An Epoch in German Physics

Intellectual Mastery of Nature. Theoretical Physics from Ohm to Einstein. CHRISTA JUNGNICKEL and RUSSELL MCCORMMACH. Vol. 1, The Torch of Mathematics, 1800–1870. xxviii, 350 pp. $55. Vol. 2, The Now Mighty Theoretical Physics, 1870–1925. xx, 435 pp., illus. $65. University of Chicago Press, Chicago, 1986.

Few books in the history of science have been more eagerly awaited than Jungnickel and McCormmach's study of theoretical physics in Germany, and the result does not disappoint. In the 800-odd pages of this densely written and formidably researched book the authors reconstruct the institutional and intellectual development of theoretical physics in Germany from J. S. Ohm in the 1830's to the establishment of quantum mechanics in the 1920's. Along the way the study sheds much light upon physics in general, from which theoretical physics as a potential subdiscipline was relatively undifferentiated until the later 19th century. This study is distinguished primarily by the authors' massive research in the still little-known archives of present and former German-language universities, including a number in Eastern Europe. From these invaluable archival sources the authors painstakingly reconstruct the minutiae of laboratory budgets, instrument collections, and student numbers; they disentangle the intrigues of faculty appointments and the professional values those appointments reflected; they explore collegial relationships among physicists; and they document the unending campaign of scientists to wring further support for physics from often reluctant ministries.

The work treats the evolution of theoretical physics in Germany first as an institutional development within the universities. Until the 1830's physics instruction had been mostly limited to the elementary, mass lectures on experimental physics for a largely "service" clientele. Then emerged the first arrangements for advanced instruction and regular laboratory exercises for specializing students. The work emphasizes three centers of institutional innovation. One was Berlin, with its Physical Society (founded in 1845) and the patronage supplied to young physicists by Gustav Magnus in his private laboratory. The authors' vignette of physics in Berlin in the 1840's and '50's is among the most fascinating and vivid portraits in the book. A second center was the University of Göttingen, where Wilhelm Weber initiated regular laboratory exercises in the early 1830's. The authors portray this innovation as a pedagogical adaptation of the research methods and apparatus developed by Gauss and Weber for studies of earth magnetism.

The third focus of institutional innovation was Königsberg. Franz Neumann and the mathematicians there obtained funds in 1834 to create Germany's first mathematical-physical seminar, in the physics section of which 138 students were trained before 1870. The authors play down Neumann's significance as a teacher and innovator, however, contending that his students have exaggerated the size and importance of his school and falsely cast him in the role of fountainhead of theoretical physics in Germany. The counterarguments are not wholly persuasive or consistent, however. The authors also trace the founding of mathematical-physical seminars after the Königsberg model at several other institutions, including the influential seminar Weber and Listing founded at Göttingen in 1850.

The growing demand for advanced courses and laboratory exercises, especially after beginners' practicums were opened for the service clienteles, carried the burden of physics instruction beyond the capacity of a single professor. By the 1870's the system had evolved by which physics in nearly all universities was represented by two men. One, the full professor for experimental physics, gave the lucrative elementary lectures to the service clientele, controlled the physics laboratory or institute, directed advanced experimental work, and led the colloquium. The second physicist was usually an extraordinary professor. He gave the regular instruction in theoretical physics to the specializing students and sometimes ran the physical section of the seminar, if one existed. He might have a few rooms in the institute and a separate budget to support his own research and that of a few doctoral students, but more likely he was thrown back on the largess of the ordinary professor whose work he was there "to support." By this arrangement, the authors stress, theoretical physics was in no way being acknowledged as a new specialty. Men whose research interests lay primarily in experiments routinely held these extraordinary posts for theory and expected promotion in the form of a call to an experimental chair; conversely, all the great theorists of the 19th century down to Planck held these dominant chairs nominally for experimental physics.

At a few universities theoretical physics acquired greater autonomy and recognition. Göttingen and Königsberg had long had second ordinary professorships for theoretical or mathematical physics; Berlin founded such a chair in 1874; and by 1900 full professorships for theoretical physics also existed at Munich, Leipzig, and Vienna. By the early 20th century a de facto separation of career lines between experimentalists and theorists was occurring. The authors note that by then theorists were less likely to be called to experimental chairs, a fact that stymied many careers, as there were so few theoretical professorships available. Conversely, a few outstanding theorists were able to build careers wholly through sequences of posts devoted exclusively to theory. Max Planck did so first, and his feat was duplicated by Einstein, Laue, and Debye in the early 20th century. Between 1921 and 1926 most of the remaining positions for theoretical physics were converted to ordinary professorships, a response in part to the soaring prestige of theoretical physics in that period.

The authors also treat the evolution of physics in Germany as a body of theories and methods. They discuss only the more important developments they consider indicative of the whole, but they also survey the broad research front of physics at regular intervals by systematically analyzing the literature appearing in the *Annalen der Physik* and other journals. Their discussions take the form of brief, authoritative descriptions of scientific papers, with the space devoted to such discussions much greater in the second volume than in the first. Their coverage of thermodynamics, the electron theory, relativity, the blackbody problem, and quantum physics to 1926 does not go beyond what is already to be found in the best secondary literature (including McCormmach's own earlier work), but here it is woven into an expert, highly useful survey of the physics of the entire period. On some of the less familiar byways of 19th-century physics the authors' accounts contain material that is wholly original or raised to a new level of clarity and accessibility. These include those of the Weber-Helmholtz controversy, work on the foundations of mechanics, and some of their scattered discussions bearing on German resistance to Maxwell's theory and the world-picture debates around 1900.

This impressive book has some self-imposed limitations, most of them freely acknowledged by the authors. This is a decriptive history, advancing no strong interpretations and espousing no explicit organizing theses. Authoritative and magnificently rich in detail, it turns inward upon the field it examines, not outward. The authors consciously eschew detailed analysis of social, political, and cultural "influences"; they are

relatively little concerned with the larger context of the growth of physics and its institutions; and their strongly narrative, descriptive approach to their subject matter allows certain hard interpretative problems to escape systematic formulation and discussion. The authors tell us nothing directly about what was unique to the organization and practice of theoretical physics in Germany vis-à-vis other nations or how the academic organization of physics compared to or was influenced by that of other disciplines, and little about how physics per se was affected by the larger development of the university system in which it was embedded. The study largely takes for granted the factors that created a growing demand for specialized instruction in physics and that allowed physics in general, and theoretical physics in particular, to command the resources and the prestige it had come to possess by 1910. Nor is the changing relationship of theory and experiment analyzed in depth, although the authors point tantalizingly to the search for the blackbody radiation formula as emblematic of a new, closer interaction between specialists for theory and experiment that had come to exist by 1900. Finally, though the relationship of physical theory to mathematics naturally occupies the authors' attention and their study contains a wealth of important new information bearing on the matter, "the torch of mathematics" serves the book more as a slogan than as a sustained thesis. How early resistance to mathematical formulation was overcome, whether innovation in mathematics determined changes in the nature of physical theory, how physicists' collective attitude toward their mathematical tools changed over the period in question—on these issues the book leaves readers to draw their own conclusions from the rich veins of material exposed.

For most of the period covered by the study the authors' deemphasis of contextuality acts merely as a prudent and justifiable self-limitation. But for the era before 1850, when both the field and the university system were still evolving rapidly toward their definitively "modern" forms, the want of a broader or more theoretical perspective on these processes of change serves the study badly. There the work adopts and retails too uncritically the views and assumptions of highly interested actors in its story, as well as espousing many of the attitudes embodied in older heroic biographies and institutional histories. It takes "physics" and the physicist's professional role as fixed and implicitly existing entities, assumes the triumphant institute system of the late 19th century as an organizational ideal, and proceeds to chronicle the heroic efforts of a few great physicists to establish themselves and their science in the face of obscurantist forces. These include a familiar roster: *Naturphilosophie* and Hegelianism, humanistic educational philosophies, ill-prepared students, and state ministries hostile or indifferent to the experimental sciences and their often costly requirements for teaching and research. There is, of course, much truth in this perspective, but it lacks the historical distancing necessary for analyzing the complex formative period of the discipline or for understanding the counterforces that allowed its victories finally to be won. The book reaches surer ground in describing the "now mighty theoretical physics" emerging by the 1860's. Its coverage of this era attains its full promise of insight, thoroughness, and rich historical understanding.

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Genotoxicants

Monitoring of Occupational Genotoxicants. MARJA SORSA and HANNU NORPPA, Eds. Liss, New York, 1986. xiv, 250 pp., illus. $42. Progress in Clinical and Biological Research, vol. 207. From a symposium, Helsinki, June 1985.

There is an explosion of interest in the use of biological markers to study human cancer and other diseases. Scientists are increasingly able to assay human cells and tissues for genetic damage caused by exposure to chemicals and radiation. The rapidly expanding armamentarium includes relatively well established methods to measure chromosomal aberrations, sister chromatid exchange, and micronuclei, as well as newer methods to quantify DNA and protein adducts, somatic cell mutations, and DNA repair and to detect oncogenes possibly activated by chemical attack.

These biological markers have a dual potential: to reveal mechanisms involved in the causation of disease and to provide an early warning system by indicating elevated risk. It is in the latter context that *Monitoring of Occupational Genotoxicants* is offered. As the editors note in their preface, biological monitoring of chemical exposure began in the occupational setting, and the field will continue to be strongly centered there, given the opportunity that setting provides to validate methods under higher exposure and more controlled conditions than are found among the general population. Moreover, as Hooper and Gold point out, exposure of workers to carcinogens remains substantial, sometimes at levels close to those that induce tumors in laboratory animals.

The book is not intended as a comprehensive review of the field. It presents proceedings of a satellite symposium following the Fourth International Conference on Environmental Mutagens and highlights subjects discussed there in more detail. Most of the papers describe progress to date, technical advances, or pilot studies. Exceptions are a valuable discussion of markers of reproductive toxicity in sperm by Wyrobek and an interesting proposal by Environmental Protection Agency researchers, Waters *et al.*, on how biological markers could be used in quantitative risk assessment.

Even though the book is most useful as an update for researchers in the field, it will provide others with general insights into this exciting research area. The first chapter, by Evans, sounds themes applicable to all types of biological monitoring: the need for sound study design, validated laboratory procedures, and consistent interpretation of results. Despite a 10-year history, cytogenetic monitoring in the workplace has had only patchy success. Studies are frequently flawed by absence of baseline data, lack of controls, and failure to ascertain levels and patterns of exposure or to take medical and exposure histories in order to allow for confounding variables.

A paper by Albertini *et al.* updates an assay for monitoring somatic gene mutations that uses cloned HPRT-human T-lymphocytes. Messing *et al.* describe a pilot study in which increased mutant frequencies were observed in medical technicians exposed to ionizing radiation. The authors note a major unanswered question, namely the significance of mutant frequency to reproductive outcome. Not only are few epidemiological data available, the assay measures a single initial step in the causative process. The uncertainties this report points up are characteristics of the field.

Two other promising and sensitive biomarkers, carcinogen-DNA and carcinogen-protein adducts, are also discussed in some detail. Studies concerned with the detection and characterization of adducts or their relationship to oncogene activation in animals are reported. A review of the growing body of data regarding these chemical-specific biomarkers in humans would have been useful.

The true benefit of biomarkers should come from their use in combination with environmental monitoring and epidemiological methods. Sforzolini *et al.* and Garry *et al.* describe novel attempts at integrated assessment of genetic toxicity in the workplace. To identify the most significant genotoxicants in their workplaces, the researchers