books

Profound and subtle ideas about the enterprise of science

Thematic Origins of Scientific Thought, Kepler to Einstein

Gerald Holton
495 pp. Harvard U. P., Cambridge, Mass., 1973. $10.00 hardcover, $3.95 paperback

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Reviewed by Stephen Toulmin

Few people in the United States have done as much as Gerald Holton to foster an appreciation of science as a social and cultural force, to promote an understanding of the links between science, philosophy and art, and to incorporate that understanding into the educational curriculum. From his position as a professor of physics at Harvard University, Holton has been able to play a major role also, in the revival of *Daedalus* and the other activities of the American Academy of Arts and Sciences, in high-school curriculum reform through Harvard Project Physics and in the broader ventures of the American Institute of Physics—particularly, its lively and enterprising Center for the History of Physics. So widespread and effective have these practical contributions been, indeed, that some people may be in danger of overlooking the complex theoretical insights that have underlain and directed Holton's labors. A careful reading of this collection of essays reveals at last how profound and subtle are his ideas about the whole enterprise of science.

Aside from the long and important introductory essay, all the chapters of the present book have appeared before in more or less their existing form. They range from examinations of Newton and Kepler as physical thinkers, by way of a sequence of six essays analyzing Einstein's work from different angles, to discussions of science as a twentieth-century profession and as an element in contemporary education. In every case, the same meticulous scholarly care, the same sensitive imagination and aesthetic perception, and the same feeling for the intellectual and personal motives of the individual scientists involved (the lesser figures, such as Niels Bohr's father, as much as the greater) are evident on every page. Whether Holton is writing about the theme of "disintegration" in contemporary art, about the visual rather than verbal character of Einstein's cognitive imagination, or about the phenomenon of multiple authorship in recent physical science, we feel ourselves in the hands of a man who truly understands the workings of the scientific enterprise from the inside, and who—more exceptionally—is able to be lucid and articulate about those workings.

Holton's analysis is built around two main ideas, both of which he explains and expounds with great clarity in the new introduction. The more general of these two ideas has to do with the *multidimensionality* of science as a human activity. For a full grasp of what is involved in any discovery, he argues, we need to consider separately at least nine aspects of the change that it brings about. Some of these aspects have to do with the intellectual and imaginative processes of the individual scientist himself, others with the public, institutionalized face of science, "dry-cleaned of personal elements." Some have to with the immediate content and structure of science, others with its "time trajectory"; some with specialized considerations arising within a special area of science, others with the broader cultural and intellectual context. Holton must be the first man to establish a substantial and convincing link between the principles of quantum theory and the philosophical ideas of Soren Kierkegaard—showing an unchallengeable connection between Kierkegaard's *Either/Or* and Bohr's doctrine of complementarity.

Too often, as Holton demonstrates, historians, philosophers, sociologists, or natural scientists themselves, begin by abstracting out some quite restricted feature of the entire enterprise, and then go on to give an unbalanced and distorted picture of what science involves. For instance, an account of scientific discovery in which a disproportionate emphasis is placed on the role of experiment—the imbalance can reach the point of outright mythologizing, as with the allegedly crucial relevance to Einstein's work on special relativity of the Michelson-Morley experiment, which Holton shows to have been, in actual fact, quite marginal in its significance. Another example is an exposition of the history of science in which the technicalities of some limited area are totally abstracted from their wider context—as though the religious speculations of a Kepler or a Newton, the musical theories of a Galileo, or Bohr's interest in the philosophical psychology of William James were connected in no more than an accidental way with his work in physics, instead of being a further, connected expression of the same mind at work.

The other, more specific, novel idea around which this book is organized has to do with the notion of *themata*, which is embodied in its very title. The missing link in too many accounts of science, Holton argues, is the role played by certain leading patterns of ideas—notably by certain pairs of contrasted ideas—most of which were introduced into the scientific debate as early as the pre-Socratic philosophers of the 6th century BC, and which have continued to guide the development of our ideas about Nature (of our scientific *Bild*, or "intellectual representation") throughout the subsequent eras. Anyone who studies the transformations of natural science down the centuries with any perceptiveness is forced to recognize that there can never be a final or definitive choice between (say) an atomistic and a continuum view of matter, or between a static, structural and a dynamic, evolutionary view of physiological form. Rather, the thema *atom* and the thema *continuum* represent poles between which the continuing debate about matter or form moves, pendulum-like—both elements in any such pair of "conjugate notions" have continuing parts to play in a comprehensive account of the theories involved. (There is thus a deep *epistemological* wisdom embodied in Bohr's theory of complementarity. This fact, quite as much as its physical significance, commended the theory to Bohr himself.)

As a crowning merit of this book, Holton writes with an easy, readable style. There is nothing in these essays beyond the grasp of the average *Scientific American* reader, and the actual manner has a bite and elegance that the *Scientific American* house-style rarely permits. Minutiae apart, one can have no complaints about the book, except those of Tantalus—that Holton whets our appetites at a hundred points for more explorations along the same lines that he has opened up here. His book deserves to have a permanent influence on the work of historians, philosophers and sociologists of science, as well as on educationists and intellectual historians, but it can also be most strongly recommended to the general reader.

HOLTON

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An Introduction to Statistical Mechanics

P. Dennery
118 pp. Halsted, New York, 1972. $9.75

Philippe Dennery is a French high-energy elementary-particle and field theorist at the University of Paris at Orsay, having previously been at CERN and at the University of Pennsylvania. He is the co-author with André Krzywicki of "Mathematics for Physicists" (Harper and Row). That book is rather formal and mathematical but well put together, and corresponds to a well defined text for American use in graduate courses. The present book does not cross the Atlantic so readily.

The dust jacket states that *An Introduction to Statistical Mechanics* is for undergraduates or for graduate students, while the introduction talks of first- or second-year graduates. It is very slim and is indeed only an introduction, so that its most likely use would be for undergraduates. However, it is far more concerned with the formulation than the applications and physics of statistical mechanics.

Dennery attempts to bypass all the usual postulates of statistical mechanics, for example, equal *a priori* probabilities, the definition of the state of thermodynamic equilibrium, and the Gibbs postulate that thermodynamic properties should be obtained by taking ensemble averages. In place of all this, he follows a treatment originally given by Henry Primakoff and A. Sher. He commences by postulating the master equation, which governs the time variation of the probability p_i that a micro-system is in a state "i." I had looked forward with interest to studying this alternative approach to the basis of statistical mechanics, but found myself very disappointed.

No discussion of the master equation is given, though a four-page appendix presents Pauli's original proof. The author does present a four page mathematical solution of the master equation for very long times $t \to \infty$, where it is found that $p_i(\infty)$ is a universal constant, for each state that is accessible to the system for a total energy given as $\mathcal{E}$ with a small uncertainty $\Delta\mathcal{E}$. Or in other words, equal probabilities for all states in a microcanonical distribution.

At this point the development merges with any standard development that simply "postulates" the microcanonical distribution for an energy isolated system. Dennery next considers a super-system made up of a system plus heat reservoir, with the super-system in a microcanonical distribution, and by doing the standard Taylor expansions he "obtains" the canonical and grand canonical distributions. (All in three pages with no physical discussion in contrast to the thorough undergraduate-level discussion given in F. Reif's *Statistical and Thermal Physics* or the graduate-level presentation with several different "derivations" given in Ryogo Kubo's *Statistical Mechanics*.) After simply defining the statistical entropy S of a supersystem, the author uses the master equation once more to "prove" that $dS/dt > 0$.

The rest of the book gives a very sketchy and brief treatment of several standard topics. There is a chapter on the various classical and quantal perfect gases, with essentially no physical discussion, and no plotted graphs. This is rather surprisingly followed by a fairly thorough introduction to the imperfect classical gas, using the method of Van Kampen and ending with a calculation of the third virial coefficient for a hard-sphere gas. This material is certainly not included in most introductory texts, even for graduates.

The level of the text then jumps