News and Announcements

de Gennes Receives Nobel Prize in Physics

On December 10, 1991, The Royal Swedish Academy of Sciences awarded Pierre-Gilles de Gennes the Nobel Prize in Physics for his discovery that "methods developed for studying order(ing) phenomena in simple systems can be generalized to more complex forms of matter, in particular, to liquid crystals and polymers."

de Gennes is widely credited with launching remarkable, world-wide advances, clearly evident since 1969, in the physics of complex systems such as liquid crystals and polymers. Through his research and teachings, he has influenced both the direction and style of contemporary physics research in systems previously thought by some to be too complex for physics. In particular, in the words of the Swedish Academy, "He has shown that phase transitions in such apparently widely-differing physical systems as magnets, superconductors, liquid crystals, and polymer solutions can be described in mathematical terms of surprisingly broad generality." de Gennes' work is characterized by profound physical insight, minimum formalism, and maximum economy and simplicity.

de Gennes has an outstanding talent for encouraging cross-disciplinary scientific interactions and is a strong advocate of the synergism generated by close collaborations between theoretical and experimental researchers. His three books, *Superconductivity in Metals and Alloys* (1966), *Physics of Liquid Crystals* (1976, 1984), and *Scaling Concepts in Polymers* (1979) are striking in their lucidity, contain original ideas, and provide a solid basis in physical thinking for researchers and students to build new knowledge. His most recent book, *Introduction to Polymer Dynamics* (1990), provides a unified theoretical framework as a guide for future experiments in a variety of nonlinear phenomena such as polymer dynamics, protein chain folding, wetting and drag reduction.

Pierre-Gilles de Gennes was born October 24, 1932 in Paris, France. Although his early preferences were towards literary disciplines, the influence of several gifted teachers at the lycée Claude-Bernard, Paris, caused him to choose to specialize in science. At the Ecole Normale Supérieure, Paris (1951–1955), de Gennes was notably influenced by Professors Yves Rocard, Alfred Kastler (Physics Nobel Prize 1966), and Pierre Aigrain. After receiving *l'agrégation de physique*, de Gennes accepted a position as engineer at the Center for Atomic Studies, Saclay. Under the aegis of luminaries such as André Herpin and Anatole Abragam, he received the doctorate degree in 1957 with a Thèse d'Etat on the theory of neutron scattering by magnetic materials. The following year, he worked with Charles Kittel at the University of California at Berkeley.

In 1961, following completion of his French military service, de Gennes became professor of physics at the University of Paris-Sud, Orsay, and formed The Orsay Superconductivity Group (1961–1967). One of de Gennes' contributions to superconductivity was his prediction of neutron scattering by vortex lines in type-II superconductors. Another was his prediction for the persistence of superconductivity on the surface of type-II materials above the critical magnetic field to drive the bulk of the material into the normal state.

Around 1968, de Gennes became interested in liquid crystals, liquid states of some organic materials characterized by long range orientational order. One of the ordered phases of liquid crystals is the "nematic" phase, in which the molecules move as in an ordinary 3-dimensional liquid state, but with their long axes mainly parallel to each other defining a direction of long range orientational order. Other phases are termed "smectic": the molecules are arranged in layers with a degree of freedom in the plane of the layers that characterizes the particular smectic phase. In smectic A, for example, the direction of long range orientational order is parallel to the layer normal and molecules move freely in the plane of the layers. To launch the study of liquid crystals, de Gennes formed The Orsay Liquid Crystal Group (1969-1972). One of his first contributions was to explain the translucence of nematic liquid crystals as arising from local fluctuations in orientational order. With this new understanding, he showed that, *inter alia*, the Leslie-Ericksen viscosity coefficients could be obtained from light scattering experiments.

de Gennes was the first to apply the order parameter concept, invented by Landau (1937), to describe phase transitions in liquid crystals. An order parameter is a field variable, a function of space and time that characterizes the symmetry and dimensionality of the ordered (usually, lower temperature) phase. Its power rests on a deep truth:

symmetry cannot change continuously even if the magnitude of the order parameter can. Second order (continuous) phase transitions are often called "symmetry breaking" because the disordered state has more symmetry than the ordered state. For example, an isotropic liquid has 3-dimensional continuous rotational symmetry, whereas nematic liquid crystals orientationally order along one spatial direction (called the director): the nematic breaks continuous rotational symmetry of the isotropic liquid. de Gennes formulated theories for the nematic-isotropic phase transition that included predictions for how orientational order grows in the isotropic liquid as the transition temperature to the nematic state is approached.

The smectic A state is layered with the director parallel to the layer normal: the continuous translational order of the nematic is broken in smectic A. When de Gennes developed the free energy functional to describe the nematic-smectic A phase transition, he noted it had similarities to the Ginzburg-Landau description for the normal metal-superconducting transition. Because smectic A and superconductors both have two-component order parameters, they belong to the same universality class of critical phenomena. However, because the correlation length for the liquid crystal system is much smaller than for superconductors, de Gennes correctly predicted that its critical regime, the domain of nonlinear scaling concepts, is much wider, making the nematic-smectic A transition an ideal model system to test the validity of many ideas of critical phenomena. Predictions based on de Gennes' theory for the nematic-smectic A phase transition have been largely confirmed by many experiments around the world.

In 1971, de Gennes was named Professor for the most distinguished French Chair in Condensed Matter Physics at the Collège de France and began to concentrate on polymer physics. In 1975, he played a key role in creating still another collaborative group, Strasacol, formed by the Center for Macromolecular Research, Strasbourg, the high resolution neutron scattering group at Saclay, and his group at the Collège de France.

A polymer is considered a flexible chain with N identical links having an extension R_N, where R_N is defined as the distance between the two ends of the chain. In a random walk model (no interactions), ${R_N}^2 \sim N$. The self-avoiding random walk (repulsive interactions) in which each lattice site can be occupied only once, is used to model the excluded-volume polymer chain problem. In the limit of large N, this problem is intractable and, in earlier days, had elicited a host of theories with widely different predictions. de Gennes pointed out that, taking n, the number of components for an order parameter in phase transitions, to be *zero*, the excluded volume problem was isomorphic to critical phenomena. Experts in critical phenomena, notably Toulouse and Pfeuty, consider this observation an exceptionally elegant synthesis: *in one stroke the excluded-volume problem is linked to phase transitions while the physically significant range of* n *is enlarged.* It raised further questions about negative values for n and suggested that critical exponents are *continuous* functions of n.

Molten polymers flow like highly viscous ordinary liquids when acted upon by perturbations slower than a characteristic time, τ, and behave like a rubber at slightly higher frequencies. Experimentally, τ is found to scale like N^a with $a \sim 3$. A coherent theoretical estimate for a was first given by de Gennes with a simple reptation model, in which, at a given instant, to avoid neighboring chains, every chain is confined to a "tube" of length $L \sim N$. The chain moves inside its tube like a snake with a characteristic mobility inversely proportional to its length (i.e. $\sim 1/N$). Mobility is proportional to a diffusion constant, D_{tube}. de Gennes defined τ as the time for the chain to move the length of the initial tube: $\tau \stackrel{\text{def}}{=} L^2/D_{tube} \sim N^3$. The reptation concept led Doi and Edwards to a detailed theory of polymer dynamics that explains a significant fraction of the experimental data, not only for small deformations, but even in the nonlinear regime, making linear polymers novel model systems for rheology.

In 1976, in parallel with his other duties, de Gennes became Director for the Ecole Supérieure de Physique et Chimie (Ville de Paris). de Gennes was elected to l'Académie des Sciences in 1979, and is a member of many other scientific organizations and distinguished academies around the world. He has received numerous prizes and awards, such as the Centre National de la Recherche Scientifique Gold Medal (1979), The Ampère Prize of l'Académie des Sciences (1977), the Lorentz Medal (1991), and the Wolf Prize for Physics (1990). The award of the 1991 Nobel Prize in Physics to Pierre-Gilles de Gennes is clear recognition of his outstanding achievement in bringing physics to complex systems and complex systems to physics.

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MAA Prizes Awarded in Baltimore

The Mathematical Association of America (MAA) awarded a number of prizes during the Joint Mathematics Meetings in Baltimore in January of this year.

LYNN ARTHUR STEEN of St. Olaf College received the MAA's Yueh-Gin Gung and Dr. Charles H. Hu Award for Distinguished Service. The award consists of $4000 and a gold cup. A citation honoring Steen appeared in the January 1992 issue of the *American Mathematical Monthly*.

Steen received his bachelor's degree in mathematics and physics from Luther College and his doctorate in mathematics from the Massachusetts Institute of Technology. He has served as the President of MAA, Chair of the Conference Board of the Mathematical Sciences, and Chair of the Council of Scientific Society Presidents. In addition, he was a member of the National Council of Teachers of Mathematics Commission on Standards for School Mathematics, and a founding member of the Mathematical Sciences Education Board of the National Research Council.

One of Steen's best-known and most influential works is the report "Everybody Counts: A Report to the