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The Role of Templating in the Emergence of RNA from the Prebiotic Chemical Mixture

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Introduction: Biological RNA is a uniform polymer in three senses: it uses ribonucelotides of only one chirality; it uses only four ribonucleotides rather than a mixture of other similar monomers; and it uses only 3'-5' bonds rather than a mixture of different bond types. We suppose that prebiotic chemistry would generate a mixture of potential monomers, and that random polymerization would generate strands of mixed chirality, monomer composition, and bond type. Here, we show that if template-directed replication is important, we can explain the emergence of all these uniform properties by the same mechanism.

Results: We studied a computational model in which nucleotides react via polymerization, hydrolysis, and template-directed ligation. In absence of ligation, random polymerization generates all oligomers of a given length with equal frequency. When template-directed ligation is added, uniform strands act as templates for ligation of shorter oligomers of the same type, whereas mixed strands do not. In the chirality problem, when the ligation rate k_{lig} is low, most monomers are incorporated into mixed oligomers (M in Fig. 1). The concentrations of uniform oligomers of the two enantiomers *D* and *L* is low. When the ligation rate is high, a symmetry breaking phase transition occurs. The concentration of uniform oligomers of one type (*D* in the figure) becomes much higher than the concentration of the opposite type or of mixed oligomers. In the monomer selection problem, we consider mixtures of ribonucleotides and an alternative monomer. The model shows that uniform RNA strands emerge when k_{lig} is high. In the backbone regioselectivity problem, strands of uniform 3'-5' bonds will emerge in the same way.

Conclusion: If template directed sysnthesis is operating in the prebiotic mixture, we expect that strands with uniform chirality, monomer alphabet, and bond type will emerge because they are better templates than mixed strands. This can lead to selection of uniform RNA at the level of oligomers before the origin of strands that are long enough to be functional ribozymes.

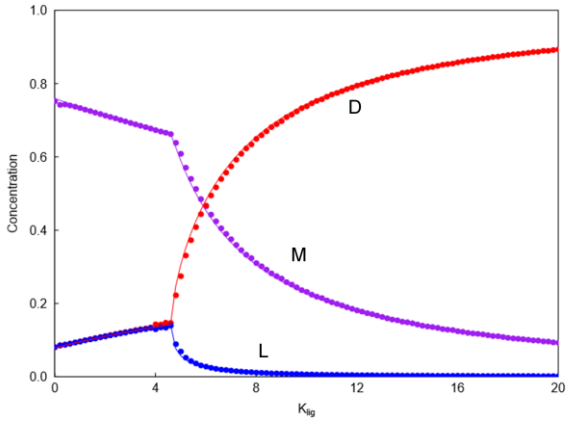

Figure 1 – Relative concentrations of nucleotides in uniform right and left-handed oligomers (D and L) and in mixed oligomers (M) as a function of the the rate constant k_{lig} for template-directed ligation.