Molecular Evolution in a Peptide-Vesicle System – The First Step Towards Life?

Christian Mayer, March 10th 2020

Abstract

How did life begin? What made molecules start to line up, and how did the resulting structures cooperate to form the first living cell? These processes happened billions of years ago in an unknown location, probably without leaving a detectable trace. Nevertheless, fascinating scenarios which may have initiated this unique process have been proposed, leading to ambitioned research on the general mechanisms of prebiotic chemistry and molecular evolution.

A regular Darwinian evolution process is based on identical or nearly identical reproduction of individual units. However, on a molecular level, the first “species” may not have been able to reproduce identically. At this point, an alternative process is proposed, based on a large pool of random structures which forms statistically. A selective mechanism accumulates a fraction of those structures which is capable of surviving in a given environment and which, in turn, also optimizes the given selection mechanism itself.

In a laboratory experiment, random chain molecules formed by 12 different amino acids are generated. The selection mechanism consists of an artificial membrane where some of the chain molecules can integrate and become protected against thermal decomposition. During the course of the experiment, the accumulated chains in turn stabilize the membrane and even develop simple functions which further increase the survival rate of the membrane structures.

The studies approach the question, if and to which extent such a selection process without identical reproduction could replace Darwinian evolution on a very early stage of the development towards protocells. Further, it is meant to elucidate the basic mechanisms leading from chaotic mixtures of small molecules with high entropy toward well ordered, complex structures.

Fig.: Stepwise development of structures with increasing complexity in a non-Darwinian evolution.
Work summary

Christian Mayer is actively doing research on membranes, membrane vesicles and capsules for over 30 years. Earlier work focused on the structure of biological membranes as studied by nuclear magnetic resonance spectroscopy. Later, he dealt with artificial polymer membrane spheres, so called nanocapsules, as carrier systems for pharmaceuticals or oxygen in case of human blood replacement. Regarding the topic of the origin of life, Christian Mayer’s work focuses on the spontaneous formation of protocell-like structures under geothermal conditions. It involves experiments leading to a controlled molecular and structural evolution simulating processes which occur at depths around 1 km in the planetary crust.

Short cv section:

Christian Mayer studied Chemistry at the University of Stuttgart (Germany) and the University of Cincinnati (USA). He earned his PhD degree on reconstituted biological membranes in Stuttgart and initially started an industrial career at Hoechst (Frankfurt, Germany) and Celanese (Winona, USA). In 1996, he returned to an academic environment accepting a professorship at the University of Duisburg. Meanwhile, he is professor at the University campus in Essen (Germany) and is presently heading the initiative on molecular evolution within the German Astrobiological Society.