CHAPTER I

INTRODUCTORY: PROTOZOAN BEHAVIOUR

UNLESS we set out with the preconception that mind is the prerogative of man, the question whether mind is coextensive with living protoplasm or is the possession of only the more highly organized animals must at some time suggest itself. But, whatever prejudices we may hold, it is incumbent upon us, before definitely accepting either view, to ascertain, if possible, the level at which the first manifestations of mind occur. On either finding, too, it is of the utmost importance for our proper comprehension of the developed mind to trace its gradual evolution from the simpler to the more complex forms; and, furthermore, the study of mental phenomena at the earliest stage of their appearance helps to demonstrate the more primitive, fundamental, and inalienable characteristics of mind.

The solution of these and kindred problems cannot be decided *a priori*, but demands the careful study and systematic observation of the behaviour of different organisms under widely varying conditions; and to this study much labour and ingenuity have been devoted during the past few decades. It is the aim, then, of this essay to present briefly certain of the more important evidence yielded by these investigations.

In view of the importance attaching to the first appearance of mind in the animal kingdom, it will be well at the outset of our survey to give some account of what is now known of the habits and behaviour of the structurally simplest animals, the Protozoa. It will be clearer and more convenient to confine our attention as far as possible to one class of these minute creatures. We will, therefore, select for our purpose the ciliate infusorian *Paramecium*, since its reactions may, in many respects, be regarded as representative of the more typical features of protozoan conduct, and are illustrative of the main points to be presented.

The most outstanding feature of a *Paramecium's* behaviour consists in its definite and well-marked reactions to certain chemicals. For instance, if a drop of weak sulphuric or proprionic acid be introduced, by means of a capillary pipette, into a slide of *Paramecia*, the animals will quickly collect within the region of the acid, and, forming a dense aggregation, will remain there. Similar behaviour may also be shown towards certain injurious chemicals: thus, *Paramecia* freely swim into a drop of corrosive sublimate, only to encounter instant death. Numerous other conditions could be cited which elicit this aggregation phenomenon, notably a certain optimal degree (which varies with adaptation) of warmth; but the instances already given must suffice for illustration.

Equally striking, on the other hand, is the marked distaste and avoidance normally shown by these animals towards certain other conditions, among which may be mentioned a solution of common salt from $\frac{1}{10}$ per cent. upwards, extreme heat, and light containing ultra-violet rays; the areas where these conditions obtain being completely deserted. The introduction of any of these stimuli is accompanied by a well-marked dispersal phenomenon which contrasts strongly with the aggregation phenomenon referred to above.

From these and like observations Loeb was led to conclude that the lower organisms are mere automata, certain stimuli attracting them with a fatal inevitableness, as a magnet attracts steel, while others no less certainly repel them. Of such simple, direct, irresistible and automatic responses Loeb conceives protozoan conduct to consist; and, on account of its analogy with certain facts in plant life, long known as tropisms, his view is commonly referred to as the 'tropistic' theory.

Another worker, Jennings, however, not content with thus recording only the end-state of the *mass* effect caused by these various stimuli, sought to observe precisely in what manner and by what processes this end-state was brought about. To do so it was necessary to scrutinise closely the behaviour of *individuals* from the moment of the first disturbance caused by the test stimulus until such time as a state of apparent equilibrium was reached. And so important are the results yielded by this minute examination that some account must now be given of them.

On observing individuals closely, it was found that when a drop of a weak acid solution was introduced, as already described, into a slide of *Paramecia*, the animals still continued swimming restlessly about in their usual random and aimless manner; but that when *by chance* any individual came into contact with the drop of acid solution, such individual entered and remained there, its activity thenceforward being confined within the boundary of the acid. Gradually, through their active exploration, all or the greater part of the *Paramecia* encounter the acid, and so a dense aggregation comes to be formed. So far it should be noted that the acid exerts no *direct* attraction on the organisms, which after its introduction swim about in a random manner in all directions, only being brought into contact with the acid by chance.

The next point of interest is to consider how the acid succeeds in acting as a trap. In order to understand this some account of the structure of a *Paramecium* must be given.

A *Paramecium* is a ciliate infusorian supposed to resemble a slipper in shape, and on that account sometimes spoken of as the slipper organism (see fig. 1, p. 7). Its body is entirely covered with fine hair-like structures or cilia set in oblique rows. In swimming the animal is carried forward by the backward movement of the cilia; retreat is accomplished by a reversal of the ciliary wave. Both movements, however, are accompanied by a slight rotation on the long axis, caused by the fact that the cilia are set obliquely. Further, one side of the organism is differentiated by bearing the oral groove, a long funnel extending from the mouth, in the middle of the body, forward to the anterior end. Owing to the fact that the cilia in the oral groove beat rather more strongly than the rest the anterior end is continually being turned away from the oral side. An admirable instance of these movements is to be seen in *Paramecium's* reaction to an obstacle (fig. 1). *Paramecium*, on the whole, tends, except in certain physiological states, to avoid contact with large, solid bodies. Its behaviour may be roughly described as follows:—One of these infusoria on coming into contact with *débris* or other objects stops suddenly, reverses the stroke of its cilia thus causing a backward movement, then pausing, turns aside, and once more starts on a forward course, thereby completing the sequence of movements known as the 'motor reflex' or 'avoiding reaction.' If the new direction also brings it into contact with the obstacle, a fresh avoiding reaction is given, this behaviour being, for a time, repeated on each contact with the obstacle. Sooner or later the combination of the backward movement with the summation of turns toward the aboral side tends to bring the animal into a direction facing a clear path where it may swim forward unimpeded for the moment. A diagrammatic representation of this behaviour is given below in fig. 1.

We are now in a position to understand how the aggregation phenomena, so frequently

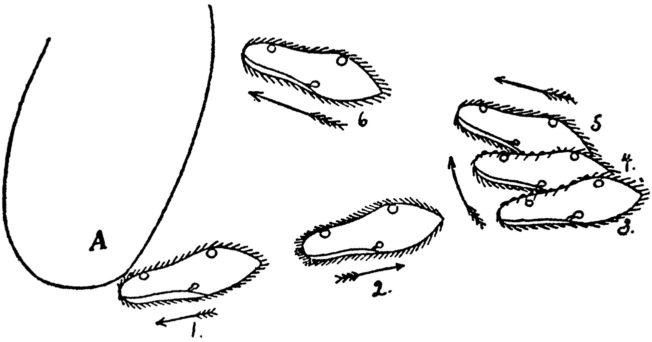

Fig. 1 Diagram of the avoiding reaction of *Paramecium*. *A* is a solid object or other source of stimulation. 1-6, successive positions occupied by the animal. (The rotation on the long axis is not shown.) (After Jennings.)

observed in the behaviour of these organisms to certain stimuli, are brought about. To return to the *Paramecia* caught (by mere accident as we have shown), in the drop of weak acid, close attention to their movements will show that the individuals which have entered this drop are frequently very active, swimming about within it restlessly in every direction. The sole uniform feature which their conduct presents consists in the 'motor reflex' (constituted, as we have just seen, of a backward movement followed by a sharp turn) which is invariably given by each animal on arriving at the margin where acid and water meet. By this reaction the animals are prevented from re-entering the water and are kept within the region of the acid. Their behaviour here is in all essentials similar to that already described in the case of the avoidance of an obstacle, the obstacle in this instance being replaced by the different medium, water, contact with which occasions the motor reflex.

The true explanation underlying the so-called 'tropistic' responses will now be readily understood. The attraction of weak acids and of the cooler region is shown on closer observation to be apparent rather than real. It is a negative and not a positive phenomenon, being ultimately due to avoidance of the adjoining conditions. And this avoidance does not occur in a definite and immediate manner but is only achieved, if at all, by a process of trial. The avoidance of extreme heat, of salt solution, and of ultra-violet rays is to be similarly explained. These unfavourable conditions arouse the animal to increased restlessness, until it finally passes out of the area of stimulation: no specially marked reaction occurs on passing out of this region; but should the animal in the course of its activity again encounter the objectionable stimuli, the avoiding reflex is repeated, and so the unfavourable area remains deserted.

The significance of the difference between the two theories of interpretation of the behaviour of the lower organisms—the one just described which will be referred to as the 'trial and error' interpretation, and the tropistic theory previously dealt with—will now be evident. Whereas the latter theory requires that the organisms shall respond to significant stimuli with a fatal inevitableness and immediacy, the trial and error hypothesis involves, potentially at least, the testing of conditions over a relatively wide area by the animals. Thus, *Paramecium*, as we have just seen, in avoiding an unfavourable region tries various directions, and only comes to rest when fatigued, or on meeting with conditions adapted to its requirements. On the occurrence of any changes, either in the internal condition of the animal or in the external conditions of the environment, such as render the latter no longer suited to the former, the animal once more swims away, testing different directions until again satisfied. Similarly, movements tending to take it out of the favourable area are corrected. In short, the facts brought out by the detailed observations upon which the trial and error theory is based, show that emphasis must be laid not so much on the intrinsic character of external stimuli as on the changes which occur in accustomed conditions. And such changes need not necessarily consist in the substitution or introduction of a novel stimulus. A mere variation in the intensity of the stimulus often suffices to effect a reversal of behaviour; a fact which is utterly at variance with the tropistic interpretation. This change of reaction consequent upon alteration in the intensity of the stimulus is usually known as sensibility to difference.

The importance of the *rôle* assumed by a change in accustomed conditions leads to a consideration of the phenomenon of adaptation or acclimatization.

It has long been known that if one hand is placed for a few seconds in water heated to about 40° C. and then transferred to water the temperature of which is approximately that of