and an ATP synthase. While each pathway has been studied in considerable detail in isolation, not much is known about the order of emergence of these pathways and their evolutionary relationships.

Wanting to address how this metabolic diversity evolved, we mapped the distribution of nine bioenergetic modes on a phylogenetic tree based on 16S rRNA sequences from 272 species of fully sequenced bacteria and archaea, which represent the full diversity of prokaryotic lineages. This highlights the patchy distribution of many pathways across different lineages, and suggests either up to 26 independent origins or 17 horizontal gene transfer events[1]. Next, we used comparative genomics and phylogenetic analysis of all subunits of the F0F1 ATP synthase, common to most bacterial lineages regardless of their bioenergetic mode. Our results indicate an ancient origin of this protein complex, and no clustering based on bioenergetic mode, which suggests that no special modifications are needed for the ATP synthase to work with different electron transport chains[1]. We then focused on the distribution and evolutionary relationships of different b-type cytochromes, which form part of a variety of bioenergetic enzymes (the cytochrome b6f complex, ubiquinol and menaquinol reductases, formate dehydrogenase, Ni/Fehydrogenase, and succinate dehydrogenase). Different cytochrome-b types form distinct groups in phylogenetic analysis, which indicates an ancient origin and diversification of b-type cytochromes before the diversification of lineages[2]. As for the ATP synthase, we find that species do not cluster based on bioenergetic mode, indicating that b-type cytochromes are not specific to any pathway. We have also re-examined available data from three major studies of the human gut microbiome, deposited on MG-RAST, to assess the diversity of the microbiota with regards to bioenergetic pathways[3].

The human microbiome has lately emerged as an important factor in health and disease but a lot of questions on how the diversity of the microbiome affects our health still remain unanswered. Our results indicate that a number of species are present in the human gut of both adults and infants which normally derive their energy from methanogenesis, iron oxidation, iron reduction, sulfate and arsenate reduction, and even anoxygenic photosynthesis [3]. We discuss the meaning of the presence of these bioenergetic pathways to the dynamics of the human gut microbial community, and future directions to better characterize this previously unsuspected diversity.

References

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2) V. L. Koumandou and S. Kossida, “Evolution of b-type cytochromes in prokaryotes,” Dec. 2015. [3] P. Agioutantis and V. L. Koumandou, “Bioenergetic diversity of the human gut microbiome,” Meta Gene, vol. 16, pp. 10–14, 2018

Day 3

10:15-10:45

A high throughput computational approach for fractionation of RNA species from whole transcriptomes, in terms of their biochemical identity

Konstantinos Papasakellariou*, Christos Kotakis, Vassiliki Lila Koumandou

**Agricultural University of Athens, Greece*

Koumandou@aua.gr

The emerging field of the RNAome landscape uncovers multiple levels of regulation in life that range from post-transcriptional epigenetics to riboswitches and trans-acting small RNAs. RNA-based interactions have a well-characterised genetic impact inside cells. On a methodological level, RNA-seq data help us to understand that RNA-RNA interactions are pivotal in understanding biological processes from a systems' biology perspective. An increasing body of experimental evidence denotes functional peculiarities of particular RNA ontogenies and thus, the latter unravel novel levels of regulation, regarding their physiological significance. In the last five years, novel computational tools allow fractionation of those RNA species that correspond to a variety of different biogenetic pathways. However, a quantitative algorithm that integrates the complex network of ribo-ecology into a common landscape of study is still missing from the literature. Here, we present a first try on quantifying the naturally occurring RNA diversity, after systematic review of already developed algorithms. Our aim is to map the primary pools of RNA sequences from experimental data, in a way that biological phenomena can be described under a consistent and concrete umbrella. A key-element in our study is the integration of biochemical signatures that characterise bona fide RNA classes, far away from falsified predictions that virtual simulations may be prone to. Our final goal is to meta-analyze RNA pools from different sub-cellular loci, towards specific RNA classes' extrapolation and then to group such biomolecules under distinct categories of similarity with respect to their: a) size, b) sequence, c) biophysical type and d) compartmental origin. Last but not least, we present preliminary results from non-coding RNA-seq data that are derived from photosynthetic organisms. Our findings will be discussed in relation to the evolutionary mobility of potent RNA signals among organellar & nuclear genomes

Day 3

11:15-11:45

Extracellular vesicles enable sophisticated cell-cell communication

Sherri Christian

Memorial University of Newfoundland, Canada

sherri.christian@mun.ca

Extracellular vehicles (EVs) are a heterogeneous group of lipid-encapsulated nano-particles that can be secreted from the cytoplasm or bud from cellular membranes. EVs can be produced by any organism, from prokaryotes to eukaryotes, and are found in all bodily fluids in multicellular organisms. EVs contain bioactive RNA, DNA, and protein that can affect the function of recipient cells. However, the role of EVs in cell-cell communication in normal development or disease states is incompletely understood. We

have recently found that membrane-derived EVs are released in response to stimulation of a cell surface receptor on immature B lymphocytes. I will discuss our findings on the characterization and function of EVs in B cells.

Day 3

11:45-12:15

Gene transfer agents: catching phage and putting them to work

Andrew Lang

Memorial University of Newfoundland, Canada

aslang@mun.ca

Gene transfer agents (GTAs) are bacteriophage-like particles produced by some prokaryotes that exclusively package small fragments of cellular DNA. Production of GTA particles by the alphaproteobacterium *Rhodobacter capsulatus* occurs in a small subset of the population (<3%), with these cells lysing to release particles that can then transfer the packaged DNA to other cells in the population. The production of GTAs in *R. capsulatus* is controlled by several regulatory systems and coordinated with the capability of non-producing cells to become competent to receive DNA from the GTA particles.

Day 3

13:30-14:15

Deciphering and designing relations between the genetic material and the fitness of cells and viruses via computational synthetic biology

Tamir Tuller

Tel Aviv University

tamirtul@post.tau.ac.il

Gene expression is a process that connects the inanimate genetic material to the phenotypes and all intracellular processes of living organisms and viruses. Thus, understanding the way this process is encoded in the genetic material and engineering it should promote deciphering the 'secrets of life'.

In my talk, I will review our novel pipeline for engineering cells and viruses based on computational models that can predict various aspects of gene expression from the genetic material. I will demonstrate how it can be used for understanding the evolution of organisms and viruses and the biophysics of gene expression. It can also be used for studying the ability of evolution to 'optimize' objectives such as growth rate, and for designing cells and viruses with required fitness.

Day 3

14:15-14:45

Exoplanets Atmospheres Mass Loss: The importance of Supermassive Black Holes Radiation

Andjelka Kovacevic
University of Belgrade, Belgrade, Serbia
andjelka@matf.bg.ac.rs

Black holes emit radiation, while accreting the gas, which can photoevaporate the atmospheres of exoplanets. Here we couple the data of Earth-like, Sagittarius Window Eclipsing Extrasolar Planet Search (SWEEPS). Planets to the models of radiation of the central supermassive black-hole of our Galaxy, Sgr A* and the Active Galactic Nuclei (AGN), up to z=0.5, and investigate how their atmospheres are influenced by black holes' active and quiescent phase. We also forecast possible effects of enlarging sample of AGN, due to future observations of the Large Synoptic Survey Telescope (LSST) and the Extremely Large Telescope (ELT), on estimation of exoplanets atmospheres mass loss.

Day 3

14:45-15:15

Percolation clusters of organics in interstellar ice grains as the incubators of life

Saibal Mitra
Independent Researcher
smitra00@gmail.com

Talk based on https://arxiv.org/abs/1711.01945 : Biomolecules can be synthesized in interstellar ice grains subject to UV radiation and cosmic rays. I show that on time scales of $\gtrsim 10^6$ years, these processes lead to the formation of large percolation clusters of organic molecules. Some of these clusters would have ended up on proto-planets where large, loosely bound aggregates of clusters (superclusters) could have formed. The interior regions of such superclusters provided for chemical micro-environments that are filtered versions of the outside environment. I argue that models for abiogenesis are more likely to work when considered inside such micro-environments. As the supercluster breaks up, biochemical systems in such micro-environments gradually become subject to a less filtered environment, allowing them to get adapted to the more complex outside environment. A particular system originating from a particular location on some supercluster would have been the first to get adapted to the raw outside environment and survive there, thereby becoming the first microbe. A collision of a microbe-containing proto-planet with the Moon could have led to fragments veering off back into space, microbes in small fragments would have been able to survive a subsequent impact with the Earth.

Day 3

15:15-15:45

Facile One Pot Synthesis of Nucleic Acid Bases by Divalent Metal Ion Doped Iron Oxide Nanoparticles from a Single Carbon Atom Precursor Molecule Formamide: A Prebiotic Chemistry Approach

Mohammad Asif Iqubal*, Rachana Sharma, Kamaluddin and Sohan Jheeta

**Indian Institute of Technology Roorkee, India*

asifiqubal.88@gmail.com

The synthesis of prebiotic molecules from simple precursor is believed to be a crucial scheme in order to study the origin of life processes. The present study describes one pot synthesis of purine and pyrimidine nucleic acid bases in the presence of prebiologically significant divalent metal ion doped iron oxide nano-particles, namely $NiFe_2O_4$, $CoFe_2O_4$, $CuFe_2O_4$, $ZnFe_2O_4$ and $MnFe_2O_4$. The products identified are cytosine, isocytosine, 4(3 H)-pyrimidinone, adenine, hypoxanthine and purine. The ability of isocytosine (constitutional isomer of cytosine) to recognize cytosine and guanine through normal and reversed Watson-Crick pairing respectively, demonstrating an important storyline for the genesis of ancient nucleic acids. The relevance of other synthesized nucleic acid bases in respect of origin of life is also discussed. The doping of divalent metal ions in iron oxide make it a novel catalytic system because it demonstrates excellent catalytic performance for the nucleic acid bases synthesis with significantly high yield as compared to pure iron oxide and some other minerals like silica, alumina, manganese oxides and double metal cyanide complexes.

Submitted an abstract only

How to stop evolution in self-replicating machines

Alex Ellery

Carleton University, Ottawa, Canada

alexellery@cunet.carleton.ca

We are in the early stages of engineering the most biological of processes - a self-replicating machine - destined for the Moon. We have defined a material metabolism of interlocking feedback loops and a transduction mechanism for exploiting solar energy sources. One of the emerging results of this work is the central importance of actuation as an under-appreciated property of life. In this study, we turn our attention to information processing mechanisms, the engineered version of DNA. We have adopted magnetic core memory as our repository of genetic memory. Of particular interest is the nature of information encoding. One of the characteristics of biological life is evolution – an evolutionary past and an evolutionary future. In life, information is mutable. In a self-replicating machine, we are intent on maintaining control of it. This means that we must prevent evolutionary change. We shall be exploring mechanisms to achieve this using redundancy and error-detection-and-correction coding methods. We shall be making direct comparison between error-detection-and-correction coding in biological and engineered systems. In particular, during the early evolution of biological life, a similar problem must have been solved to prevent the error catastrophe. Of course, if we are successful in preventing evolutionary change in the self-replicating machine for an arbitrary number of generations, this has potentially profound implications – it effectively denies one of the properties of life, namely,

subjection to evolutionary processes. Yet if we permit evolutionary change, our self-replicating machine fulfils all the properties of life.