THE FUNCTION OF THE BRAIN IN LOCOMOTION OF THE POLYCLAD WORM, YUNGIA AURANTIACA.

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As a result of his experiments on the polyclad worm, *Thysanozoon brocchii*, Loeb[1] concluded that spontaneous progressive movements were a function of the part of the body containing the brain. He suggests, however, that failure of spontaneous movement in decapitated *Thysanozoon* may be the result of chemical or physical constitution and that an alteration in the composition of the surrounding solution may cause the posterior half to show spontaneous movements.

The marine polyclad worm, *Yungia aurantiaca*, is favorable material for such studies and behaves similarly to *Thysanozoon* in that decapitated individuals no longer show progressive movements in sea water. Normal specimens of *Yungia* either creep about over surfaces by means of cilia and muscular contractions, or swim through the water using the two lateral halves of the body as swimming organs. Only forward locomotion is possible in this form. In starting to swim the animal bends the head and sides of the body ventrally. This is followed by an upward bending of the head and rapidly succeeding waves of dorsal and ventral flexion of the lateral halves, such waves beginning at the head on both sides and passing simultaneously to the posterior end. These movements exert a propeller-like action which drives the animal forward through the water.

The existence of two associated muscle groups which perform the swimming movements may be proven by selective stimulation of the respective motor elements. When either entire animals or decapitated pieces are put into strychnine sulfate solution, 1:100,000 in sea water,

[1] Loeb, J., Comparative physiology of the brain and comparative psychology, New York, 1900, 78, 79.

ventral flexion of the two lateral halves ensues, followed by rhythmically recurring contractions resembling the beating of a heart. Likewise, the dorsal musculature can be demonstrated by immersing the worms in nicotine solution 1:10,000 in sea water. In this case after 3 or 4 minutes the lateral halves bend dorsally, and decapitated pieces make spontaneous swimming movements.

The action of strychnine and of nicotine prove, therefore, that the body of *Yungia* apart from the head contains the locomotor apparatus necessary for progressive movement. It should be possible, then, to produce by means of proper stimulation progressive movement and swimming in decapitated pieces. This can in fact be accomplished in the following ways.

(1) By mechanical stimulation of the anterior median locus of decapitated pieces. Regular swimming movements of the sides occur as long as stimulation lasts. (2) By chemical stimulation of the motor elements. Phenol 1:25,000 in sea water causes decapitated specimens to swim through the water, the movements differing in no way from those of a normal worm except that they are slower. (3) By altering the ion ratio. Since all the locomotor elements requisite for spontaneous movements and swimming are present in decapitated pieces, it seems apparent that the failure of such pieces to make movements may be due to low irritability of the system. It was, therefore, attempted by the use of proper salts to bring about spontaneous movement in decapitated pieces. The experiments were successful in that spontaneous movements occurred when the pieces were put into solutions having an excess of Na and K ions over Ca and Mg. Actual swimming through the water did not take place, presumably owing to the injurious action of unbalanced salt solutions upon the tissues.

When the pieces of worm are put into pure NaCl or KCl solutions isosmotic with sea water (0.6 M) at once violent swimming movements begin and continue until the onset of disintegration. The latter happens in from 10 to 15 minutes. Both disintegration and swimming movements are inhibited by Ca and Mg ions in proper proportion. The following tables illustrate this point. The numbers indicate in each case the cubic centimeters of solution used.

NaCl	99	98	97	96	95
$CaCl_2$..........	1	2	3	4	5
Result.........	Movement.	Movement.	No movement.	No movement.	No movement.

NaCl..........	99	98	97	96	95
$CaCl_2$..........	1	2	3	4	5
KCl...........	1	2	3	4	5
Result.........	Movement in each solution.				

The action of Mg in antagonizing Na ions is shown by the following:

NaCl..........	98	96	92	84	76
$MgCl_2$.........	2	4	8	16	24
Result.........	Movement.	Movement.	Movement.	Slight movement.	No movement.

It thus requires about 30 molecules of $MgCl_2$ to inhibit the action of 100 $NaCl_2$ while only 3 molecules of $CaCl_2$ accomplish the same result. Consequently $CaCl_2$ is about ten times as powerful as $MgCl_2$ as an antagonist to NaCl. In a van't Hoff solution of the composition 100 NaCl + 2.2 KCl + 2 $CaCl_2$ + 12 $MgCl_2$ and in a solution composed of 100 NaCl + 2.2 KCl + 2 $CaCl_2$, the decapitated worms are entirely quiescent.

CONCLUSION.

Coordinated swimming movements in *Yungia* are not dependent upon the presence of the brain. The neuromuscular mechanism necessary for spontaneous movement and swimming is complete in the body of the animal apart from the brain. Normally this mechanism is set in motion by sensory stimulation arriving by way of the brain. The latter is a region of low threshold and acts as an amplifier by sending the impulses into a great number of channels. When the head is cut off these connections with the sensorium are broken, consequently peripheral stimulation does not have its usual effect. If, however, the motor nerves are stimulated directly as by mechanical stimulation of the median anterior region, then swimming movements result. Also if the threshold of the entire nervous mechanism is lowered by phenol or by an increase in the ion ratios $\frac{\text{Conc. Na}}{\text{Conc. Ca}}$ and $\frac{\text{Conc. Na} + \text{K}}{\text{Conc. Ca} + \text{Mg}}$ then again peripheral stimulation throws the neuromuscular mechanism into activity and swimming movements result.