

19, No. 10, pp. 317-334, one plate, two text-figures. February 13, 1920.

Professor Kofoid, the leading student of the Flagellata, in a brief but important paper, discusses convincingly the morphology and relationship of *Noctiluca*. The data and their bearing are well indicated in the author's summary, as follows:

1. *Noctiluca* is a tentacle-bearing dinoflagellate with a sulcus, girdle, and longitudinal and transverse flagella.

2. The sulcus is longitudinal and midventral. It includes the apical trough and the recessed oral pouch and cytostome.

3. The tentacle arises from its posterior end.

4. The girdle has hitherto been overlooked. It is a shallow trough at the left of the sulcus and at right angles to it. It is seen best in small individuals.

5. The longitudinal flagellum is reduced and lies within the oral pouch. The transverse flagellum is represented by the prehensile tooth at the proximal end of the girdle at the left of the base of the longitudinal flagellum. This organ exhibits structural undulations and spasmodic or rhythmical contractions.

6. Distention by hydrostatic vacuoles, with flotation replacing active locomotion, has led to degeneration of the flagella and their reduction in size, and to the almost complete disappearance of the girdle.

7. *Noctiluca* belongs in the Noctilucidae, a family of the tribe Gymnodynoidae, with *Pavillardia*, another tentaculate, naked, non-ocellate dinoflagellate.

8. There is no morphological justification of a separate order of flagellates to hold *Noctiluca*, such as the Cystoflagellata Haeckel.

9. The Cystoflagellata may be retained as thus emended to receive *Leptodiscus* and *Craspedotella* pending discovery of their affinities.

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SPECIAL ARTICLES

THE EFFERENT PATH OF THE NERVOUS SYSTEM REGARDED AS A STEP-UP TRANSFORMER OF ENERGY

THE properties of nervous tissue which fit it for its peculiar rôle in the animal economy

are given by Sherrington as (1) excitability (2) spatial transmission of impulses and (3) control of the liberation of energy in contiguous tissues. Pawloff and others have emphasized the rôle of the peripheral sense organs as energy transformers, since the energy of light or heat or sound is transformed, by appropriate mechanisms, to the energy of a nerve impulse. Lucas and Adrian's all or none hypothesis of nerve conduction calls attention to another aspect of the work of the nervous system as a transformer of energy. According to this hypothesis, the nerve impulse conducted by any single nerve fiber is at all times the maximum impulse which it is capable of conducting. The evidence in favor of this view appears to be steadily accumulating, although there are still conditions under which the energy relationships are not clear. The efferent paths of the nervous system appear to me to furnish additional confirmation of the general truth of the hypothesis.

Neurologists have frequently commented on the relatively few nerve fibers in the main motor tracts of higher animals, *i. e.*, the pyramidal tracts, as compared to the number of fibers in the ventral roots of the spinal nerves and the great mass of muscles to be activated. According to von Monakow, Redlich, Schäfer and others, fibers of the pyramidal tract do not end directly about the cells of origin of the motor nerves, but about some intermediate or intercalated cells in the spinal cord. Von Monakow has supposed that each of these intermediate cells comes into relation, through the branching of its processes, with more than one motor cell in the spinal cord. Furthermore, the axone of each peripheral motor nerve may branch on its way to its effector. There is a possibility, therefore, that each descending fiber in the pyramidal tract of the spinal cord may ultimately be able to actuate several terminal axones in the peripheral motor system. Suppose that one pyramidal fiber may, through the intercalated neurone, come into relation with three cells of origin of peripheral fibers,

and that each of these peripheral fibers, in its turn, is divided into two. These relationships may be indicated diagrammatically. One pyramidal fiber may, therefore, be represented

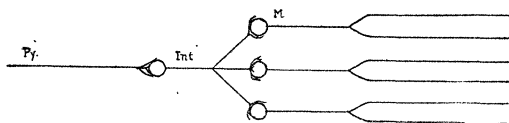


FIG. 1.

at the periphery by six branches of axones, each of which is in its turn capable of acting upon an effector. The energy, a , coming down the first fiber in the series, Py , is, according to the all or none hypothesis, the maximum which the fiber is capable of conducting. Similarly, the energy passing over the intercalated (*Int.*) fiber before its branching is also the maximum which it is capable of conducting. Suppose that it is equal to a . At the point of branching, the energy conducted along each branch must either be brought up to some quantity closely approximating a , or else it must fall to $a/3$. In the latter case, the energy passing over the proximal unbranched portion of the fiber M must either be brought up to the value a , or else in its turn be close to the value $a/3$. Going on out to the bifurcation of this fiber, there must again be a raising of the energy in each of the branches to some value closely approximating a , or else it must fall to a value $a/6$. There is little or no evidence that the energy of the nerve impulse falls off in any such degree in its passage from central system to periphery. The presumption is, therefore, that the efferent distribution path acts as a step-up transformer of energy, although the manner of its action is as yet unknown. It should be stated here that the nerve fiber itself furnishes the energy, derived in some manner as yet unknown from its own metabolic processes, and that there is, in all probability, no change in voltage at the expense of the amperage, as in the electrical transformers with which the physicist is familiar.

Reference to Ranson's¹ diagram of the sympathetic system will show that the same considerations apply there. In fact, the diagram given in this paper was suggested by Ranson's diagrams.

One more link in the scheme of the step-up transformer may be what Langley has called the receptive substance, interposed, chemically if not histologically, between the motor end plates and the contractile substance in muscle. It is certain that there is a great increase in the energy of a muscle contraction as compared with the energy of the nerve impulse, which, starting in the central system, finally evokes the muscle contraction at the periphery. It seems reasonable to suppose, in the light of our present knowledge, that the efferent nerve path is a part of this transformer system.

Such general relationships of the energy of the response to the energy changes in the processes preceding the response have long been recognized. Balfour Stewart² (p. 163) remarks: "We have seen that life is associated with delicately-constructed machines, so that whenever a transmutation of energy is brought about by a living being, could we trace the event back, we should find that the physical antecedent was probably a much less transmutation, while again the antecedent of this would probably be found still less, and so on, as far as we could trace it." We should recognize, however, that such relationships have a limit in the living organism. Otherwise, we would arrive at perpetual motion.

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ON SPIRAL NEBULÆ

ONE of the privileges of the vacation is the opportunity of making one's own tea in one's own vessels. I did so recently, aided by a deep precipitation glass, g , with a lip, l , running far down the sides. On stirring the

¹ Ranson, S. W., 1918, *Journal of Comparative Neurology*, Vol. 29, p. 306.

² Stewart, Balfour, 1874, "The Conservation of Energy," New York, p. 163.