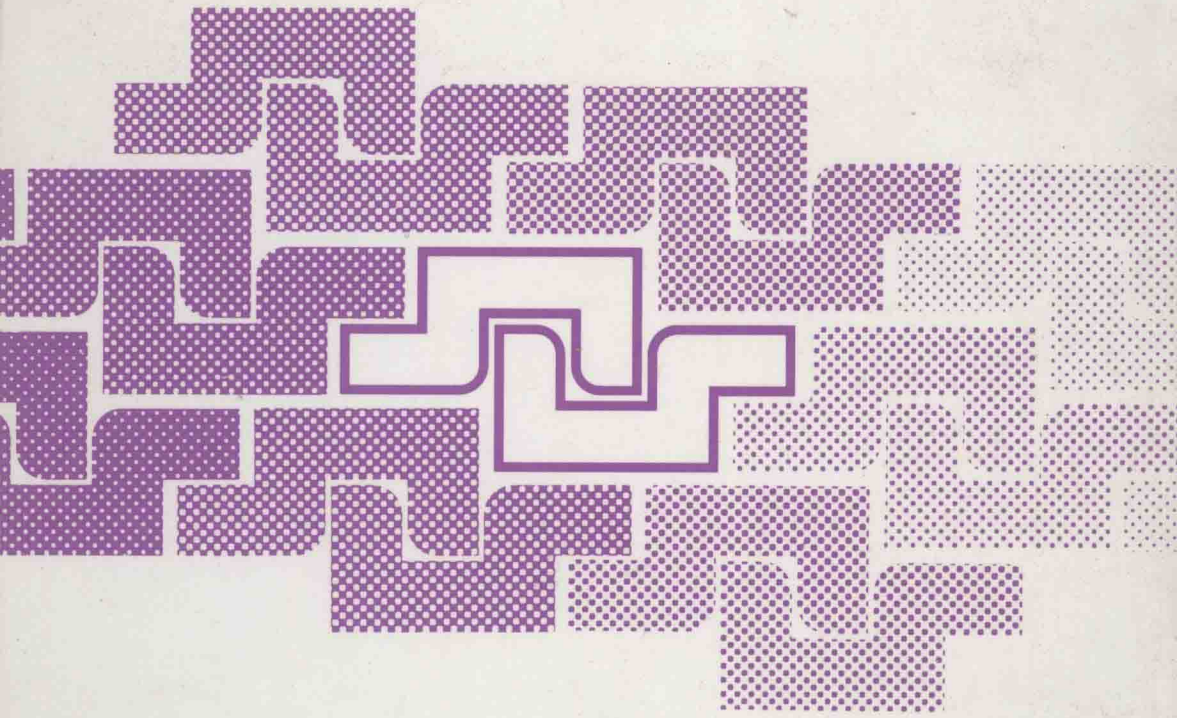

Soft Condensed Matter: Configurations, Dynamics and Functionality

Edited by

A. T. Skjeltorp and S. F. Edwards

NATO Science Series

Series C: Mathematical and Physical Sciences – Vol. 552

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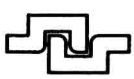

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PREFACE

This volume comprises the proceedings of a NATO Advanced Study Institute held at Geilo, Norway, April 6 - 16 1999. The ASI was the fifteenth in a series held biannually on topics related to cooperative phenomena and phase transitions, in this case applied to soft condensed matter and its configurations, dynamics and functionality. It addressed the current experimental and theoretical knowledge of the physical properties of soft condensed matter such as polymers, gels, complex fluids, colloids, granular materials and biomaterials.

The main purpose of the lectures was to obtain basic understanding of important aspects in relating molecular configurations and dynamics to macroscopic properties and biological functionality. To our knowledge, the term Soft Condensed Matter was actually coined and used for the first time in 1989 at Geilo and some selected topics of soft matter were also given at Geilo in 1991, 1993 and 1995. A return to this subject 10 years after its instigation thus allowed a fresh look and a possibility for defining new directions for research.

Soft condensed matter encompasses a wide range of substances which are neither ordinary solids nor ordinary liquids, but have much more complexity and subtlety of character than either as well as having vestiges of each. Systems range from foams and complex fluids to granular materials and biomaterials like protein, DNA and membranes. They exist in a wide variety of structures that are driven by subtle competition between intermolecular interaction energies and entropic forces, both of which are often close to thermal energies at room temperature. These same forces, plus the constraints imposed by the configurations adopted by these systems also have a strong effect on the molecular motions or dynamics. Both the configurations and their dynamical evolution are known to be important in determining a wide variety of mesoscopic and macroscopic properties, including those linked to "function" in the case of biomolecular assemblies.

Many of these so-called "soft materials" display what one can call "adaptive" behaviour – that is strong changes in some physical property that results from a small change in an internal or external driving force. Indeed, such effects are likely a prerequisite for life itself but are only beginning to be understood in physical terms. Among the adaptive phenomena themselves there is a kind of logical progression, from the behaviour of disordered cooperative systems to evolved cooperative systems such as RNA, proteins, and possibly the immune system.

The language needed to discuss these systems are reviewed and basic questions regarding phenomena such as competing ground states, nonlinear feedback and slow dynamics are presented in introductory lectures, with later talks emphasizing subfields in more detail. Granular matter are discussed in regard to segregation of powders, equations of granular materials, granular flow and mechanics as well as the modeling of granular flows. Various aspects of interfaces and confinement are reviewed in relation to nucleation and engineering of crystalline architectures at the air-liquid interface, as well as x-ray and neutron studies of complex confined fluids. Soap films and general properties of the evolution of froth are discussed, both theoretically and experimentally. Broad reviews are given of hierarchical protein folding and protein evolution in vitro. Related to this, DNA recognition and computation, gene expressions and measurements as well as torsion-induced phase transition in single DNA molecules are also discussed. Fungus growth modeling and cell attachment and spreading are also presented.

The Institute brought together many lecturers, students and active researchers in the field from a wide range of countries, both NATO and NATO partners, and non-NATO. The lectures fulfilled the aim of the Study Institute in creating a learning environment and a forum for discussion on the topics stated above. They were supplemented by a few contributed seminars and a large number of poster presentations. These seminars are included in the proceedings and the posters were collected in extended abstract form and issued as an open report available at the Institute for Energy Technology, Kjeller, Norway (Report IFE/KR/E-99/008).

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June 1999

Arne T. Skjeltorp Sam Edwards

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WHAT IS SOFT CONDENSED MATTER ?

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1. Context

A well identified community of physicists has established itself over the last thirty years, which was present in the 1999 Geilo Institute. Looking back at the themes of the 14 previous institutes, it is easy to recognize constant themes throughout the meetings as well as a drift away from the initial ones. We are dealing with Material Science as analysed by Solid State physicists using the tools of Statistical Physics. The study of electronic properties which was present in the first meetings has progressively been dismissed. From microscopic systems, the studies have been progressively turned towards mesoscopic -supramolecular- ones using analogies with the microscopic case : an example is the numerical study of granular media based on models developed in molecular dynamics studies of liquids and gases. There has been a progressively significant place given to Continuum Mechanics and Rheology, a field not much in fashion for physicists and chemists. Finally, the opening towards Biological systems is a new and strong component of the present institute. In fact, Soft Condensed Matter does not characterize a field of study, rather a spirit!

Consideration of terminology is not of great use to characterize the field of study. It has been long associated with sligthy depreciative names: ""ill condensed", "complex", "dirty", "mou" ("weich"), "tenuous", "fragile". The qualificative "soft" which apparently was introduced first in a Geilo Institute 10 years ago [1] is more appropriate and with a positive connotation *"yielding readily to touch, easily penetrated or changed in shape"* (the word thixotropy involves indeed the notion of touch , θιξισ). The late Tormod Riste, the organiser of the first 12 Institutes, and David Sherrington characterized it in 1989 by *"the weak interactions between polyatomic components, important thermal fluctuations, mechanical softness with emphasis on fundamental collective physics, plus a rich range of behaviours "*, a definition mostly shared by the examples treated in this meeting, except possibly for the role of thermal fluctuations since several of the examples treated here fall beyond the range of systems where Brownian effects play a role. I will myself not take into account this restriction and consider, following Henri Van Damme, that we are just working with "condensed matter".

The notion of "soft" indeed implies that of touch and feeling; there is an amusing developing field in Engineering Sciences called "psycho-rheology" in which the qualitative appreciation of properties of materials used by man is expressed in terms of

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