REVERSAL OF REACTION BY MEANS OF STRYCHNINE IN PLANARIANS AND STARFISH.

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Experiments on the Planarian, Bdelloura.

It has been shown that a single excitation at a median point in the earthworm elicits a shortening of the body anterior and a lengthening posterior to that point. Active extension of the body is produced by contraction of the circular muscles, and by inhibition of contraction of the longitudinal muscles of the body. This is a case of reciprocal innervation.[1] Further, it has been found that in the earthworm, just as in vertebrates, strychnine converts inhibition into excitation, thus causing upon stimulation a contraction of the longitudinal muscles, which results in a shortening posterior to the point of stimulation.[2]

Flatworms have, in addition to longitudinal and circular systems of muscles, transverse muscle fibers. These, with the circular muscles, cause an increase in length and decrease in width and thickness of the animal upon contraction, while the shortening and thickening characteristic of the quiescent position are necessarily associated with a contraction of the longitudinal musculature and a relaxation of their antagonists. This implies also reciprocal innervation.

In order to determine whether the nervous mechanism in flatworms is similar in its reaction to that of the earthworm, the following experiments were made with specimens of *Bdelloura*. This is a marine flatworm, ectoparasitic on *Limulus*. If an active individual is touched with an instrument such as a pair of forceps, it stops locomotion, shortens and thickens; *i.e.*, the longitudinal muscles contract and the circular and transverse muscles relax. In case the animals are first

[1] Garrey, W. E., and Moore, A. R., *Am. J. Physiol.*, 1915, xxxix, 146.

[2] Knowlton, F. P., and Moore, A. R., *Am. J. Physiol.*, 1917, xliv, 490.

strychninized by placing them for a few minutes in a solution of strychnine sulfate (1 : 10,000), mechanical stimulation produces the opposite effect; *viz.*, extreme extension and activity of the animal. The action of the strychnine is, therefore, to convert the inhibition of the transverse and circular muscles in the normal response into an excitation.

Experiments on the Starfish, Asterias forbesii.

Animals which orient themselves by means of contact sensitivity or stereotropism are in a state of motor equilibrium when their sensitive (ventral) regions are in contact with a surface. When this normal relationship is disturbed, as by putting the animal on its back, rapid and exaggerated body movements take place, until by chance, the specific receptors come into contact with a surface. Immediately from this point of contact excitatory and inhibitory impulses are sent out, the effect of which is to bring the animal without further waste effort into its normal orientation again.

In the starfish the tube feet are the stereosensitive organs. In an inverted specimen of normal vigor all the arms show initial twisting movements. From the arm whose tube feet first get into contact with a solid surface an excitatory impulse starts to an adjacent arm, as from A to B (Fig. 1), causing the latter to twist as so to face A ventrally and to attach its tube feet to the solid surface. Inhibitory impulses passing from A to D and from B to C cause D and C to release any initial hold they may have had and to bring E more or less passively with them, thus turning a somersault over A and B.[3]

This reaction evidently implies reciprocal innervation. If it were possible to reverse the functioning of this system by means of strychnine, we would have a still closer parallel with the corresponding mechanism in vertebrates. The similarity of the reaction of the earthworm to that of the vertebrate in this respect, is perhaps to be expected since the histology of the nervous system of the annelid also shows the synaptic structures. But because the nerve tracts of the starfish do not contain elements histologically similar, we must suppose that the strychnine acts, if it acts at all, on certain chemical elements of the neuron, rather than upon some special anatomical

[3] Moore, A. R., *Biol. Bull.*, 1910, xix, 235; *Am. J. Physiol.*, 1910, xxvii, 207.

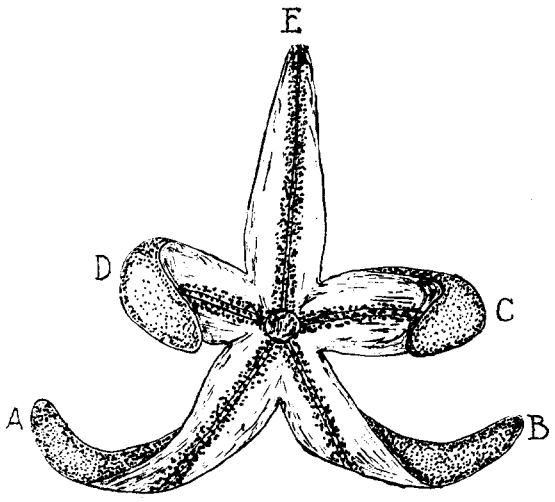

FIG. 1.

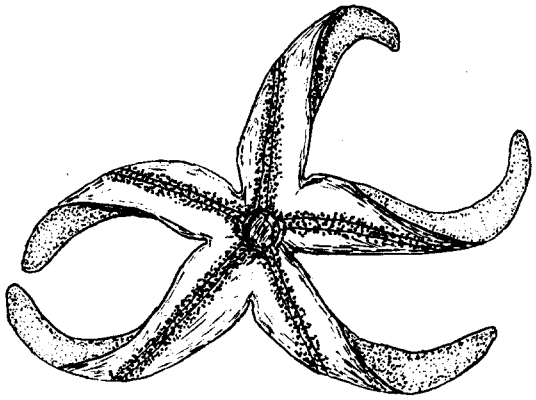

FIG. 2.

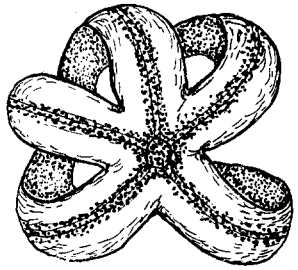

FIG. 3.

structure. It has been shown that strychnine causes hyperirritability in the starfish.[4] Proof that inhibition is reversed, *i.e.*, converted into an excitation, may be obtained by observing a strychninized starfish (strychnine sulfate 1 : 10,000) in its attempts to right itself. All of the arms take hold and retain their attachment to the bottom (Fig. 2), finally resulting in the knotted situation shown in Fig. 3. The usual inhibitory impulses which make the righting possible are no longer effective; all of the arms twist so that the tube feet maintain their hold on the bottom. Strychnine has reversed the normal inhibition.

SUMMARY AND CONCLUSIONS.

Two cases have been described, that of the marine planarian *Bdelloura* and that of the starfish *Asterias forbesii*, in which strychnine reverses reciprocal inhibition. These facts indicate that the nervous systems of these invertebrates function in a manner similar to those of the earthworm and vertebrates. Moreover, it would seem that strychnine acts upon some chemical component of the neuron which is always present in synaptic structures but which also occurs in the simpler neurons of lower forms. The fact that strychnine is without this characteristic effect on such forms as medusa and sea anemone, indicates that the nervous systems of the starfish and planarian have chemical affinities with the vertebrates which the cœlenterates do not possess.

[4] Moore, *J. Pharm. and Exp. Therap.*, 1916, ix, 167; *Proc. Nat. Acad. Sc.*, 1917, iii, 601.