ON THE REACTIONS OF ISOLATED PARTS OF
PARAMECIUM CAUDATUM

BY FRANCES M. HORTON, PH.D.

(From the Zoologisches Institut, Königsberg, and the
Zoology Department, University of Birmingham.)

(Received 31st July, 1934.)

(With Three Text-figures.)

I. INTRODUCTION.

A study of the reactions of isolated parts of Paramecium is relevant to two distinct
problems; firstly to that of the possible location of receptor organs or of a receptor
area in the cell, and secondly to the question of the rôle played in swimming, by the
cilia of different regions.

The behaviour of pieces of infusoria was first studied by Verworn (1889) and
Balbiani (1889). Both authors stated that parts of ciliates move in general in the
same manner as do the whole organisms. As no detailed analyses of protozoan move-
ment and reaction had at that time been made, their observations are interesting
only in relation to the first of the above questions.

More recently, Jennings (1902) and Alverdes (1922, 1923) have done work of a
similar but more exhaustive nature. Jennings subjected various parts of Stylonychia
and Oxytricha, and front and hind halves of Paramecium to mechanical and chemical
stimulation. He was led by his results to say that “as any portion of a crystal is
organised like the entire crystal, so in the ciliate any piece of the body is organised
so as to move and react to stimuli in the same manner as does the entire animal.”

In the experiments of Alverdes Paramecium was cut transversely into two. Fore
and hind parts were obtained from cuts made at various distances from the front
end of the body and their reactions to heat and sodium chloride observed. It was
concluded that the perception of a stimulus is confined to the front end of the animal.

The following experiments were made with the intention of obtaining conclusive
evidence on the problem which gave rise to the conflicting results of these two
workers1.

II. METHOD OF EXPERIMENT.

A drop of water containing about ten individuals of Paramecium was placed on a
slide and most of the water removed with cotton-wool. The animals were then cut
transversely into two with Spemann needles under the low power of a binocular.
It was found that cut pieces continuing to swim for more than 2 min. after operation
had a good chance of survival. Such pieces were kept isolated in a drop of water
in a moist chamber until needed for experiment.

1 I wish to thank Prof. Otto Koehler for his kind hospitality and for his helpful direction of this
work, most of which was done in his laboratory. I wish also to thank his staff for their courtesy and
assistance.
Cuts were made at various places across the body and at least twelve fore and twelve hind parts, obtained from each type of cut, were tested. Fig. 1 shows the exact positions of these cuts, numbered 1–5. Hind ends made by cut 4 possessed no oral or buccal groove cilia. It was impossible to conserve living fore ends from cut 1 or hind ends from cut 5 as in these cases protoplasm exuded from the smaller part as soon as an incision was made.

Jennings' "ring technique" was made use of in these experiments. The piece of Paramecium to be tested was placed on a slide in a very small drop of water. From twenty to thirty normal individuals were then added to this drop. Fine glass threads thinly covered with vaseline were laid across the slide, one on each side of the drop, and a cover slip was lowered on to them.

Sulphuric acid (0.05 per cent.) was introduced under the centre of the cover-slip by means of a fine pipette. The reactions to acid of the whole animals and of the part were observed and their paths were traced with a camera lucida.

After the acid had been introduced the animals collected round it in a ring, making avoiding reactions at the inner and outer boundaries of an optimum zone. These boundaries were outlined on paper. The part-animal was next located and its path traced. As it was only possible to follow its movements for a few seconds at a time, several records of its track were made during each experiment. Any one of the normal animals was then chosen as a control, and its path was traced in the same way. The strength and nature of the reaction, and the manner of swimming were noted in all cases. The details of two typical experiments are given below.

Reactions of a fore end obtained by cut 3. After operation, this part-animal was seen to swim in exactly the same manner as a whole individual. Fig. 2 shows the nature of its reactions to acid. The piece made avoiding reactions by jerking backwards, revolving on its axis and swimming off in a new direction, at both the inner and the outer boundaries of the optimum zone. It behaved in all respects like a whole animal.

Reactions of a hind end obtained by cut 2. This hind end was seen to swim in the normal way. When tested with acid (Fig. 3) it made very strong reactions, jerking
On the Reactions of Isolated Parts of Paramecium caudatum

further back than is usual. The avoiding reactions occurred further away from the acid than in the case of whole animals, showing that the optimum zone for the hind end is weaker than that for fore ends and normal individuals. The mode of reaction and the types of movement accomplished were the same as those of the control.

III. COLLECTED RESULTS.

(a) Fore ends from all cuts.

The behaviour of fore ends differed in no way from that of whole animals. The typical swimming movements were accomplished, and the pieces, when tested with acid, made the usual avoiding reactions at the same boundaries as did the controls.

(b) Hind ends from all cuts.

Hind ends also proved capable of the normal mode of swimming and of the usual reactions, invariably moving with the cut surface first. In some cases they appeared to be more sensitive than either the controls or fore ends, for their optimum zone was further removed from the acid and the backward jerk during the avoiding reaction was particularly vigorous. More difficulty was experienced in preserving hind ends than fore ends, the former frequently dying during the course of an experiment.

IV. DISCUSSION.

Experiments showed that all pieces of Paramecium tested were sensitive to weak sulphuric acid. These results agree with those of Jennings (1902), but they directly oppose those of Alverdes (1922) who maintained that in the Paramecium cell only the front part could perceive chemical stimulation.

In my experiments hind ends were found to be more sensitive than fore ends, the former making exceedingly violent backward jerks during an avoiding reaction, and restricting themselves to a zone of weaker acid intensity. Jennings and Jamieson,
on the contrary, found that hind ends were less sensitive than fore ends or controls (1902). It is suggested that the observed hypersensitivity of hind ends may be due to the newly-formed pellicle being more permeable to acid than the original cell boundary. As a hind end invariably swims with the cut surface in front, the first part to come into contact with the acid is the newly-formed pellicle, and comparatively great permeability of the latter would tend to cause the avoiding reaction to an abnormally low concentration of acid.

An early attempt to account for the spiral swimming path and rotation on the long axis during an avoiding reaction in the infusoria was made by Jennings (1902), who stressed the importance of the strong oral cilia, and regarded the movement as due to the shape of the body. Pearl (1900), working on *Colpidium*, and Pütter (1900), on *Stylonychia*, came to similar conclusions; while Schaeffer (1920) speaks of the correlation between the axis and the spiral path of the organism. Further experiments forced Jennings (1906) to abandon his original theory and to attribute the type of movement to the "variable direction of contraction of the general body cilia." Bullington (1925) found that ciliates possessing an oral groove swim with the typical spiral track, and that the position of a groove, when present, has no relation to the direction of the spiral, which is in some cases right-handed and in others left-handed. On the other hand Ludwig (1929) states that the normal spiral movement is produced by the aboral cilia beating more strongly than those of the oral surface. The experiments described above show that pieces of *Paramecium* possessing no oral cilia were seen to accomplish the type of movement typical of the whole animal, thus providing additional evidence to show that the spiral swimming track is not dependent on shape or on the action of oral groove cilia, but is produced by the co-ordinated activity of the body cilia.

V. SUMMARY.

1. The mode of swimming and reactions to acid of parts of *Paramecium* have been compared with the behaviour of the intact animal.
2. Hind ends are more sensitive to acid than fore ends, which in this respect do not differ from whole individuals.
3. Pieces lacking oral cilia swim spirally like intact animals.

REFERENCES.