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OLIVIER COSTA DE BEAUREGARD

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# TIME, THE PHYSICAL MAGNITUDE

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*To*

*Louis de Broglie,*
*who introduced me to*
*theoretical physics*

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## PART 3 LAWLIKE TIME SYMMETRY AND FACTLIKE IRREVERSIBILITY

## EDITORIAL PREFACE

In an age characterized by impersonality and a fear of individuality this book is indeed unusual. It is personal, individualistic and idiosyncratic — a record of the scientific adventure of a single mind. Most scientific writing today is so depersonalized that it is impossible to recognize the man behind the work, even when one knows him. Costa de Beauregard's scientific career has focused on three domains — special relativity, statistics and irreversibility, and quantum mechanics. In *Time, the Physical Magnitude* he has provided a personal *vade mecum* to those problems, concepts, and ideas with which he has been so long preoccupied.

Some years ago we were struck by a simple and profound observation of Mendel Sachs, the gist of which follows. Relativity is based on very simple ideas but, because it requires highly complicated mathematics, people find it difficult. Quantum mechanics, on the other hand, derives from very complicated principles but, since its mathematics is straightforward, people feel they understand it. In some ways they are like the *bourgeois gentilhomme* of Molière in that they speak quantum mechanics without knowing what it is. Costa de Beauregard recognizes the complexity of quantum mechanics. A great virtue of the book is that he does not hide or shy away from the complexity. He exposes it fully while presenting his ideas in a non-dogmatic way.

That is perhaps one of the finest features of this book. So often scientists claim impartiality and disinterestedness, while actually arguing in the most intolerant and parochial way. Costa de Beauregard's treatment of the Einstein—Podolsky—Rosen paradox is eminently fair to both Einstein and Bohr as well as their innumerable spiritual descendants. He even has the courage to consider the paranormal. So his book is a scientific adventure. It is also a scientific autobiography which shows how an imaginative and honest mind grapples with the philosophical concerns of time and physics.

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Costa de Beauregard wrote on these themes before, notably in his two

monographs, *Le second principe de la science du temps* and *La notion de temps — equivalence avec l'espace*. He meditates, muses, wanders down interesting byways that seem far from his main path and then turn out to be urgent for understanding as well as exploring. His papers invariably stimulate his admiring (but often irritated) readers for they are the results of an original and extraordinarily intelligent philosopher-physicist, one who thinks long and deeply before setting his thoughts to paper. We recall, among his many contributions which will interest readers of the present book, the following:

'Two Lectures on the Direction of Time', in *Hans Reichenbach: Logical Empiricist*, ed. W. Salmon (Dordrecht, 1977), pp. 341—366.
'Discussion on Temporal Asymmetry in Thermodynamics and Cosmology', reported by Costa de Beauregard, *Proc. (Cardiff) Intern. Conf. Thermodynamics*, ed. P. T. Landsberg (London, 1970).
'Irréversibilité quantique, phénomène macroscopique', *Louis de Broglie, Physicien et Penseur*, ed. A. George (Paris, 1952), pp. 401—412.
'*CPT* Invariance and Interpretation of Quantum Mechanics', *Foundations of Physics* **10** (1980), 513—530.
'Lorentz and *CPT* Invariances and the Einstein—Podolsky—Rosen Correlations', *Phys. Rev. Letters* **50** (1983), 867—869.

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# PREFACE

Although this book contains many historical references, it is not a book in the history of science; and although it contains quite a few equations, it is not a book in theoretical physics. Historical references and equations are brought forward as aids, the book being one in the philosophy of science.

Time is a concept needing a multidisciplinary approach, as members of the 'International Society for the Study of Time', to which I belong, know well. And of course physics is a full participant at the conference table where time is discussed.

The main aspects discussed here in *Time, the Physical Magnitude* are:

1. Time as an entity measurable with reference to space via motion, motion being formalized in 'universal' equations: initially, those of the Galileo—Newtonian dynamics; but now, those of the 1905 special relativity theory.

At the October 1983 Session of the General Conference for Weights and Measures it was decided that the velocity of light *in vacuo*, $c$, is an absolute constant by definition, and that the standard of length is thus no longer a primary standard, but an 'alter ego', so to speak, of the standard of time. Thus the physical 'equivalence' between space and time, which is the essence of the relativity theory, is legalized.

2. Irreversibility, or dissymmetry between past and future, is another fundamental aspect of physical time, appearing in the theories of wave propagation, thermodynamics, the probability calculus, statistical mechanics, and information theory. All these aspects of irreversibility are interconnected, being manifestations of one single fundamental universal irreversibility. This irreversibility is 'factlike, not lawlike', meaning that it resides not in the equations but in the solutions selected as significant. Therefore intrinsic reversibility of physical time needs an in-depth discussion, the origins of which are found in Laplace's 1774 thoughts on the probability calculus, in Loschmidt's 1876 well-known reversibility argument, and in the cybernetical discovery of a mutual convertibility of 'negentropy' and 'information'.

So 'arrowed (directional) causality', where 'cause precedes effect', turns out to be 'factlike, not lawlike', statistical in its nature, and nothing else than one more aspect of physical irreversibility.

3. Relativistic quantum mechanics tightly binds these two main aspects of time. It is a 'wavelike probability calculus', displaying paradoxical interference and beating of 'probability amplitudes'. It is endowed with an extended relativistic invariance where time reversal is allowed. Thus '*CPT* invariance', as it is called (*C*, particle—antiparticle exchange; *P*, space reversal; *T*, time reversal) supplants Loschmidt's *T* reversal. *CPT* invariance, together with Born's wavelike probability calculus, are, according to me, the two pillars of a true understanding of the paradoxical phenomenon known as the 1935 'Einstein—Podolsky—Rosen (EPR) correlations', which display direct, long-range, and arrowless spacetime connections. Here again causality shows up as arrowless at the microlevel.

4. Although the general relativity and relativistic cosmology theories are outside my professional field of inquiry, I have found it necessary to include a brief discussion of each of them, as they have direct bearing upon the characterization of physical time.

And so this book, which finally grew out of my lifelong interest as a theoretical physicist in the aspects and the nature of physical time, is intended to nurture the meditations of all who are interested in Time: physicists certainly, who very often are led to reflect on time as do philosophers of science; philosophers of science mainly interested in physics; scholars of other disciplines needing (or wishing) to see what physicists have to say on time; and finally, of course, interested laymen who are amateurs in such matters.

As a final touch of controversy, I might add that the existence of lawlike time reversal, especially in the form of the negentropy—information reversibility, together with time extendedness in relativity theory and arrowless causality in the EPR correlations, have convinced me that there might very well be some truth in 'the claims of the paranormal'.

So, as I have mentioned, I see the heart of my book in the epistemological interpretation of relativistic quantum mechanics. The reader is advised that he will not be led there along a straight, or even a conveniently arranged, path. Climbing Mount Everest is no affair of a travel agency. Indeed, seeing its pyramidal top in the distance — or not seeing it if there are clouds — from various places in the plains helps



inspire one to undertake the long, arduous journey to the very side of the peak, and the final assault on it. Colonel Everest's geodesic surveys had to precede the toils of the climbers of the Chomo Lungma. Somewhat similarly, in this book *time, the physical magnitude* will be presented from a number of not unconnected vantage points. And the reader is advised that there may be some really arduous climbing and some delicate holds on the way up.

Practical advice for use of the book is as follows:

Chapters are numbered in the form $p \cdot q$, sections in the form $p \cdot q \cdot r$, and equations in the form $(p \cdot q \cdot r)$; reference to an equation inside the same section is often abbreviated in the form $(r)$, and reference to a section inside the same chapter in the form $q$.

Notes, numbered in the form $^n$, are found at the end of Part 5. A numbered note may be referred to more than once inside the same chapter.

Bibliographical details, referred to in the text by author(s) and date(s) of publication, are placed in alphabetical order at the end of the volume.

Of course I am aware that quite a few books both on time in general and on physical time do exist, of which I know some, but not all. By fear of doing an injustice, I choose to mention none of them here. Time is sufficiently important and intricate a question that one need not 'apologize for one more book on time', and I hope that this one will arouse the interest of the reader.