CONTRIBUTIONS TO THE STUDY OF THE BEHAVIOR OF LOWER ORGANISMS

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649211708

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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BY

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PUBLISHED BY THE CARNEGIE INSTITUTION
OF WASHINGTON
1904

PREFATORY NOTE.

The investigations the results of which are herein set forth were carried out by the aid of certain grants from the Carnegie Institution of Washington. The author desires to express his deep sense of obligation for the aid thus rendered. The first five papers were prepared at the Zoological Laboratory of the University of Michigan, and were submitted to the Carnegie Institution for publication August 1, 1903. To the third paper some additions were made in February, 1904. The sixth and seventh papers were prepared at the Naples Zoological Station, while the writer was acting as Research Assistant of the Carnegie Institution, and were transmitted for publication in January and March, respectively, 1904.

LIST OF PAPERS.

FIRST PAPER.

REACTIONS TO HEAT AND COLD IN THE CILIATE INFUSORIA.

REACTIONS TO HEAT AND COLD IN THE CILIATE INFUSORIA.

To explain the movements of organisms toward or from a source of stimulus, we find given almost universally in one shape or another a certain general formula. This is the schema set forth, with unessential variations, by Verworn (1899, pp. 500–502) for the orientation of a ciliate or flagellate infusorian to a one-sided stimulus, and by Loeb (1897, pp. 439–442) for the tropisms of organisms in general. Essentially, the schema is as follows: An agent acting upon the organism from one side causes the locomotor organs of that side to contract either more strongly or less strongly than those of the opposite side.

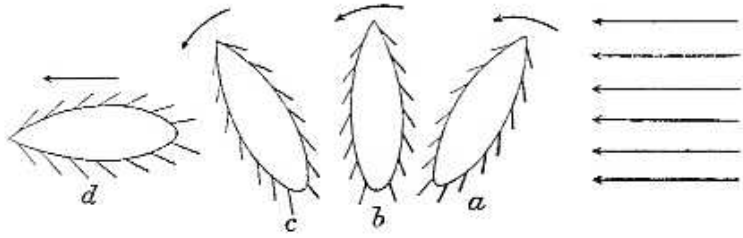

FIG. 1.*

In the former case (Fig. 1) the animal is turned away from the source of stimulus, till it comes into a position in which the motor organs of the two sides are similarly affected. Then progressing straight forward, it of course moves away from the source of stimulus (negative taxis or tropism). If the motor organs on the side most affected are caused to contract less strongly than those on the opposite side (Fig. 2)

*FIG. 1.—Diagram of a negative reaction of an organism, according to the tropism schema. The motor organs which act more effectively are shown more heavily drawn. The more pointed end is the anterior. A stimulus is supposed to impinge upon the organism *a* from the direction indicated by arrows; this causes the motor organs directly affected by the stimulus to beat more strongly, as indicated by the darker shade. The result is to turn the anterior end in the direction indicated by curved arrows. The organism thus occupies successively the positions *a*, *b*, *c*, finally coming into the position *d*. Here the motor organs of the two sides are equally affected by the stimulus, hence there is no further cause for a change of position. The usual forward motion of the organism now takes it away from the source of stimulus, as indicated by the straight arrow at *d*.

the organism is necessarily turned with anterior end toward the source of stimulus; then its usual forward movements take it toward the source of stimulus (positive taxis or tropism). Loeb lays especial stress on the *direction* from which the stimulus comes, as it is this that determines which side shall be most strongly affected by the stimulus; otherwise the theory as he sets it forth is essentially like that held by Verworn. Both these authors apply this schema to the movements of organisms to and from many sorts of stimuli, making it a general formula for *taxis* or *tropisms*. Verworn says (1899, p. 503):

> Thus the phenomena of positive and negative chemotaxis, thermotaxis, phototaxis and galvanotaxis, which are so highly interesting and important in all organic life, follow with mechanical necessity as the simple results of differences in biotonus, which are produced by the action of stimuli at two different poles of the free living cell.

In the present series of papers the writer proposes to examine the behavior of a number of lower organisms, in order to determine

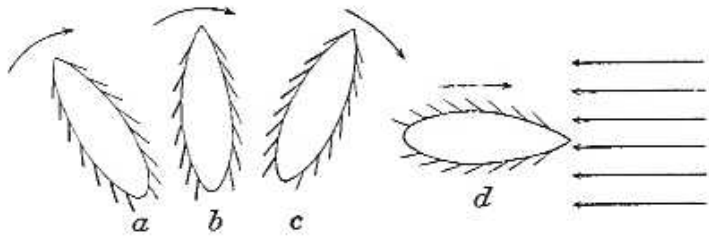

FIG. 2.*

whether the reactions to the usual stimuli take place in accordance with this tropism schema or not, and if not, to determine the real nature of the reaction method. In this first paper we shall deal with reactions to heat and cold.

In his recent series of papers on the reactions of infusoria to heat and cold, Mendelssohn (1902, *a*, *b*, *c*) develops a theory of thermotaxis in accordance with the general theory of tropisms, above set forth. In an earlier paper (Jennings, 1899) the present author, on the other hand,

*FIG. 2.—Diagram of a positive reaction, according to the tropism schema. A stimulus coming from the direction indicated by the arrows to the right acts upon the organism *a*. The effect of the stimulus is to cause the motor organs directly affected by it to contract less strongly, as indicated by the lighter shade on the right side of *a*. As a result the animal is turned as shown by the curved arrows, occupying successively the positions *a*, *b*, *c*, *d*. At *d* the stimulus affects the two sides alike, hence there is no cause for further turning, and the usual forward movement of the organism takes it toward the source of stimulus.