a permanent place among the great chemists of the world. He was only fifty when he died, but bad health, and perhaps it must be added marriage and a fortune, marred his latter years, and if he had not lived beyond forty his fame would have stood as high as it does. When he began his work chemistry was entering on a new era. It had all but cut itself free from the doctrine of phlogiston, that mysterious principle of fire, sometimes ponderable, sometimes imponderable, and sometimes even possessed of negative weight, which had dominated it for more than a hundred years. Lavoisier had shown that in the explanation of combustion and kindred processes the final appeal must be to the balance, and gradual progress had been made towards establishing the conception of the chemical elements that still holds, even though the atom is no longer regarded as the ultimate unit of matter, and has become itself a complex microcosm of electrons whirling round a still more complex central nucleus. With the invention of the voltaic battery a new and potent instrument of research was put into the hands of experimenters, and Davy seized eagerly upon the possibilities it offered. Using it to direct chemical theory into fresh and unexplored channels, he not only demonstrated the compound character of many substances which previously had been accepted as elementary, but also forged a link between chemical and physical phenomena, and thus entitled himself to rank as a pioneer of the electric theory of matter.

If a certain impetuosity of temperament, coupled with an ambitious desire for "the honorable meed of the applause of enlightened men," sometimes betrayed his flashing intellect into the hasty publication of insufficiently verified hypotheses which the steady glow of Faraday's genius would have avoided, he always had an exalted view of the dignity and the importance of science no less in its utilitarian than in its moral and intellectual aspects. He realized that, in his own words, the prosperity and the riches of a country are intimately connected with the progress of the arts and sciences, and that no people has attained any considerable degree of civilization independent of the chemical arts, and—taking science as *illustrans commoda vitæ,* in the Lucretian phrase which serves as the motto of the Royal Institution where most of his work was done—he could turn to the study of the practice of tanning, the application of chemistry to agriculture, or the construction of a safety lamp for miners, with as much zeal and enthusiasm as he displayed in the abstract inquiries of the laboratory. Some of his contemporaries held a high opinion of his capacity as a poet, but time has not endorsed their judgment. The poetic and imaginative quality of some of his prose writings may be admitted, but his excursions into verse are forgotten, and it is as a natural philosopher that his fame endures.—*The London Times.*

SCIENTIFIC BOOKS

The Nature of the Physical World. By A. S. EDDINGTON. The Macmillan Company, New York, 1928. xvii + 361 pages, $3.75.

THIS book contains substantially the course of Gifford Lectures delivered by Professor Eddington at the University of Edinburgh during the first three months of 1927. Intended for the general public, it is written in popular style without recourse to mathematical symbolization. Nevertheless in his aim to show how recent scientific developments have provided new material for the philosopher the author has not shirked the more recondite aspects of scientific discovery and the reader will find that the reasoning in many places demands his closest attention.

The subject-matter covers the great changes in our concept of nature that have taken place during the last twenty-five years, especial attention being paid to the relativity theory and to the new quantum dynamics of Heisenberg, Dirac and Schrödinger. As a pure exposition in non-mathematical language of these recent developments in physics Professor Eddington's book certainly has no equal in the English language. The author proves himself a marked exception to the rule that the scientist lacks the capacity to write entertainingly and in terms which are intelligible to the reader who is not a specialist. The seriousness of the argument is relieved by apt illustrations and the reader's chuckles are aroused by flashes of humor and striking epigrams. Nothing excited the reviewer's delight more than Professor Eddington's emendation of the first law of motion: "Every body continues in its state of rest or uniform motion in a straight line, except in so far as it doesn't."

The author's object, however, is far more than mere exposition. His real interest lies in the philosophical implications of modern physics and in the light thrown by scientific discoveries on such questions as the conflict between the ideas of free-will and predestination. After showing that science forms a closed cycle he investigates those values in human experience which lie outside the domain of the scientific method. The ripples on a moonlit lake conform in their scientific aspects to the equations of hydrodynamics, but the romance of the summer night can never be expressed by a differential equation. Even the scientist loves and sometimes hates. After all, science can not evaluate its own purposes. The motive force back of scientific investigation is something which transcends science itself.

The *motif* underlying the book is the passage from the mechanistic ideals of the latter half of the nineteenth century to the state where science looks for nothing more than mathematical formulation and realizes that even a description of microscopic phenomena in terms of concepts of space and time derived from macroscopic experiences may be unattainable. Science has discarded the services of the engineer and turned to the mathematician to construct its world. Instead of resorting to an ether whose particles have the properties of meshed gyrostats we have learned to be satisfied with abstract relata and relations. The rub to-day comes in the identification of the relata with the pointer-readings of the laboratory. The result has been that "the external world of physics has become a world of shadows. In removing our illusions we have removed the substance, for indeed we have seen that the substance is one of the greatest of our illusions. . . . The frank realization that physical science is concerned with a world of shadows is one of the most significant of recent advances. . . . From their [the physicists'] point of view it is not so much a withdrawal of untenable claims as an assertion of freedom for autonomous development."

While space is something quite external to the human consciousness, the author points out that time plays a dual rôle. In its external aspects it unites with space to form the four-dimensional continuum of Minkowski. But the sense of duration is one of which the mind is immediately conscious. The astonishing characteristic of time is its irreversibility. Classical dynamics—even the relativity theory—gives no reason why time should always advance forward and never backward. Professor Eddington thinks that the explanation of the one-way progression of time is to be sought in the statistical laws of nature such as the second law of thermodynamics. The time-arrow has the direction to make the entropy of the universe increase. These secondary laws of science are essential in order to determine the sense of its flow.

In spite of the fact that the author entertains little doubt that the universe is finite and closed after the manner of Einstein or De Sitter he adheres to the gloomy view that the mechanism is running down in accord with the demands of the second law of thermodynamics. He admits that this conclusion is incredible, but states that he can make no suggestion to evade the deadlock. May it not be, however, that in generalizing the statistical laws which apply to gas molecules to the cosmos he is paying insufficient attention to the difference in scale? A million million gas molecules may be in the condition which we call the state of equilibrium and may have occupied this state for years, but if we examine a few hundred contiguous molecules for a millionth of a second it would not be at all surprising if we found that conditions among them were very far from the state of equilibrium during the whole of this brief interval of time. On the cosmic scale our observation of the stars is equally limited both in extent and in duration. To be sure, energy seems to become dissipated in space, but we are not without signs that the opposite effect may take place under appropriate conditions.

In his discussion of the wave mechanics Professor Eddington naturally stresses the abandonment of causality as well as causation in present concepts of atomic phenomena. Whereas the laws of classical physics are deterministic in form those of the new mechanics yield nothing more definite than measures of probability. But even in the classical era science made use of statistical relations in dealing with problems concerned with aggregates of particles such as are met with in the kinetic theory of gases. From the statistical point of view we calculate the probability of an assigned state of the gas and so obtain an estimate of the time during which the gas will find itself in that state. Here, however, we frankly admit that our use of the theory of probabilities is a cloak to conceal our incompetency to solve the problem by the deterministic methods of particle dynamics and to hide our inability even to state the initial conditions involved. The reviewer would like to think that the resort of physics to probability considerations in the atomic domain is a like confession of ignorance. Professor Eddington points out that while we can calculate the probability that an atom excited to the third quantum level may return to the second level and the probability that it may return to the first level, we can not predict which of these two events is the one which will occur. To the reviewer's mind, the fact that one and only one of the two possible transitions *does* occur makes it inconceivable that the choice of the transition is not related in some way—as yet unknown—to other events in the physical world. We are not demanding causation, which is arbitrary, but we still plead for causality. Indeed it hardly seems possible that science will ever find complete satisfaction in a formulation which makes the computation of probabilities its final achievement. The mind will refuse to discontinue the search for something deterministic beyond.

Heisenberg's principle of indetermination has introduced a new element into science. While this principle denies the possibility of predicting with exactness future microscopic events, Professor Eddington makes clear that it does not preclude an exact description of events after they have occurred. He feels that this principle provides the believer in free-will with a loophole to escape the conclusions of the mechanistic philosophy of classical science. But have you or I any power of free choice? I turn either to the right or to the left—certainly I do not turn both ways at once. If you tell me that I can turn only to the right, I may refute you by turning to the left, but then your assertion has become a factor determining the direction which I take.

LEIGH PAGE

SCIENTIFIC APPARATUS AND LABORATORY METHODS

PRACTICAL HINTS IN THE LABORATORY STUDIES OF PROTOZOA AND EARTHWORM

As far as the writer is aware no laboratory manuals have given the following time-saving devices for the studies of Protozoa and the earthworm.

PROTOZOA

In the study of Protozoa, ordinary cultures will show more free-swimming than sedentary forms. The latter are not difficult to study if a sufficiently high magnification is used, but the former are exceedingly hard to keep in the field. To try to keep track of the swimmers by moving the stage of the microscope is at best an unsatisfactory method. Students are prone to exclaim, "It is impossible to watch these wriggling beasts closely"; "I wish I could tie a string around one of them." The first statement is quite true; the wish is quite impossible.

Several methods have been suggested to reduce the difficulty: the use of cherry-tree gum, of potassium-iodide or, as is highly recommended by some workers, quince-seed solution. The writer is much in favor of the less complicated lens-paper method which is more easily cleaned and shows the animals in comparatively more natural conditions. The lens-paper method: Lay a piece of lens paper (smaller than the cover glass) on a clean slide; place a drop of the infusion from the top of the culture; then place a thin cover slip over the top surface and the preparation is ready for examination. Some of the infusorians and other protozoans will be imprisoned between the fibers of the paper, but their usual activities and metabolism will continue.

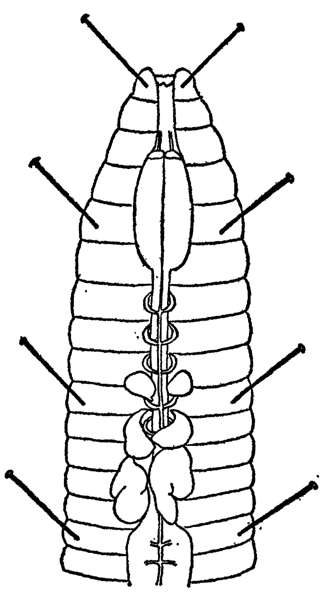

FIG. 1. One way of pinning the earthworm.

There are several distinct advantages of this method:

(1) The animals are kept from active movements and can therefore be closely watched. (2) When a glass slip is dropped on small animals like Protozoa, it is very apt to crush them. In order that they may move about, means must be provided to support the slip at a short distance above the slide. Lens paper again fulfils the requirement and is less complicated than the making of a cement cell or the use of broken fragments of glass, as some workers suggest. (3) This method also serves well in the measurement of these protozoans. Measurement is necessary in the identification. (4) There is still another advantage. Some infusorians, Paramecium for example, will double and twist between the fibers, showing the flexibility of their bodies.

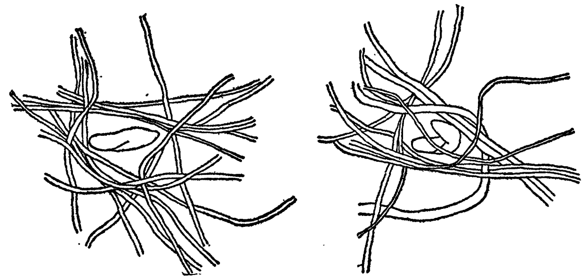

FIG. 2. Paramecia imprisoned between the fibers of lens paper.

EARTHWORM

In the laboratory study of the earthworm much time is wasted in counting segments in order to figure out the positions of the different organs. This trouble can be much reduced if, after proceeding in the usual manner to cut the body wall along the median dorsal line, the pins are placed on the first, the fifth, the tenth and the fifteenth segments, etc. Thus there is a definite system of pinning and the number of segments can be counted by fives and some time is saved.

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