Fresnel drag formula to solid substances ; neither did he give any cogent reasons for having adopted this particular method ; so that his remarkable research has scarcely attracted any attention.

After a comprehensive survey of the problem, however, the present writer is convinced that the surface polarisation method does provide a means of measuring a first-order effect of ether drift, and that Fizeau's experiments have actually demonstrated such an effect. There seem to be various possibilities for simplifying the method, with which it is hoped to experiment before long ; but in the meantime, this account of Miller's and of Fizeau's experiments may do something to revive interest in this important problem and to dispel the prevalent belief that it is insoluble.

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The Study of Behaviour*

By DR. E. S. RUSSELL, O.B.E.

IT was Descartes who imposed upon European thought for at least two centuries, and upon biology for much longer, that 'bifurcation' of Nature into matter and mind which has raised so many insoluble problems for philosophy, and diverted biology from its true method. As to its effect on philosophy, Prof. A. N. Whitehead writes :

"The seventeenth century had finally produced a scheme of scientific thought framed by mathematicians, for the use of mathematicians. . . . The enormous success of the scientific abstractions, yielding on the one hand *matter* with its *simple location* in space and time, on the other hand *mind*, perceiving, suffering, reasoning, but not interfering, has foisted on to philosophy the task of accepting them as the most concrete rendering of fact. Thereby, modern philosophy has been ruined. There are the dualists, who accept matter and mind as on equal basis, and the two varieties of monists, those who put mind inside matter, and those who put matter inside mind. But this juggling with abstractions can never overcome the inherent confusion introduced by the ascription of *misplaced concreteness* to the scientific scheme of the seventeenth century."

Actually, instead of being the most concrete of realities, both matter and mind are highly abstract concepts, the product of the reflective intelligence working upon the data of immediate experience.

There is given in individual experience only the perceiving subject and his objective world. This dualism does not correspond, is not synonymous with, the dualism of matter and mind. Subjective experience as we know it directly is a function of organism, not of pure mind ; objective experience is a relation between organism and other processes or events. The concept of matter is arrived at by abstracting from the data of sense, by leaving out the 'secondary qualities' such as colour, smell and sound, and retaining the so-called 'primary qualities' of resistance and extension, with location in time and space.

By accepting this abstract definition or concept of matter, we substitute for the objective world of perception a symbolic or conceptual world of discrete material particles, which we may call the 'world of matter'. This world of matter the materialist takes to be in some sense more real than the perceptual and colourful world from which he has derived it. Actually it is less real, less concrete. It is important to remember that the world which we perceive through the senses, with its shapes, colours, smells, tastes and so on, is not identical with the conceptual 'world of matter' ; we do not perceive 'matter' at all, any more than we perceive mind ; we perceive things or relations or events.

Complementary to this abstract material universe is the concept of mind as an inextended, immaterial, thinking entity, and this also is

* From the presidential address before Section D (Zoology) of the British Association, delivered at Aberdeen on September 6.

derived by abstraction from the data of immediate experience, and principally from the subjective aspect of experience.

As applied to biology, this abstract dualism has saddled us with the theory that the organism is a machine, with the pale ghost of a mind hovering over its working, but not interfering. What chance is there for a real science of animal behaviour if this metaphysical view is accepted?

Obviously from the Descartian point of view, behaviour becomes a subject for the physiologist to study from his analytical point of view; he must regard behaviour as the causally determined outcome of the working of the animal machine, under the influence of external and internal stimuli, and he must seek to determine the elementary physico-chemical processes out of which behaviour is built up. The physiologist as such can have nothing to do with mind, and hands over its study to the psychologist, who finds that he can know nothing directly about the minds of animals. Hence we get the study of animal behaviour split up between physiology and psychology, with no possibility of a connecting bridge. The scientific study of behaviour thus becomes divorced from natural history, and ceases to take its rightful place as an integral part of zoology.

Aristotle knew better than this; he regarded life and mind as continuous one with another, and the basis of his zoological system was the form and activity of the animal as a whole. But then Aristotle was a first-rate field naturalist and observer.

Let us try to rid our minds of the abstract notions of matter and mind, and regard the activities of living things without metaphysical preconceptions. As zoologists, our job is to study animals in action. Let us try to approach our task with the same directness and *naïveté* that Aristotle showed when he laid the foundations of our science. Instead of assuming *a priori* that the physico-chemical or analytical method of approach is the only possible and the only fruitful one, let us try the alternative of considering first the most general characteristics of the organism as a whole, and working down from the whole to the parts, rather than up from the parts to the whole, as is the more usual method.

Taking this simple and direct view of living things, abandoning theory and accepting the obvious facts at their face value, we see first of all that the complete phenomena of life are shown only by individuals, or organised unities. Sometimes these units are combined loosely or closely in unities of higher order, as in social insects and in colonial animals, such as corals, but these cases scarcely affect the main thesis that life is a function of individuals. There is accordingly no such thing as 'living matter', save as part of an organised unity.

The second thing we note is that all living things pass through a cycle of activity, which normally comprises development, reproduction and senescent processes leading to death. This life-cycle is in each species a definite one, passing through a clearly defined trajectory, admitting of little deviation from normality; it takes place generally in an external environment which must be normal for the species, and as a rule the internal environment also is kept constant round a particular norm. The activities whereby the needs of the organism are satisfied and a normal relation to the external and the internal environment is maintained, may be called the maintenance activities of the organism, and they underlie and support the other master-functions of development and reproduction.

Our general definition or concept of organism is then an organised unity showing the activities of maintenance, development and reproduction, bound up in one continuous life-cycle. A static concept is inadequate; time must enter into the definition; the organism is essentially a spatio-temporal process, a 'dynamic pattern in time', as Coghill aptly calls it.

Now all these activities are, objectively considered, directed towards an end, which is the completion of the normal life-cycle. One is tempted to use the word 'purposive' in description of these activities, but this term is used in many senses and has a strong psychological flavour about it, so I shall use instead the neutral word *directive*, which I borrow from C. S. Myers. It is quite immaterial from our simple objective point of view whether these directive activities, or any of them, are consciously purposive. The directiveness of vital processes is shown equally well in the development of the embryo as in our own conscious behaviour.

It is this directive activity shown by individual organisms that distinguishes living things from inanimate objects. The peculiar character of this directiveness, its orientation towards a cyclical progression of organisation and activity, clearly distinguishes it from the static directedness of a machine, constructed for a definite purpose. It should be noted too that the living thing shows a certain measure of adaptability in completing its life-cycle, so that the end is more constant than the way of attaining it.

Now from this point of view, which is, I maintain, strictly objective, behaviour is simply one form of the general directive activity of the organism; it is that part of it which is concerned with the relations of the organism to its external world. Plants show behaviour in this general sense just as much as animals do, but they, being for the most part sessile and stationary creatures, respond to the exigencies of environment, and satisfy their basic needs, mainly by processes of growth and differentiation, and only exceptionally by active movements. Thus the dune plant seeking water grows an enormously long root which burrows down through the sand until moisture is reached. Animals on the other hand respond to environment and satisfy their needs by means of movements, either of the body as a whole or of certain organs. But sessile animals, like plants, may also respond or show behaviour by means of morphogenetic activity. The hydroid, *Antennularia*, for example, if suspended in the water may send out 'roots' or holdfasts to regain contact with the bottom.

Behaviour, whether of plants or animals, is thus to be regarded simply as one form of the general directive activity which is characteristic of the living organism. It holds no privileged position; it does not require 'mind' as an immaterial entity to explain it.

If we accept this view of organism, which is to my mind a simple generalisation of fact, we escape or elude the difficulties of dualism; we need no longer regard behaviour as either the mechanically determined outcome of the material organisation of the body, or the result of the activities of an immaterial mind or entelechy influencing in some utterly mysterious way the mechanical workings of the body. By taking as given and as fundamental the plain objective characteristics of the living and intact organism, by refusing to split it up into matter and mind, we avoid both materialism and its counterpart vitalism.

This is, as I conceive it, the central position of the modern organismal theory—the substitution of the concept of organism for the concepts of matter and mind. The concept of organism, or more generally of organised system, may of course be applied right down through the inorganic realm, wherever organised unities are found. Thus a molecule is an organised system, and so also is an atom. I do not, however, agree with those who think that all real unities, both organic and inorganic, are adequately characterised as 'systems'. In certain most general characteristics an atom and a living organism agree, for both are systems or wholes. But the living organism has characteristics which are lacking in inorganic systems, and it can be adequately defined or characterised only by reference to those peculiarities which we have just considered—the weaving together in one cyclical process of the master functions of maintenance, development and reproduction. These distinguish it from any inorganic object or construction, from any inorganic system. Underlying these characteristics is the general directiveness of its activities, their constant drive towards a normal and specific end or completion.

It will be noted that this organismal view makes no real distinction between life and mind, between vital activities and those which in immediate experience appear as mental or psychical activities. In this respect we hark back to a pre-Descartian mode of thought, and call Aristotle our master.

Simple observation shows us that living animals exhibit activities which are obviously not, on the face of them, those of a mechanism. Many of their behaviour actions are strictly analogous to those which in immediate experience we should describe as psychological. Thus we see animals trying hard to achieve some aim or end—a salmon struggling to surmount a fall, for example, or a cat using all its skill to catch a bird. We do not know whether these actions are consciously purposive or not, but we cannot dismiss the objective facts of striving merely by assuming that they are mechanically determined. There are the facts; animal behaviour is predominantly directive, or in an objective sense purposive, and there is no use closing our eyes to it.

It is well known too that many animals can learn and profit by experience. Thus if you train a puppy to play with a ball, this becomes of functional significance to it; it will go and look for its ball, which it remembers; and other objects of a similar size or shape acquire for it the functional value of a ball, and are used in play. There is here definite evidence of memory, or retentiveness.

In the same way, there is abundant evidence that animals perceive their surroundings, singling out those objects and those events that are of importance in relation to their needs. Of course we cannot know what the quality of these perceptions is, but we *can* determine by suitably planned experiments just what it is to which the animal responds, and we often find that the response is to patterns or images or relations, and not to a simple summation of physico-chemical stimuli. From the organismal point of view there is no difficulty in assuming that animals perceive and react to an external world of their own; here, as in our own case, perception may be regarded as a function of organism, not of 'mind'.

This is essentially the attitude of ordinary common sense. In practice we treat our fellow men and at least the higher animals as being real individuals with perceptions, feelings, desires, similar to our own; and common sense is in principle justified, though of course it runs a great risk of reading human motives, human ways of thought, into the behaviour of animals, and of assuming without sufficient warrant that their perceptual worlds are the same as ours. But because there is a danger of faulty interpretation, due mainly to inaccurate or inadequate observation, we are not thereby compelled to throw over the general conception that the animal organism is capable of perception, conative behaviour, and memory, if the facts of observation lead us to this conclusion. I do not mean that we should explain behaviour as being due to psychological functions labelled conation, perception and memory—that would be an empty and barren explanation. We are concerned only with behaviour, not with the subjective experience of the animal, which cannot be the subject of scientific study. But we must describe the behaviour fully and adequately, using if necessary terms of psychological implication, refusing to be bound or hampered by the metaphysical notion that the animal is merely a machine or can be treated as such.

In affirming as we do that the animal organism in its behaviour shows a kind of activity which cannot be adequately described in terms of material configuration we are taking no great risk. Our own immediate experience is there to assure us that in one case at least the organism certainly does perceive, strive, feel and remember.

From the organismal point of view, the study of behaviour is neither comparative physiology nor comparative psychology; it is the study of the directive activity of the organism as a whole, in so far as that activity has reference to the organism's own perceptual world. It must start with what Lloyd Morgan calls the 'plain tale' of behaviour, the full and accurate description of what animals do, and of what they are capable.

The plain tale description of animal behaviour must begin with a study of the natural history and ecology of the animal. Most animals are restricted to one definite and rather specialised kind of environment; they are adapted both in structure and activity to inhabit some particular ecological norm or ecological niche. We must discover by field observation how the animal finds this ecological niche to begin with, and how it maintains itself therein. We must investigate how it counters changes in its environment, how it defends itself against enemies, how it finds or captures its food. All this is straight natural history in the old sense, the study of the 'habits' of animals, and it is linked up closely with the modern study of ecology. It is the necessary basis for the more detailed study of behaviour. It is also the clue to much of the behaviour shown in the artificial conditions of a laboratory experiment.

Clearly then we must start with direct observation of the animal's behaviour in the field, or in experimental conditions that approximate as nearly as possible to the normal. We must then ask what is the animal trying to do, what is the objective end or aim of its action? Sometimes the animal is doing nothing in particular; it is resting or merely waiting for something to turn up. Usually, however, the animal is active, is showing behaviour; its actions are directed to some end, are aimed at satisfying some need, and we can determine by observation and experiment what that end is; the sign that the end is attained is the cessation of the train of action.

We find very often that a simple directive activity is part of a general directive process of long range, which may take months to reach its goal; and to understand the simple action we must relate it to, or integrate it in, the general process of which it is a part. Take for example the building of a nest by a bird. This taken by itself is a directive activity, aimed at the construction and completion of an adequate brooding place for the eggs and young. It is a fairly stereotyped and specific activity, but unusual materials may be pressed into service if the normal materials are hard to come by. But nest-building is simply one link in the long reproductive cycle, which may commence with migration, and its relation to that cycle, which includes both behavioural and physiological activities, must be studied if we are to understand it fully.

This illustrates the general rule of biological method which we have just discussed—that the whole life-cycle of activity must be regarded as the primary thing, and that the parts of it which may be isolated for study must be re-integrated in the whole-activity. The human mind is prone to analysis, and we must be on our guard against its inveterate tendency to separate and distinguish parts or elements in what are, fundamentally, continuous processes.

In thus relating partial events to life-cycle, we must of course consider above all their time-relations, not only their relations to what has gone before, but also and more particularly to what follows after. I should like to refer in this connexion to a recent address by Coghill, in which the organismal view of development, including the development of behaviour, is set out with great clearness and authority. He tells us that:

"the neuro-embryologic study of behavior shows that events within a behavioral system can be understood scientifically only as their relation is known to subsequent as well as to antecedent phases of the cycle. The antecedent tells a part of the story about the present, but not all of it; for within the present are events that have behavioral significance only in that which follows. . . . The purely scientific method, dealing exclusively as it does with space-time relations, can not reject the future from its explanation of the present in behavior, because any event in an organismic cyclic system is an integral part of both the future and the past."

To conclude—it is time biology shook itself free from the limitations imposed upon it by a blind trust in the classical doctrine of materialism. This doctrine is not in harmony with the modern development of philosophical thought, nor with the modern development of physical science, and it is not well adapted to the study of living things.

We must adopt a more concrete and more adequate concept of the living organism, one that will take account of its essential characteristics. We must think of the organism as a four-dimensional whole, or directive cyclical process, and no longer attempt to contain it within the static scheme of the classical materialism. This does not lead to any form of dualistic vitalism. The relation of behavioural or 'psychological' activities to physiological is not the relation of mental to physical activities, but is, quite simply, the relation of a whole spatio-temporal directive process to its parts.

Finer Structure of Chromosomes

RECENT studies of the chromosomes in various somatic tissues of *Drosophila* and other insects is throwing further light on the processes of heredity. It has been known since 1881, when Balbiani studied the chromosomes in the salivary gland cells of the *Chironomus* larva, that they are relatively very large and are marked with transverse bands or discs. Last year, Prof. T. S. Painter expressed the view that these bands, which show equally in the giant chromosomes of the salivary glands of *Drosophila* larvæ, correspond with the locations of the genes. An exciting line of investigation is now being pursued, in which the positions of the discs or bands are compared in different genotypes of *Drosophila* having deficiencies, translocations and other alterations in their chromosomes.

In two recent papers in *Genetics* (May and September, 1934), Painter has made further studies of the bands of varying widths which occur at fixed positions on the chromosome, making a pattern which may be compared with a spectrogram. It is well known that in Diptera the somatic chromosomes are often closely paired, but he finds that in the salivary gland cells of old larvæ the homologous chromosomes fuse completely, "line for line and band for band", but it is not at present clear how this can take place. This somatic synapsis is accompanied by separation of the long chromosomes into two parts at the spindle fibre attachment, while about three-eighths of the X-chromosome—the portion found genetically to be free from genes—as well as the greater part or the whole of the Y, disappear completely.

By studying deletions and translocations in which a series of genes are present the position of which on the X-chromosome has been mapped, particular bands can be closely identified with particular genes. When certain genes are deleted, corresponding bands will be absent, and if a section of the chromosome is transposed, its bands and their affinities are correspondingly altered. By such methods the chromosomes can be more accurately mapped, and much breeding work can be eliminated by the direct observation of the position of known bands in the chromosomes.

In an investigation of the ganglion cells of *Drosophila*, Dr. Kaufmann (*J. Morph.*, **56**, No. 1) has shown that some of them have satellites, and that, as in plant cells, certain chromosomes (in this case loci of the X and Y) are concerned in producing the nucleolus. He also finds the anaphase chromosomes double, consisting of two coiled chromonemata as in plant nuclei.

Following these advances in knowledge of the morphology and inner structure of *Drosophila* chromosomes, come fresh observations and speculations regarding the relation between the visible discs and the hypothetical genes. Prof. N. Koltzoff announces (*Science*, Oct. 5, 312) that the diploid somatic non-dividing cells in the salivary glands of insect larvæ contain giant chromosomes because the chromonema in each has divided successively to form probably 16 strands, which he calls genonemes. In addition to the discs at intervals on the chromosome, chromomeres are seen on the individual strands, and these structures can be photographed in the living cell. Koltzoff is inclined to regard the gene as corresponding, not to the chromomere but to the intervening portion of thread between two chromomeres, the discs being regarded as joints between the genes.

Dr. C. B. Bridges has independently come to conclusions in many respects similar, as announced by Science Service in the same number of *Science*. The chromosomes in the salivary glands of fruit-fly larvæ are in some cases seventy times the size of the ordinary chromosomes. By using a method for removing the outer chromatin, Bridges finds the solid discs composed of a bundle of parallel rods like a handful of cigarettes, threads connecting corresponding rods from one disc to another to