Transfer RNA as a written molecular history of the life transition on earth

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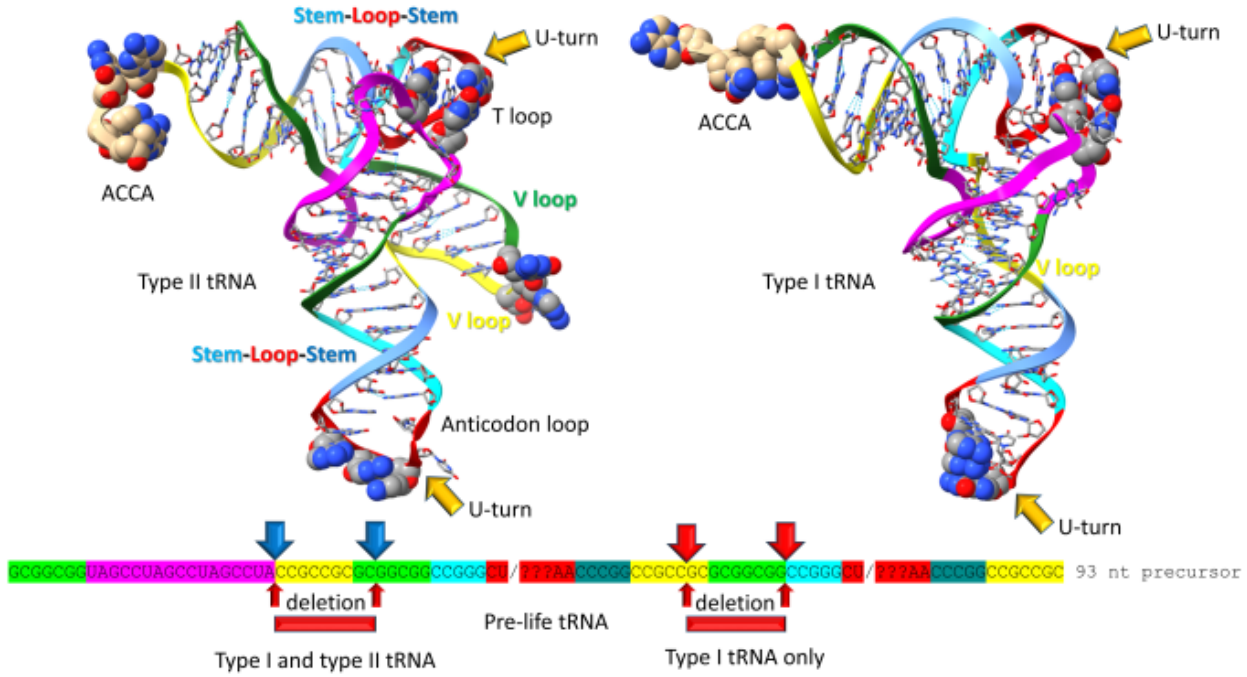

Figure 1. Chemical evolution of type I and type II tRNAs. 3 31 nucleotide minihelices of known sequence were linked to form the 93 nucleotide tRNA precursor, which was processed to type I and type II tRNAs by internal 9 nucleotide deletion(s). The colors are consistent with the model. Molecular graphics were done using ChimeraX

Zachary Burton, Ph.D., Professor Emeritus, Department of Biochemistry and Molecular Biology, Michigan State University, reports on tRNA (transfer RNA) as a written molecular history of the pre-life to life transition on Earth ~4 billion years ago

Friends, coders, gamers, puzzlers, historians, linguists, geneticists, lend me your brief attention. I come to report history recorded ~4 billion years ago during pre-life, inscribed and preserved in genetic code and tRNA sequence.

The pre-life sequence of tRNA (transfer RNA)

The pre-life sequence of tRNA (transfer RNA) was recorded in the tRNA sequences of living organisms, preserving a historic record ~4 billion years after its initial composition. As such, tRNA sequences in living organisms record events that occurred before life began on Earth. By this measure, tRNA sequence is a molecular fossil of the pre-life to life transition, and tRNA sequences relate a simple story that is the core history of the pre-life to life transition.

Without tRNA, there is no life as we understand it on Earth because there is no genetic code. Once tRNA chemically evolved in pre-life, however, a genetic code and life became inevitable. Through limited mutation and selection, tRNA was a molecule that taught itself to code. If one searches for life on another moon or planet, one must search for a genetic adapter as good or better than tRNA. It is unclear to me what an alternate genetic adapter might look like if it is much different than tRNA. If you think you can solve the problem of constructing an alternate genetic adapter to tRNA, you should do this and publish it. It is a difficult problem.

The original tRNA was formed by ligation of 3 31 nucleotide minihelices of known sequence. Two of these minihelices were identical. The identical minihelices formed the anticodon loop and the T loop of tRNAs. The 17 nucleotide anticodon stem-loop-stem and the 17 nucleotide T stem-loop-stem are clearly genetically related today (i.e., initially identical sequences). The tRNA D loop minihelix had the same 7 nucleotide 5' and 3' end sequences, but a distinct 17 nucleotide core sequence.

Despite their antiquity, The pre-life type I and type II tRNA sequences are known with essential certainty (6 nucleotide ambiguities). Type I and type II tRNAs were formed identically except for a single additional 9 nucleotide internal RNA deletion to form type I tRNA. Statistical tests confirm every feature of the tRNA evolution model.

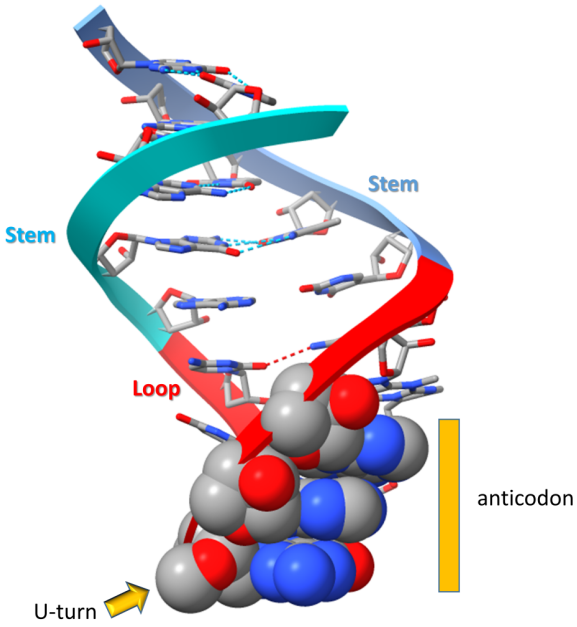

Figure 2. The compact anticodon stem- loop-stem is the most important intellectual property in the chemical evolution of a 3-nucleotide genetic code and the evolution of life. A genetic code must evolve to a 3-nucleotide code.
Life | Free Full-Text | The 3 31 Nucleotide Minihelix tRNA Evolution Theorem and the Origin of Life (mdpi.com)

Transfer RNA research

So, to generate type I and type II tRNAs, 3 31 nucleotide minihelices were joined and processed by a known mechanism ~4 billion years ago (Figure 1). The original sequence print was deciphered because tRNAs were generated from 7 nucleotide 5' acceptor stems (GCGGCGG; a GCG repeat), 7 nucleotide 3'-acceptor stems (CCGCCGC; a CGC repeat), a 17 nucleotide D loop minihelix core (UAGCCUAGCCUAGCCUA; a UAGCC repeat) and an anticodon and T stem-loop-stem (CCGGG_CU/???AA_ CCCGG) (_ separates stems and loop; / indicates a U-turn in RNA; ? indicates sequence ambiguity). ACCA-glycine was attached to the pre-life tRNA 3'-end to synthesize polyglycine, a component of protocells. The story was recorded in the tRNAs of living organisms with only six pre-life nucleotide ambiguities, making tRNA a living fossil of the pre-life to life transition on Earth.

So, during pre-life, repeating RNA polymers and inverted RNA repeats (stem-loop-stems) formed. These were processed into 31 nucleotide minihelices. 3 31 nucleotide minihelices were joined and processed to form type I and type II tRNAs. tRNAs were duplicated and diverged into tRNAomes (all of the tRNAs of an organism). The genetic code, which specifies protein sequences, coevolved with tRNAomes. Once a genetic code evolved, life on Earth became inevitable. Such is the condensed history of evolution of life on Earth, which at its core is the story of chemical evolution of tRNA. Pre-life and first life on Earth can now be largely reproduced in a laboratory according to the blueprints provided in tRNA sequences.

If the tRNA chemical evolution puzzle and its solution seem difficult, they are not. Anyone who can read four letters can solve this puzzle. As a guide, the puzzle solution is published. The puzzle was first solved by inspection of typical tRNA diagrams from ancient Archaea, which are very similar to LUCA (the last universal (cellular) common ancestor).

Life evolved around tRNA. Once tRNA chemically evolved, the evolution of life became inevitable. Essentially, tRNA is the molecule that taught itself to code.

The history of tRNA chemical evolution

The history of tRNA chemical evolution is surprisingly ordered. I initially thought tRNA evolution must have been by a chaotic process. Seeing patterns in the tRNA sequence led to the solution for tRNA evolution.

My initial identification was the obviously genetically-related 17 nucleotide anticodon and T stem-loop- stems. After this recognition, the rest of the puzzle was pretty easy to solve. If the original tRNA sequence had not been so highly ordered, no solution would have been possible. For tRNA, a search for repetitive sequence motifs was rewarded.

Life on Earth evolved chemically from a complex RNA-protein-protocell- energetics world that, so far, is only partly characterized. Chemical evolution of tRNA, tRNAomes and the genetic code is the core story. Remarkably, sequences of tRNAs in living organisms allow the history to be read and reported.

tRNA is the core intellectual property in the chemical evolution of life on Earth. The 7 nucleotide anticodon U-turn loop (initially CU/???AA) is undoubtedly the most important biological intellectual property on Earth (Figure 2). Without the compact tRNA anticodon loop, a 3 nucleotide genetic code could not have evolved. By “intellectual property”, I do not imply “intelligent design”. I see no evidence for intelligent design in the chemical evolution of tRNA. All current evidence indicates that life evolved by a simple chemical process.

The solution of type I and type II tRNA evolution to the last nucleotide provides the clearest view to date of the pre-life to life transition on Earth ~4 billion years ago. The solution stands for all time on this planet.

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