Thermodynamics and kinetics of protein adsorption

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Protein adsorption plays a central role in many biological processes. For example, fibrinogen adsorption is believed to trigger platelet adhesion when a foreign body is put in contact with the blood stream. Biosensors can require ordered arrays of proteins adsorbed in their biological active conformation. Protein adsorption is a very challenging fundamental problem since the energy scales involved are in general large compared to the thermal energy. Proteins have colloidal type of interactions due to their large size. Furthermore, they have additional complexity due to the fact that they are largely inhomogeneous in their size, shape and interactions, they can be charged and they can change their conformations upon adsorption. Water soluble polymer molecules grafted at one of their ends to surfaces have been shown to reduce the ability of proteins to adsorb to surfaces. In this talk we present a statistical mechanical approach that enables us to study the thermodynamics and kinetics of protein adsorption on surfaces with and without grafted polymer molecules. The role of the different energetic contributions to determine the amount of adsorbed proteins and the structure of the layer will be shown. We will discuss how the grafted polymer layer can change the adsorption behavior. In particular we will show that increasing the polymer chain length has no effect on the equilibrium adsorption isotherms. However, the polymer molecular weight has a very pronounced effect on the kinetics of adsorption. We will show how the complex kinetic behavior of adsorption and desorption of the proteins on surfaces with grafted polymers depends upon the structural properties of the mixed protein/polymer layer. We will demonstrate how functionalization of the polymer free end with a charge moiety can be used for the controlled adsorption of proteins. Finally, we will discuss the thermodynamics and kinetics of competitive adsorption on mixtures of proteins. This example will show the delicate interplay between the electrostatic, van der Waals and excluded volume interactions in determining the composition and structure of the adsorbed layer. In particular, we will demonstrate how to tune the adsorption by manipulating the electrostatic screening length through added salt. The limitations and possible generalization of the theory will be discussed.