Learning from Nature: QM/MM Car-Parrinello Simulations of Biological and Biomimetic Systems

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Through millions of years of evolution, Nature has managed to develop highly efficient and sustainable processes and the idea to understand and copy natural strategies is therefore very appealing.
We have used quantum mechanical/molecular mechanical (QM/MM) Car-Parrinello simulations in ground and electronically excited states to study the mechanisms of action of biological systems and employed the obtained information to guide the design of biomimetic analogs.
In this talk, I will present our results on the structural, dynamical and optical properties of the visual pigment rhodopsin along the photocycle[1-3]. We performed a systematic study of the size and sampling dependence of the optical properties and assessed the performance of a variety of different electronic structure methods in describing the photoabsorption spectra[4]. By applying feature selection and causality inference algorithms, we were able to identify the main factors that influence the color tuning in this system.[5]
We have also performed simulations of the enzyme Human Carbonic Anhydrase that is a natural model for CO_2 fixation. Very recently, a weakly active HCA mimic based on a trihelical peptide bundle has been synthetized. Applying a genetic algorithm based optimization procedure, we were able to re-engineer and optimize the biomimetic system towards its natural counter part.

[1]U. Roehrig, L. Guidoni, and U. Rothlisberger, Biochemistry *41*, 10799 (2002)
[2]U. Roehrig, L. Guidoni, A. Laio, I. Frank, and U. Rothlisberger, J. Am. Chem. Soc. *126*, 15328 (2004)
[3]M. Neri, S. Vanni, I. Tavernelli, and U. Rothlisberger, Biochemistry *49*, 4827 (2010)
[4]O. Valsson, P. Campomanes, I. Tavernelli, U. Rothlisberger, and C. Filippi (submitted)
[5] P. Campomanes, U. Rothlisberger (submitted)