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Model suggests how life's code emerged from primordial soup

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(PhysOrg.com) -- In 1953, Stanley Miller filled two flasks with chemicals assumed to be present on the primitive Earth, connected the flasks with rubber tubes and introduced some electrical sparks as a stand-in for lightning. The now famous experiment showed what amino acids, the building blocks of proteins, could easily be generated from this primordial stew. But despite that seminal experiment, neither he nor others were able to take the next step: that of showing how life's code could come from such humble beginnings.

By working with the simplest amino acids and elementary RNAs, physicists led by Rockefeller University's Albert J. Libchaber, head of the Laboratory of Experimental Condensed Matter Physics, have now generated the first theoretical model that shows how a coded genetic system can emerge from an ancestral broth of simple molecules. "All these molecules have different properties and these properties define their interactions," says first author Jean Lehmann, whose work appears in the June issue of PloS One. "What are the constraints that allow these molecules to self-organize into a code? We can play with that."

The genetic code is a triplet code such that every triplet sequence of letters on messenger RNA (mRNA) corresponds to one of the 20 amino acids that make up proteins. Molecular adaptors called transfer RNAs (tRNAs) then convert this information into proteins that can achieve some specific tasks in the organism. Let's say that each triplet sequence on mRNA, known as a codon, represents an outlet that can only accept a tRNA with a complementary anticodon. Translation works because each codon-anticodon match corresponds with an amino acid. As each tRNA is plugged in, a chain of amino acids is formed in the same order as the codons until translation is complete.

However, primitive tRNAs were not as finicky as tRNAs are today and could load any amino acid known to exist during the time of prebiotic Earth. Without the ability of tRNA to discriminate between various amino acids, such a random system might not be able to self-assemble into a highly organized code capable of supporting life.

To find out if it could, Libchaber and Lehmann, together with Michel Cibils at Ecole Polytechnique Federale de Lausanne in Laussane, Switzerland, worked with a simple theoretical system. They took two of the simplest amino acids thought to exist billions of years ago, two primitive tRNAs and an RNA template with two complementary codons, and then developed an algorithm to incrementally change the concentration of each molecule. Their goal was to see which conditions, if any, could coax the system to specifically translate codons in a non-random fashion. They found that the properties of the molecules set the concentrations at which the molecules needed to exist for a coded regime to emerge.

At these concentrations, the scientists found that a vetting process began to unfold whereby the tRNA and the amino acid began to seek each other out. All in all, an elementary translation process depended on two time scales: the time during which a tRNA remains bound to its codon (hybridization) and the time it takes for the amino acid on that tRNA to form a new chemical bond with the amino acid next to it (polymerization).

“It takes a lifetime for the tRNA to dissociate from its codon,” says Libchaber, who is also Detlev W. Bronk Professor at Rockefeller. “If it takes the amino acid loaded on the RNA longer than a lifetime to polymerize to an amino acid nearby, the selection of tRNA and amino acid doesn't occur. But when the two lifetimes are comparable, even when there is nonspecific loading of an amino acid, a selection process begins to take hold because some amino acids would be more adaptive during that time span -- and start what would be the beginning of a code."

Although Libchaber and Lehmann point out that the analysis certainly does not provide a full picture of the problem, the work nonetheless brings us one step closer to understanding how Life first began. "The dream of physicists is to create elementary life," Libchaber says. "Then we would know that we understand something."

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