# Stuttgarter Physikalisches Kolloquium

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# On the Quantum Origin of Chirality in the Life Sciences

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## Abstract

Chirality – the handedness of molecules and larger structures – profoundly influences biological, chemical, and physical processes. Its impact is evident in chiral molecules like peptides and DNA helices, where differences in handedness can lead to dramatically distinct interactions with biological receptors. For instance, taste variations like chocolate versus mint, or divergent effects such as tranquilization or birth defects (e.g., thalidomide), underscore chirality's significance. Mirror symmetry breaking is well documented in living organisms – only L-amino acids are encoded into proteins, and only D-sugars form the backbones of DNA and RNA – yet the origin of this selection remains unclear.

A pivotal discovery in 2011 revealed chiral-induced spin selectivity (CISS) during photo-electron passage through self-assembled monolayers of double-stranded DNA on gold surfaces, resulting in electron spin polarization exceeding the thermal equilibrium value by orders of magnitude. These observations suggest the hypothesis that chirality is preserved in biology not purely because of structural effects, but also for its capacity to polarize electron spin during transport. Yet, the underlying microscopic mechanism that gives rise to CISS remains elusive, prompting us to explore the non-equilibrium quantum dynamics of delocalized phonon modes within chiral molecules, coupled with spin-dependent energy and momentum conservation principles as a possible origin.

In this colloquium, I will introduce the subject matter, discuss the potential interplay between electron spin and vibrations, and make the case for designing specific experiments that can verify or falsify hypothesized models, moving beyond mere confirmation of the existence of CISS.