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Quantum simulation meets quantum biology

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Quantum biology has attracted increasing interest in recent years [1]. It is remarkable that quantum effect such as quantum coherence and entanglement has been found existing in several examples of biological processes, such as light harvesting and animal magnetoreception [2]. In quantum biology, there are mainly two fundamental questions: (1) how does quantum effect sustain in biological environment that is generally complex, "hot" and noisy; (2) how does quantum effect play its non-trivial role in these important biological processes. The complexity of biological systems implies the extreme difficulty on tackling these two open questions. There are many unknown factors in biology that would affect the relevant quantum dynamics, and it is not clear what the most essential ingredients are. A new technique that can provide a *clean* platform to help investigate various aspects of quantum effect in biological processes would certainly be valuable. Quantum simulation is one appealing candidate to provide such a platform, which also has potential applications for the study of condensed matter physics, material science, and high-energy physics [3].

In the chemical compass model of animal magnetoreception, two unpaired electrons appear to be in entangled states. The quantum nature of electron spin dynamics as governed by the hyperfine interaction with the surrounding nuclei determines the functioning of a chemical compass [4]. However, it is unknown what is the physiological basis of a chemical compass if it is indeed responsible for animal magnetoreception. The fact that very weak electromagnetic noise of a broad range of frequencies would disturb the orientation ability of European robin remains mysterious [5].

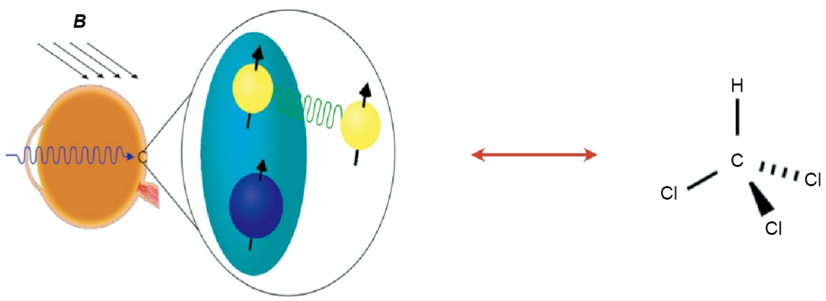

Figure 1 (Color online) Quantum simulation of a simple chemical compass model using a nuclear magnetic resonance system (Reproduced from Pearson et al. [6]).

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In ref. [6], Pearson et al. experimentally simulate the dynamics of a simple model chemical compass using a nuclear resonance quantum information processor, see Figure 1. It makes a first step towards the study of quantum biology using the technique of quantum simulation. The model chemical compass that has been simulated is the simplest reference-and-probe model. In the next step, it will be more important to simulate chemical compass model with flexible hyperfine couplings. This task is quite challenging which is however necessary to investigate the relation between the hyperfine couplings and the sensitivity of a chemical compass, and thus may provide insights into the design principle of a chemical compass. The other interesting open question is how to simulate the effect of noise/decoherence on a chemical compass by engineering environment in quantum simulation. The better controllability of quantum simulation as compared with complex biological environment would be helpful to reveal the complicate interplay between quantum coherent dynamics and noise in animal magnetoreception.

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