Project B9: Modelling self-assembly of natural polysaccharides

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Outline. Polysaccharides are stable, non-toxic, biodegradable, and biocompatible macromolecules that offer a wealth of biochemical and biomechanical functionality. These merits make them promising molecules for the development of functional materials. In natural polysaccharide materials, properties are finely tuned for a wide range of functions with hierarchically ordered nano-structures achieved through controlled self-assembly. In order to use these versatile molecules to their full advantage, a detailed understanding of the correlations between molecular interactions, material structure and function is required. Aim of this project is to gain a detailed understanding of the factors governing the self-assembly of these molecules using molecular simulation methods.

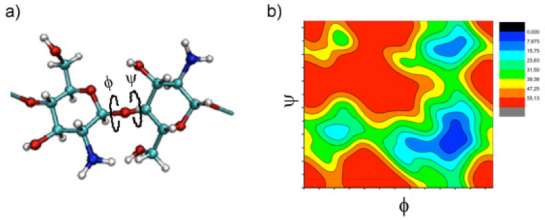

Figure 3: *a) the glycosidic angles ϕ and ψ are the most flexible degrees of freedom. b) free energy map for the conformations of ψ and ϕ.*

Research within the German group. Many polysaccharide properties and conformations can be accurately modelled based on the free energy landscapes of the glycosidic angles, the most flexible degrees of freedom for example shown in *Fig. 1*. Such a relatively simple model is able to accurately predict many polymer properties. For denser systems, details of the non-covalent interactions between sugar monomers and between monomers and other system components gain greater significance. Potential functions for these interactions need to be introduced to the system.

In the course of the project, a coarse-grained (CG) model for the polysaccharides will be developed based on atomistic molecular dynamics (MD) simulations of small saccharide molecules and other system components. Inter-molecular interaction potentials suitable for CG-MD simulations will be developed using bottom-up coarse-graining strategies, aiming to reproduce conformations, forces or free energies of the system. The effect of pH and ionic strengths can be approximated with protonation moves for titratable sugars.

Complementary work in US partner group. The above CG simulations will be complimented by all atom MD simulations of the interaction of Chitosan, Hyaluronan and Dextran oligosaccharids with lipid bilayers, to gain a better understanding of the differences observed in coating vesicles with these molecules (1). The Berkowitz group has considerable experience with modeling and analyzing the interactions of lipid bilayers with other molecules.

Status of the project. Currently, we use a model based on the free energy landscapes of the glycosidic angles as well as steric repulsion between the stiff rings and Debeye-Huckle electrostatics. Polysaccharide conformations are sampled with a Monte Carlo algorithm, taking PH and ionic strength of the solution into account via protonation moves for the titratable sites. The simple model is able to accurately predict properties of single polymers with over 1000 monomers and a large range of physic-chemical conditions. The project will interact closely with the groups of Prof. Gradzielsky and Dr. Dimova studying polysaccharide coated nano-particles and vesicles and their aggregation properties.

Bibliography

(1) Quemeneur, F., M., Rinaudo, G. Maret, and B. Pepin-Donat. 2010. Soft Matter 6