PHYSICS OF PROTEINS

Life is based on biomolecules. Biomolecules determine how living systems develop and what they do. They store and propagate information, build the systems and execute all processes, from transport of energy, charge, and matter to catalysis. A knowledge of the structure and function of biomolecules is essential for biology, biochemistry, biophysics, medicine, and pharmacology and it even has technological implications.

To a considerable extent, the study of biomolecules is similar to that of atoms, molecules, solids, and even nuclei. Understanding of these simpler systems help in investigations of the more complex biomolecules. Many features are alike in all these quantum-mechanical systems; ideas and concepts from molecular and solid state physics can thus be taken over directly. Biomolecules, however, show some beautiful characteristics that cannot be found in simpler systems. It is even poissble that some laws of physics and chemistry can be studied in biomolecules more easily and directly than in other places.

The present course should provide a first introduction to the structure and function of biomolecules, particularly proteins. Emphasis is on aspects of interest to physicists. The number of unsolved problems is very large. Any new development in physical tools usually leads to exciting advances in our understanding of biomolecules. Tools and concepts of experiments will therefore be stressed.

In the present lectures we will discuss only a few of the physical tools, and we neglect chemical ones. We try to avoid techniques that are already well established and concentrate on those that may make major new steps possible. New tools appear regularly; laser, synchrotron radiation, muons, proton radiology, holography, gamma-ray lasers (?), inner-electron spectroscopy are some of the ones that either have recently been introduced into biomolecular physics, or are likely to become important.

Our approach is that of physicists. In recent years it has become customary to distinguish **biophysics** and **biological physics**. In biophysics, physics is the servant and the gola in unambiguously to understand the biology of living systems. In biological physics, the situation is not so clear, but one goal is to describe the physics of biological systems, to discover physical models, and possibly even find new laws that characterize biological entities.

Progress in physics has often followed a path in which three areas are essential: structure, energy levels, and dynamics. Of course, progress is not linear and occurs usually in all three areas at once. Moreover, experimental results and theoretical understanding are both needed for progress. Nevertheless, the three steps can often be seen clearly and often they can be related to specific names. The present deep understanding of atoms and atomic structure is linked to a chain fo discoveries and theories. Every student is familiar with the Balmer series, the Rutherford atom, the Bohr model and the theories of Schroedinger, Heisenberg, Pauli, and Dirac. Similar discoveries, models, and theories have elucidated solids (Einstein, Laue, Debye, . . .), nuclei and particles. We try to follow a similar path here. In Part I, we give a brief and superficial introduction into biomolecules. In

Part III, we describe the structure of two main classes of biomolecules, proteins and nucleic acides, and treat the relevant methods. In Part III, we discuss the energy levels or, more properly the energy landscape, of proteins. Since proteins are complex system, their energy can no longer be described by a simple level diagram, but requires more general concepts. In Part IV, we treat the dynamics of some selected proteins.

The sequence structure — energy landscape – dynamics suffices for "simple" systems such as atoms and nuclei and for "passive" complex systems such as glasses and spinglasses. "Active complex systems, such as biomolecules, computers, or the brain, perform functions. We do not discuss biological function in detail, but consider some specific examples together wit synamics in Part IV.

As we will describe briefly in Chap.2, the number of the biological molecules in extremely large and indeed, the literature, while covering only a small fraction of existing systems, is vast. Since we are interested in concepts and general features, we only cover a very restricted set of biomolecules, but hope to nevertheless cover many of the essential idea.s