The return of entropy

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Maxwell's Demon: Entropy, Information, Computing. Edited by H.S. Leff and A.F. Rex. *Hilger/Princeton University Press: 1990. Hbk $75; pbk £17.50, $24.95.*

Complexity, Entropy and the Physics of Information Edited by W.H. Zurek. *Addison-Wesley: 1990. Pp. 530. Hbk £40.95, $48.50; pbk £24.95, $29.25.*

PAST glory and contemporary rejuvenation is the story of entropy. The terms 'aura of unplumbed depth', 'untarnished lustre of novelty' which I applied to it in my 1960 inaugural lecture seem to be valid still. It would, after all, have been excusable had one imagined in 1920 that only pedestrian applications of the entropy concept were to be expected in the future. But one would have been quite wrong.

Past glory is covered in *Maxwell's Demon*. We start with the demon who separates fast from slow molecules, so establishing a temperature difference in what was an equilibrium system, thus violating the entropy law. But the demon has to see the molecules, so photons are needed and energy dissipation through the measuring process exorcises the demon. If instead a one-way trap door is used, dissipation connected with the measurement saves thermodynamics (L. Szilard, 1929; corrected by E. Lubkin, 1987). A new chapter in this history was the entry of entropy into statistics through information theory (C. E. Shannon, 1949). Entropy is now regarded in some contexts as a purely statistical measure (like standard deviation, say) which can be associated with any probability distribution. But the discovery that the demon could be interpreted as a computing automaton reveals some further problems (R. Laing). Both computer and demon must have their memory wiped clean to be in the pristine condition required for the next series of experiments and to achieve a true cycle of operations. This requires the generation of entropy for every bit of information erased (R. Landauer, 1961; C. H. Bennett, 1973), thus making unnecessary the earlier exorcisms. Indeed the whole demoniacal procedure can be approximated as thermodynamically reversible were this erasure to be omitted. All this and more is well told in *Maxwell's Demon*, the editors of which have given us a reliable and well-organized book containing 25 published papers (only four are post-1985). These include all papers mentioned above, except for Shannon's work. I would have preferred a shorter book omitting one or two papers (editors really must be more severe), but I whole-heartedly recommend it as it stands, for general reading and as a supplement to physics courses.

The contemporary rejuvenation of entropy is exemplified by *Complexity, Entropy and the Physics of Information*, which is replete with modern ideas and matching jargon (glossary not provided).

So to rejuvenation. The percolation of entropy into statistics since the 1950s and into computing since the 1970s is impressive enough. But in addition, the 1970s and 1980s brought increasing preoccupation with the problem of measurement in quantum mechanics and hence consideration of entropy generation in the measurement process. Entropy also entered into the quantum mechanical uncertainty relation (surprisingly, noted only by B. Schumacher and M. H. Partovi). But perhaps the most exciting element of rejuvenation came from classical general relativity in yielding black-hole thermodynamics, when no thermodynamic elements had been inserted into the foundations of the theory. All these aspects are discussed in Zurek's highly stimulating but rather diffuse multi-author book, the usefulness off which would have been increased by improved grouping of the 32 papers into chapters. The book touches on key problems such as the statistical mechanics of the interior of a black hole, complexity, and whether statistical and algorithmic entropy can be combined to yield a deeper insight into the second law of thermodynamics. Both this book and *Maxwell's Demon* discuss the drop in the entropy of a system due to measurement. But if a measurement recognizes a quantum state to be actually a doublet, then the entropy is increased by the measurement. In such cases entropy and 'order' can both increase together.

Of course there is also some nonsense in these papers, and this is expected (because the importance of a subject can be estimated by the amount of nonsense written about it), but this highly stimulating book can be strongly recommended to all (theoretical) physicists.

I end with a few questions, not actually raised in these books, but related to them. What is the effect of gravity on entropy calculations? We need a reference maximum entropy of the universe. Could it be obtained by regarding the whole mass of the universe as concentrated in a single black hole? Is the universe the result of a vacuum fluctuation? Is thermodynamics violated by a macroscopic process which lowers the entropy by a microscopic amount? I expect that the answers must be left to future discussions, for, even on the Maxwell demon problem, they are still in full swing. □

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