

## TROPISTIC REACTIONS OF CERIANTHUS MEMBRANACEUS.

By MARY MITCHELL MOORE.

(From the Zoological Station, Naples, Italy.)

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### *General Description.*

*Cerianthus membranaceus* is an actinian that lives in the sand. Only the oral part bearing the tentacles extends above the sand, while the rest of the animal remains below, protected by a mucoid sheath which is smooth within but covered with adhering sand without. If the animal is disturbed, as by a touch directed below the tentacular ring, the tentacles and body withdraw so that the whole animal is hidden under the sand. The stimuli which cause retraction are direct sunlight, strong touch, and excessive feeding. The oxygen content of the water appears to have no influence upon retraction or expansion, but a small current of water hastens re-expansion. Lack of food, darkness (or diffuse daylight) favor expansion also. At the aboral end is a small pore, and the end of the outer protecting sheath is always open, possibly allowing water currents to pass through the animal. Loeb<sup>1</sup> describes accurately the formation of a new sheath by mucous secretion after the animal has been removed from the sand and carefully slipped out of its sheath. The whole surface of the body, except tentacles and a small area near the oral disk, actively secretes mucus in which sand particles are soon caught. When the animal is first removed from the sand, the longitudinal (inside layer) muscles contract, the tentacles become limp, and the body hard so that its appearance is that of a short stubby brush. This contraction forces the water out of the body cavity, consequently when the animal relaxes directly after this it has lost all turgor and resembles an empty sac. If, however, it is

<sup>1</sup>Loeb, J., Studies in general physiology, Chicago, 1905, 164.

left undisturbed, it fills with water, regains turgor, and soon burrows into the sand and spreads out its tentacles as before. The animals used in our experiments varied between 3 and 15 cm. in length.

*Stereotropism.*

Loeb<sup>2</sup> made the observation that *Cerianthus* would dig its way under small blocks of lead placed upon the sand. If instead one places a glass tube upon the glass bottom of the aquarium so that the foot of the animal (which has been removed from its sheath) just touches the open end of the tube, the animal is forced by its positive stereotropism to crawl into the tube, and spread out its tentacles normally. If the tube is too small the animal will enter only part way. If the tube is larger than the animal, then it expands its diameter and shortens its length so that the whole lateral surface of its body is touching the inner surface of the tube. I found that as long as they were fed regularly these animals remained indefinitely long in the tubes open at both ends.

*Geotropism.*

The glass tube containing *Cerianthus* lies horizontally on the floor of the aquarium. The oral disk bearing its rows of tentacles extends nearly vertically upward, while the foot touches the lower surface of the tube. This condition exists also in the dark, so that we may speak of the oral end as being negatively, the foot, positively geotropic. Specimens of *Cerianthus* in glass tubes retain this position even when placed on the sand, unless the aboral end be tipped down slightly, when the animal burrows into the sand, leaving its glass house behind. If a *Cerianthus* in a glass tube be suspended midway in the water so that no part of the animal touches the aquarium, the oral end extends upward, and the foot touches the lower surface of the tube or hangs down a very little beyond the tube. If, however, the tube is not long enough to support the foot, then both ends of the animal hang down, and tentacles are limp (Fig. 1). Such

<sup>2</sup>Loeb,<sup>1</sup> p. 158.

an animal will regain turgor only when the whole surface of the body is touching some solid object.<sup>3</sup>

Stereotropism in *Cerianthus* may be counterbalanced by the reaction to gravity. For instance, a specimen will crawl upward into a tube placed at 35° with the horizontal, although instead of the usual  $\frac{1}{2}$  hour it takes 4 to 5 hours. In such a position the animal will expand its tentacles and eat. But if a *Cerianthus* be suspended oral end down at an angle of 45°, the two tropisms are nearly balanced. One specimen so suspended remained expanded in this position 1 day, but on the 2nd day the foot reacted to gravity by turning back on the body and boring downward inside the tube (Fig. 2). The

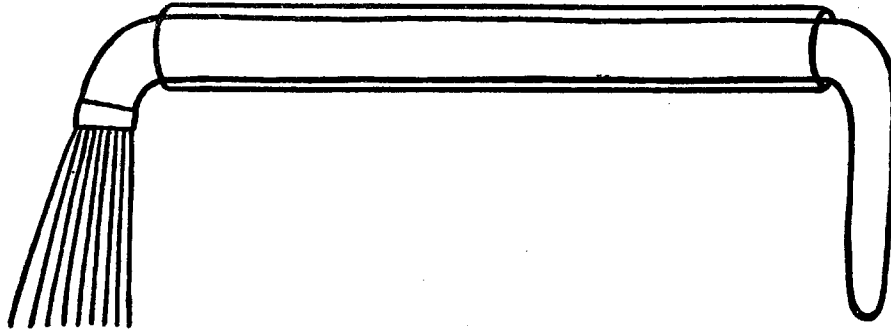


FIG. 1. *Cerianthus* in which only the middle part of the body is in contact with a surface; head and foot hang freely in the water of the aquarium. Note complete loss of turgor.

oral end extended horizontally and tentacles remained expanded for 2 days, during this time taking food as usual. On the 3rd day the oral end and tentacles were withdrawn into the tube, and in  $1\frac{3}{4}$  hours the position of the animal was reversed and normal orientation with respect to gravity was regained. The movement was slow and

<sup>3</sup> When specimens are suspended in tubes the function of the foot in boring holes may be observed. The tip of the foot follows the inside surface of the glass tube in a clockwise direction, in such a way that the body becomes twisted like a corkscrew. At intervals the longitudinal muscles of the body contract, so that if the animal were boring in the sand this would have the effect of drawing the oral end farther under the sand. But the suspended animals only remain hanging in the glass tubes. If the foot is cut off the *Cerianthus* is no longer able to dig a hole but remains lying on the sand in a more or less limp condition.

continuous, apparently being accomplished by ciliary action. Therefore, the critical angle for stereotropism in *Cerianthus* is about  $45^{\circ}$ .

*Heliotropism.*

Haime<sup>4</sup> observed that the direct rays of the sun cause complete retraction of *Cerianthus* and that these animals emerge in sunlight but to a slight extent. In summer, in the port of Mahon, he says that

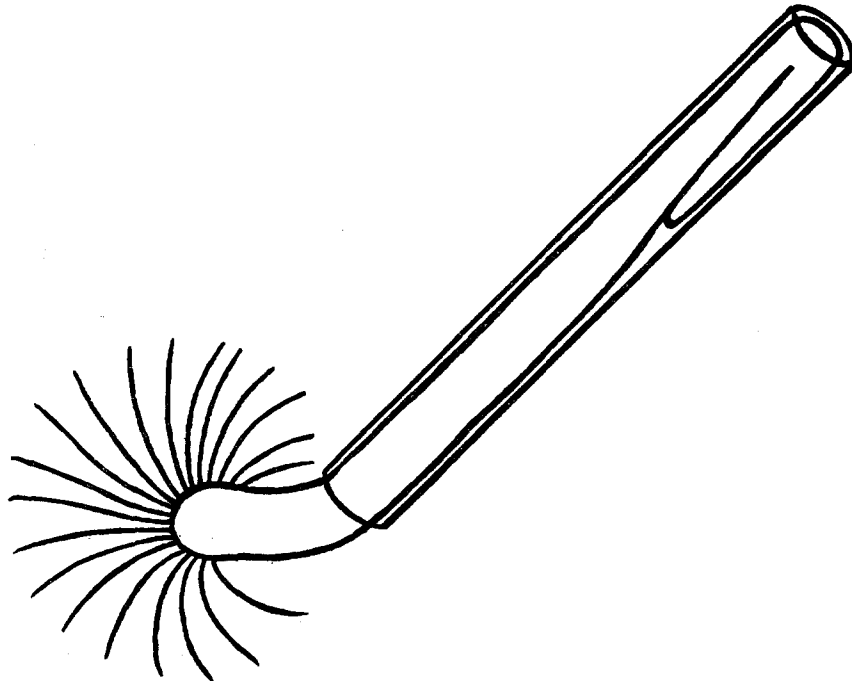


FIG. 2. Tube containing *Cerianthus* suspended at an angle of  $45^{\circ}$ , showing beginning of movement of the foot downward in response to gravity.

*Cerianthus* remains under the sand until the sun goes down. He put specimens in tubes of cloth for observation and also studied their embryology, but reports that he did not discover any nervous system.

Nagel<sup>5</sup> (1894) states that if *Cerianthus* has been kept in the dark and is brought into bright daylight the oral disk retracts. C.

<sup>4</sup> Haime, J., *Ann. sc. nat. zool.*, 1854, i, series 4, 341.

<sup>5</sup> Nagel, W. A., *Arch. ges. Physiol.*, 1894, lvii, 495.

Hess<sup>6</sup> in 1913 published photographs showing how *Cerianthus* turns toward the light of an electric bulb, but he did no quantitative experiments.

Light has the general effect of increasing tone. Only in the dark do the animals reach a stage of complete expansion of body and tentacles, the length of the body protruding from the tube or burrow being sometimes as much as three times the length attained in ordinary daylight. When the animal is extended in the dark room it is very sensitive to the light. The oral disk turns toward the electric light in less than a minute, the final orientation with a strong light being such that symmetrical tentacles are equally illuminated, since they are struck by the light at equal angles. This means that the longitudinal axis of the exposed part comes to rest in a position parallel to the path of the rays of light.

The following experiments were made with a view to determining the relation of the intensity of the light to (1) exposure time and (2) reaction time. The animals used in these experiments were those living in glass tubes. This enabled the experimenter to move them about without causing the animals to draw in their tentacles, thus avoiding delay in the work. The animal to be tested was put into a rectangular glass dish with parallel sides and containing fresh sea water. The dish was placed on a table in the dark room, and an hour allowed for necessary dark adaptation to take place in the animal. Between exposures the animal was kept in the dark for  $\frac{1}{2}$  hour. The electric bulb was enclosed in a black box with a rectangular slit covered with a black paper shutter which could be raised or lowered. The time was measured with a stop-watch. The intensity of the light was varied by changing the distance of the light from the animal.

Measurements were made of the amount of light necessary to cause the heliotropic reaction (exposure time). The animals were illuminated for a measured length of time with a light of known intensity, and under a red glower it was observed whether the animal turned the oral disk toward the light. If the amount of light was sufficient to cause turning, the time of exposure was lessened until by successive trials an exposure was found which was just sufficient to cause the animal to turn.

<sup>6</sup> Hess, C., *Zool. Jahrb., Abt. allg. Zool. u. Physiol. Tiere*, 1913, xxxiii, 387.

After the exposure time a few seconds elapse before the animal turns which may be called the latent period. The total reaction time was considered to be the time which elapsed between the instant when the beam of light was thrown on the animal, and the instant when the ends of tentacles began to move. The total reaction time is, therefore, the sum of the exposure time and the latent period. The experiments were repeated on three animals and averages of at least six readings at each intensity are given.

Table I shows that in *Cerianthus* the relation between the exposure time and the intensity of the light may be expressed mathematically by the equation  $K = I \times T$ , in which  $I$  = the intensity of the light,  $T$  = the exposure time, and  $K$  is a constant. This equation expresses the Bunsen-Roscoe law.

TABLE I.  
*Relation between Intensity of Light, and the Time of Exposure Necessary to Produce Heliotropic Turning.*

Relative intensity.*	Average presentation time (obs.).	Presentation time (calc. $K = 0.46$ ).	$I \times T$ .
	<i>sec.</i>	<i>sec.</i>	
1.00	0.8	0.4	0.8
0.25	2.6	1.8	0.65
0.11	4.1	4.1	0.45
0.062	7.6	7.4	0.47
0.04	11.5	11.5	0.46
0.027	(No turning.)		

\*8900 candle meters were taken as unity.

The first two observed values of  $K$  are large, possibly because of the difficulty of accurately measuring small amounts of time with the crude apparatus at hand. Since, however, the last three values show such good agreement, the constant was taken equal to their average value.  $1/100$  actual intensity is plotted against observed exposure time in Fig. 3, Curve A.

Total reaction time is plotted against  $1/100$  actual intensity in Curve B. The theoretical curve is of the same type as that in Curve A, namely a hyperbola of the type  $XY = K$ . If the point 10,0 is taken as the origin, and intensities are taken as  $1/100$  their actual value in meter candles, then the equation is  $I \times (t + 0.25) = 28.29$ . Abscissæ show actual reaction time, and ordinates  $1/100$  intensities.

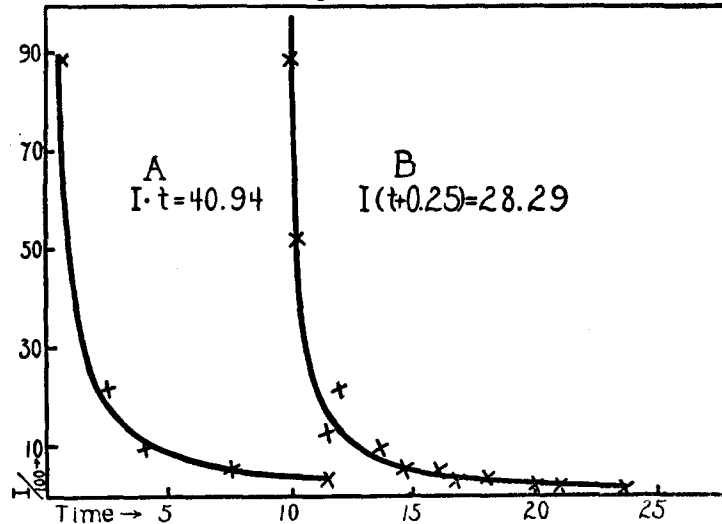


FIG. 3. Curve A shows the relation of exposure time to intensity. Intensity 89 is taken as unity, so that the constant =  $(0.46 \times 89) = 40.94$ . The curve follows the equation  $I \times t = 40.94$ . Curve B shows the relation between reaction time and intensity. The curve follows the equation  $I \times (t + 0.25) = 28.29$ , if the point 10,0 is taken as the origin, and 1/100 actual values of intensities are used.

#### CONCLUSIONS.

1. *Cerianthus* shows stereotropism and if fed regularly will remain indefinitely in glass tubes. The animal retains turgor only so long as the entire surface of the body is in contact with the glass.

2. *Cerianthus* is positively geotropic as regards the foot and body. It will work upward into a glass tube suspended at an angle of  $35^\circ$  as a result of stereotropism, but if the tube is raised to an angle of  $45^\circ$  the foot turns back and the animal reverses its position in the tube so that foot is down, head, up. Thus at an angle of  $45^\circ$  stereotropism and geotropism very nearly balance each other.

3. Light increases the muscle tone of *Cerianthus*; this results in positive phototropism.  $I \times t = K$  where  $I$  is the intensity of the light,  $t$  is exposure time, and  $K$ , a constant, = 0.46. Where reaction time is considered,  $I(t + k) = K$ , in which  $I$  is intensity of light,  $t$  is reaction time,  $k = 0.25$ , and  $K = 28.29$ . The two equations prove the operation of the Bunsen-Roscoe law.

My thanks are due to Professor F. Bottazzi, director of the physiological section of the Zoological Station at Naples for giving me the facilities of the laboratory, and to Professor S. E. Brasefield, Professor of Applied Mathematics in Rutgers College, for assistance with the equations.