July 16-21, 2017 at UC San Diego, CA, USA

Hosting early evolution in heated pores of rock

Christof Mast, Friederike Möller, Simon Lanzmich, Lorenz Keil and Dieter Braun*
Physics Department, Center for Nanoscience,
Ludwig-Maximilians-Universität München, 80799 Munich, Germany
* dieter.braun@lmu.de

Introduction: Life as we know it is a stunningly complex non-equilibrium process, keeping its entropy low against the second law of thermodynamics. Therefore it is straightforward to argue that first living systems had to start in a natural non-equilibrium settings. Recent experiments with non-equilibrium microsystems suggest that geological conditions should be able to drive molecular evolution, i.e. the combined replication and selection of genetic molecules towards ever increasing complexity.

Biochemistry in non-equilibrium settings: As a start, we explored the non-equilibrium setting of natural thermal gradients. Temperature differences across rock fissures accumulate small monomers more than millionfold [1] by thermophoresis and convection [2]. Longer molecules are exponentially better accumulated, hyperexponentially shifting the polymerization equilibrium towards long RNA strands [3]. The same setting implements convective temperature oscillations which overcome template poisoning and yield length-insensitive, exponential replication kinetics [4]. Accumulation and thermally driven replication was demonstrated in the same chamber, driven by the same temperature gradient [5].

Replication and selection for increasing complexity: The replication of long nucleic acid sequences was required for the evolution of biological complexity during the origin of life; however, short sequences are normally better replicators than long ones. Recently, we showed how a common physical environment provides a simple mechanism to reverse this trend and enables long sequences to flourish [6]. On a similar note, the trap is creating gels from oligonucleotides - and sorts them in a phase transition with equal sequence and single base pair discrimination [7]. Replication and trapping of DNA persist over long time in a constant influx of monomers, closely approaching the criteria for an autonomous Darwin process.

References: [1] Baaske, Weinert, Duhr, Lemke, Russell & Braun, PNAS 104, 9346–9351 (2007). [2] Duhr & Braun, PNAS 103, 19678–19682 (2006). [3] Mast, Schink, Gerland & Braun, PNAS 110, 8030-8035 (2013). [4] Braun, Goddard & Libchaber, PRL 91, 158103 (2003). [5] Mast & Braun, PRL 104, 188102 (2010). [6] Kreysing, Keil, Lanzmich & Braun, Nature Chemistry 7, 203–208 (2015). [7] Matthias Morasch, Dieter Braun, and Christof B. Mast, Angewandte, (2016) doi: 10.1002/anie.201603779.

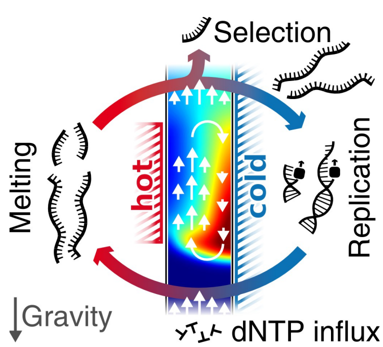

Figure 1 – Local heat flux across pores of rock create an interesting setting for early accumulation, replication and selection.