Ecology of early replicators

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I’m an ecologist who studies the origin of life.
The central hypotheses of ecology

- Any population in Nature can be found anywhere, anytime and in any amount
  Pál Juhász-Nagy

- This is evidently not true.
- How much and to what extent it is not true?
The central hypotheses of the origin of life

- Any population of replicators in Nature can be found anywhere, anytime and in any amount

- This is evidently not true.

- How much and to what extent it is not true?
• The origin of life leads to a living cell.
• A living cell is a **community** of molecules and supramolecular structures which coexist and maintains its constituents (homeostasis)

Tibor Gánti’s Chemoton
The Origin of Life – Structure and dynamics

**Structure**
- What can the pieces do?
- Is it (bio)chemically possible?

**Dynamics**
- How do the pieces fit together?
- How can they evolve?

RNA World
Coexistence
Parasites
Microfluidics
Coexistence with parasites

RNA World

- RNA acts as information carrier and as enzymes
- We want to understand the development of the RNA world

Coexistence of independent replicators

- RNA replicators compete for the same 4 nucleotides
- They could have different replication rates
- Our best estimate of the minimal gene number is around 60–100 genes
- How can so many genes coexist?

The problem of parasites

- „Useful replicators” are those that contribute to the systems (e.g. enzymes)
- What about parasites? RNA replicators that accept the benefits of the system, but do not contribute to it
- Can an enzyme coexist with parasites?
- Will small RNA molecules always overwhelm the system (c.f. Spiegelman)?
- We study these questions in a compartmentalized experimental and theoretical system
• We were familiar with the ribozyme
• Replicated with the Qβ replicase
• There are some true parasites

<table>
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<th></th>
<th>Length (nt)</th>
<th>$T_d$ (s)</th>
<th>$r$ (s$^{-1}$)</th>
<th>Relative $r$</th>
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Transient compartmentalization of RNA replicators prevents extinction due to parasites

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The appearance of molecular replicators (molecules that can be copied) was probably a critical step in the origin of life. However, parasitic replicators would take over and would have prevented life from taking off unless the replicators were compartmentalized in reproducing protocells. Paradoxically, control of protocell reproduction would seem to require evolved replicators. We show here that a simpler population structure, based on cycles of transient compartmentalization (TC) and mixing of RNA replicators, is sufficient to prevent takeover by parasitic mutants. TC tends to select for ensembles of replicators that replicate at a similar rate, including a diversity of parasites that could serve as a source of opportunistic functionality. Thus, TC in natural, abiological compartments could have allowed life to take hold.

Microfluidics

- A technique to follow small droplets of water in which reactions can occur.
- Droplets can be formed, split, fused and selected.
We follow the number of wild-type ribozyme

Mutants in classes according to their replication rates

The resource (NTP)

\[
\dot{W}(t) = a_w (1-\mu) \frac{W(t)}{K_M + W(t) + \sum_i M_i(t)} \frac{R(t)}{\Omega + R(t)}
\]

\[
\dot{M}_i(t) = \left( a_w \frac{\mu}{\nu} W(t) + a_{M_i} M_i(t) \right) \frac{1}{K_M + W(t) + \sum_j M_j(t)} \frac{R(t)}{\Omega + R(t)}
\]

\[
\dot{R}(t) = -\dot{W}(t) l_w - \sum_i \dot{M}_i(t) l_{M_i}
\]

Summary

• The origin life as a dynamical and evolutionary problem poses many of the same questions (theoretical) ecologists study.

• The **coexistence of replicators** is a key problem

• We are studying the **ecology of molecules**
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