restrial encounter) petroleum and gasoline. What a remarkable celestial filling station such a comet must be!

One other bovine encounter, forgotten by Velikovsky, deserves mention. In 1871 a tremendous fire destroyed the city of Chicago. A cow, history has alleged, started the conflagration. But now we know! A comet, of course, was the fire bug, a fact that the O'Learys the world over will undoubtedly rejoice to learn. Don't worry about the slight discrepancy that seems to exist between 1500 BC and the recorded time of the fire. The incident really happened at the earlier date, but Chicagoans were so hypnotized by the catastrophe (as indeed were other ancient historians, according to Velikovsky), that they did not awake until 1871. For further details see "The Sleeping Beauty" by the eminent historians, the brothers Grimm.

This clarification of cometary sex also resolves another age-old mystery. We have all read of the cow that jumped over the moon, and perhaps have worried about the details of such remarkable bovine activity. The whole event becomes clear, however, if the cow and comet assume identical or associated personalities.

Even the other characters of the nursery rhyme take visible shape. The "cat and the fiddle", of course, are none other than the heavenly constellations Lynx and Lyre. The minor alteration of name is poetic license; "Lyre" obviously does not rhyme with "Diddle". The fact that both names begin with "Ly" is also significant of *something or other*. The "little dog" is *the constellation* Canis Minor. The dish that ran away with the spoon was the original flying saucer. And the spoon, clearly the Little Dipper, was used as a paddle to propel the unusual vehicle through the sky. The Milky Way marks the trail left by the cow in its magnificent leap, but science has not yet determined whether or not the milk is homogenized. Cannot Velikovsky help here? Anyway the milk was probably not pasteurized. Velikovsky indicates that vermin and germs inhabited the comet's tail. If terrestrial cows were equally unsanitary we should call in the board of health.

Mother Goose is full of cow references: Little Boy Blue, The Purple Cow (or was that Mother Goose? No matter! It serves the purpose quite as well). But don't forget the Cow with the Crumpled Horn! The comet, no doubt, after her sad encounter with old Mother Earth!

What fun the Velikovsky method is—and how relaxing! Out go the tomes on differential equations and wave mechanics. Goodbye to hydrodynamics and electromagnetic theory. No more cyclotrons or electronic brains. Bring on Mother Goose, Grimm's Fairy Tales, and Aesop's Fables. Here's to the science of tomorrow!

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Unity, Knowledge, and Control

MODERN SCIENCE AND ITS PHILOSOPHY. By Philipp Frank. 324 pp. Harvard University Press, Cambridge, Massachusetts, 1949. $4.50.

The present collection of essays, by one of the well known adherents of modern positivism, deserves attention from scientific workers on at least two counts. First, it deals with important topics in science and the philosophy of science. Second, the movement which the author represents claims an especially close affinity with the scientific spirit, a claim about which those in science should wish to form their own judgment. The seventeen essays included in the book have been written over a period of about forty years. About half of this material has been published in a previous collection (*Between Physics and Philosophy*) now unavailable. Four general categories would include most of the essays: discussion of problems raised by the developments in physics within the last hundred years, culminating in relativity theory and quantum mechanics; expositions of positivist philosophy; critical examination of other philosophers and philosophies; and essays concerned with the cultural relations of science and with the broadening of science curricula to give recognition to these relations. These rough categories are not exclusive, and most of the essays fall in more than one.

The philosophy of Ernst Mach, to which the second and third essays are devoted, forms the acknowledged starting point of modern positivism. In Frank's opinion (and in this reviewer's) Mach has been widely misunderstood to be a proponent of a kind of Berkeleyan subjectivism (which for that matter Berkeley himself did not always or even predominately hold), according to which the "real constituents" of the objects of our experience are sensations, these objects then being classified as "mental" or "physical" depending on the nature of our selective interest in them. According to Frank the real motivation and meaning of Mach's position was in no sense metaphysical. Mach is not talking about the "nature of things" at all, but attempting to lay the foundations for a program of unification in science. For this purpose he found it necessary to go back to the foundations of all knowledge in sense-experience. Concepts which cannot be interpreted in such terms have no ultimate place in science, and propositions which involve such concepts in an irreducible way are unverifiable and "metaphysical".

According to Mach, and Frank adopts this view as his own, no other analysis of the propositions of science will permit the unification of such diverse sciences as physics and psychology, which if interpreted "metaphysically" by such concepts as "mind" and "matter" are either unrelatable or implicitly contradictory. Moreover the "auxiliary concepts" of science are doomed to evolution, whereas the known associations among phenomena form an empirical network to which all future theories must conform. In a period such as our science has lived through since the time of Maxwell, when older conceptualizations such as those of mechanics have been shown inadequate to the purpose of science, science is liable to attack from

those who confuse its permanent accessions with its transitional conceptualizations. By saying that the essential content of science is not bound up with such concepts, but can be stated solely in terms of observed connections among sensations, positivism purports to offer science a means of defending itself.

The distinctive contribution of recent positivists, of the Vienna school to which Frank has belonged and others, has been an emphasis, lacking in Mach, upon the character and importance of mathematical formalism in science. Like most older empiricists, Mach was somewhat hostile toward the rationalistic aspects of science, associated as these were with conceptions of rational intuition and self-evident truth. The contemporary positivists, accepting and contributing to the development of modern axiomatic methods, have rendered this aspect of science acceptable to the empiricist viewpoint. Mach's criterion of "economy" remains the sole essential criterion for deciding which theoretical formulation fits best the established phenomena; but its range is extended by the techniques of formal theory-construction.

A review is no place to join issue on basic problems. In addition, the present reviewer is in sympathy with much that is said in these pages. Certain cautionary remarks are, however, in order. The book makes reference to the more technical works of modern positivism without much indication of their often provisional and controversial character. Thus for example the equivalence of the "phenomenalist" and the "physicalist" languages is assumed to have been proved by the work of Carnap, although this is at least doubtful. Again the operationalism of Bridgman is presented, but without any indication of the serious qualifications to which this very useful viewpoint must be subjected.

Finally, one should after reading this book ask whether modern positivism, as seen through its exposition, suffers from any serious limitations as a philosophical framework for modern life and thought. Certainly some of its central theses are ones with which most reflective scientific workers will agree: the need to clarify and explain the meaning of our scientific knowledge, to defend it against confusion and misinterpretation, and to broaden our understanding of the role of science in culture. In this connection there will be widespread agreement with the anti-metaphysical stand with which Frank is identified. Knowledge to be knowledge must be empirically testable. If so it is science, if not it is pretense. Much more than is usually recognized, this position leaves room for fundamental differences, leaves open the whole question as to the substantive content of science. A Machian-strict phenomenalism, which insists that only that content of science which is translatable into the language of direct sensory experience can be accepted as knowledge, will label everything else as "metaphysics". There can result, whether or not there must result, an erosion of the significant content of science.

In the earliest essay, the familiar conventionalist position is defended by saying that the law of causality is "only the establishment of a terminology". As an illustration we are presented with two iron rods whch lie quietly beside each other. If we call this state A, we can formulate the empirical proposition that state A is followed by state A. But now we replace one of the rods by another of the same appearance which is however magnetized. To say that state A is now followed by state B (the rods move together) would violate the language of causality. Therefore we say that the initial states were only apparently the same. We "save the principle" of causality by imputing to the second initial state other properties, called "magnetization", which is really only a reading back into the initial state, as a "property", the fact that it is followed by B.

It would be interesting to prepare a list of all the possible ways in which the difference between the magnetized and the unmagnetized rods could be detected. The acceleration of a compass needle or a beam of electrons, the difference in length between magnetized and unmagnetized rods, the difference with respect to polarization of scattered light, the difference of potential energy —all these and many other differences could be enumerated, by which the nonfictitious character of "magnetization" could be demonstrated. Evidently the two rods could be "apparently" the same only to a perception from which we have arbitrarily excluded all possibility of detecting differences!

Another example of the same tendency is the treatment in a later essay of the Copernican versus Ptolemaic description of the solar system. According to this account the difference is only one of degree of "convenience". This is of course quite true in one sense. It is possible to translate planetary motions from Ptolemaic epicycles to those which have the geocentric path of the sun as their common deferent, and from these to the full heliocentric description. The essential advance of the work of Copernicus was not merely a change of coordinate system. In fact, such a translation is not in general possible. Only *certain* Ptolemaic systems can be even approximately translated into Copernican systems, and the discovery that our solar system is one of these is a factual discovery of high order. The reduction of the number of independent parameters which this discovery makes possible does not depend on the coordinate system one uses. Nor is this gain in "simplicity" merely a matter of convenience, but affects the whole epistemological status of the theory. For since the Copernican theory has many fewer independent parameters, the probability that it would be found false, if it were false, is greatly enhanced as compared with the earlier theory. In fact it was just the subsequent discovery of the second-order falsity of the Copernican picture which made possible the emendations of Kepler and the discoveries of Newton, which still further reduced the number of independent parameters in the system and related the whole structure to common terrestrial experiences. This development in turn made possible Newton's clarification of the concept of mass, which provided one of the pillars of the general theory of relativity.

It was Mach, as Frank points out, who insisted upon the "metaphysical" character of Newton's conception of absolute space, and who in doing so raised another of the pillars of relativity theory. It was also Mach, we should

add, who failed to understand Newton's conception of mass as involving the equivalence of inertial and gravitational measurement of the "quantity of matter", and who in doing so obscured the profoundest of Newton's discoveries, his unification of terrestrial and celestial mechanics.

The moral is that the unity of science is not only, or primarily, methodological. It is a matter of content. If science can work toward the unified understanding of nature and man's place in it, the unity achieved will be the material unity of nature, not the semantic unity of scientific language. This latter is an important and sometimes crucial aspect of scientific progress, but by its nature subordinate. Whether the positivist program is an adequate account of methodology must be judged, in the end, by the actual progress of scientific knowledge and control. In this sense, certainly, we can agree with Frank: "There are no boundaries between science and philosophy".

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Applied Mathematics

NON-LINEAR PROBLEMS IN MECHANICS OF CONTINUA. (PROCEEDINGS OF SYMPOSIA IN APPLIED MATHEMATICS, VOLUME I.) **219 pp. American Mathematical Society, New York, 1949. $5.25.**

This book is a collection of the papers which were given in a symposium held at Brown University in the summer of 1947. In a few cases the papers are given in abbreviated forms, the complete papers having been published elsewhere. There are sixteen papers on hydrodynamics, and eight on elasticity and plasticity. The names of twenty-seven different authors appear.

With the exception of a paper by F. D. Murnaghan on the foundations of the theory of elasticity, the papers are all intended for specialists, and they are so highly technical that they cannot be described in any detail in a review such as this. Consequently, it will be necessary to limit the present discussion to some general remarks on the nature of the problems under consideration, and on certain broad tendencies which the papers seem to suggest.

As indicated by their titles, five of the sixteen papers devoted to hydrodynamics deal with various aspects of the motion of compressible fluids, two deal with problems concerning motions with free boundaries. The remaining five papers are concerned with various problems which are less easy to classify. In the second group, we find that five of the papers are concerned with the non-linear theory of elasticity, in which the strains and deflections are not assumed to be infinitesimal. The remaining papers are on dynamic structural stability, stress-strain relations for strain hardening materials, and discontinuous solutions in the theory of plasticity, respectively.

Physicists, when they examine this book, will be impressed by the extent to which the classical subjects of hydrodynamics and elasticity have progressed from their traditional and rather academic forms, and have come to adopt very realistic attitudes toward their subject matters. Modern methods of computation, which are discussed in several of the papers, have had much to do with this change of attitude.

For mathematicians, one of the most interesting features of the book consists of the references, in a paper by A. Weinstein, to work in which modern mathematical subjects, such as topology and the theory of Banach spaces, are used to establish the existence of certain discontinuous motions of a fluid in the presence of obstacles. It has long been recognized that these subjects are potentially usable for such purposes, but the number of actual applications has remained small. Hence the novel applications which are alluded to here are very welcome, and no doubt they will form the incentive for much further work.

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Books Received

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SAFE HANDLING OF RADIOACTIVE ISOTOPES. 30 pp. National Bureau of Standards Handbook 42. Government Printing Office, Washington 25, D. C., 1949. $0.15.

HANDLING RADIOACTIVE WASTES IN THE ATOMIC ENERGY PROGRAM. 30 pp. U. S. Atomic Energy Commission. Government Printing Office, Washington 25, D. C., 1949. $0.15.

ISOTOPES . . . A THREE-YEAR SUMMARY OF U. S. DISTRIBUTION. 201 pp. U. S. Atomic Energy Commission. Government Printing Office, Washington 25, D. C. $0.45.

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