The Last Nanometer – The way Water Meets Molecules and Surfaces in X10,000,000 Magnification

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Water, "the liquid of life", is actively involved in innumerable biological processes from ion channels to molecular recognition, enzymatic reactions and electrochemistry. All these processes take place on a sub-nanometric scale, namely 1-3 water molecules. Probing water structure on this scale is challenging, especially near individual molecules and surfaces where conventional methods fail. We have dedicated the past 5 years to the development of an alternative approach based on ultra-high resolution atomic force microscopy, which now provides unprecedented atomic resolution, three-dimensional maps of interfacial layers next to individual molecules and surfaces. The home-built microscope supports simultaneous measurements of the conservative and the dissipative components of the force, yielding quantitative information on the association of water with these objects. Since the hydration structure governs the energetics of solvation and interactions between objects immersed in solution, the new data are invaluable when trying to resolve fundamental questions such as the identification of molecular binding sites and interaction mechanisms.

After a short presentation of the microscope, the talk will focus on two representative studies. The first will disclose our recent finding that in solutions in contact with atmosphere, hydrophobic surfaces are generically coated with a dense layer of adsorbed gas molecules. This layer renders the hydrophobic interaction a certain universality, regardless of the underlying surface. Its discovery contributes significantly to the elucidation of the molecular origin of hydrophobic interactions, one of the outstanding puzzles of physical chemistry. The second study will present our recent success in obtaining ultra-high resolution images of DNA and 3d maps of its hydration structure. This study shows that labile water molecules concentrate along the DNA grooves, in agreement with known position of DNA binding sites.