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THE PSYCHOLOGY OF A PROTOZOAN.

By H. S. Jennings.

The nature of the psychic activities of unicellular organisms has of late become the object of considerable interest, though little work dealing with the problems in a fundamental way has been published since the researches of Verworn. The writer has recently made a perhaps more thorough study of the life activities of a typical infusorian, *Paramecium*, than has ever been made heretofore of any unicellular organism; the results of this study have been published in a number of papers in physiological journals.[1] This work was not done primarily from the psychological standpoint, and the papers referred to give nowhere a full and connected account of the bearings of these studies upon the psychological problems presented by the behaviour of the Paramecia. Yet taken together they enable an almost complete presentation to be given of the psychology of this animal; while there is reason to believe that Paramecium is in this matter typical of nearly or quite the whole class to which it belongs. In the present paper an attempt is made to bring together succinctly the observations which bear upon the psychic powers of this organism, in such a way as to present a complete outline of its psychology.

Paramecium is well known in every biological laboratory, living by thousands in pond water containing decaying vegetable matter. It is a somewhat cigar-shaped creature, about one-fifth of a millimeter in length, plainly visible to the naked eye as an elongated whitish speck. The entire surface of the animal is covered with cilia, by means of which it is in almost constant motion.

Now what are the phenomena in the life of Paramecium which require explanation from a psychological standpoint?

Examination shows that under normal conditions Paramecia

[1] Studies on Reactions to Stimuli in Unicellular Organisms. I. Reactions to Chemical, Osmotic, and Mechanical Stimuli in the Ciliate Infusoria. *Journal of Physiology*, May, 1897, Vol. XXI, pp. 258-322. II. The Mechanism of the Motor Reactions of Paramecium. *American Journal of Physiology*, May, 1899, Vol. II, pp. 311-341. III. Reactions to Localized Stimuli in Spirostomum and Stentor. *American Naturalist*, May, 1899, Vol. XXXIII, pp. 373-389. IV. Laws of Chemotaxis in Paramecium. *American Journal of Physiology*, May, 1899, Vol. II, pp. 355-379.

are usually engaged in feeding upon the masses of Bacteria which form a thick zoogloea on the surface of the water in which they are found. These Bacteria form almost or quite their entire food. A first question then might be: How do they choose their food, selecting Bacteria in preference to something else?

If Paramecia are placed on an ordinary slide such as is used for examining objects with the microscope, together with a small bit of bacterial zoogloea, and the whole covered with a cover-glass, it will soon be found that almost all the Paramecia, which were at first scattered throughout the preparation, have gathered closely about the mass of zoogloea and are feeding upon it. It will be seen even, that many Paramecia which cannot on account of the crowd get near enough to the mass to touch it are pushing close and shoving their more fortunate brethren, all apparently trying to get as near to the delicacy as possible. Some may be ten times their own length from the mass, but nevertheless crowd in from behind, apparently with the greatest eagerness. Here we have a related problem. How do the Paramecia collect thus from a distance about the mass? And what is the psychology of their crowding together thus, like a human crowd about a circus door? In the human crowd somewhat complex psychological qualities are involved; must we say the same for the Paramecia?

If we mount the Paramecia in the manner above described, but without the mass of bacterial zoogloea, we shall soon notice another phenomenon reminding us of human beings under like conditions. The Paramecia do not remain scattered as at first, but soon begin to collect into assemblages in one or more regions. It appears as if they did not enjoy being alone and had passed the word along to gather and hold a mass meeting in some part of the preparation; at least we soon find them nearly all in a little area near one end of the slide, with perhaps another smaller crowd off near the other end, while all the rest of the space is empty. Sometimes such a crowd becomes very dense; the Paramecia jam each other after the most approved human fashion, crowding as if all were trying to get near some popular orator in the center. If we watch such an assembly for some time, we find that the interest is apparently gradually lost; the Paramecia begin to separate a little,—not leaving the crowd entirely, but extending the area and wandering about its edges. The assembly thus becomes more and more scattered, the area in which the Paramecia swim back and forth being continually enlarged; but a rather sharp boundary is nevertheless maintained on all sides, as if by common consent no Paramecium was to pass farther out than all the rest.

Here we have what seems a decidedly complex psychological problem,—the beginning, or perhaps even a high development, of social conditions. In the culture jars, also, we find the Paramecia gathered into swarms, and any proposed psychology of the Protozoa must account for these social phenomena.

Further, we find that Paramecia seem to have decided preferences in taste. They have a special predilection for sour, gathering with apparent eagerness into a drop of any solution having a weakly acid reaction, while their pet antipathy is toward anything alkaline in character. A drop of fluid having an alkaline reaction is therefore left severely alone and remains entirely empty when introduced into a slide of Paramecia. They also seem to show decided preferences as to heat and cold; they collect in regions having a certain temperature, leaving a colder or warmer area to gather in such an optimum region, just as human beings do. The whole question of how animals are attracted by certain influences and repelled by others is one of the most fundamental problems to be solved.

Thus the ordinary daily life of a Paramecium seems, on the face of it, to present many complex psychological problems. Apparently they feel heat and cold and govern themselves accordingly, have decided preferences as to the nature of the substances dissolved in the water, seeking some, fleeing from others; they live upon one definite sort of food and find ways of discovering a mass of such food even when scattered at a distance from it, and finally, they are social, being commonly found in swarms together and finding means of getting together even when scattered over a wide area.

From observations of this sort, some authors have concluded that such animals have a complex psychology, lacking few of the factors to be distinguished in the psychology of the higher animals. Thus, Binet says, in the preface to his book on *The Psychic Life of Micro-organisms* "We could if necessary, take every single one of the psychical faculties which M. Romanes reserves for animals more or less advanced in the zoölogical scale, and show that the *greater part* of these faculties belong equally to micro-organisms." Thus, it could be maintained from the brief summary I have given of the activities of Paramecium that these animals have *sensations* of various sorts, since they distinguish heat and cold, acids and alkalies; that they exercise *choice* in that they gather in the regions of certain agents, while they turn away from others; that such choice in itself implies *intelligence*; that the choosing and gathering about masses of food implies a *memory* of the qualities of this substance as compared with others; that they show such *emotions* as fear by fleeing from injurious substances (Binet expressly states this); that finally, acute senses, memory, choice, social instinct, intelligence, and a whole host of higher mental attributes, are necessarily implied in the phenomenon of their seeking each other's society and gathering together even from a considerable distance into crowds.

Is it possible by a closer analysis of the phenomena to simplify this complex psychology which seems forced upon us by the observed facts?

First, we should examine a little more closely the structure of the animal to see what is here available for the production of these results. Often function depends upon structure to such an extent that what appears to be a complex activity is found to be only the automatic result of the simplest movements of a peculiarly constructed organ or set of organs.

Paramecium is an elongated animal, with one end (the anterior) narrower and blunter, while the other (the posterior) is broader and pointed. On one side of the animal (the oral side) a broad oblique depression, called the oral groove, runs from the anterior end to the mouth, in the middle of the body. Near the opposite side (the aboral side) are two contractile vacuoles imbedded in the protoplasm. The mouth is a small opening at the end of the oral groove in the middle of the body; from it a narrow ciliated tube, the gullet, passes into the internal protoplasm. In the center of the animal are imbedded the single large macro-nucleus and the single small micro-nucleus. The entire body is thus a single cell. Under ordinary conditions all the cilia of the body strike backward, which of course drives the animal forward. The stroke of the cilia is apparently somewhat oblique, for as the animal moves forward, it at the same time continually revolves on its long axis: in this way the oral and aboral sides continually interchange positions.

Now the structure and ordinary movements of the animal explain a certain activity which in higher forms may be associated with some degree of psychological complication, namely, the taking of food. Since the oral groove is ciliated like the rest of the body, when the cilia strike backward in the ordinary forward motion a current of water is produced running in the oral groove backward to the mouth. Small particles such as Bacteria, are thus carried automatically to the mouth. The mouth and gullet are ciliated and the cilia strike toward the interior of the animal, hence the particles arriving at the mouth are carried by the cilia into the interior, where they undergo digestion. The taking of food is thus purely automatic.

Moreover, as has long been known, Paramecia and similar animals seem not to exercise a choice as to the nature of the food which they take. Any small particles such as will pass readily down the gullet are swallowed with the same avidity as the Bacteria, it matters not how indigestible they may be.

But, as we have seen above, if a small piece of bacterial zoogloea on which the animals feed is introduced into a preparation of Paramecia, the latter soon find it and crowd around it. It seems possible, therefore, that the choice of food takes place merely a step sooner than with higher animals, the Paramecia choosing the food by gathering around it,—then taking whatever comes. To test this we introduce a bit of filter paper into the preparation in place of the bacterial mass. The Paramecia collect about it exactly as about the zoogloea. They gather from all parts of the preparation and crowd upon it with the same apparent eagerness as previously upon the food mass. The same results are gained with bits of cloth, cotton, sponge, or any other loose or fibrous bodies. The Paramecia remain assembled about such bodies indefinitely, the oral cilia working away at bringing a current to the mouth, which current carries no food particles whatever.

Thus it appears that Paramecia exercise no choice as to the nature of the substances which they use for food, gathering indifferently about loose fibrous bodies of any sort, and swallowing particles of any kind or none at all, as chance may direct. We may cut out, therefore, any psychological qualities deduced alone from the supposed choice of food, putting in their place merely the fact that Paramecia react in a peculiar way when they come in contact with bodies of a certain physical texture. The reaction consists essentially of a quieting of the cilia over the greater part of the body, while those in the oral groove continue to strike backward, causing a current toward the mouth,—the body of the animal remaining nearly or quite at rest. It is important to recognize, in calling this a reaction, that it is not shown by a movement, but by a *cessation* of part of the usual motion.

Having been so successful in reducing the matter of feeding to simple factors, we may attack at once the most complex problem of all—the social phenomena shown in the gathering together of the scattered animals into a close group, as already described. Is there any way of dispensing with the sharpened senses, memory, social instinct, intelligence, and the like, which seem to be involved in these phenomena?

The possibility suggested itself that these collections might be due to the presence of some substance which was attractive to the Paramecia, and into which all would gather with one accord,—so that the fact that they approached each other would be a secondary result. This led to an extended study of the chemotaxis of Paramecia, the results of which are detailed in the first of the papers above referred to. It was found that Paramecia are attracted by all acids, and that in the case of any unknown substance having marked attractive properties, it can be predicted with a high degree of certainty that this substance will be found to have an acid reaction. Carbonic acid (CO_2) especially was found to exercise a strong attraction on the infusoria.

Now these animals, like all others, of course excrete carbon dioxide, which must therefore find its way into the water. The quantity of CO_2 thus produced by one of the dense assemblages of Paramecia was shown to be distinctly appreciable by chemical reagents, by means of the following experiment: Paramecia were mounted in water to which a distinctly reddish color was given by mixing with it a small quantity of rosol. This substance has the property of being decolorized by carbon dioxide. The rosol does not injure the Paramecia, and they soon gather together in a dense collection, as in ordinary water. By observing the slide against a white background it is soon noticed that the solution is losing its color about the group of Paramecia. The colorless area after a time spreads, and at the same time the group of Paramecia begins to break up, as previously described. The Paramecia swim back and forth in the colorless area (that is, the area containing (CO_2), from one side to the other, but without passing its boundaries. The colorless area increases in size, and the area in which the Paramecia swim back and forth keeps exact pace with it; the two coincide throughout.

The same phenomena may be produced by introducing a small bubble of CO_2 into the slide. The Paramecia collect closely about the CO_2, pressing against the bubble. In this way a dense mass is soon formed. After a time, as the CO_2 diffuses, the mass loosens; the Paramecia swim back and forth in the area of diffusing CO_2, not overpassing its boundaries. The phenomena caused by the presence of a bubble of CO_2 are identical in every respect with those which are apparently spontaneous. There is no question but that the assembling of the Paramecia into crowds is due to the presence in these crowds of CO_2 excreted by the animals themselves.

Thus it appears that our social phenomena, with all their implications of higher mental powers, have evaporated into a simple attraction toward carbon dioxide.

But how do the animals succeed in collecting from a distance? At first they are distributed throughout the entire preparation; when we introduce the bit of bacterial zoogloea or filter paper, how do the Paramecia discover its presence, so as to collect about it? From the general wreck of higher mental qualities, can we not save at least the *acute senses* necessary to account for these phenomena?

To determine how the Paramecia succeed in finding and collecting about a small solid placed in the middle of a large slide, it is necessary to study the ordinary method of locomotion of the animals. "If a preparation of Paramecia on a slide, containing in one spot a small bit of filter paper is closely observed, the Paramecia are seen at first to swim hither and thither in every direction, apparently without directive tendency of any sort. . . Soon a single individual strikes in its headlong course the bit of paper. It stops at once, often starts backward a slight distance, and whirls about on its short axis two or three times, then settles against the bit of paper and remains. Quickly another and another strike in the same way and remain. Now the excretion of CO_2 by the animals gathered together begins to take effect; the region becomes a strong center of attraction, and in ten to fifteen minutes, and often less, the paper is surrounded by a dense swarm of Paramecia, containing a large majority of all those in the preparation." (I, p. 299.) Thus, the finding of the bit of paper is due simply to the roving movements of the animals. Moreover, for gathering in an area containing CO_2 or other acid alone, a similar dependence upon chance motions appears. There is no swimming in straight radial lines to the area of CO_2 as a center; the Paramecia swim at random until they come by accident into the region of CO_2; there they remain. The precise place where a group of Paramecia is formed in some part of a slide into which nothing has been intentionally introduced that would act as a center of attraction is determined by chance factors. One or two individuals, perhaps, strike by accident a bit of solid matter suspended in the water, or a slight roughening of the cover glass; the thigmotactic reaction is set up, so that they stop, and as a result the region becomes a center for the production of carbon dioxide. The remainder of the collection is then due to CO_2, and takes place in the manner last described.

We must, therefore, along with the rest, dispense with specially acute senses. The Paramecia do not react until they are in actual contact with the source of stimulus, and for coming in contact with the source they depend upon roving movements in all directions.

Thus we find that all more complex psychological powers deduced from the "social phenomena," as well as those from the choice of food, must fall to the ground. For explaining all the phenomena with which we have thus far dealt, but three factors are necessary: (1) the customary movements of the unstimulated animal; (2) the cessation of these movements, except those in the oral groove and gullet, when in contact with solids of a certain physical character; (3) attraction toward CO_2.

We have still remaining to be accounted for psychologically the *attraction* toward certain reagents and conditions, as toward CO_2 and toward the optimum temperature, and the *repulsion* toward other reagents and conditions, such as alkalies, and cold or great heat. This selective attraction and repulsion is a phenomenon of great importance, seeming in itself to imply a *choice* on the part of the organisms. If they move toward certain sources of stimuli and away from others, this seems to involve a perception of the localization of things, and this can hardly be regarded otherwise than as at least the beginnings of intelligence. Moreover, from its apparent general occurrence, much theoretical significance has been attached to it. Now *how* does this attraction and repulsion take place? Organisms usually move by means of certain organs of locomotion; attraction and repulsion cannot therefore be left as abstract ideas, but it must be shown how the attractive agent sets these organs in operation in such a manner as to bring the animal nearer; how the repellent agent succeeds in affecting the locomotor organs so as to carry the animal away. To apply this to the particular case in hand, when a drop of some attractive solution is introduced into a slide of Paramecia, how does it succeed in affecting the cilia of the animals in such a way that they turn toward and enter the drop?

Exact observation of the method by which the Paramecia enter such a drop shows that this question is based on a false assumption. *The animals do not turn toward the drop.* Such a drop diffuses slowly, so that its margin is evident, and the Paramecia may be seen in their random course to almost graze the edge of the drop without their motion being changed in the slightest degree; they keep on straight past the drop and swim to another part of the slide. But of course some of the Paramecia in their random swimming come directly against the edge of the drop. These do not react, but keep on undisturbed across it. But when they come to the opposite margin, where they would, if unchecked, pass out again into the surrounding medium, they react *negatively*—jerking back and turning again into the drop. Such an animal then swims across the drop in the new direction till it again comes to the margin, when it reacts negatively, as before. This continues, so that the animal appears to be caught in the drop as in a trap. Other Paramecia enter the drop in the same way and are imprisoned like the first, so that in time the drop swarms with the animals. As a result of their swift random movements when first brought upon the slide, almost every individual in the preparation will in a short time have come by chance against the edge of the drop, will have entered and remained, so that soon all the Paramecia in the preparation are in the drop. If, however, the drop is not introduced until the Paramecia have quieted down, it will be found to remain empty; this shows the essential part played by the roving movements in bringing the collection together.

Thus it appears that the animals are not attracted by the fluid in the drop; they enter it by chance, without reaction, then are repelled by the surrounding fluid. This is true for all apparently attractive reagents or conditions. *Paramecia are not directly attracted by any substance or agency;* the assembling in the region of certain conditions being due to the repellent power of the surrounding fluid, after the Paramecia have entered by chance the area of the conditions in question.

There remains then as a motor reaction only the *repulsion* due to certain agents and conditions. Is this repulsion an ultimate fact in the psychology of the animal, or is it possible to analyze it further?

The first thing which a Paramecium does on coming in contact with a drop of repellent solution is to reverse all its cilia, so as to swim straight backward,—at the same time revolving on its long axis in a direction opposite to that in which it was previously revolving. Next it turns to one side a certain amount, then swims forward again, on a path which lies at an angle to the path in which it was first swimming. Briefly stated, it adopts the very rational plan of backing off, turning to one side, and swimming on past the obstacle. We must apparently concede the Paramecium at least a modicum of intelligence for the very practical way in which it meets this emergency.

But suppose the animal touches the margin of the drop obliquely, or brushes it only on one side as it swims past it through the water; what course will it then take? From its sensible behavior under the previous conditions we shall expect it to sheer off, away from the drop, and keep on its way undisturbed or at a slight angle to the original path. But when we observe such a case, we find that the Paramecium backs off, swimming straight backward, as before, then turns through an angle, then swims forward, exactly as in the previous case. And curiously enough, it by no means turns directly away from the drop, but fully as often turns toward it, so as to strike it squarely the next time it moves forward. If this occurs, the whole operation is repeated; the animal tries, as it were, for a new opening. Sometimes it is necessary to repeat the operation several times before the Paramecium succeeds in getting away from the repellent object.

Under these circumstances the animal evidently gives much less indication of intelligence, and the fact that it reacts in exactly the same way under such different conditions is especially fitted to shake confidence in its mental powers. Apparently the swimming backward has no relation to the position of the source of stimulus, but occurs merely as a result of the fact of stimulation, without reference to its localization. Whether this is true as a general statement can be tested by giving the animal a general shock without localizing the source of stimulus at all. This is easily done by immersing the Paramecia directly into solutions of such a nature that they act as stimuli. In such a case the stimulus acts upon the entire surface of the animal at once, so that there is no obstacle to be avoided and no reason for swimming backward.

Immersing Paramecia thus into solutions of different kinds, it is found that the first thing they do in every case is to reverse the cilia and swim backward. Nor is this all. The entire reaction is given, just as when the source of stimulus was at one end or one side; the animal first swims backward, then turns, then swims forward. This is true for all classes of stimuli,—chemical solutions of all sorts, water heated considerably above the optimum temperature, water at the freezing point, and solutions active only through their osmotic pressure. The duration of the different parts of the reaction varies much in different agents, but the essential features of the reaction are the same everywhere.

It therefore appears that not only the backward swimming, but also the turning to one side takes place without reference to the localization of the stimulus,—both occurring equally when the stimulus is not localized at all. But what determines the *direction* in which the Paramecium turns?

Careful observation of Paramecia under conditions which compel them to move slowly shows that after stimulation *they always turn toward the aboral side*,—that is, the side opposite the oral groove. The direction of turning is thus determined by the structure of the animal, and has no relation to the position of the source of stimulus. The mechanism of the turning is as follows: after the first reversal of cilia, those in the oral groove begin to strike backward again, tending to drive the animal forward, while the remainder of the cilia on the anterior half of the animal *strike transversely toward the oral side*. This results in turning the animal toward the aboral side.

We find, therefore, that the direction of motion throughout the entire reaction depends upon the structure of the animal and has no relation to the localization of the stimulus. The reaction may be expressed completely, omitting all reference to the position of the stimulus, as follows: after stimulation the animal swims with the more pointed end in front, turns toward the aboral side, then swims with the blunter end in front.

It is of course a matter of chance whether this turning toward the aboral side carries the animal away from the source of stimulus or toward it. Frequently the latter is true; in this case the operation is repeated when the animal comes again in contact with the stimulating agent. As the animal revolves continually on its long axis, the aboral side will probably lie in a new position at the next turning, so that the animal will turn in a new direction. If this is repeated, the chances are that in time the obstacle will be avoided.

Thus, not only is it true that Paramecium is not attracted by any agent or condition, but also we cannot say, speaking strictly, that it is repelled by any agent or condition. Certain agents set up a reaction in the animal, the directive features of which depend entirely upon the structure of the organism,—just as certain stimuli cause an isolated muscle to react. We cannot say that the Paramecium is repelled by the stimulus, any more than we can say that the contraction of the muscle is due to the muscle's being repelled by the stimulus. It is true that the source of stimulus is more often at the blunt or "anterior" end, in the case of Paramecium, so that swimming toward the sharp end does, as a matter of fact, usually result in taking the Paramecium away for a short distance from the source of stimulus. But this usual position of the source of stimulus is from a physiological standpoint purely accidental, and the reaction produced is the same whether it occupies this position or another. If the animal is stimulated at the posterior end, it swims backward, therefore toward the source of stimulus; in this way it may enter a destructive chemical solution and be immediately killed, though the same chemical acting upon the anterior end would of course have caused the animal to swim away. This is seen in a particularly striking manner in the larger infusorian *Spirostomum ambiguum*, which is so large that it is easy to apply a stimulus to any desired part of the body. It is then found that the animal reacts in exactly the same manner whether stimulated at the anterior end, the posterior end, or the side, the direction of motion having absolutely no relation to the position of the source of stimulus. The same is true for Paramecium, though its smaller size makes the demonstration more difficult.

A strict parity is therefore to be observed between the reactions of Paramecium and those of an isolated frog's muscle. Paramecium responds to any stimulus by a definite, well characterized reaction. "The same may be said of the isolated muscle of a frog. The intensity of the reaction varies with the nature and intensity of the stimulus; this also is true for the muscle. Under certain influences the Paramecium remains quiet; likewise the muscle. The directive relations of the motions are determined both in the Paramecium and in the muscle by the structure of the organism, not by the position of the source of stimulus. There seems, then, no necessity for assuming more in order to explain the reactions of the Paramecium than to explain the reactions of the muscle. We need, therefore, to assume nothing more than irritability, or the power of responding to a stimulus by a definite movement, to explain the activities of Paramecium" (II). The long catalogue of psychical qualities required to account for the movements of Paramecium is thus reduced to simple protoplasmic irritability.

The method by which Paramecia collect in the regions of influences of a certain character and leave other regions empty, may be stated in general terms as follows: Certain stimuli cause in the animals random motions, in which the direction is frequently changed, especially at the moment when the stimulus begins to act. These random movements result, through the laws of chance, if continued long enough, in carrying the Paramecia out of the region of influence of the agent causing the stimulus. Coming thus by chance into a region where such movements are not caused, the Paramecia remain; if this ineffective area is small, the Paramecia are crowded together within it and give the impression of being strongly attracted by it.

"It is evident that we have in this case as near the reaction postulated by Spencer and Bain for a primitive organism—namely, random movements in response to any stimulus—as is likely to be found in any organism. The motions are strictly random in character so far as the position of the source of stimulus is concerned. . . . And by the repetition of the reaction the direction of movement is frequently changed,—always without reference to the localization of the stimulus. It appears not to have been foreseen theoretically that such random movements would of themselves, if continued, carry the animal out of the sphere of influence of the agent causing them and keep it from re-entering. To accomplish this result it is only necessary that the direction of motion should be changed at the moment when the stimulus begins to act and at intervals so long as it continues" (II).

An examination of the activities of a number of other unicellular organisms in the light of the observations above detailed shows that they react in essentially the same manner. For each organism a simple statement can be given for the reaction to any stimulus. For *Spirostomum ambiguum* the reaction is as follows: the animal contracts, swims backward, turns toward the aboral side, and swims forward. *Stentor polymorphus* contracts, swims backward, turns toward the *right* side, and swims forward. A number of flagellates also have been found to have such a fixed method of reaction. In all these cases the direction of motion has no relation to the position of the source of stimulus, and the conclusions to be drawn for Paramecium apply equally to these organisms.

In regard to the position in the psychological scale to be assigned to Paramecium the following may be said: The reactions of Paramecium are, as we have seen, comparable in all essentials to those of an isolated muscle. In neither case has the direction of motion any relation to the position of the source of stimulus. Reaction in such a manner as to show a relation to the position of the stimulating agent has rightly been regarded as a first and lowest step in perception; this lowest step is quite lacking in Paramecium. Moreover, Paramecium has no "life history" in the sense of a change in its reactions such as between the reactions of a young and an adult higher animal. An individual undergoing division reacts exactly like the ordinary Paramecium, as do likewise the halves immediately after division. In the words of Professor Baldwin, "the fact of life history is just what distinguishes an organism from what is a 'mechanical arrangement.'" While we cannot deny that Paramecium is an organism, this fact shows the machine-like nature of its activities. An animal that learns nothing, that exercises no choice in any respect, that is attracted by nothing and repelled by nothing, that reacts entirely without reference to the position of external objects, that has but one reaction for the most varied stimuli, can hardly be said to have made the first step in the evolution of mind, and we are not compelled to assume consciousness or intelligence in any form to explain its activities.