

A matter of phenomenology

The 1991 Nobel prize for physics recognizes the incisive contributions of a condensed-matter theorist.

The Royal Swedish Academy of Sciences announced on 16 October that this year's Nobel prize for physics is awarded to Pierre-Gilles de Gennes of the Collège de France in Paris 'for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers'.

de Gennes is a condensed-matter theorist in a rather general sense of the term. His distinctive style has been to get interested in some branch of condensed matter, tackle a variety of problems, deliver a course of lectures and follow it up with a delightful monograph on the subject, and then move on to another topic. (One is reminded of S. Chandrasekhar, the celebrated astrophysicist, though the theoretical styles of the two are quite different.) Topics that have interested de Gennes include superconductivity, and, more recently, wetting phenomena, apart from liquid crystals and polymers specifically mentioned by the Swedish Academy. He is the author of *Superconductivity of Metals and Alloys* (1966), *The Physics of Liquid Crystals* (1974), *Scaling Concepts in Polymer Physics* (1979), and *Introduction to Polymer Dynamics* (1990).

An extraordinary capacity to discern the essential physical process and tackle it with the minimum mathematical apparatus (he even calls himself a 'semi-theorist!') has enabled de Gennes to clarify a bewildering variety of phenomena in the subjects he has taken up for study. He has often published just short letters, which still launched a flurry of experimental activity, besides detailed theoretical calculations. Quite naturally, thriving experimental schools grew around him, whatever be the subject of his interest.

His first major contribution to the field of liquid crystals was in developing the correct continuum theory of the strong light scattering from nematics arising from orientational fluctuations of the director. Using the hydrodynamic

theory which had just been completed by Leslie, the 'Orsay group' worked out the thermal fluctuation spectrum of the director in nematics¹. This theory helped to do away with the long prevalent but incorrect 'swarm' model, and, further, paved the way for the development of light-beating spectroscopic techniques of measuring elastic constants and most of the viscosity coefficients of nematics. The formulation of the 'Landau-de Gennes' model² of the nematic-isotropic transition led to many quantitative measurements of the pretransitional effects in the isotropic phase. Perhaps one of his most important contributions was to point out the



An ability to get to the essence of a problem

formal similarity between the smectic A-nematic and superconductor-normal transitions³. The order parameter is complex in both cases, the A-phase order parameter being characterized by both the amplitude and the phase of the one-dimensional density wave. This led de Gennes to predict several phenomena: (a) pretransitional divergences of twist and bend elastic constants in the nematic phase, (b) suppression of the A-N transition point by a curl \mathbf{n} distortion which changes the layer thickness, (c) existence of a 'second sound' related to

the changes in interlayer spacing, and whose magnitude has a very strong angular dependence. The smectic A phase remains a topic of continued interest: it has only a quasi-long-range order, due to the well-known Landau-Peierls instability of one-dimensional systems, and the non-vanishing k_{11} -term which allows for a bending of the layers, makes the A-N transition far more complicated than the superconductor-normal transition. Interestingly, the (Abrikosov) screw-dislocation lattice for 'type-II' smectic A made of chiral molecules was discovered just about two years ago, and is called the 'twist grain boundary' phase⁴. de Gennes also worked out the Landau model for the smectic C-A transition, which has been subsequently developed by several authors. Anharmonic effects have been found to have rather interesting consequences for the hydrodynamic properties of the A and C phases.

The Orsay group developed a detailed model for the electrohydrodynamic instabilities exhibited by certain types of nematics. Though Helfrich had worked out the basic physical mechanism for an applied DC field⁵, the importance of the ratio of charge relaxation and director relaxation times in the problem was recognized by the French school and their model could predict different electrohydrodynamic regimes under an AC field⁶. This subject has been revived in recent years, necessitating further developments of the Orsay model. de Gennes has also worked on several problems connected with defects in liquid crystals, like edge dislocations in smectic A and χ -edge disclinations in cholesterics, and has predicted a network of point disclinations at the nematic free surface under the action of an appropriate external field⁷. He also initiated studies on defects in liquid helium-3, which in many ways behaves like a nematic liquid crystal. The subject of liquid crystals itself has steadily grown in recent years. For example, only four types of liquid crystals are described in

de Gennes' book, whereas more than 20 types are known at the present time.

The importance of polymeric materials in the present-day world is quite obvious. The material is however quite messy and a theoretical description of its physical properties has emerged only in the past decade or two, and de Gennes has contributed to a wide variety of problems on this subject. He has used scaling arguments very effectively to tackle problems of adsorption and confinement of polymer chains in tubes in different dilution regimes, segregation of incompatible polymers, formation of swollen polymer gels, effect of swelling on the mechanical properties of the chains, etc. Other problems that interested him include 'internal friction' of a coil and influence of 'backflow' on the flow of a polymer inside a cylinder. In concentrated polymer solutions the chains are entangled like in spaghetti, and their viscoelectric properties are fascinating. Though they flow like a liquid at very low shear rates, beyond a threshold frequency $\omega = 1/\tau$ they behave like rubber. Experimentally it was established that $\tau = \tau_0 N^a$ where N is the number of monomers in the chain. The exponent a was known to be $\approx 3-3.4$. In

a well-known paper, de Gennes introduced the concept of reptation⁸ or snake-like motion of individual chains in an effective 'tube' formed by the network and used a scaling argument to get $a = 3$. (The slightly higher value found in some systems is not yet fully understood.) He also applied the self-consistent field method to calculate response functions of densely packed chains, and used an analogy between the crossover from a semidilute to a dilute regime of polymer solutions and the critical point in magnetic systems to discuss many statistical problems in polymers. A large number of polymeric materials exhibit liquid-crystalline phases. Quite naturally de Gennes has contributed to a phenomenological description of these phases.

Early in his career de Gennes worked on magnetic systems, and later, on many problems in superconductors connected with alloying and effects at a superconductor-normal metal interface. More recently, he has turned his attention to wetting phenomena⁹, and calculated detailed profiles of a spreading liquid film, which has attracted many experimental studies.

de Gennes is a charismatic speaker.

He visited Bangalore in 1973 to take part in a school and a conference on liquid crystals held at the Raman Research Institute. He is now 58, and one looks forward to many years of his incisive contributions to condensed matter physics.

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Transforming NMR spectroscopy: adding new dimensions

Richard Ernst, this year's winner of the Nobel prize for chemistry, is responsible for several revolutions in NMR spectroscopy.

The phenomenon of nuclear magnetic resonance (NMR) in bulk matter was discovered by Felix Bloch and Edward Purcell in 1946, an event quickly recognized by the award of the Nobel prize for Physics in 1952. In the four decades since, NMR has become indispensable in the practice of chemistry, grown into the most powerful technique for determining three-dimensional structures of biological macromolecules in solution, and developed into an invaluable, non-invasive diagnostic tool in medicine. The evolution of NMR from an esoteric phenomenon in physics to a central technique in chemistry, biology

and medicine has been shaped by three major revolutions. The standard-bearer of these revolutions, Richard R. Ernst, of the Eidgenössische Technische Hochschule (ETH), Zürich, has now been recognized by the award of this year's Nobel prize for chemistry for his contributions to developments in the techniques of high-resolution NMR. Ernst has earned the nickname 'father of FT NMR'; he indeed transformed NMR into one of the most powerful spectroscopic techniques. NMR as it was practised in the pre-Ernst era up to the mid-sixties had already been recognized as an important analytical tool

with many applications in chemistry. High-homogeneity magnets had been developed but NMR being a low-frequency method continued to be plagued by low sensitivity, an inevitable consequence of the use of the continuous-wave (CW) method of its inventors of the late forties.

During the sixties Ernst transformed NMR from a frequency-domain method to a time-domain method, changing completely the practice of NMR, dramatically increasing its use, opening up applicability to biomolecules and to low-sensitivity nuclei, and to the design of many new experiments. During the