BOOK REVIEWS

Time to change

T. W. Marshall

THIS book deserves to be read, and discussed, at several different levels, and not all levels can be covered in a single short review. The chemist or physicist who wishes to understand Prigogine's concept of "dissipative structure", and its application to systems far from thermodynamic equilibrium, for which he received the Nobel prize for chemistry in 1977, will find in Part II — "The Physics of Becoming" — a clear explanation of where both equilibrium and linear non-equilibrium thermodynamics become inadequate, and of how an externally imposed inhomogeneity, such as a temperature gradient, produces a new kind of order. Examples are given from physics (convection in the atmosphere), chemistry (periodic chemical reactions) and biology (cell accretion).

As its title implies, the book is more than that. Prigogine's Nobel award citation referred to his "bridging the gap between biological and social fields of enquiry", and he sets out here to share his insights with a wider reading public. His central character is Time, and he states the problem in his preface: to relate three different concepts of time occurring in dynamics (time as a simple parameter with no preferred direction), thermodynamics (time has direction, but leads inescapably towards "heat death") and biology (time as evolution and, ultimately, history).

In the preface, Prigogine acknowledges a debt to past giants in the field, Ludwig Boltzmann and Jacques Monod. In this work and its companion volume (*La Nouvelle Alliance,* written jointly with Isabelle Stengers and published by Gallimard in 1979), he makes a strong bid to join them.

But he is no philosophical soulmate of these two. Both describe themselves unhesitatingly as materialist in outlook, and Prigogine recounts how Monod rebuffed his attempt to establish common ground, classifying his programme for unifying the physical and social worlds as a variety of animism. Possibly this somewhat intemperate rejection led Prigogine, in his turn, to misunderstand Monod. For he quotes the passage from *Chance and Necessity* about man being "a stranger in the world from which he evolved by accident" as though Monod was referring to *life* as the strange feature. A more careful reading reveals that the strange feature, peculiar to our species, is *consciousness* — that which leads us ultimately to scientific and philosophical enquiry about our environment. So if, as Prigogine proposes, we need a "second time" to describe irreversible processes, including life, how can he be sure that we do not need a "third time" to describe consciousness?

From Being to Becoming: Time and Complexity in the Physical Sciences. By Ilya Prigogine. Pp.272. ISBN hbk 0-7167-1107-9; ISBN pbk 0-7167-1108-7. (W. H. Freeman: 1980.) Hbk $24.95, £16.70; pbk $12.95, £7.95.

It is to Boltzmann, however, that Prigogine mainly addresses this work. He begins by noting, like Boltzmann and Gibbs before him, that in a purely dynamical system, based on a hamiltonian evolution function, it is not possible to construct a state function having the time-directional property of entropy. The "Poincare–Misra theorem" (Chapter 7) simply puts this long-known result into the modern terminology of Lyapunov functions. Yet every thermodynamic system has an entropy. Ask a physical chemist and he will measure it for you. Hence the problem.

Gibbs's solution, which Prigogine rejects, was to say that the irreversibility of thermodynamic processes is an illusion, a creation of the physical chemist's imagination. Prigogine quotes some fragments of the Einstein–Besso correspondence which suggest that Einstein also held this view. But a closer examination of those letters, especially the passages dealing with Brownian motion, shows that, in fact, Einstein supported Boltzmann.

Boltzmann's solution was to propose that, in addition to the dynamical laws of evolution of a large system, we should require the initial state to be one of "molecular chaos". He anticipated Prigogine's diagram 7.3 and asserted that, since a state with all the molecular velocities reversed does not have this property, it will almost never occur in any actual physical system.

Prigogine, applying some new results obtained by mathematicians working in ergodic theory, thinks he has *derived* Boltzmann's molecular chaos from the dynamics. But has he? I believe not.

That is not to deny that he and his co-workers have achieved a great deal. They have shown, more clearly than most, that Boltzmann's definition of chaos has to be extended to include higher order correlations in the motions of neighbouring molecules. And, for certain simple time-evolving systems, of which the most discussed is the non-dynamical Baker's transformation, they show how to construct an entropy operator which is compatible with the evolution operator. But the very fact that they end up with an entropy *operator* shows that they, like Boltzmann, are considering not a single microstate, but a set of states on which only certain averages are specified. To specify a probability measure on this set is to impose a more sophisticated molecular chaos hypothesis. So Boltzmann, rather than Prigogine, invented the concept of "second time".

In his remarks on Einstein's refusal to accept quantum mechanics, Prigogine is really out of his depth. It is the case that some quantum theorists are now proposing to abandon the 400-year-old notion of space going from Galileo through Einstein, on which all science since the Renaissance is based, preferring a "biological" space in which a change in one place produces instantaneous changes everywhere else. Such a feature, called "non-locality", seems to be an unavoidable consequence of quantum theory, and Einstein drew our attention to it nearly 50 years ago. But, in his enthusiasm for biological models, based on such phenomena as the cooperative motion of the parts of a chicken embryo, Prigogine thinks he sees common ground with the elementary particle "zoologists" in their high-energy physics laboratories. This is unwise, because the non-locality some physicists speak of has never been observed, and quite possibly it never will be. On the other hand, the non-locality exhibited by a chicken embryo certainly does not require superluminal signals to sustain it. It is easily subsumed within a materialist world-picture of the type supported by Boltzmann and Einstein. This is especially the case once full account is taken of the field concept, something which Prigogine almost totally ignores — Faraday does not rate a mention, and Maxwell enters only through his contribution to kinetic theory.

This is not a great book, and Prigogine has not yet achieved what Boltzmann did in *Populäre Schriften* or Einstein in *The World As I See It.* But it is a very good book, and the ideas contained within it promise better things to come.

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