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Scientists from Arizona State University, Northwestern University, and the University of California, Los Angeles, will explore fundamental quantum effects in biological systems. They plan to develop and to use predictive theory and advanced spectroscopic, magnetic, and local probe techniques to elucidate the fundamental mechanisms by which molecular chirality (handedness) and spin polarization influence electron motion within biological molecules. First, they will use synthetic mirror-image (enantiomeric) pairs of DNA hairpins with additional electron donors and acceptors as part of their structures to probe chirality-dependent electron transfer. These model systems are characterized as a function of donor-acceptor distance, temperature, redox properties, and coupling to their surrounding environment to determine how chirality influences the electronic, vibrational, and spin degrees of freedom controlling electron transfer from photoexcited donors to acceptor sites as spin-coherent entangled electron-hole pairs are generated. Second, they will use magnetic substrates, nanoscale chemical patterning, and multimodal spin-polarized scanning tunneling microscopy and spectroscopies with oriented enantiomeric pairs of DNA and intercalated metals to elucidate and to quantify the molecular and interface contributions to chirality-induced spin selectivity. Since most biological molecules, including amino acids in proteins and nucleotides in RNA and DNA, are chiral, how the critical interrelated roles of spin coherence polarization, and entanglement influence electron transport within and between biological molecules will be determined. In addition to studying the unexplored roles of spin coherence in quantum biology, how it can coexist with spin polarization and how or if it can create entangled states will be addressed. The goal of this proposal is to answer these questions, which are central to and underpin the emerging field of quantum biology.

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The generation and control of electromagnetic waves has helped shape the development of our society. Approaches like thermal radiation (light bulbs), thermionic emission (vacuum tubes), stimulated emission (lasers and spasers) and electroluminescence (LEDs) have been incorporated into everyday technologies. Conversely, Cherenkov radiation (CR) has been limited to niche applications such as medical imaging, dosimetry, and particle hadat a7 e9 0 -(at)2.9 (D)-hci(d 5 0 Tc 04 (v)5.7 (v)6hc) Gof66.4 6 (913h)-0.9 (g.2 .8 (hJ -(at)02(t)117 (d) e)-7(r)-r3 precise measurements of atoms or molecules to look for time symmetry violating moments of nuclei. The PI plans a transformative approach that will use just a single radioactive molecule, enabled by two sensitivity enhancements: the highly deformed radium nucleus and large, controllable molecular electric fields. Despite the experiment being intrinsically small, his analysis shows that it is possible to achieve record levels of sensitivity to time symmetry violating physics. This sensitivity will enable the detection of new physics at significantly lower cost, less time, and with a table-top scale experiment. The experiment builds upon recent advances in his group to synthesize and control radioactive molecules and work with highly sensitive, radioactive elements. The work is further supported by recent technical advances, derived from quantum information science research, that allow for record levels of control and measurement precision of molecular ions. The tabletop experiment will complement massive efforts to search for new particles and forces, but at a fraction of the cost of a collider.

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