Quantum Coherence in Biology

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Quantum coherence became a topic of a much-heated debate about a decade ago, when it was claimed that presence of electronic quantum coherence enhances ultrafast excitation energy transfer in some natural photosynthetic light-harvesting antennae. Initial experimental evidence came from a rather poorly understood (then new) experimental technique of two-dimensional coherent electronic spectroscopy, and the initial claims were made on top of a much-simplified theoretical model of photosynthetic energy transfer [1]. In the course of next several years, the initial claims became an uncontested basis of a wide spectrum of theoretical and experimental works, in which beneficial influence of electronic coherence on energy transfer was taken for granted rather than tested. In about 2012, it was shown that the oscillatory signals in the original experiment are of vibrational rather than electronic origin [2,3]. Electronic coherence as a source of functional enhancement in photosynthetic light-harvesting was quickly discredited, however, the believe that the source of potential functional enhancements is coherence (now in its vibrational form), did not seem to wither away [4]. One of the possible reasons for survival of the idea against both experimental and theoretical evidence is the existence of a plethora of meanings behind the term “coherence” in the context of quantum theory. This allows its identification both with classical limit of quantum theory and with the most profoundly unique quantum effects such as entanglement of spatially separated systems [5–7]. In this contribution, we will present a consistent picture of excitation energy transfer in molecular systems, in which coherence plays a rather minor role [7,8]. We will discuss the various meanings of coherence as they appear in the theory of excitation energy transfer in molecular systems, identifying those which were observed in the original coherent experiments and those that have been linked to it later. We will discuss reasons, why putting “coherence” of any kind among the fundamental causes of efficient energy transfer is not a good idea. While most of the discussion will circle around molecular systems and photosynthetic antennae, the audience will certainly be able to decide, which of the arguments pertain to the broader issues in physics.

Literature

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