The Structure of Scientific Revolutions. By Thomas S. Kuhn. 172 pp. Univ. of Chicago Press, Chicago, Ill., 1962. $4.00. *Reviewed by Richard Schlegel, Michigan State University.*

ONE widely held conception of science is that its development is an accumulative process: each working scientist adds his contribution, large or small, and as a result, science continually grows in adequacy and coherence. Even "revolutions" are but very extensive revisions of foundations, with resulting new achievements but little disturbance of what already exists. Professor Kuhn, who has a background training in physics but is now professor of the history of science at California, has written an argument against this view of science. He finds in the history of science a recurrence of a certain pattern rather than continuous progress toward a goal of final truth or completeness.

For Professor Kuhn, the key element in a science is the "paradigm", defined as an approach, to some domain of nature, that is "sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity" and also "sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve". Aristotle's *Physica*, Newton's *Principia*, Lavoisier's *Chemistry*, and Lyell's *Geology* provided such paradigms in their day. In current science, textbooks provide the introduction to the accepted principles of science and the foundations for further practice. Working within the framework of the paradigm, scientists carry out what Kuhn calls "normal science"; essentially, he writes, this is "problem-solving", a working out of solutions that are permitted by the paradigm, often with neglect of problems that could be treated under a previously accepted paradigm.

Generally, there are some questions that have received attention under the paradigm of a science, but remain unsolved; for the most part, however, during the period of dominance of a paradigm, the science moves forward steadily, and progress is through cumulative achievement. Eventually, not only unresolved problems but outright anomalies accumulate and discredit the paradigm. A period of search and confusion follows, but then a new paradigm is found and adopted. A scientific revolution has been effected. With the acceptance of the new paradigm, the scientist comes to live in a new world, for he selects different aspects of nature to study, and puts a different interpretation on old observations. Thus, science has gained new vigor—revolutions give the scientific community a selection by conflict of "the fittest way to practice future science".

The reader can raise objections as he goes through this book. The accumulation of scientific knowledge perhaps gives more continuity from one age of science to another than Kuhn recognizes. I doubt if the separation of "paradigm" creation from the doing of "normal science" is as clear as he implies. Still, to use his term, Professor Kuhn has suggested a challenging paradigm for the history of science itself—one that will enable us to see a clarifying order among the myriad annals of science. Further, he writes with a winning intelligence and modesty that invite questioning and revision of the interpretation of the history of science that he has presented.

Aristotle as depicted in a 16th century Italian edition of his works. (*The Bettmann Archive*)

Aristotle's Physics. Transl. by Richard Hope. 242 pp. Univ. of Nebraska Press, Lincoln, Nebr., 1961. $6.00. *Reviewed by Eric Mendoza, University of Manchester.*

THIS book is a new translation of the lectures given by Aristotle between the years 334 and 323 B.C. at Athens. As a physics text, it has exerted enormous authority for a longer time than any other, for it was rediscovered 1500 years after it was written, and it was one of those books whose study initiated our scientific era. Philosophers and historians of science therefore regard it as one of the basic texts for understanding the origins of modern science; they speak of its profound insights and call it one of the noblest accomplishments of the human intellect.

Readers of this journal might be more interested to take the viewpoint of a physicist today rather than that of a philosopher. (After all, one of the objects of reviewing a book is to suggest whether other readers' understanding of their subject will be enhanced or their knowledge of its development will be deepened by reading it.) Most physicists know that the ancient Greek texts, having been studied in highly debased versions for many centuries, were rediscovered in something like their original forms in mediaeval times, and that this rediscovery constituted the revival of learning. But then, these products of the lively ancient Greek mind soon became shackles which prevented knowledge from developing, for fear of flouting authority. Only when this authority was thrust aside could science progress. The works of Aristotle therefore have a dual aspect. On the one hand, they are indeed fascinating records of the speculations of one of the most profound of philosophers who ever lived; on the other, they were the dead weight which retarded the progress of science.

As physicists, it is almost impossible for us to read his book on physics without judging it with the hindsight of later centuries, and quite unfairly attaching ominous significance to certain notorious passages merely because of their effects on later, lesser men. The physicist's judgment of Aristotle is therefore a loaded one.

In certain areas of science, Aristotle's contributions were profound and lasting. As a biologist, he recorded the results of large numbers of experiments, dissections, and the like, and his book on meteorology is full of useful observations. It is his astronomy and his physics which we regret today. He did, it is true, make the basic assumption that even the heavens obeyed "laws" and were not actuated merely by caprice, an assumption on which all subsequent progress is founded; but then he took some disastrously wrong turnings. As we know today, physics develops out of a delicate balance between observations and speculations, between experiments and theories. The advances are made sporadically and at odd intervals, but nowadays we are all well aware that undisciplined speculation usually leads to ludicrous results, experiments without a guiding theoretical basis are for the most part sterile. It happened that, when it came to dealing with animals, Aristotle was capable of striking a reasonable balance between observation and theory. But when he came to contemplate the heavens or the universe, he quite deliberately tried to rely almost exclusively on intuition. It is this contrast of attitude to the two sciences which is perhaps the most interesting aspect of Aristotle's thinking.

Greek physics and chemistry had gone through a healthy phase earlier. Some scientists of the sixth and fifth centuries B.C., Democritus among them, had gone so far as to propose an atomic hypothesis to explain the phenomena of melting and boiling, which they encountered in the techniques of their primitive industries. They even produced that hero Glaucus who invented the soldering iron. But with Socrates and his pupil Plato, the interest in observational science of this kind waned. Many reasons have been suggested for this change. Perhaps science had given rise to a mechanistic attitude toward the universe which, regrettably, left little place for the gods. Perhaps the development of a society where technical processes were regarded as fit only for slaves meant that speculation and not observation became the occupation of a gentleman. Certainly Socrates himself said, "If we are ever to know anything absolutely, we must be free from the body and must behold actual realities with the eye of the soul alone." In modern terms, we must all be theorists, never experimenters. Thus, reality became identified with what is logical; the goal was not to know nature but the absolute. This was why Aristotle's lectures on physics were concerned with the nature of reality, the meaning of space and time, but hardly ever with descriptions of phenomena. It was his earliest book, written when he adhered closely to his predecessors' ideas; in his biology, he dealt with earthly matters, and he was not afraid of using the eye of the body.

When Aristotle did quote the results of observations of physical events he had an instinct for seizing on what we know today to have been the "wrong" ones. He must have seen very light and heavy bodies falling through air and water; he concentrated on the terminal velocities and concluded that the speeds of bodies varied proportionally to their weights and inversely as the resistances of the media. It followed logically that their speeds through vacuum would be infinite, and since infinities are objectionable he was driven to the conclusion that no vacuum can exist in nature. Later generations extended this line of reasoning: if matter is composed of ultimate atoms, these particles must exist in a vacuum. But since a vacuum cannot exist, atoms cannot either. . . . Aristotle himself did not reach a definite conclusion whether matter was a continuum or not, though he tended to think that it was. He even managed to dismiss the powerful argument that the expansions and contractions of bodies are evidence for vacuum between the particles, stating that if bodies changed their volumes, it is merely because they were capable of doing so. Indeed this last attitude, which to us can only seem curiously perverse, comes from his method of dealing with the whole problem of *change*—of how an object can alter in some way while still remaining the same thing. Thus Aristotle discussed change of position on much the same basis as change of color, change from a state of rest to one of movement in the same way as one from illness to health. He assumed that nature always had some end in view and never did anything in vain. Thus the expansion of a solid, which to the imagination of the Ionians suggested an atomic constitution, to Aristotle merely meant that the body could expand, in the same way as a sick man could get better.

Aristotle starts each section of his book with a careful and up-to-date analysis of the meanings of the words he uses: what is meant by saying that an object is "in" a certain place, what is meant by "luck" and "chance" and so on. It is a tribute to the extraordinary skill and knowledge of the translator, the late Professor Richard Hope of the University of Pittsburgh, that even these passages, which depend critically on the nature of the Greek language, should appear meaningful and relevant.

But a physicist cannot help regretting that it was Aristotle's *Physics* which survived while the work of Democritus was lost.

Unpublished Scientific Papers of Isaac Newton. Edited and Transl. by A. Rupert Hall and Marie Boas Hall. 416 pp. Cambridge Univ. Press, New York, 1962. $11.00. *Reviewed by R. Bruce Lindsay, Brown University.*

NEWTON was one of the greatest scientists of all time and probably the greatest to have been born in the British Isles. It is therefore all the more strange and deplorable that no complete edition of his writings has ever been issued. The last printed selection, col-