QUANTUM DYNAMICS OF PHOTOSYNTHETIC LIGHT HARVESTING: DESIGN PRINCIPLES FOR STEERING ENERGY

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Abstract: Control of excited state dynamics at the nanometer to micron scale remains a grand challenge for solar fuels catalysis, energy science, optical communications, and artificial photosynthesis. Interestingly, it hasn't been a grand challenge for biology for over 2 billion years: nature has already done it. My research group seeks to dissect microscopic mechanisms and quantum dynamics of photosynthetic light harvesting and export these ideas to chemical and material systems. We want to know how photosynthetic antenna complexes collect light and funnel it to the reaction center with near perfect quantum efficiency and exquisite precision. We create new instruments to probe these femtosecond dynamics, and we can use these signals to intuit excitonic transport from the spectral signals. Recently, we acquired data showing a complex interplay between the chlorophyll molecules and their environment within the protein. The resonance between delocalized excited states and vibrations on individual chromophores is used to steer excitonic energy toward the reaction center. This approach represents an entirely different approach to dictating energy transfer from what we can create in a beaker. This data has forced us to reconsider the role of a structured environment in energy transfer and continues to fuel the debate on coherent mechanisms of energy transfer in photosynthesis. Moving beyond traditional spectroscopy to gain more direct spatial information, we implemented chiral nonlinear spectroscopy to track wavefunction collapse after excitation to reveal how biology exploits dephasing to efficiently absorb light while systematically frustrating re-emission.

Bio: Greg is currently a Professor at The University of Chicago in the Department of Chemistry, Pritzker School of Molecular Engineering, The James Franck Institute, and The Institute of

Biophysical Dynamics, and the College. His research group focuses on new strategies to observe, measure, and control excited state reactivity. Using spectrometers of their own design, the Engel Group explores bio-inspired design principles for steering excitonic transport, open quantum dynamics, and photochemical reaction dynamics. The group's scientific approach involves parallel efforts in theory, spectroscopy, biophysics, and synthesis. Greg is currently the Director of the NSF QuBBE QLCI, a collaborative effort among 23 PIs to bring quantum sensing to biology and biophysics. He has served as Chair of the ACS Physical Chemistry Division and has served as chair of the ACS Biophysics subdivision. His research has been recognized with the Coblentz Award, National Security Science and Engineering Faculty Fellowship, Vannevar Bush Fellowship, Sloane Fellowship, Searle Scholar Award, Presidential Early Career Award in Science and Engineering, DARPA Young Faculty Award, AFOSR Young Investigator, DTRA Young Investigator, Dreyfus New Faculty Award, and Scientific American's SciAm 50 Award. Greg's teaching has been recognized with the Quantrell Award for Undergraduate Teaching and the Camille Dreyfus Teacher/Scholar Award.

Greg Engel was born in Pennsylvania in 1977. He obtained his A.B. from Princeton University in 1999 and his Ph.D. from Harvard University in 2004. Working under Prof. James Anderson at Harvard University, Greg designed and built ultrasensitive spectrometers to enable in situ measurements of atmospheric tracers and isotopic fractionation profiles of water vapor in the tropical tropopause transition layer. In 2005, he moved to UC Berkeley as a Miller Fellow to study photosynthetic energy transport. Working with Prof. Graham Fleming, Greg discovered coherent excitonic energy transfer in photosynthesis by observing quantum beating signals with 2D electronic spectroscopy.