

Introduction Two questions sit at the border of physics and biology. First, does physical reality decompose into independent, local pieces—or are there relations that cannot be reduced to parts? Second, is life merely complicated chemistry or an emergent process in which matter and information become inseparable? The Einstein-Podolsky-Rosen (EPR) argument posed the first question sharply. The origin-of-life problem keeps returning us to the second. Both questions probe the completeness of our descriptions.

The EPR Argument EPR highlighted that quantum theory predicts correlations between separated systems that cannot be reduced to local, separable properties, common causes or direct interactions. Experiments have established that such entanglement is real. The lesson, conceptually, is that relations can be more fundamental than the individual parts that enter them. The analogy used here is heuristic: no claim is made that biological systems violate Bell inequalities. The shift of focus from objects to relations (quantum entanglement instead of classical correlation) guides the discussion that follows.

The Problem of Life: From Chemistry to Self-Referential Dynamics Origin-of-life research proceeds along two complementary routes. A top-down route infers minimal ancestral features from universal biochemistry. A bottom-up route starts from plausible prebiotic reactions and asks how networks gain complexity and autonomy. Both routes hint that the key transition is organizational. A system becomes life-like when loops of energy, matter, and information close so that the system constrains its own future, shifting from rules applied to the system to rules maintained by the system. In that sense, life emerges not in matter alone but in the organization of matter.

From Quantum Correlations to Biological Networks In an EPR system, the state of each particle cannot be described independently; only the whole system carries meaning. Similarly, in biology, vital features such as metabolism, repair, and self-reproduction arise only at the level of the entire biological network. Individual molecules are neither alive nor purposeful; yet, within a web of mutual feedback, they behave as a coherent whole exhibiting emergent properties. This resemblance is not merely metaphorical. At the molecular level, research in recent decades has debated that genuine quantum correlations play a role in processes such as photosynthesis, avian magnetoreception, and enzymatic catalysis. The origin of life likely occurred on scales between angstroms and microns—precisely at the threshold where molecular behavior remains fundamentally quantum. From this viewpoint, entanglement and quantum correlations may have played a foundational role in organizing the earliest biological systems.

Hidden Variable of Life

EPR assumed that quantum mechanics was incomplete and that there existed hidden variables which, if known, would allow us to predict particle behavior deterministically. Although later experiments constrained that path but the idea still can work. Similarly, in the study of life, there may also be hidden variables, but this time at the levels of information and organization. It has been argued that purely chemical descriptions cannot account for the emergence of self-reference, replication, or genetic information. What may be missing is a “biological hidden variable”: informational or quantum relations that exist only at the level of the whole system. Just as the quantum wavefunction encodes complete knowledge yet is itself unobservable, living systems may embody hidden relational structures—patterns of energy and information coherence that determine behavior but are not reducible to local observables.

From Locality to Holism: Life as Nonlocal Reality By revealing the inability of local theories to explain quantum phenomena, EPR guided us toward accepting a kind of nonlocal and holistic reality. Life, too, emerged precisely at the transition from locality to holism. No biological component functions on its own; every molecule derives its meaning from its position within the network. Just as a change in one entangled particle instantly affects the other, in a living cell, an alteration in a small part of the reaction network can transform the entire system—not through classical forces, but through intrinsic informational and structural dependencies. Life is a system in which “the response to change itself changes.” This is akin to the quantum wavefunction, which only has meaning over the whole state space and transforms with each measurement.

Measurement in Quantum Physics and Natural Selection in Life Quantum measurement collapses a superposition into a definite outcome; the observer’s act selects reality. In prebiotic evolution, natural selection plays a similar role. From countless molecular configurations, the environment “selects” those

that persist and replicate. In this view, nature functions as a cosmic observer, collapsing the spectrum of chemical possibilities into stable, self-maintaining structures. Recent interdisciplinary work, such as the Earth-Life Science Institute’s “Evolution of Networks” projects, suggests that early prebiotic systems were open entangled systems, continuously exchanging matter, energy, and information with their surroundings while preserving internal correlations. The boundary between “system” and “environment” was fluid, echoing the open nature of quantum entanglement itself.

The Observer Within Once loops close, a system can act as its own “observer”. EPR led to the problem of the observer and their role in defining reality. In quantum theory, the observer is part of the system. In biology, a living organism is likewise an observer of its environment: it “measures” chemical states, responds to them, and redefines itself through feedback; responses come to depend on relations internal to the system, not just on external forcing. One could say that life marks the first appearance of “the observer within nature.” In this sense, the emergence of life is the moment when nature first becomes aware of itself—just as in quantum measurement, a system manifests itself through observation. Primitive awareness here does not mean consciousness; it means closed-loop inference that co-defines the organism.

Conclusion The EPR paradox and the origin of life converge on the same philosophical horizon: both expose the limits of classical locality and linear causality. Both invite us to view the world as a network of relations, entanglement, not a classical correlation of parts. If quantum entanglement represents the continuity of being at the foundational level, then life is the embodiment of that continuity at the emergent level; the universe’s way of experiencing its own coherence. Perhaps one may say: Life is the way the universe experiences its own entanglement.