questions. He calls himself and most of the others at the conference reductionists, but apparently on the gounds that he and they believe that biological phenomena can be explained by natural causes. That does not involve anything that is usually or can properly be called "reductionism." Moreover Campbell finally reaches conclusions, such as recommendation of "recognition of a Creator that is what It is for Its own purposes, and free to change those purposes," that are difficult to reconcile with his profession of naturalism and antivitalism. Popper hails examples of limited or partial reductions, considers methodological reduction as one essential in the pursuit of science, but rejects what he calls "philosophical reductionism," which is the epistemological reduction of Ayala and of this review. He maintains that even within the sciences of physics and chemistry, still more in biology, there has never been a *complete* (epistemological) reduction and never can be. In that connection he stresses the phenomenon of consciousness and gives considerable discussion of the old but ever fresh body-mind question.

Goodfield has written a historical review of the philosophies of 19th- and 20th-century physiologists. She finds that they have run the whole gamut from extreme reductionism to extreme antireductionism. She concludes that this has had little influence on the problems they attacked or the methods they used but that it did make a difference in their theoretical approaches. The two other primarily historical chapters will be mentioned even more briefly because I find them somewhat outside the main current of the discussion, Montalenti's because (in my opinion) he fails to substantiate his claim that "the source of . . . the scientific attitude towards the world is to be found in Greek philosophy," and Boesiger's because in his attempt to reinstate Lamarck in the foundations of modern biology he surprisingly omits the most essential part of Lamarck's (admittedly mistaken) theory of evolution.

Beckner was one of the first to distinguish himself as specifically a philosopher of biology (*7*), and his chapter in this book merits special comment although it is far too complex to summarize here. Beckner bases his discussion on hierarchies and discusses reduction as a relationship between theories at different levels of a hierarchy. In the course of doing so he carefully redefines concepts and terms and shows the fallacies in some considerations of reduction. He does not take a stand between extreme reductionism and antireductionism, and his treatment makes it clear that such a stand is neither necessary nor advisable. He says, "The important thing is not so much the truth about certain reductionist theses, but insight into the conditions and strategies of the *application* of one science to another."

In addition to their organizing and editorial duties and to Ayala's summarizing, unifying, and clarifying introduction, Ayala and Dobzhansky have each written a chapter in the book, both among the best. Dobzhansky's chapter is a splendid summary of the synthetic theory of evolution which he has done so much to establish and advance. Ayala discusses the concept of biological (evolutionary) progress, with emphasis on a distinction between general and particular (what I call ad hoc) progress. Neither chapter, perhaps rather oddly, is devoted primarily to questions of reductionism, but both involve considerations essential to that subject. That is demonstrated by Ayala's last words: "Evolutionary progress . . . can be interpreted as a gradual departure from the importance of physicochemical laws in determining the relevant aspects of the behaviour of organisms."

After discussion with Medawar, Edelman, and Popper at the conference, Goodfield added a mournful postscript to her manuscript, including the feeling that perhaps "So far as the course of science goes, [the question of reductionism] becomes as irrelevant as whether or not [a scientist] regularly beats his wife on a Saturday night." No reader of this volume will agree, and certainly their contributions to the subject demonstrate that Goodfield herself, Medawar, Edelman, and Popper do not really agree.

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Post-Copernican Transformations

The Heritage of Copernicus. Theories "Pleasing to the Mind." The Copernican Volume of the National Academy of Sciences. JERZY NEYMAN, Ed. MIT Press, Cambridge, Mass., 1974. x, 542 pp., illus. $25.

The U.S. National Academy of Sciences has had the splendid idea of preparing a festschrift to commemorate the recent 500th birthday of Nicholas Copernicus. It opens with an account of Copernicus's life and work by Jerzy Neyman. This emphasizes the intensity of Copernicus's desire to understand the motions of the planets in terms of a theory in which the intellectual qualities of simplicity and clarity were more important than the mere capacity to produce verifiable predictions. Moreover, what appeared clear and simple to Copernicus had none of that appeal to the intellectual establishment of his day. Copernicus himself, who put off publication to the last minute, died before the displeasure of the Church could be fully expressed, but his book remained for two centuries on the Index of books forbidden to Catholic readers, and it was not until the time of Kepler, almost two full generations after Copernicus's death, that astronomical observation revealed facts that were easier to interpret on his theories than by reference to the classical system of Ptolemy. Copernicus does indeed set an extraordinarily high standard of devotion to intellectual clarity, in the face of disapproval of powerful public figures and at best lack of positive support from the known facts.

The remainder of the book consists of 24 essays which explore 20th-century advances in science to see whether any of them match up to Copernicus's work, either in intellectual boldness or in transforming the picture man has of his place in the universe. This is a most happily chosen formula, since it justifies concentration on all the most exciting and novel developments in recent science. There are four essays on astronomy and cosmology, six on biology, four on chemistry and physics, three on mathematics in general with another three on statistical modes of thought, and finally four on various aspects of technology. All the writers are leaders in their fields, and they have written here in a manner that transcends any narrow specialization. Most of them give a good deal of the background history, which serves to emphasize the character and scale of the recent advances they are describing. They have also taken great trouble to make comprehensible some of the very difficult and noncommonsensical ideas which are the real triumphs of science's penetration into the unknown. There is a remark in the introduction to the section on chemistry and physics that in fact can be applied to the book as a whole:

We find it hard to subdue our intuitions and "get a feel" for space-time, but the authors of the essays in this chapter have taken great pains to present their topics via phrases and analogies, which the layman can at least reach after. In here using ordinary language (instead of the technical language of theoretical physics) to describe either the submicroscopic or the pancosmic, to transcend the five senses, they are attempting something very difficult and attempting it with their hands voluntarily tied. The lay reader should not limply surrender but should respond with his own reciprocal effort, reading, skipping, turning back a page or two, and rereading until at last the flavor of the subject permeates. Thus he will learn what it entails to vanquish the preconceptions of human intuition, in which conquests lie Copernican revolutions.

It is, of course, not possible to review such a book. It is far too diverse. One of the contributors, J. N. Hammersley, remarks in his contribution, "A principal cause of indigestion is too many breakfasts with the same companion." This is a danger the reader will certainly be spared. Perhaps the 25 different companions would prove rather a strain if taken at the rate of one every successive day, but they write with such charm and good manners that most people will find themselves lured into disquisitions about subjects which they had previously thought themselves quite incapable of understanding.

Of course it might be difficult to claim that all the doctrines are truly of Copernican magnitude. Was the discovery that our sun is not in the center of our galaxy—the topic of the first major article in the book—comparable in importance to the discovery that the earth rotates round the sun rather than vice versa? Indeed, are any of the other extraordinary discoveries of the astronomers, the gigantic explosions on a galactic scale, the mysterious quasars, black holes, and so on, any more than signs that once Copernicus had displaced man from the center of the universe we have no rational grounds for finding anything more extraordinary than anything else? Yet there is no doubt that we do continue to find these things both fascinating and very, very queer. Again, once we had got rid of the idea of vitalism—that "the least imaginable part [of an animal] which we can separate is as much alive as the whole," in a formulation quoted by Robert L. Sinsheimer—we can continue to marvel, but no longer be surprised, at what chemistry can do. We find ourselves confronted by what Sinsheimer describes as "an extended series of major discoveries both expanding and complicating the concept of life on the one hand, and both expanding and deepening the concepts of chemistry on the other." There is no doubt that one of the major influences in displacing the classical types of vitalism was the Darwinian notion of evolution, followed by Mendel's discovery of the particulate nature of heredity. R. C. Lewontin has no difficulty in making a very good case that these two together constitute a "materialist revolution" of truly Copernican magnitude; though I am glad to see that he admits that "until that interaction of gene and environment in determining [the phenotype of the] organism is fully integrated into scientific and social thought, the Darwinian and Mendelian revolutions will remain incomplete." I would myself have thought that a demonstration that the gene is a material particle, by T. H. Morgan and his colleagues, was a more Copernican sequel to Mendel than the one chosen here, the elucidation of the structure of DNA and protein, which seems to me more Keplerian in character.

One could, of course, go on almost indefinitely arguing, interestingly if inconclusively, about the claims of the various topics to be classed with the heliocentric theory. However, there would be little point in doing that here. Like Little Jack Horner, I will just pull out one further plum: a complete specification for a thorough piece of operations research by Florence Nightingale in a letter addressed to Francis Galton in 1891, quoted here by Herbert Robbins in his piece on "The statistical mode of thought." There is plenty of other unexpected treasure to suit the taste of almost any reader in this very rich book.

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Fifty Years in Physics and Chemistry

Solid State and Molecular Theory. A Scientific Biography. JOHN C. SLATER. Wiley-Interscience, New York, 1975. x, 358 pp., illus. $18.95.

As one of the first and few American-trained physicists to participate significantly in the development of quantum theory and a leading contributor to solid state physics and molecular chemistry, J. C. Slater enjoys an eminent position in 20th-century physics. Therefore, the appearance of his "scientific biography" is an event of note. The subtitle of the book, however, is ambiguous. The author points out that because of the strong interplay "between autobiography and history of science and technology on the one hand, and pure science on the other . . . it seemed worthwhile to make this book something half-way in between." The book does indeed have something of all these qualities, but the compromise is not entirely successful. There is, for example, textbook material that is only partially relevant for the reader who is already acquainted with the subject matter and is probably not understandable to the reader who is not. Portions relevant to the history of science and technology suffer from the absence of references to original sources. As an autobiography, the book, though subjective, is curiously aloof and impersonal. It is nevertheless deliciously spiced with strong, no-nonsense statements about physics, scientists, politics, and economics.

Slater first introduces himself to the reader as a Ph.D. candidate at Harvard completing an experimental thesis with Bridgman. (There is no mention of his earlier life except for a passing reference later in the book to boyhood and undergraduate studies at Rochester.) The next two years, 1923–24, were spent in Copenhagen with Bohr and at the Cavendish on a traveling fellowship and marked a turn to theoretical physics. The important Bohr-Kramers-Slater paper on the interaction of the radiation field with atoms was written during this period. In its introduction of virtual oscillators, an idea due to Slater, it hinted at the probabilistic notions that were to be developed a few years later in Born's statistical interpretation of the Schrödinger equation. The relationship with Bohr, apparently, was not entirely happy, because of a strong disagreement about the photon concept. Slater believes his views concerning the relationship between photons and electromagnetic waves to have been the same as those of de Broglie and to have been arrived at practically simultaneously. He writes somewhat bitterly that since de Broglie "did not have the antagonism of Bohr to contend with, . . . he followed his ideas to their obvious conclusion." The conclusion in question evidently is the recognition that the particle-wave duality extends to electrons and other elementary particles.

Slater returned to Harvard. During 1926–27 his work on quantum electrodynamics closely overlapped that of Dirac. It must have been a frustrating time, since Dirac was always slightly ahead. This experience evidently marked