FOREWORD

During a meeting in Haïfa in 1992 Joseph Kestin from Brown approached me for a common project concerning a book on thermodynamics. Both Prof. Kestin's untimely death in the Spring 1993 and another reason made, or would have made, such an enterprise impossible. The second reason is that I wanted to remain in friendly terms with Joseph Kestin. Once Louis de Broglie, creator of *Wave Mechanics*, was asked why he had co-authored so few papers in his very long career (he died having reached the age of 96). His answer was that he did it once with Maurice de Broglie, his own elder brother, while he was in his twenties, and they almost went to the point of rupture in their brotherhood, so that, being a gentleman, he never tried such an experience again. If this adventure reflects well the situation with spectral analysis and atomic theory in the early 1920s, the situation would even be more touchy with *thermodynamics*, a field for which it is, as we all know, an extremely difficult, perhaps even insuperable task, to find two individuals who fully agree on all its basic aspects and the way it should be taught to students and researchers alike. In other words, therefore, this book had to be written by one author only, even though we cannot forget the immense debt that we owe to Joseph Kestin, Paul Germain and others, especially in France. My own pragmatic standpoint concerning thermodynamics, or as we prefer to say, *thermomechanics*, is expressed at length in Chapter 1 which has some historical and controversial flavor. Here, however, we simply want to point out a drastic change in the physical view of the World that took place during the last two or three decades, and which somewhat justifies, if there is any need for that, the existence of this book. We are all aware of the arrogant reductionism brought by elementary particle physics in the physical landscape after World

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War II. But it is our view, shared by some prominent physicists (e.g. P. W. Anderson) that *condensed-matter physics*, through both its object and methods, have had a radical influence that, to some extent, has helped to counteract this type of intellectual imperialism. In particular, if many good fundamental equations are definitely known, it is the *solutions* to the equations, and not the equations themselves, that provide a mathematical description of the physical phenomena. Furthermore, although no one would be so ridiculous as to reject any attempt at looking for some ultimate building block of matter — a search which closely parallels the childish ambition to reach the *horizon line* — and we certainly gain a better understanding of our World, if not a higher spiritual status, through this quest, we must also recognize that the behavior of a *large* and *complex* aggregate of "elementary" entities is not to be understood "in terms of simple extrapolation of the properties of few particles" (P. W. Anderson). Parodying the French epistemologist Gaston Bachelard, physics at our scale seems to have become more a science of *effects* than of *facts*.[1] This was particularly well captured by L. D. Landau, John Bardeen, and P. G. de Gennes. Our conception of the *thermomechanics of complex irreversible behaviors* goes along this direction, being conceived from the start as a field of cross fertilization of many subdisciplines, accompanied by a deep experimental foundation and precise time and space scales of observations. This combines in a blend of P. Duhem (for his rigor), P. G. Bridgman (for his operationalism), and J. Kestin (for his inquisitiveness), and others. This may seem unbearable to either elementary-particle physicists who reject such developments in the darkness of macroscopic science, or to applied mathematicians who cannot stand the view of a thermometer and who presently have the tendency to mistake the proof of existence for a solution. We hope that this book (perhaps nothing more than a pamphlet), with all its defects and shortcomings, can bridge the gap between these two communities. But our natural naïveté is also bounded by our own pragmatism.

A paradox exists in the thermodynamic literature. Practically all the books and treatises dealing with irreversible thermodynamics simultaneously claim an unbounded generality and present a very restricted range of applications only. These are essentially linear irreversible thermodynamic processes limited to the phenomena of viscosity in Newtonian fluids, diffusion-like processes

[1] But the joke works only in French ("*d'effets*" and "*de faits*", practically with the same pronounciation). We could say that physics has become a science of *artifacts* more than of *facts*. This is what happened to chemistry in the recent past.

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such as in mixture theory, and the traditional linear coupling between heat and electricity conductions. Sometimes an application to plasmas (another example of mixture) and a remark on electric relaxation are presented as ultimate examples. From this it would seem that only physico-chemists and chemical engineers may get some benefit from a thermodynamical framework. Our attitude is completely different as this book testifies and the title implies. Rich in our experience in several fields of physics and engineering science, we *do* present *irreversible thermodynamics* in its *realm* and *splendor*. The reader will find here the application of this inclusive science to both fluids and solids, to viscous as well as viscoelastic, viscoplastic or purely plastic continua, to solutions of polymers and polyelectrolytes, to liquid crystals, to the phenomena of damage and creep in solids, to the fracture of solids, to phase transitions, to complex phenomena in electromagnetic bodies (dielectric relaxation in ceramics, application to shock wave propagation, electric and magnetic hysteresis, dissipation in deformable superconductors, the fracture of electromagnetic solids) and, finally, reaction-diffusion systems such as those exhibited in models of nerve-pulse dynamics or the propagation of phase-transition fronts. This richness and wide vision are, we believe, unmatched by other books. Most of the time we have tried to give general theorems which find applications in several fields and we have not hesitated to have recourse to modern mathematical techniques such as *convex analysis* or the theory of *generalized functions*. This is the price we had to pay to reach a sufficient degree of generality. Vector and tensor analysis on flat manifolds, are used systematically.

The origins of this book are to be found in the lectures which I delivered at the *Institut Français du Pétrole* in Paris in 1987 in a seminar devoted to *irreversible thermodynamics*. I have had several opportunities to improve, polish, and elaborate upon those notes, especially through my yearly lectures on plasticity and fracture at the University of Paris (*Pierre et Marie Curie*), during the writing of a long review paper on *internal variables* together with Prof. Wolfgang Muschik of T. U. Berlin during my stay at the *Wissenschaftskolleg zu Berlin* in 1991–1992, during our research on *complex fluids* together with Prof. Raymonde Drouot in the years 1980–1988, during our research in the field of *material forces* with Prof. Marcelo Epstein (Calgary, Canada) and Prof. Carmine Trimarco (Pisa, Italy) in the years 1989–1994, during our research on the thermodynamics of nerve-pulse dynamics together with Prof. Jüri Engelbrecht (Tallinn, Estonia), while writing my lecture notes for a course in Udine (C.I.S.M., Italy, 1992) on the applications of thermodynamics to

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electromagnetic solids, during the preparation of my previous two books, respectively on the *Thermomechanics of Plasticity and Fracture* (C.U.P., 1992) and the *Theory of Material Inhomogeneities in Elasticity* (Chapman, 1993), and obviously in fruitful discussions with colleagues (in particular, D. Lhuillier) and students and co-workers (especially, M. Motogi, M. Sabir, E. Bassiouny and C. Dascalu, respectively from Japan, Morocco, Egypt, and Romania) at the *Laboratoire de Modélisation en Mécanique*, Université Pierre et Marie Curie, Paris, over the last two decades. My early experience with continuum thermodynamics was deeply influenced by Prof. A. C. Eringen at Princeton University. Private discussions with Joseph Kestin, wherever we could meet in the World, have enriched this view to an extent that the reader can hardly conceive. My heart felt thanks go to all the individuals mentioned and many whom I have unjustly forgotten. We wish an enjoyable time to our readers as pleasure should always accompany study . This is what I felt during the writing of this book.

Paris, January 1997. G.A.M.

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