Closing Conference: ANR-DFG GenDar (IHPST Paris – Leibniz Universität Hannover)
Evolution at the Edges of Life:
Origins, Artificial Systems, and the Conceptual Limits of Evolutionary Theory

Institut d'Études Avancées - Paris 22-23 April 2024
Ile Saint Louis, Hotel de Lauzun, 17 Quai d'Anjou

Program

Monday, April 22

9.00 – 9.15 **Introduction** (Philippe Huneman, CNRS, IHPST Paris & Thomas Reydon, Leibniz Universität Hannover))

9.15 – 9.45 **Presentation of the book** *Evolutionary Thinking Across Disciplines: Problems and Perspectives in Generalized Darwinism* (Springer, 2023); presented by Agathe du Crest (Université Paris 1 Panthéon-Sorbonne) & Martina Valković (Leibniz Universität Hannover)

9.45 – 10.15 **Presentation of the book *S****ex, Gender, Ethics and the Darwinian Evolution of Mankind: 150 years of Darwin's 'Descent of Man'* (Routledge, 2024); presented by Michel Veuille (Muséum National d'Histoire Naturelle)

10.15 – 10.45 Coffee Break

10.45 – 11.45 André Ariew (University of Missouri)
Why is natural selection so hard to understand?

11.45 – 12.45 Hugh Desmond (Leibniz Universität Hannover)
Varieties of Darwinism and minimal agency

12.45 – 14.00 Lunch Break

14.00 – 15.00 Sylvain Charlat (Université Lyon 1)
How does evolution begin?

15.00 – 16.00 Ludo Schoenmakers (Konrad Lorenz Institute for Evolution and Cognition Research)
Minimal evolutionary theory at the origins of life

Tuesday, April 23

9.30 – 10.30 Thomas Heams (AgroParisTech)

10.30 – 11.00 Coffee Break

11.00 – 12.00 Karim Baraghith (Leibniz Universität Hannover)
From tradition to algorithm: Emerging dynamics of human-AI cultural evolution

12.00 – 13.00 Andreas Kirschning (Leibniz Universität Hannover)
Approaches to the origin of life - from prebiotic chemistry to the first forms of life

13-14.30 Lunch break

14.30-15.30 Nicolas Bredeche (Sorbonne Université)
Exploring Adaptive Collective Systems with Swarms of Learning Robots

15.30-16.30 Olivier Rivoire (Collège de France)
From physics to evolution

16.30-17.15 ***Future Directions*** (Philippe Huneman; Thomas Reydon)

17.30 Aperitif -

Inscription à l'avance auprès de l'IEA information@paris-iea.fr

LIST OF ABSTRACTS.

How does evolution begin?

Syvain Charlat[1], Denis Kuperberg[2], Etienne Rajon[1] & Nicolas Lartillot[1]

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Without necessarily replacing the question of the origins of life, the question of the origins of Darwinian evolution is an aspect of it whose importance cannot be ignored, given that this phenomenon, and more precisely the theory that aims to account for it, is the cornerstone of biological reasoning. To date, this question presents itself not only as atheoretical challenge, but also, in our view, as a paradox [1,2], the resolution of which could require a re-formalisation, towards greater generality, of the principle of evolution by natural selection. In this presentation we shall first present a conceptual and epistemic analysis of this problem, and then discuss the modelling work undertaken in an attempt to resolve it, i.e. to account for this necessary articulation, this transition, from the physical to the Darwinian, and perhaps to the biological. Based on a minimalism that obeys only the elementary laws of thermodynamics, these models aim more specifically to grasp the conditions for the emergence, probably gradual, of the two key ingredients of Darwinian processes: individuality and mutation (which generates heritable variance, in other words, heredity itself). These are essential ingredients, but - and here's the paradox - they are also products of evolution, unless we assume that their appearance was fortuitous, i.e. non-Darwinian, and as sudden as it was improbable. In this theoretical framework, autocatalytic cycles are objects of great interest [3–5], whose increasing complexity could gradually generate systems that can be understood in both a physical and a Darwinian framework, and in equally relevant ways. The systematic detection of these objects in complex "physical soups" is a first computational challenge, which our recent algorithmic developments have made it possible to meet.

1. Charlat S, Ariew A, Bourrat P, Ferreira Ruiz M, Heams T, Huneman P, et al. Natural Selection beyond Life? A Workshop Report. Life. 2021;11: 1051. doi:10.3390/life11101051
2. Charlat S, Heams T, Rivoire O. Is Natural Selection Physical? In: Du Crest A, Valković M, Ariew A, Desmond H, Huneman P, Reydon TAC, editors. Evolutionary Thinking Across Disciplines. Cham: Springer International Publishing; 2023. pp. 287–296. doi:10.1007/978-3-031-33358-3_12
3. Liu Y, Sumpter DJT. Mathematical modeling reveals spontaneous emergence of self-replication in chemical reaction systems. Journal of Biological Chemistry. 2018;293: 18854–18863. doi:10.1074/jbc.RA118.003795
4. Blokhuis A, Lacoste D, Nghe P. Universal motifs and the diversity of autocatalytic systems. Proc Natl Acad Sci USA. 2020;117: 25230–25236. doi:10.1073/pnas.2013527117
5. Sarkar S, England JL. Design of conditions for self-replication. Phys Rev E. 2019;100: 022414. doi:10.1103/PhysRevE.100.022414

Minimal Evolutionary Theory at the Origins of Life

Ludo Schoenmakers

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Evolutionary theory has a tremendous explanatory power when it comes to understanding the biological world. While evolutionary theory is multifaceted, its logic is fairly straightforward, which has led to numerous evolutionary research programs in various fields of research (economy, literary studies, epistemology, et cetera). These research programs tend to have at least the following two properties: (i) they are non-biological; (ii) they rely on the assumption that evolutionary is sufficiently ontologically and epistemically domain-independent to be applied to domains other than organismal biology.
In my project at the KLI, I focus on a near-biological evolutionary research program that is both theoretical and empirical, namely evolutionary theory as applied to Origins of Life (OoL) research. The central question is 'How, if at all, can evolutionary theory be applied to the pre-biological emergence and development of life?' Answering this question requires solving several issues surrounding (i) the extension of evolutionary theory from a theoretical and philosophical perspective, (ii) the conceptualization of the transition from prebiotic chemistry to cellular life, and (iii) the current use of evolutionary theory and its concepts by the OoL community.
In this talk, I will give a brief overview of the project, but otherwise I will focus on elucidating the requirements for extending evolutionary theory beyond organismal biology. I will try to make sense of a 'minimal evolutionary theory.'

Approaches to the origin of life - from prebiotic chemistry to the first forms of life

Andreas Kirschning

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How did life on planet Earth begin? This is probably the most important unanswered question in the natural sciences.[1] The study of the origin of life becomes tangible for our own experience when we consider that existing life still bears the imprint of its origin and that it is possible to extract ancestral concepts from the realm of existing mechanisms.
In technical and simplified terms, life is based on a fixed set of instructions and a machinery. The instructions correspond to today's DNA code, which represents the evolution of life in coded form from its early beginnings to the present day. Williams´ argues in his thoughtful 1997 article that the code is not the source of evolution, but rather the reproduced code should be considered conservative.[2] Rather, DNA damage, i.e. (external) stress, causes evolutionary development that is constantly resisted, even though it can lead to progress. It can be assumed that the availability of energy and material increases the organism's ability to survive. And so the availability of chemical elements in the environment of the early Earth was an important prerequisite for its development. Environmental changes through geochemical activities, but also life itself once it had occupied earth, changed the environment and thus the availability of resources itself.

In my report, I shall cover different of these aspects with a link to prebiotic chemistry exemplified for metals like nickel and first organic catalysts that are resemble modern coenzymes and cofactors.[3]

1. The first conceptual ideas on prebiotic chemistry were developed by a) A. I. Oparin, J. B. S. Haldane in: A. I. Oparin, Proischogdenie Zhizni, Moscovsky Robotschii, Moscow, 1924; translated into English by A. Synge in: J. D. Bernal, The Origin of Life, Weidenfeld & Nicolson, London, 1967, pp. 199-234; b) J. B. S. Haldane, Ration. Annu. 1929, 148, 3, new print in Bernal ´s book (ref. 1a, pp. 242-249).
2. R. J. P. Williams, The natural selection of the chemical elements. Cell. mol. life sci. 1997, 53, pp. 816–829.
3. a) L. L. J. Schoenmakers, T. Reydon, A. Kirschning, Evolution at the Origins of Life? Life 2024, 14, 175; A. Kirschning, Coenzymes and their role in the evolution of Life. Angew. Chem. Int Ed. 2021, 60, pp. 6242 –6269; c) A. Kirschning, On the evolution of coenzyme biosynthesis., Nat. Prod. Rep. 2022, 39, pp. 2175–2199; d) A. Kirschning, On the evolutionary history of the twenty encoded amino acids, Chem. Eur. J. 2022, e202201419.

From tradition to algorithm: Emerging dynamics of human-AI cultural evolution

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Cultural evolution, one of many frameworks for understanding the dynamic nature of human societies, elucidates how cultural practices, ideas, and technologies propagate, transform, and stabilize over generations. This process, akin to biological evolution, involves mechanisms of variation, selection, and inheritance, yet operates within the realm of symbolic and behavioral transmissions among individuals and communities. The advent of artificial intelligence (AI) might introduce a novel dimension to cultural evolution, extending the scope of traditional human-to-human transmission to encompass human-to-algorithm interactions: the cultural evolution of AI systems.

This thematic expansion bridges cultural and artificial evolution, spotlighting AI's role not just as a product of human ingenuity but as an active participant in cultural dynamics. Algorithms, with their capacity for learning and adaptation, are now woven into the social fabric, influencing decision-making processes, social norms, and even creative expressions. The complex interplay between human cognitive biases and algorithmic problem-solving strategies presents a fertile ground for exploring the mutual influence of human and AI agents on cultural evolution.

Drawing upon recent research exemplified by Brinkmann et al. (2022), which investigates hybrid social learning in human-algorithm cultural transmission chains, we delve into a specific instance of this broader theme. The study highlights how algorithms, when introduced into human cultural transmission processes, can temporarily enhance performance but face challenges in long-term integration due to human biases and copying fidelity. This special case demonstrates the nuanced dynamics at play in the cultural evolution of AI systems for future exploration.

Brinkmann, L.; Gezerli, D.; Kleist, K.; Müller, T.; Rahwan, I.; Pescetelli, N. (2022): Hybrid social learning in human-algorithm cultural transmission. Phil.Trans. R. Soc. A 380: 20200426. doi.org/10.1098/rsta.2020.0426

From physics to evolution.

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How far is evolution from physics? I will present our efforts to design elementary physical systems that undergo a form of evolution by natural selection and show how the results contribute to a related question: What constraints, if any, does physics impose on the material emergence of evolution?