BOOKS: HISTORY OF PHYSICS

A Hodgepodge of Controversies

Philip W. Anderson

I approached Neil Porter's *Physicists in Conflict* anticipating considerable pleasure. There are rich and largely untapped veins of material illustrating the causes and consequences of folly, obduracy, and fallibility in physics, and I looked forward to a rewarding feast of examples. My expectations were not met. I was disappointed in the author's conceptualization of the topics, the limited selection of examples, the lack of depth in his research, and the infelicity of the writing.

Physicists in Conflict
by Neil A. Porter
Institute of Physics Publishing, Bristol, UK, 1998. 291 pp. $39.50, £25. ISBN 0-7503-0509-6.

Porter presents, in historical order, a series of conflicts involving physicists, summarizing the facts and then trying to bring out parallels among his examples. He devotes the first third of the book to the premodern period, in which such figures as Hypatia of Alexandria, Roger Bacon, Bruno, Galileo, and Kepler experienced religious persecution. Then, skipping 300 years that contain such interesting (and famous) conflicts as Newton versus Descartes, Porter proceeds to the 20th century. Here, he examines an assortment of incidents—some famous, some obscure—including Boltzmann's troubles about atomic theory with the positivist philosophers, Blos Cabrera's mysterious detection (unrepeated) of a magnetic monopole, the U.S. Atomic Energy Commission's withdrawal of Oppenheimer's security clearance, and the Cherwell-Tizard conflict over the effectiveness of strategic bombing in World War II.

Porter fails to demonstrate what these very diverse examples have in common. For instance, the early ones are of historical importance in the birth of modern science, but they have little to do with the two cases on science's dealing with simple blunders (the reported effects of Blondel's nonexistent "N-rays" and Cabrera's monopole). These, in turn, do not resemble in any way the Oppenheimer or Tizard and Blackett versus Cherwell controversies, which highlight the political difficulties of scientists who choose to advise governments. And again very different are the four conflicts involving deep, initially unresolved, questions within science proper: the atomic hypothesis, continuous versus big-bang creation of matter, quantum measurement, and multiple production of mesons in nuclear collisions.

The chapters on specific examples provide well-documented historical and biographical sketches of the principal characters and their interactions. I found the detailed explanations of the various contributions of Bruno, Kepler, and Galileo and their relations to the ideas of Copernicus to be interesting and enlightening; however, to historians of science this must be a well-cultivated field. For Porter's 20th-century examples, I was more familiar with the science involved and with some of the sources he tapped. I repeatedly found Porter's histories to be derived from one or a few sources, and I was put off by what he chose to emphasize in these stories.

Much of the Boltzmann story, for instance, seems to have come fairly straight from Brush's history of statistical mechanics (*1*). Porter portrays Boltzmann as a victim of persecution by Mach and the Vienna circle. It would have been more informative, however, to focus instead on the aberration of the Mach and Ostwald's positivist objections to atomism. That would have provided an excellent example of the atmosphere of Kuhnian "crisis" that, we now recognize, signaled the birth of quantum theory.

One might also question Porter's choice of examples of conflict. The case of "N-rays" was told better, and with more details, in Langmuir's pamphlet on "pathological science" (*2*). Why not discuss cold fusion or polywater instead?

Porter's account of the classic Bohr-Einstein debate ignores the realization, which has become increasingly clear, that both sides were far from the truth. Though victorious, and useful for particular purposes, Bohr's philosophy of "complementarity" was obscure and nonsensical. Neither Einstein nor Bohr realized that the measuring apparatus must be described quantum mechanically in order to attempt a consistent theory.

In his treatment of the Oppenheimer case, Porter again reprises a familiar story. To me, the case is not simply a quaint incident of the McCarthy era, but the first losing skirmish in a half-century of struggles by selfless scientists to contain nuclear overkill. In these struggles Edward Teller again and again played the key role of villain. His actions against Oppenheimer helped Teller gain the confidence of the political establishment, in spite of a history of behavior counterproductive to the interests of the country extending from his noncooperation in wartime Los Alamos through his proven deceptions about key components of the Strategic Defense Initiative boondoggle.

The chapters discussing Hoyle's continuous-creation universe and multiple production in cosmic-ray collisions involve an entirely different kind of dispute. Such "conflicts" are the life and soul of fundamental science; they are in no sense aberrations and indicate healthy fields. Significant figures like Hoyle can often promote hypotheses to an importance they may not deserve. (For example, the continuous creation of hydrogen atoms violated enough fundamental symmetry laws to render the idea implausible to quantum physicists.) It is not, however, at all unusual or undesirable to have at hand several competing hypotheses from which, it is hoped, experimental facts will determine a choice. Some of these ideas, in the end, will appear to have been misguided ("particle democracy" from the 1960s, for example) or advanced somewhat prematurely and contentiously ("excitonic superconductivity" comes to mind). But early hypothesis formation is what theoretical physics is about, and there are many successful examples: the electroweak unification, asymptotic freedom, localization. Each of

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BROWSINGS

The Attentive Brain. *Raja Parasuraman, Ed.* MIT Press, Cambridge, MA, 1998. 589 pp. $65. ISBN 0-262-16724-9.

The contributors take attention to be a finite set of interacting brain processes. After describing neuroscience techniques for studying it, they examine its major components (selection, vigilance, and control) from a cognitive neuroscience perspective, discuss links to memory and language, and consider attention's development and pathologies.

The Genetic Gods. Evolution and Belief in Human Affairs. *John C. Avise.* Harvard University Press, Cambridge, MA, 1998. 287 pp. $29.95, £18.50. ISBN 0-674-34625-4.

Avise proposes that genes and the mechanistic processes shaping them "assume many of the roles in human affairs traditionally reserved for supernatural deities." He offers the general reader a review of recent findings in evolutionary genetics and molecular biology, and discusses their relevance to questions about human origins, the meaning of life, and fate.

these ideas had its controversial period, its convinced opponents, and its apparent experimental failures. It may be amazing how deep scientists' emotions can run in the midst of this process, but, except for the case of Boltzmann, Porter hardly documents that. Nor does he discuss an extraordinarily contentious field, like high-temperature superconductivity.

Finally, I found the brief (four-page) chapter on Blas Cabrera's observation of a single magnetic monopole out of place. Any single observation, no matter how bizarre, allows for too many alternative explanations: pranks, coincidence, inattention, thoughtless mistakes, some anomalous type of cosmic radiation, vermin, et cetera. If Porter needed an example of implausible and controversial observations, there were others available from the same laboratory (free quarks and falling electrons were aberrations of Cabrera's predecessor). To Cabrera's credit, he never oversold his monopole (assuming one accepts publishing as an isolated event).

The "Conclusions" chapter does not succeed in unifying Porter's diverse examples. These suggest that scientists' controversies are not settled by bargaining, compromise, mediations, or bluffing, and that lying and fraud are quite uncommon. Inevitably, there is a right answer, although it may not win politically and its victory may only be recognized after a lot of history. That scientific theories often die only with their advocates is a true, but not new, insight.

Unfortunately, Porter sometimes repeats as fact folklore that is questionable or even wrong. That the effectiveness of the physics community "reached its highest point in the 1920s and 1930s" seems merely the reminiscence of a survivor looking back at his youth. Those years may have been a Golden Age, but there are others: the Standard Model was produced in the 1960s and 1970s by a rather small, tight community; modern condensed matter theory dates from the 1950s and 1960s; modern astrophysics is still growing and, with the advent of the Hubble telescope, may be in its greatest period. Also, in contrast to Porter's claim that "in recent years most Nobels are for high-powered and expensive experiments," only a quarter of the last 40 physics prizes have rewarded such efforts and, notably, the most recent awards have gone to individual or small group efforts.

Physicists in Conflict suffers from other shortcomings. The writing is often puzzling, leaving one wondering what "this" refers to. The discussions, such as those on kinetic theory and the complex set of ideas about the multiple production of particles, sometimes fail to explain the science.

In summary, stories of conflict in science, or between scientists and the establishment, can be fascinating and enlightening, but I feel that the source materials offer better reading than this collection. Unfortunately, a great book that captures internal conflicts in science has yet to appear.

References

1. S. Brush, *Statistical Physics and the Atomic Theory of Matter* (Princeton Univ. Press, Princeton, NJ, 1983).
2. I. Langmuir, *Pathological Science*, transcribed and edited by R. N. Hall (General Electric, Schenectady, NY, 1968).

PERSPECTIVES: SURFACE CHEMISTRY

Reactions on Semiconductor Surfaces

Harry E. Ruda

Chemical reactions on surfaces are important in many areas of science and technology. On metal surfaces, the electronic states of the surface atoms are spatially extended and can therefore easily be shared with those of reactive species, dramatically influencing the structure of these species as they approach the surface. In contrast, bonding on semiconductor surfaces is largely covalent, and surface electronic states tend to be spatially localized. Many technologically important processes—epitaxial layer growth, dopant incorporation, and the patterning of semiconductor surfaces by self-assembly, for example—proceed through semiconductor surface reactions. This has important implications for the structural and electronic properties, and thus the performance, of semiconductor devices, particularly nanostructured devices that require high local control over surface properties. In this active and fertile area, recent studies have highlighted the importance of specific surface sites and local response to adsorbed species in surface reactions on semiconductor surfaces.

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Understanding of the interactions of species with semiconductor surfaces has been considerably advanced by the now widespread use of scanning tunneling microscopy (STM). STM can probe the spatial extent of electron density on a surface with atomic resolution. Bias-dependent STM studies, in which images are taken at different voltages between the STM tip and the sample, allow the determination of the energy spectra of surface electronic states, and, in special cases, enable discrimination between different chemical species. For example, in the case of GaAs, charge transfer from Ga to As atoms makes the Ga sites visible for positive sample bias and the As sites visible for negative bias. STM can also be used to distinguish different chemical species on more complex semiconductor surfaces, especially in combination with laser excitation.

On metallic surfaces, so-called nucleation-growth and related models have successfully explained a number of molecular adsorption reactions. Key assumptions are (i) relatively high sticking coefficients for the molecules on the surface, (ii) surface diffusion of adsorbates, and (iii) clustering by attractive interactions between adsorbates. Unfortunately, these models often fail to explain molecular reactions on semiconductors. Sticking coefficients of chemical species on semiconductor surfaces are often very weak, and chemical species tend to adsorb preferentially at specific atomic sites, with adsorption rates decreasing once these sites have all reacted. In addition, surface diffusion of the adsorbed species is usually insignificant because of the presence of localized surface electronic states that reduce the surface mobility (as compared with metals). It is, therefore, difficult to understand a priori how molecular reactions starting at specific sites on semiconductor surfaces progress to completion across the whole surface.

We have studied how site-specific chemical character influences surface organization for GaAs(111) A and B surfaces (*1*). Here, the A surface is the one terminating with only Ga atoms, and the B surface is the one terminating with only As atoms. The surface is termed (111) according to a convention that defines the

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