Conclusion

We have now the privilege of building upon the empirical findings of pre-scientific workers; upon the wholesome activities of those who swept pharmacy clear of magic and confusion; and upon the freshly gathered though still largely empirical results of the past fifty years. This paper has attempted to acknowledge our debt to each of these classes of investigator but in particular to connect the wider aspirations of the first with the experimental findings of the last of these groups. To earlier workers, who produced their effect by taking material from one organism and applying it to another, it was more apparent that connexions might exist between the origin of drugs and their actions. It was necessary to separate these two aspects for their initial scientific investigation, and views narrowed. An author, while giving as his aim the discovery of the laws of interaction between drugs and cells, limited himself to physico-chemical methods and interpretations; the study of drug-antagonism was divorced from the natural origin of the drug and the antagonist; text-books of chemotherapy were arranged according to the chemical structures of the agents. A conclusion supported by this paper is that for the understanding and theoretical presentation of pharmacology and chemotherapy, biochemistry and general biology are among the most immediately relevant sciences.

I am glad to acknowledge the advice received in discussing this subject with Drs. H. A. Krebs and A. Wilson of the University of Sheffield.

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FUNDAMENTAL CONCEPTS OF NATURAL PHILOSOPHY

IN his recent James Scott Lecture, delivered before the Royal Society of Edinburgh, on "The Fundamental Concepts of Natural Philosophy" (*Proc. Roy. Soc. Edin.*, 62, Pt. 1, No. 2. Pp. 10–24. 1*s*. 3*d*.), Prof. E. A. Milne gave a comprehensive sketch of the theory of kinematical relativity which, with his collaborators, he has been developing during the last dozen years. The lecture contained no essentially new material, but it gave a very useful summary of the scope of the theory, with attention concentrated on the fundamental ideas, and its appearance marks a suitable occasion for forming an estimate of the significance of this new approach to the basic problems of natural philosophy.

The most fundamental concept of the scheme is that of the 'substratum', which is an idealized system of relatively moving particle observers, indefinitely numerous and each provided with a clock which he can graduate, in the first instance at pleasure. All such observers can send beams of light to the others and receive them back, by which means they become aware of the readings of the others' clocks, and they agree so to graduate their clocks that, for every pair of observers, A and B, "the totality of observations A makes on B coincide with the totality of observations B can make on A". They are then said to be "equivalent". Now suppose they wish to observe an external object. Each observer must (*a*) emit a beam of light at a time t_1 by his clock, and (*b*) observe his clock reading, t_2, at the instant at which he thereby observes the object. He must then form two specified independent functions of t_1 and t_2, involving the choice of a particular value for a conventional constant, c, and these functions he calls the *distance* and the *epoch*, respectively, of the object. Successive observations give a series of values of distance and epoch, and the relation between these constitutes the equation of motion of the object. The *law* of motion (or law of gravitation in the general case) is then determined by the condition that the totality of motions in the universe shall be described in the same way by all substratum observers; that is to say, if A observes an object at distance r and epoch t as determined by his clock, B must also observe an object (not necessarily the same object) at distance r and epoch t as determined by *his* clock. "Gravitation", writes Prof. Milne, "is only the name given to the inevitable way in which particles must move in one another's presence and in the presence of the rest of the universe, if they are to move according to the same rules for all equivalent observers in the universe".

The function of the substratum is thus to provide a stage for the display of natural motions; it corresponds in this theory to Euclidean space in ordinary geometry or to space-time in Minkowskian kinematics. It is not something which actually exists in the naïve sense of the phrase, but a conception which serves to determine the form in which observations of actually existing bodies shall be tabulated, and to define the sphere of possibility of actually occurring motions. "The theoretical, the ideal, the abstract substratum", writes Prof. Milne, "this system of moving particles, monads, observers . . . possesses a great many strange and surprising properties. . . . Just as the Euclidean plane is the stage, the scene, the background against which the phenomena of geometry—its figures and its theorems—display themselves, so the substratum is the background against which the phenomena of dynamics and gravitation display themselves".

Against this background, then, the actual bodies of the universe are to be contemplated and their behaviour observed, and here we encounter an ambiguity which I have invariably felt in reading Prof. Milne on this subject, and which remains unresolved here. Just as the Euclidean character of space tells us nothing about the number or distribution at any moment of the objects observable in space, so one would expect that the characteristics of the theoretical, ideal, abstract substratum would tell us nothing about the number or distribution of practical, real, concrete objects which present themselves for description in terms of it. This, however, appears not to be so. The behaviour of a free particle is determined not only by the demands of the observers in the substratum, but by the "rest of the universe"—that is, all the other concrete particles—also: and, furthermore, the "rest of the universe" is controlled, in both content and behaviour, by the condition that the substratum observers shall give the same general description of the whole. When one asks the reason for this, however, the answer is puzzling. We cannot deduce the motion of a single free particle without considering the rest of the universe, says Prof. Milne, for "if we are asked what is the motion of a free particle in 'empty space', *i.e.* in the presence of one observer alone, the question is an illegitimate one, and we cannot answer it". But we do not ask what is the motion of a free particle in the presence of one observer alone, but what is the motion of a single concrete particle in the presence of all the ideal substratum observers, and no reason is given why we cannot state it. We can only assume that the universe cannot contain only a single particle, because if so the substratum observers could not give the same account of it; but it would have been more satisfactory if this had been plainly stated.

The theory proceeds to deduce the way in which the universe must be populated with concrete bodies, and how those bodies must move in one another's presence, in order that it shall conform to the requirements of the substratum. This, of course, involves much mathematics, of which the chief conclusions are given in the lecture, and we reach a point at which the resulting "law of gravitation" can be compared with the familiar Newtonian law. The classical "constant of gravitation" turns out to be a function of time, but it can be made to "masquerade as a constant" by a transformation of the time-scale to that used by Newton. The deductions of the theory, however, are at present of less interest than the foundations, and we turn to an examination of the fundamental postulates.

It must be admitted that Prof. Milne speaks no more than the truth when he describes the substratum as possessing strange and surprising properties. We have become accustomed to 'spaces' which turn back on themselves and do other queer things, and it is an axiom of general relativity that the properties of space vary with its material content—that space, in fact, is less aptly described as a frame into which bodies must fit than as a garment shaped to their figure. But of all previous thinkers who have taken liberties with space, none, so far as I know, has given it intelligence. The substratum, however, is *essentially* intelligent. Each particle of it is necessarily accompanied by an observer—*is*, in fact, an observer, since it has no function but that of observing, recording and calculating. "Observers are an essential element in the situation", writes Prof. Milne. Nor is "observer" here merely a picturesque term for "observing instrument", as in the popular accounts of Einstein's relativity. The substratum observers must not only record the pointer-readings of clocks; *they must also agree to give the same value to a conventional constant*, c, otherwise their readings are useless. This cannot be done without communication by means of an agreed conventional language, and for this minds, and not merely instruments, are essential. We cannot escape from this, nor, apparently, does Prof. Milne wish to do so, for he states as one of his two principal motives throughout the work, "the attempt to say exactly what is meant by a quantitative statement in terms of operations that could be actually carried out, and communicated to a distant observer elsewhere in the universe, who could repeat similar observations, on these instructions, himself".

Parenthetically, it is worth while to point out a common misunderstanding, which Prof. Milne seems to share, concerning the meaning of 'observer' in Einstein's theory of relativity. It is often said that the purpose of the theory is to reconcile observations of observers in relative motion. That is a mistake, arising from a well-meant but unfortunate device widely adopted for explaining the theory in an attractive way. What the theory actually does is to prescribe how a single observer must change his measure numbers when he changes his co-ordinate system; for example, when (absolute motion having no significance) he changes his arbitrary standard of rest from one body to another. As a theory based on experience it can obviously do no more, for we have measurements of only one observer—a terrestrial one. The Michelson-Morley experiment did not compare observations by terrestrial and solar observers. It showed that the single result obtained by a single observer was to be expected, no matter whether that observer regarded himself as at rest or as moving round the sun. Of course, we can deduce what the theory would require a solar observer to measure if he used the same kinds of instruments and the same rules of calculation as ourselves, and the deduction, like any other, might turn out to be incorrect if we ever succeeded in observing a terrestrial experiment from the sun. In that case the theory would have to be revised. The essential point is that hypothetical observers play no part in the theory *per se*. Anything we may say about them has the character of a scientific romance.

If the substratum postulate referred to above were shown to issue in the actual laws exhibited by moving bodies, and to form a simpler axiomatic basis than any other so far devised, it would have to be given serious attention. We might try to reformulate it so as to bring it more into line with general physical convention, but if we failed to do so, no plea of apparent absurdity would justify its rejection. We have learnt—or should have learnt—by now that nothing is too fantastic (that is, contrary to expectation) to be true. But this would not at all win Prof. Milne's approval, for it would subject the postulate to the test of *experience*, and its significance to him is that its validity is *beyond* experience ; the postulate is advanced as self-evident and inevitable. The other of his two principal motives already mentioned is "the desire never to introduce, unsuspectedly, any elements of *contingent* law". He proposes in his lecture to show how "we are led to quantitative laws relating phenomena in the external world which are *inevitable* [my italics] relations between the elements of perception". "The more advanced a branch of science", he writes, "the more it relies on inference and the fewer the independent appeals to experience it contains. . . . The question arises as to whether this process of inferring can come to a stop, and if so, where. Is there an irreducible number of brute facts derived from observation ? . . . The answer seems to me to be that we can reduce the appeals to *quantitative* experience to zero".

My mind must be made on a different pattern from Prof. Milne's, for the necessity of the substratum as a background for phenomena does not appear to me at all self-evident. I find myself capable of doubting the possibility of existence of the army of equivalent observers, of doubting their significance for natural philosophy or anything else if they did exist, and of doubting the ability of stars and planets to know where the decisions of the substratum conference required them to be. I have a conviction that, like Adam in Blanco White's sonnet, I should not have known that the universe contained numerous bodies outside the earth if no one had observed them. I am not persuaded that Einstein "still relied on an empirical assumption—the constancy of the speed of light—in his derivation of the Lorentz formulae, not realising that the same ideas could be developed further so as to dispense with this assumption". It seems to me that this "empirical assumption" was nothing more than a statement of the time-scale adopted in relativity theory, just as Newton's First Law of Motion is a statement of the time-scale adopted in classical theory, and the substitution for it of an animistic philosophy in which the same constant is adopted as a convention by hypothetical observers instead of as a unit of measurement by actual ones seems to me neither an improvement nor a logical necessity. In short, while I am perfectly ready to adopt Prof. Milne's postulates as an axiomatic basis for physical theory if he can show that they lead to a simpler and more comprehensive correlation of experience than any other, and very much hope that he will be able to give his voluminous and elegant mathematical work some acceptable meaning, I retain sufficient imagination to conceive, and liberty to choose, postulates of very different character.

Finally, I find it impossible to understand what Prof. Milne means by his claim that he has said "exactly what is meant by a quantitative statement in terms of operations that could be actually carried out". Having, through the kindness of the General Electric Co., recently acquired the charge of a particularly bright lamp, and having access also to a Riefler clock and other ticking devices, I felt myself in a position to become an "equivalent observer", and began to consider how I should set about deriving the laws of the universe. The first step was to send a beam of light to another such observer, but, having noted the instant by the clock at which my lamp was uncovered, and, just to emphasize its arbitrariness, decided to move that c be given the value $2 \cdot 99796 \times 10^{10}$, I found I could get no further, for the next observer failed either to pick up my beam or else to send it back to me. This, perhaps, was only to be expected, since he was theoretical, ideal, abstract, but it left me in a dilemma : I could not communicate with an equivalent observer since he did not exist, and it was useless to communicate with a possibly existing observer (say on Mars) since he was not equivalent. My clock jeered at me in the old Greenwich rhythm, and I could not even begin to measure the first distance and epoch.

What was to be done ? In all sincerity, I do not know. I can understand that it *would* be possible "in principle" for me to carry out Prof. Milne's instructions if the theoretical observers existed and were complaisant, though I am not so clear why, if he can reduce the appeals to quantitative experience to zero, he makes this superfluity a principal guiding motive. But the fact is that there is still a great deal about the universe that I do not know and would very much like to know. I am prepared to accept any indirect procedure which can be shown to yield the same result as the ideal one, but Prof. Milne has described none and I can imagine none myself. So I remain unable to understand what is meant by the claim that the meaning of quantitative statements has been stated "in terms of operations that could be actually carried out".

HERBERT DINGLE.

BUDGETARY AND DIETARY SURVEYS

A WHOLE-DAY Conference of the Nutrition Society was held on February 5 at the London School of Hygiene and Tropical Medicine to discuss "Budgetary and Dietary Surveys of Families and Individuals". The meeting was devoted in the main to a consideration of different methods of conducting such surveys and their comparative value.

The Society is doing valuable work in bringing together social workers and experts interested in different aspects of the subject of nutrition and able to speak from knowledge and experience. Thus each comes to view the problems which arise with a due sense of proportion and to correct the impression which might otherwise be formed that one particular approach to a solution is all-important. As Sir John Orr, who presided, pointed out, food will occupy a key position in post-war reconstruction. The Prime Minister put it first in his Guildhall speech. It is essential, therefore, that all the relevant facts should