PREFACE

In the Pantheon of Science, a few giants emerge: they opened avenues in our quest for more knowledge of our surrounding world. Among them, a tall, elegant man is still very present in our minds and hearts — Pierre-Gilles de Gennes. He has influenced many fields of science and many of us.

The ideas Pierre-Gilles introduced were almost always very novel, creating many possibilities. Hundreds of people would start working right away on a new suggestion of Pierre-Gilles'! His ideas bear important consequences in the present as well. Thus, it became natural to pick out a few of these contributions and ask some of the leaders in their fields first to explain the ideas, and then to show how it led to the current state of the art. This is what World Scientific asked Francoise Brochard-Wyart, Julien Bok and myself to organise in two volumes. The first one is dedicated to solid state and liquid crystal physics. The second deals with soft condensed matter and biological physics. The general title "P.G. de Gennes' Impact on Science" reflects the goal that we would like to attain: to give the reader an idea of Pierre-Gilles' contribution to science. Rather than just "an idea", perhaps "a measure" would be better but how is it possible to gauge more than 500 original papers in more than 15 different areas from solid state physics to biology?

Three aspects of his contributions will be missing though. The first one concerns Pierre-Gilles' impact in chemistry: he had a great admiration for the inventiveness of chemists and was able to make many relevant suggestions during his conversations with synthetic chemists. His papers on asymmetric synthesis, written to commemorate Pierre and Jacques Curie's discovery of piezoelectricity, are in Pierre Curie's vein: they are important for theorists but do not reflect the real influence he had on liquid crystal, polymer and colloidal chemistry. The second one concerns the impact he had on the industry. He has been the scientific advisor of companies such as General Electric, Exxon, Rhône Poulenc and Rhodia. He was also on the board of directors of several other companies. I know he had a significant influence in many important decisions, but by their nature they cannot be public knowledge. The third important aspect is Pierre-Gilles' dedication and gift for communicating his passion for science. To give an example, after being awarded his Nobel Prize, Pierre-Gilles went throughout France to high schools for several years and gave lectures on soft matter which triggered many vocations in this area of science. In the following paragraphs, I try to explain how Pierre-Gilles' scientific life helped us narrow the scope of the present books.

When he starts his career in 1955, Jacrot and Cribier at Saclay have just observed antiferromagnetic order with neutron scattering. The young Pierre-Gilles works out the theory, which is still a landmark nowadays. Philippe Monod tells me that Pierre-Gilles is also the first to suggest the use of neutron scattering to show the existence of vortex lattices in the superconducting Schubnikov phase. During his postdoc in Charles Kittel's group at Berkeley in 1957, he keeps working on magnetism, in particular, on double exchange and ferromagnetic resonance in rare-earth garnets. Jacques Friedel has fully understood the scientific interest motivating all this work and attracts him to Orsay. In 1958, they write a paper together discussing resistive anomalies in magnetic metals: early "spintronics"! We are very grateful to Jacques Friedel for accepting to describe this work along with its consequences.

All throughout his life, Pierre-Gilles will be eager to learn new fields. He quickly gets interested in superconductivity. He sets up a very active group where theories and experiments are simultaneously investigated. Superconductivity is a very competitive field, which blooms after the BCS theory provides the long expected microscopic understanding of the phenomenon. Here, Pierre-Gilles provides us with an original perspective. He understands that the gap between the phenomenological Landau–Ginzburg theory and the microscopic BCS theory must be bridged, which he does simultaneously with Gork'ov in Moscow. This allows him and his collaborators to discuss surface effects and vortices. With Saint James he predicts the existence of a surface critical field H_{c3}, which is subsequently observed by Alexis Martinet, one of his young collaborators. He also predicts with Saint James, one year before Andreev what is now known as the Andreev–Saint James reflection: electrons impinging on a normal superconductor interface from the normal side can be reflected as holes when a Cooper pair is transmitted on the superconducting side. The experimental activity is also brilliant. Pierre-Gilles has built a very active young group world-renowned as the "Orsay superconductor group". In 1967, he summarises his thoughts on superconductivity in the book *Superconductivity in Metals and Alloys* which is still a reference in the domain. It is time for him to sail towards new continents.

Yet, he will always keep an eye on superconductors and superfluids, and once in a while publish a paper. In 1988, when high temperature superconductors are discovered, he proposes a mechanism based on magnetic interactions. At the same time, he attracts his friend Julien Bok to ESPCI (Ecole Supérieure de Physique et Chimie Industrielles), asking him to develop the activity on "High T_cs". Julien is a brilliant proponent of the Van Hove singularity with conventional electron-phonon interactions, Pierre-Gilles is not a man of cliquishness; he is only concerned with the quest for understanding and he knows Julien will do well.

It was thus natural to ask Julien Bok to write a contribution on high T_cs in this volume. He discusses the high T_c problem in the light of Pierre-Gilles' very last paper, which he published in 2007 with Guy Deutscher who was one of his early collaborators. In turn, Guy Deutscher has played an important role in convincing the international community that the Andreev effect should be named the Saint James–Andreev effect. He was indeed a witness at Orsay when this important work was made. Guy tells us that he asked Pierre-Gilles if he wanted the effect to be called "de Gennes–Saint James–Andreev" but Pierre-Gilles declined the offer although he was a co-author in the first paper. Guy Deutscher's contribution deals naturally with elementary excitations in the vicinity of a normal metal-superconducting metal contact.

One cannot switch to another field of interest of Pierre-Gilles without mentioning uncharged superfluids. He contributes to the description of the dynamics of triple lines involving superfluid helium, to that of the symmetries of the helium 3 superfluid order parameter, and in these last years becomes very interested in supersolids. This leads him to describe what is, to my knowledge, the first theoretical description of the motion of a dislocation in the quantum regime. He has long discussions on supersolids with Sébastien Balibar. In the book, we asked Sébastien to discuss Pierre-Gilles' suggestions together with the state-of-the-art results.

In 1967, the new continent is soft matter. Pierre-Gilles starts by describing the dynamics of dilute polymer suspensions. Neutron scattering provides a check of his theory on conventional polymers. Nowadays, light scattering in dilute DNA solutions allows us to observe all predicted regimes with excellent accuracy and to confront theory with essentially no adjustable parameter. He also discusses the "coil-stretch" transition of polypeptides.

In the following few years, Pierre-Gilles focuses his attention on liquid crystals. The community wavers between a completely obsolete "short range" view and a mathematically formal continuum description. In 1968, Pierre-Gilles simplifies the continuum description, showing where the relevant physics is. He explains the strong light scattering by nematics, and much of their dynamical behaviour. He draws around him again a large number of bright physicists. The "Orsay liquid crystal group" soon becomes as famous as the "Orsay superconductor group" was. One of the young experimentalists working on nematodynamics at that time is Pawel Pieranski in Etienne Guyon's lab. We asked him to give his view on this aspect.

Pierre-Gilles also used the Landau approach to describe phase transitions in liquid crystals. He is first very successful with the isotropic-nematic transition which he argues should be mean field-like. All his predictions are born out by experiment. He then shows a beautiful analogy between the nematic-smectic A transition and the normal conductor-superconductor transition. The smectic density modulation is analogous to the superconductor order parameter, the nematic director analogous to the vector potential, the dislocations analogous to vortices; gauge coupling is an expression of rotational invariance. The only difference is that there is no gauge invariance in general. Among the key predictions is Helium-like critical behaviour and the existence of a phase equivalent to the Schubnikov vortex phase. The success of the isotropic-nematic transition theory has been so impressive that laboratories all around the world jump to work on the problem. The critical behaviour turns out to be only qualitatively in agreement with the predictions. In particular, critical exponents seem to be anisotropic. It takes about fifteen years to observe the equivalent of the vortex phase and to work out a complete theory but the initial prediction is beautifully confirmed! Tom Lubensky, who coined the name Twist Grain Boundary to that phase is no doubt the physicist who contributed most to the fine understanding of the nematic-smectic A transition: his contribution is the penultimate of the first volume. Pierre-Gilles' strong ties with liquid crystals ends soon after the publication of the book *The Physics of Liquid Crystals* in

1972. As for superconductors, he keeps on following new developments in the field and from time to time introduces one more original idea like that of "artificial muscle" or fracture and spreading in smectics.

Somewhat arbitrarily, we have included in the first volume a discussion on Pierre-Gilles's impact in the physics of macroscopic random media, by Jean-Pierre Hulin, Etienne Guyon and Stephane Roux. This could have appeared in the second volume as well. Etienne, who was a member of the early superconductor and liquid crystal groups, was asked by Pierre-Gilles to reorganise the ESPCI hydrodynamics laboratory, opening its research areas to a wide variety of problems including dynamic instabilities, turbulence, magnetic fluids, wetting, and the physics of macroscopic random media. Indeed Pierre-Gilles had taken responsibility of ESPCI a few years after being appointed at the College de France. The style introduced by Etienne is in perfect harmony with Pierre-Gilles' conception of research.

Coming back to the early seventies, the years of 1971–1972 are *Anno Mirabilis* for Pierre-Gilles. While making major contributions to liquid crystals, he provides fundamental input in polymer science. Improving on the tube image introduced earlier by Sam Edwards, he introduces the reptation concept which provides an elegant and powerful tool for discussing polymer dynamics. This opens the way to a large number of theoretical and experimental works which Michael Rubinstein discusses in the second volume dedicated to soft matter and biological physics.

A long-standing problem is that of a self-avoiding random walk. It describes, among other things, the statistics of polymer chains in good solvents. K. Wilson has just invented a renormalization group expansion, which explains the origin of the non-trivial critical exponents characterising continuous phase transitions. He sends his preprint to friends. This is not an easy paper to read and understand. Pierre-Gilles sees right away that when the number of components of the vector is set to zero, the described situation is that of a self-avoiding random walk, a conceptual *tour de force.* He is so fast that his paper on the self-avoiding walk comes out before K. Wilson's paper on the renormalisation group approach to phase transitions! Tom Witten, who has worked on the renormalisation group description of polymers during his postdoc with Pierre-Gilles, provides an analysis of this exceptional contribution to science.

The renormalisation group techniques are not easy to handle: Pierre-Gilles invents the image of "blobs" which allows anyone to use the corresponding concepts without knowing it! The polymer community can now discuss very complex situations in simple terms and understand the emerging scaling laws! The price to pay is the absence of prefactors in the formulae, but the physics comes out nicely. In the second volume, Françoise Brochard-Wyart and Karine Guevorkian illustrate the use of this beautiful tool in the context of polymers in confined geometries. Some aspects of polyelectrolytes can be discussed with scaling laws, some others like the semi-dilute polyelectrolyte solutions require keeping track of prefactors. Pierre-Gilles' long time friend Philip Pincus discusses these cases together with Omar Saleh.

In 1979, Pierre-Gilles publishes the book *Scaling Concepts in Polymer Physics.* Contrarily to what happened with superconductors and liquid crystals, the publication of this book does not really slow down his activity on polymers. Among some of the important areas he tackles a few years later are those of adhesion and friction in which polymers are essential. All the knowledge acquired on polymer dynamics proves to be important in understanding these phenomena — the use of which is ubiquitous in every day's life. We asked Hugh Brown to expose Pierre-Gilles' contributions.

Although Pierre-Gilles keeps in touch with the development on polymers, he sails towards new continents. After the first oil crisis, oil recovery motivates strong research activity on micro-emulsions. Pierre-Gilles again contributes with a few seminal papers, introducing an important length characterising interfaces, and describing the main features of complex phase diagrams.

He also becomes interested in wetting and dewetting phenomena, which play an important role in areas as diverse as textile and printing industries on the one hand, and automobile and aeronautical industries on the other. Spreading of a fluid on a wettable surface is surprisingly universal, independent of the substrate wettability. Macroscopic theories fail to explain experimental observations. Pierre-Gilles shows how the idea of a precursor film reconciles observations and theory. First, a film of microscopic thickness spreads on the substrate and then the bulk fluid spreads on the film. As always, he investigates a large number of situations: he shows the importance of van der Waals forces, discusses the spreading of polymers, smectics, magnetic fluids as well as superfluid Helium IV. He also discusses the influence of volatile impurities on the spreading velocity, the importance of the substrate topographic and chemical heterogeneities, describing in detail the case of a pinning point. Dewetting in situations mimicking either aquaplaning or printing is also investigated. A book comes naturally to summarise this activity. The French version *Gouttes, bulles, perles et ondes* comes out in 2002, the English version *Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves* in 2004. For a change, there are three authors: Pierre-Gilles de Gennes, Françoise Brochard-Wyart, and David Quéré. We asked Lyderic Bocquet to write the article on wetting/dewetting phenomena.

Looking just at Pierre-Gilles' scientific production, one easily overlooks the fact that he was awarded the 1991 Nobel Prize! Answering an enormous amount of mail, giving television and radios interviews, interacting with high-level politicians and visiting high schools does not really slow him down.

After retiring from Collège de France and ESPCI, Pierre-Gilles joins the Curie Institute and learns a great deal of biology. In his amazingly elegant style, he shows an analogy between bacterial chemotaxis and gravitational interactions! He predicts the existence of a number of original phenomena, which are currently being tested experimentally. Naturally, Pierre-Gilles is interested in cell adhesion and cell spreading. He shows that the collective dynamics is important and predicts scaling regimes. Pierre Nassoy, who collaborated on the experimental side, describes the current situation. In 2006, Pierre-Gilles gives a "biologist" series of lectures on the brain function: almost no equations, but a fascinating description of the state-of-the-art knowledge. He works on olfactive memory storage and neuronal growth.

In May 2007, he is working simultaneously on superconductivity with Guy Deutscher and on the creeping behaviour of a cell subjected to a uniaxial tensile stress. He has just published a few papers on solid friction with Jacques Friedel, and the analysis of the quantum motion of a dislocation! On the 18th of the same month, we lose one of the brightest scientists of the second half of the twentieth century and a dear friend.

Françoise Brochard-Wyart, Julien Bok and myself are extremely grateful to the authors, who did not hesitate one second to accept the difficult task that we were asking for. I am personally very grateful to Françoise and Julien who have been doing all of the editorial work and to Jacqueline Bouvier whose help has been essential in all aspects of the preparation of the two volumes.

Jacques Prost