6908

Fiber Distribution in Optic and Saphenous Nerves.

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"Either the nerves themselves may communicate impressions different in quality to the sensorium, which in every instance remains the same; or else the vibrations of the nervous principle may in every nerve be the same, ... ", etc.[1]

"The results therefore fail to support the view (of Bishop and Heinbecker), that there are fiber types distinguishable by time to maximum, conduction rate, irritability and refractory period. . . . . Since it is possible to recognize differences in the physiological responses of individual axons, it is no longer incumbent upon physiologists to adhere to the doctrine of specific nerve energies."[2]

The latter quotation seems to present a third alternative to those recognized by Johannes Müller in the former, a formulation of his doctrine of specific nerve energies. Müller emphasized the specificity of the whole sensory pathway, being unable to decide whether the differences in sensory pathways were assignable to qualitative differences in the responses of the nerve fibers concerned, or to differences in their terminal connections. The possibility apparently never occurred to him that the *same fiber* mediated different sensations by means of *impulses* of *different character,* which appears to be the interpretation placed by Blair and Erlanger on the variations they observe to take place in the responses of one and the same nerve fiber. Other suggestions, such as that of Adrian, that repetitive response of a fiber to its sense organ is a factor in sensation, or that the pattern in which different fibers respond is significant, are only elaborations of Müller's hypothesis, and the possibility which Blair and Erlanger propose offers the first escape since medieval philosophers debated the question in an experimental vacuum, to physiologists chafing at the restrictions of Müller's dictum.

Before availing oneself of this avenue of escape, however, one would like to know, in relation to nerves dissected out of the body, and subjected to experimental procedures of stimulating and record-

[1] Müller, Johannes, *Physiology,* 1844, (Engl. trans. 1848, 1059).

[2] Blair, E., and Erlanger, J., PROC. SOC. EXP. BIOL. AND MED., 1933, **30**, 728.

ing by means of complicated mechanical arrangements, what fortuitous factors might themselves cause variations in the responses of individual axons. One might also wonder whether such variations as are observed in excised axons do in fact cause demonstrable variations in sensory effect in animals or man. The other differences between the experimental results of Bishop and Heinbecker and of Blair and Erlanger are quantitative ones, and if one reads "groups" in place of "types" in the objection cited above, these would be unimportant. But Blair and Erlanger's present hypothesis still fails to account for the finding that stimulation of the first group of axons in animal or human skin nerves causes sensations of touch, and stimulation of a quite different group of axons causes sensations of pain.[3]

Further evidence is now at hand, concerning the same structure that Müller used to illustrate his thesis, the optic tract. Heinbecker, Bishop and O'Leary, in various studies of sensory nerves [3, 4, 5], have pointed out correlations between the physiological properties of groups of axons and, on the one hand, the histological structure of these fibers, and on the other, the function served by them in the body. These sensory nerves have now been compared with the optic nerve. The latter in the frog exhibits 3 major groups of potentials separating out on conduction, with rates of 18, 4, and 0.5 meters per second respectively. In the rabbit, the optic nerve being recorded in the body with blood supply, the first 2 groups correspond, with rates of 50 and 20 meters per second respectively, and a third smaller group, at about 3 meters per second, appears not to correspond precisely with the third group in the frog. Comparing this situation with that in the mammalian saphenous nerve, where a first group of fibers mediates sensations of touch and joint and muscle sense, and a second mediates pain and temperature, the first group, at least, in the optic nerve, excites impulses that give rise to action currents in the optic cortex, and no sensation except vision is known to arise from optic nerve stimulation.

The physiological properties of the corresponding groups of fibers in the saphenous and optic nerves are quite similar, but the sensations aroused by their activities are presumably different. It

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[3] Heinbecker, P., Bishop, G. H., and O'Leary, J., *Arch. of Neur. and Psychiat.*, 1933, **29**, 771.

[4] O'Leary, J., Heinbecker, P., and Bishop, G. H., PROC. SOC. EXP. BIOL. AND MED., 1932, **30**, 302.

[5] Heinbecker, P., Bishop, G. H., and O'Leary, J., PROC. SOC. EXP. BIOL. AND MED., 1932, **30**, 304.

would thus be improper to infer that one type of fiber always performed the same function everywhere in the body, and no such claim has been presented. On the other hand, the demonstration that stimulation of fibers with one set of properties has sensory effects determined mainly by their central connections, leaves the alternative proposed by Blair and Erlanger at best a subsidiary one, and leaves it possible for physiologists to adhere with some degree of fortitude to the doctrine of specific nerve energies.

6909

Asphyxia of the Frog's Kidneys.

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Urine formation was measured in normal frogs by repeatedly weighing individuals whose cloacae were bound for a known period of time and later unbound. It was observed that in the absence of oxygen no urine formed. Even when diuresis was favored, by subcutaneous injection of water or 1% urea solution, no urine reached the bladder. When the breathing was interrupted by appropriate pithing or anesthesia the same inhibition of urine formation occurred, provided the frogs were kept at temperatures (20° to 27° C.) high enough so that oxygen was not adequately supplied to the blood through the skin. After 2 hours of asphyxia, anuria persisted for 1 to 4 hours, until such time as the frogs resumed breathing. As the frogs recovered, extra urine was formed until the initial net body weight was reestablished. The heart's circulation was maintained throughout. Two alternatives presented themselves: did (glomerular) fluid cease to form, or was the fluid that formed completely reabsorbed (by the tubules)? If no fluid formed was the circulation inadequate, or was oxygen indispensable for the excretion of water?

The exposed kidneys were examined in pithed frogs that were lying in a closed gas chamber. Blood invariably ceased to flow through the glomeruli within 1 minute after deprivation of oxygen. Often the glomeruli emptied completely of blood, and the whole kidney became paler. No corpuscles and hence presumably no plasma flowed through the glomerular capillaries until 1 minute