ticipated. Measurements of the wave length show that this change is of the order of one-half meter.

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Heterochronism in the Single Fiber Nerve-Muscle Complex of the Retrolingual Membrane.

HARRY GRUNDFEST. (Introduced by D. W. Bronk.)

From the Eldridge Reeves Johnson Foundation for Medical Physics, University of Pennsylvania.

A series of measurements has been made on the excitability of the single muscle fiber preparation in the retrolingual membrane of the frog's tongue. The relation between liminal intensity and stimulus duration has been studied with the direct excitation of normal and curarized fibers and also with indirect stimulation through nerve fibers lying in the membrane. In many experiments it has been possible to carry out all 3 types of measurements while observing throughout the response of the same single muscle fiber.

The preparation is made according to the method described by Pratt,[1] which permits the use of transilluminated membranes with intact circulation. Stimulation has usually been by condenser discharges. The stimuli are applied through a localized cathode which is a capillary tube having an opening 20-80μ in diameter and which is filled with Ringer's solution.

These experiments were carried out to test the validity of Lapicque's[2] "law of isochronism" that transmission of excitation from a nerve to its muscle is possible only when the "chronaxies" of the 2 tissues are equal or differ by no more than a ratio of 1:2. That a block in transmission produced by drugs is due to an overstepping of this ratio. In particular, a curari block is supposedly due to an increase in the chronaxie of the muscle.

In the present experiments it has been found that the nerve fiber always has chronaxies from 2-8 times smaller than does the muscle fiber. The chronaxie of the muscle fiber does not change upon curarization. The values of the chronaxies range from about 0.03 to 0.06σ for the nerve and from 0.1 to 0.3σ for the muscle fiber. Furthermore, it has been possible to obtain compound curves of the

[1] Pratt, F. H., *Am. J. Physiol.*, 1930, **93**, 9.

[2] Lapicque, L., *L'Excitabilité en fonction du temps.*, 1926.

general type described by Lucas[3] and Rushton[4] but, of course, with time values entirely different from theirs and corresponding with those given above. Since stimulation of the nerve produces a response in the entire motor unit, while on direct stimulation only the one muscle fiber responds, the 2 types of response appear entirely different to the observer. The discontinuity in the compound curve is therefore unambiguous. Because of this fact, it is also possible to obtain the suppressed branches of the 2 individual curves.

These results are in conflict with the theory of isochronism expounded by Lapicque. On the other hand, they are in agreement with the view held by Lucas and by Rushton that the excitable substances of nerve and muscle are different and that this difference manifests itself in a condition of normal heterochronism. Such heterochronism can also be demonstrated in the membrane preparation which is not covered with Ringer's solution and which is stimulated with silver-silver chloride wire electrodes. Consequently, Lapicque's[5] latest objections to the view of Lucas and of Rushton disappear.

A more serious conflict seems to exist between my data and those of Moore and Brücke[6] which appeared after the above experiments were finished. They found chronaxies of 2.5-70σ for retrolingual muscle fibers and 0.9-1.5σ for the hypoglossal nerve trunk. I have repeated their experiments using a Ag-AgCl wire anode running the length of the tongue and perpendicular to the fibers. The cathode has been alternately a coarse Ag-AgCl wire point electrode and the usual capillary electrode. In one experiment both nerve and muscle fibers have been stimulated and compound curves obtained successively with the different cathodes. Using the coarse wire cathode, the chronaxie of the nerve fiber was 0.1σ and of the muscle fiber 2.1σ. With the capillary electrode, the chronaxies became 0.04σ and 0.12σ, respectively. The difference between my results and those of Moore and Brücke is, therefore, due to the effect of electrode size upon chronaxie which was found by Davis.[7]

No relation has been found between the chronaxie and the diameter of the muscle fiber in the region of the cathode. I cannot, therefore, agree with the attempt of Moore and Brücke to reconcile their data with Lapicque's theory. Both their experiments and mine

[3] Lucas, K., *J. Physiol.*, 1907, **36**, 113.

[4] Rushton, W. A. H., *J. Physiol.*, 1930, **70**, 317.

[5] Lapicque, L., *J. Physiol.*, 1931, **71**, 189, 219.

[6] Moore, A. R., and Brücke, E. Th., *Pflüg. Arch. ges. Physiol.*, 1931, **228**, 619.

[7] Davis, H. W., *J. Physiol.*, 1923, **57**, Proc. lxxxi.

seem to indicate that the theory of isochronism is not valid for the retrolingual preparation.

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Afferent Impulses from Single End Organs in the Carotid Sinus.*

D. W. BRONK AND G. STELLA.

From the Eldridge Reeves Johnson Foundation for Medical Physics, University of Pennsylvania.

Previous experiments revealed the general character of the discharge in the carotid sinus nerve and its relation to the pulse curve.[1] They showed a large burst of impulses resulting from the rapid rise in pressure at the beginning of systole followed by comparative inactivity during diastole. As the pressure increases the impulses become more continuous, extending throughout the heart cycle.

This work has been much extended and many observations have been made on the discharge of impulses from single end organs in the carotid sinus of the rabbit. Electrodes lead from the exposed nerve to a vacuum tube amplifier and thence to either a loud speaker or a Matthew's oscillograph for photographic registration. The procedure has been to divide the nerve in such a way that only one of the remaining fibers is in connection with a functionally active end organ. It is easy to decide when this stage in the dissection has been reached for either the sound furnished by the loud speaker or the photographic record from the oscillograph reveals a single series of regularly spaced impulses. The pulse curve has been recorded simultaneously by means of a Wiggers' manometer.

A typical record, Fig. 1, shows that with the beginning of the rapid rise in pressure the end organ starts to discharge impulses at a rate of about 55 a second, which then decreases as the pressure falls. The duration of this discharge in the heart cycle varies largely from one preparation to another and is obviously a function of the threshold of the end organ, the mean blood pressure and the form of the pulse curve. The first condition is well illustrated by preparations in which there are 2 or 3 active fibres remaining. In such cases one commonly finds one of the end organs continuing to function later in the cycle than the others.

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[1] Bronk, D. W., PROC. SOC. EXP. BIOL. AND MED., 1931, **28**, 1014.