and Einstein's successful use of the idea to explain the photoeffect, then the Rutherford atom and Bohr's and Sommerfeld's explanation of spectra. This explanation is rounded off by considering Pauli's exclusion principle and his introduction of spin. This brings us to the end of the "semiclassical" period of quantum theory, about 1925. De Broglie's and Schroedinger's wave theories, Heisenberg's matrix theory and uncertainty principle, and Dirac's successful unification of quantum theory and relativity bring this period to a certain close. Fermi and Yukawa's application of the previous results to nuclear forces are treated in two chapters.

The presentation is such that it should be understood by a nonscientist, although the background of the arguments may sometimes be unfamiliar. The book is characterized and made delightful by the fact that the author attaches the development of the physics to the personalities of those who were responsible for its development—Planck, Bohr, Pauli, de Broglie, Heisenberg, Dirac and Fermi, and others. Gamow has known most of the people involved, and he tells illuminating anecdotes and stories about personal encounters with them. The book is illustrated with a number of photographs, most of them not previously published, which show the human sides of these scientists. Each chapter begins with an impressionistic pen drawing by Gamow, which shows the head of the person concerned. The only one that I find uncharacteristic is the sketch of Heisenberg (compare with the excellent photographs of Heisenberg on plates 4 and 8). Because few of Heisenberg's personal characteristics are described, I would like to relate an anecdote.

Heisenberg's father was professor of Byzantine Greek at the University of Munich, and when I taught at that University (1920 to 1926) I occasionally walked home with Professor Heisenberg. The latter commented on the difference between philology and physics, emphasizing the long hesitation of the philologist to publish a new theory or attack somebody else's theory, and continued: "On the other hand, my son says that he ought to put at the end of each of his papers: Six months guarantee."

Gamow's book ends with a parody of Faust which was performed in the spring of 1932 at Bohr's Institute.

Although the printing is very good, there are a few errors, and three of them may confuse the uninitiated: On page 45 a plus sign is used instead of a minus sign; on page 112 two minus signs are used instead of plus signs; and on page 66 the eight-line comment on Fig. 15b appears as comment on Fig. 15a.

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The Boston Colloquium for the Philosophy of Science

Like Professor Philipp Frank, to whom this volume is dedicated, its contributors range widely over science and philosophy, concentrating mainly in the areas of philosophy of science and physics. The volume, **Boston Studies in the Philosophy of Science,** volume 2 (Humanities Press, New York, 1965. 511 pp., $9.75), edited by Robert S. Cohen and Marx W. Wartofsky, is the proceedings of the Boston Colloquium for the Philosophy of Science, 1962–1964.

The longest sequence of connected essays contains an analysis by J. J. C. Smart of "Conflicting views about explanation" in the work of Nagel, Feyerabend, and Sellars. In an entirely sympathetic manner, Smart presses some of the objections to Feyerabend's radical and seemingly paradoxical thesis that "theory" and "meaning" are interchangeable, and that even our commonsense language must be seen to embody theory, and *false* theory at that, so that it is, in principle, due for replacement. Sellars then enters some caveats with regard to the dispensibility-in-principle of the observation language, and Putnam launches a crisp attack on the whole Feyerabendian enterprise, earning from Feyerabend some equally tart replies. In his essay, "Reply to criticism," Feyerabend develops explicitly his belief in the positive value of theoretical pluralism, and replies more carefully than before to the charge that if alternative theories infect all observations with their own categories and concepts they are incommensurable and untestable. In another interesting contribution in the same area, Sellars discusses "The identity approach to the mind-body problem" in terms of an analogy with the reducibility of chemistry to physics, concluding that the analogy breaks down at the point where we ask what *is* the theory of brain-states which would be adequate to reduce the percipient's "raw feels." We have no such theory, and if we had, it might turn out to require raw feels as irreducible categories.

Three essays are concerned with topics closer to logic and mathematics. In "Instantiation and confirmation" G. Schlesinger has some genuinely new and significant things to say about the much canvassed paradoxes of confirmation. N. R. Hanson explores an admittedly "loose" analogy between the absence of consistency proofs in elementary number theory and the absence of stability proofs in gravitation theory. D. Follesdal carries the attempt to quantify causal contexts into some highly undesirable predicaments, and concludes in despair that all the causal modalities of interest to science should be avoided. The history of physical and biological ideas are represented ably and respectively by E. McMullin's "From matter to mass" and E. Mendelsohn's "Explanation in nineteenth century biology."

Altogether this is in substance an entirely worthy offering to Professor Frank, and the organizers of the Boston Colloquium are to be congratulatd on assembling a series of essays of such consistently high quality. Unfortunately standards of printing and proofreading leave something to be desired; for misprints sometimes interfere quite seriously with sense—for example, on page 69, line 6, where I take it "fact" means "face."

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History of Science

Editions of classics in the history of science are always welcome. But when the writings of two early investigators, who worked in consort, appear at the same time it is a double treat and an invaluable clue to the ways in which modern science struggled to protect its birthright. The two volumes reviewed here are such a treat: **The Anatomy of Plants: With an Idea of a Philosophical History of Plants and Several Other**

Lectures Read Before the Royal Society (Johnson Reprint Corp., New York, 1965. 322 pp., $35) by Nehemiah Grew, with a new introduction by Conway Zirkle, and **The Reverend John Clayton: A Person with a Scientific Mind—His Scientific Writings and Other Related Papers** (published for the Virginia Historical Society by University of Virginia Press, Charlottesville, 1965. 244 pp., $6.50) by Edmund Berkeley and Dorothy Smith Berkeley.

Grew (1641–1712; F.R.S., 1671) and Clayton (1657–1725; F.R.S., 1688) shared a like concern with Nature in her many forms, despite the fact that their respective contributions affected the growth of science to an unequal degree. Yet Grew, the pioneering professional, and Clayton, the enthusiastic amateur, represent the far ends of the spectrum of the work carried on by the Royal Society of London, the first modern scientific institution.

In his informative account of Grew's contributions, Conway Zirkle notes that he "may be described as the first microscopist who limited his investigations to the anatomy of plants, or he might just as accurately be classified as the first botanist who used the microscope for studying plant morphology" (in the introduction, p. ix). Despite its title, Grew's major publication was not confined to anatomy in the narrower sense. Rather, like his modern counterpart, the electron microscopist, he attempted to learn all he could of plant life through his chosen instrument. This led him from gross morphology to microscopic anatomy, with excursions into the then-unexplored fields of plant physiology and chemistry. As a pioneer in these areas, he was unable to benefit from the contributions (and errors!) of predecessors. Thus, although it is easy to find flaws in his work, we must not forget that Grew was trying to answer questions that contemporary investigators admit to be far from simple.

It is a wonder that Grew, who was faced with two serious limitations—the lack of proper equipment and a precise terminology—went as far as he did. Thanks to his gift for experimental procedure, he devised sectioning techniques that rerouted plant anatomy away from a concern with organs and toward cellular structure. By using a shrewd combination of observational data and conjecture, Grew phrased the question of sexual reproduction (pp. 171 to 173) in such a way that it became, in the hands of others, subject to experimental confirmation. If he was prone to "explain" plant behavior and various responses such as tropisms by an outmoded chemistry and by analogies with animal behavior, he nevertheless set future scientists on the track of explaining growth, not in static anatomical terms, but in terms of the biochemical dynamics of a living organism. His program, he wrote, was "to examine . . . not only all the Parts, but Kinds of Vegetables, and comparatively, to observe divers of the same size, shape, motion, age, sap, quality, power . . . which may also agree, in some one or more particulars, as to their Interiour Structure" (p. 9).

It was Grew's curiosity and demand for empirical data that led to his contact with Clayton. The former, following the custom of the time, issued a set of queries regarding the drugs and other natural productions of America. Clayton replied in an open letter to Grew, which was posthumously printed in the *Philosophical Transactions* (1739) and is reprinted in the present volume (pp. 21 to 39). Clayton's correspondence is, in fact, his major scientific claim for, despite his once-famous research on coal gas (pp. 138 to 140), his studies of the avifauna of the Virginia Coastlands (pp. 93 to 104), and his various agricultural proposals (pp. 78 to 90), his few published papers failed to open up new avenues of inquiry.

But, as the Berkeleys emphasize, Clayton's activities did much to popularize science and to alert the skeptical to its practical applications. The biographical sketch preceding the edition of Clayton's writings (pp. xvii to lxiii), a bibliography, and an index make the present volume a valuable guide for scholars to use in reassessing the accomplishments of other forgotten amateurs who, like Clayton, tend to be overshadowed by luminaries of Grew's stature.

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Vegetational Changes in the Sonoran Desert

Nothing in nature, we are reminded, is more certain than change. Change in vegetation not only affects its utility to man, but may indicate other conditions of great importance to him, for example, climatic trends, habitat deterioration, and the effects of his own behavior. Yet few of us are taught to understand the significance of such change, or even to observe it.

In addition to historical records and on-site study of naturalistic landscape paintings, we now have the more precise methods of micropaleontology and long-interval photography, the method used here. Long-interval photography, effectively employed by the late Homer Shantz and B. L. Turner in *Vegetational Changes in Africa* (1958) and more recently by W. S. Phillips in *Vegetational Changes in the Northern Great Plains* (1963), is applied to the Sonoran Desert region in **The Changing Mile** (University of Arizona Press, Tucson, 1965. 328 pp., $12.50), by J. R. Hastings and R. M. Turner.

This varied region includes not only desert proper but also desert grassland and oak woodland. These three ecosystems, all subject as they are to available moisture and strong insolation as limiting factors, are sensitive indicators of change.

Even so, as the introduction makes clear, the impact of climatic, geological, biotic, and cultural influences is so involved that it is not easy to factor them out. Impressive studies now under way in the Tree Ring, Geochronology, Atmospheric Physics, and Arid Lands laboratories of the University of Arizona are expected to help greatly in resolving these problems.

An analysis of the physical characteristics of the desert habitat and two chapters on early and more recent human influences precede 97 pairs of photographs, taken as nearly as possible from matched sites [see, for example, the illustration on page 920 of the giant cactus, *Pachycereus pringlei* (from Melisas Islands in the bay at Guaymas, Sonora)]. Some of the earlier photographs date back to the 1880's, many to the early 1890's, and the remainder to the present century, especially the 1930's. The recent photographs by the authors were taken during the present decade. Although the quality of reproduction varies, each pair tells a graphic story.

Unfortunately none of the photographs antedate the cattle industry, although there are a few examples of sites unaffected by it. Yet there is good evidence that climatic trend has been