MATERIALS SCIENCE

The Soft Sector in Physics

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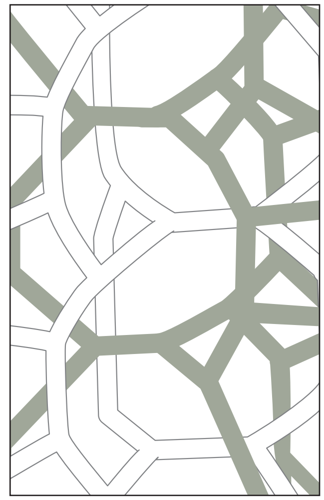
Soft matter occupies a middle ground between the solid and fluid states. These materials have neither the crystalline symmetry of solids, nor the uniform disorder of fluids. For instance, a smectic liquid crystal consists of a one-dimensional, solid-like, periodic stack of two-dimensional fluid monolayers. Liquid crystals, polymers, and colloids are commonly cited examples, but soft matter also encompasses surfactants, foams, granular matter, and networks (for example, glues, rubbers, gels, and cytoskeletons), to name a few.

The interactions that govern the behavior of soft matter are often weak and comparable in strength to thermal fluctuations. Thus these usually fragile forms of matter can respond much more strongly to stress, electric, or magnetic fields than can solid-state systems. Common themes in the behavior of soft matter include the propensity for self-organized structures (usually at length scales larger than molecular sizes), self-organized dynamics, and complex adaptive behavior (often in the form of large macroscopic changes triggered by small microscopic stimuli). These themes can be seen in a wide range of examples from the recent literature: shape-memory polymers for "smart," self-knotting surgical sutures (*1*), DNA-cationic membrane complexes in artificial gene delivery systems (*2*), colloidal crystals for templating photonic-bandgap materials (*3*), cubic lipid matrices for crystallizing integral membrane proteins (*4*), and electronic liquid crystalline phases in quantum Hall systems (*5*). (In the last case, we have come full circle, to where soft and hard condensed matter physics meet.) To a traditional condensed-matter physicist, the above list may sound at best like the animal classifications in Jorge Luis Borges's imaginary Chinese encyclopedia (*6*), but the field's broad conceptual reach is one of its strengths.

A young but already diverse field, soft condensed matter physics is expanding the province of physics in new and unexpected directions. For example, it has generated a new branch of biophysics. Most larger physics departments now have faculty who specialize in soft matter, and such materials are beginning to be covered in the undergraduate curricula in physics, chemistry, materials science, and chemical engineering. However, introducing students to the field has been a challenge because of the lack of suitable textbooks. Thus the appearance of *Structured Fluids: Polymers, Colloids, Surfactants* by Tom Witten and Phil Pincus, two pioneers in the field, is particularly welcome.



Structured Fluids
Polymers, Colloids, Surfactants
by Thomas A. Witten with Philip A. Pincus
Oxford University Press, Oxford, 2004. 230 pp. $74.50, £39.95. ISBN 0-19-852688-1.

Witten and Pincus (from the physics departments at the University of Chicago and the University of California, Santa Barbara, respectively) give us a tutorial for thinking about polymers, colloids, and surfactants using a unified-scaling approach in the tradition of de Gennes's classic monograph in polymer physics (*7*). They begin with a review of statistical mechanics, and then they proceed to develop the tools needed to make simple estimates by thinking in terms of important length scales and time scales in a given phenomenon. For example: How do we estimate viscosities? How do colloids aggregate? What does a polymer look like at different length scales in different conditions, and how does that influence the way it moves? What concentrations of surfactant do we need for entangled wormlike micelles to form? Witten and Pincus demonstrate how to come up with real numbers for actual materials systems.

Another unusual strength of the book is the authors' attention to chemical and experimental details. Too few physics textbooks explain how a polymer is made, much less mention recent synthetic strategies for controlling sequence and length with recombinant DNA technology. This book also offers an excellent, concise introduction to scattering methods, in which diffraction is presented not so much as the interference of scattered waves from atomic planes (as described in classic solid state physics textbooks) but as a Fourier transform of a density-density correlation function. This more powerful formulation facilitates generalization to diffraction from fractals and weakly ordered systems.

The authors describe a number of pedagogical "home" experiments. These cover questions including the elasticities of gels and rubber, turbidity assays, and the electrostatics of skim milk and employ such readily available household components as gelatin, rubber bands, and laser pointers. Many interesting concepts are relegated to the appendices, which reward careful reading. These range from a consideration of the dilational invariance of random walks to a presentation of the celebrated Gauss-Bonnet theorem (which seems as much a miracle as it is differential geometry).

The book's fairly short length required the authors to make hard choices. As a result, the coverage is uneven and there are notable omissions. (For example, the rotational-isomerization-state model for polymer conformations is only discussed qualitatively, as are semiflexible chains.) In addition, readers would benefit from having more worked problems. On the other hand, the book is very readable, and it can be easily adapted for a one-semester or a one-quarter course. Instead of opting for an encyclopedic treatment, Witten and Pincus cultivate a physicist's style of thought and intuition, which often renders knowledge weightless. *Structured Fluids* belongs on one's shelf beside recent works by Paul Chaikin and Tom Lubensky (*8*), Jacob Israelachvili (*9*), and Ronald Larson (*10*). These books rectify and expand prevailing notions of what condensed matter physics can be.

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References and Notes

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3. J. O. Rädler, I. Koltover, T. Salditt, C. R. Safinya, *Science* **275**, 810 (1997).
4. E. Pebay-Peyroula, G. Rummel, J. P. Rosenbusch, E. M. Landau, *Science* **277**, 1676 (1997).
5. S. A. Kivelson, E. Fradkin, V. J. Emery, *Nature* **393**, 550 (1998).
6. Borges describes "a certain Chinese encyclopedia called the *Heavenly Emporium of Benevolent Knowledge*. In its distant pages it is written that animals are divided into (a) those that belong to the Emperor; (b) embalmed ones; (c) those that are trained; (d) suckling pigs; (e) mermaids; (f) fabulous ones; (g) stray dogs; (h) those that are included in this classification; (i) those that tremble as if they were mad; (j) innumerable ones; (k) those drawn with a very fine camel's hair brush; (l) et cetera; (m) those that have just broken the flower vase; (n) those that at a distance resemble flies." J. L. Borges, *Selected Non-Fictions*, E. Weinberger, Ed. (Penguin, New York, 1999), pp. 229–232.
7. P.-G. de Gennes, *Scaling Concepts in Polymer Physics* (Cornell Univ. Press, Ithaca, NY, 1979).
8. P. M. Chaikin, T. C. Lubensky, *Principles of Condensed Matter Physics* (Cambridge Univ. Press, Cambridge, 1995).
9. J. N. Israelachvili, Ed., *Intermolecular and Surface Forces* (Academic Press, London, ed. 2, 1992).
10. R. G. Larson, *The Structure and Rheology of Complex Fluids* (Oxford Univ. Press, Oxford, 1999).

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