Epistemic Selection in the Photosynthetic Reaction Center: Revisiting the GluL104 Mutation

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Sir — In a 1988 *Nature* letter, we reported that mutation of GluL104 in the *Rhodobacter capsulatus* photosynthetic reaction center (RC) affected the absorption properties of BpheL but did not alter the quantum yield or directionality of electron transfer, which remained exclusive to the L-branch (or A-branch) [1]. The prevailing interpretation at the time was that GluL104 modulates local pigment environment but is not essential for pathway selection. This conclusion, though appropriate within a classical structural-electrostatic framework, merits reexamination in light of later developments in quantum biology and the theory of decoherence.

Photoexcitation of the special pair (P) in the bacterial RC initiates charge separation via a superposition of two symmetrical electron transfer pathways. These proceed through either the L-branch (BChl_L → Bphe_L → Q_A) or the M-branch (BChl_M → Bphe_M → Q_B). Structural asymmetry, including the presence of GluL104 only near BpheL, led us to hypothesize that this residue might stabilize or direct electron transfer along the L-branch, perhaps via hydrogen bonding or electrostatic effects. Mutations at this site altered BpheL absorption but left the functional outcome unchanged, leading to the inference that GluL104 is not a mechanistic determinant of directionality.

However, under a quantum mechanical view of electron transfer, the initial state after excitation is a coherent superposition of L- and M-pathways. This superposition is subject to rapid decoherence driven by interaction with the protein environment. Small structural differences—such as pigment couplings or local dielectric variations—can influence which branch decoheres into a classically

stable charge-separated state. In this light, the exclusive observation of L-branch transfer may be not solely the result of structural determinism, but the product of *epistemic selection*: a filtering process in which only one of many quantum possibilities becomes classically accessible.

Crucially, this filtering is not merely a matter of inadequate time resolution. Even with ideal instrumentation, coherent processes that collapse via decoherence before they yield measurable signatures remain epistemically erased. The M-branch pathway may be briefly populated or participate in interference, but if it does not result in a net charge-separated state, it leaves no record. The experimental system observes only what survives decoherence. Thus, the apparent exclusivity of L-branch transfer may reflect the collapse of a quantum system into a single observable history, not the absence of alternative histories.

In this reinterpretation, GluL104 may influence the early quantum phase of electron transfer by modulating amplitude weighting, phase coherence, or interaction with the local environment. Its role may reside not in the outcome, but in shaping the initial conditions of the quantum system—a role that classical measurements cannot resolve. Its apparent irrelevance in the original study may therefore be an artifact of epistemic erasure rather than mechanistic neutrality.

Comparable constraints are seen in the radical pair mechanism of avian magnetoreception, where cryptochrome proteins form spin-entangled states sensitive to magnetic fields [2,3]. These states cannot be directly measured; their existence is inferred from behavioral changes. Similarly, unmeasured M-branch dynamics may have existed without persisting into the experimental record.

We propose that such experiments be reinterpreted not only in terms of what they revealed, but in terms of what they were epistemically equipped to reveal. The conceptual framework of the 1980s offered a binary view: if mutating a residue does not alter an outcome, it is not functionally relevant. Today, quantum biology allows for a more nuanced view, where influence may exist even if it never enters the recordable domain.

This is not to invalidate the original conclusions, but to highlight that the absence of observed effect is not necessarily evidence of absence. The GluL104 mutation experiment remains valid and informative—but its meaning may be incomplete. As our models of biological quantum processes mature, it is essential to revisit foundational work with frameworks that integrate decoherence, entanglement, and epistemic constraints.

These ideas align with growing recognition that quantum coherence plays functional roles in photosynthesis [4], olfaction [5], and enzyme catalysis [6], even when these roles are epistemically obscured. Revisiting classic experiments with this in mind may uncover subtle layers of function once considered inaccessible, not because they were unreal, but because they were unmeasurable.

References

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