Life before genes? A search for ancient protein-based inheritance

Life on Earth emerged billions of years ago. Its origins remain one of the greatest unsolved mysteries in science. What kind of molecules were the first to store and transmit biological information? While most research has focused on relatively unstable nucleic acids like RNA and DNA, growing attention is now turning to much more resilient molecules - proteins, and in particular, prions.

Our project is built around a groundbreaking hypothesis: some prions may have been among the very first carriers of heritable information, operating through mechanisms entirely different from today's genetic systems. Prions are proteins capable of changing their three-dimensional shape in a way that "infects" other copies of the same protein, forcing them to adopt the same structure. This self-propagating shape change creates a unique form of inheritance, one that requires no nucleic acids.

In our earlier research, conducted in collaboration with NASA and Stanford University, we developed new methods for identifying such proteins in primitive organisms - archaea. As a result, we were the first to discover prion-based inheritance systems in this ancient branch of life.

But this was just the beginning. Our latest bioinformatic analyses, supported by machine learning, have identified a list of proteins whose functions have been conserved for billions of years. Many of them show hallmarks of protein-based memory systems. We now aim to test whether these proteins can form heritable aggregates, structures that transmit their conformation from one cell generation to the next.

In the lab, we will also investigate whether and how these aggregates affect the adaptability of microorganisms. Could this form of protein-based inheritance help cells survive environmental stress, such as changes in temperature, salinity, or nutrient availability? Early evidence suggests this may be the case.

The results of this project could fundamentally reshape our understanding of life's early evolution, suggesting that inheritance may have started not with genes, but with the shape of proteins. This could open entirely new directions not only in evolutionary biology, but also in biotechnology and synthetic biology, where controlling protein aggregation may become a powerful tool for shaping the traits of microbial populations.