7023 P

A Possibility of a Sympathetic Innervation of the Fish Heart.

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The heart activity in all vertebrates is regulated by the nervous system and in the phyla above the fishes the heart is under the control of augmentor and inhibitory nerves. In the Teleost fishes there is an abundance of evidence that the vagus exhibits a powerful control over the heart. McWilliam,[1] Mills,[2] Bottazzi,[3] Armstrong,[4] and Brinley[5] have shown that the hearts of various fishes can be arrested either by direct or reflex vagal stimulation. On the other hand, there is no positive evidence that the heart of the Teleost fishes is innervated by the sympathetic system. Bottazzi[3] found that stimulation of the sympathetic system produced no effect on the heart rate. Brücke[6] stated that there is no evidence that the fish heart is controlled by accelerator fibers. However, Izquierdo[7] has shown that the heart of the shark, *Scyllium,* is under the control of the vagus and sympathetic nerves much the same as in the other cold blooded vertebrates.

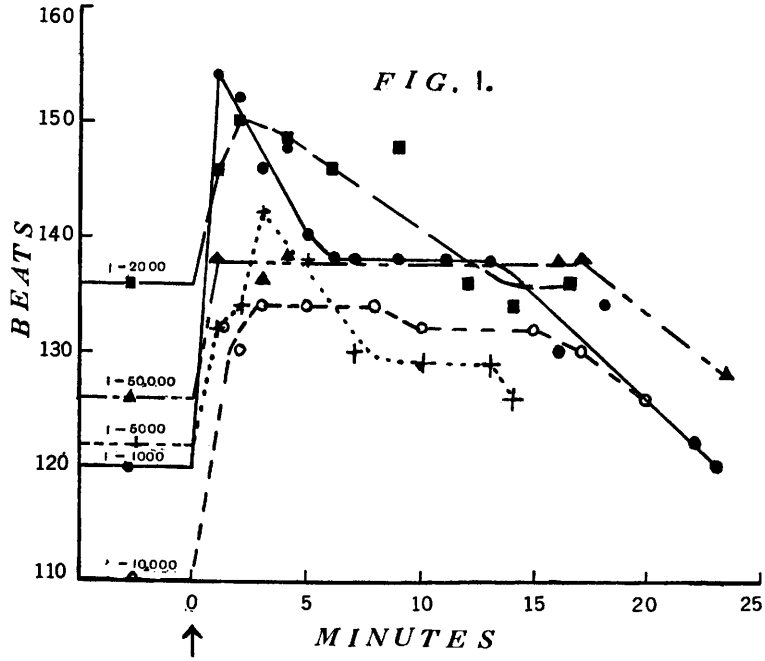
The work of Izquierdo opens the question as to whether or not there is a sympathetic innervation of the Teleost heart. In connection with a study on the effect of drugs on the fish heart, a study was made on the action of substances known to stimulate the sympathetic system of higher vertebrates, on the embryonic and adult fish heart, to determine if the cardio-regulator nerves contain accelerator fibers. It is realized that no drug is strictly specific in its action on the nerves of the cardiac apparatus but it is believed that adrenalin and nicotine in proper concentrations approach this condition to a fair degree. This paper is concerned only with the action of adrenalin on *Fundulus heteroclitus* embryos.

A minute droplet of adrenalin chloride, from 1 part in 1000 to 1 in 50,000 distilled water was injected into Fundulus embryos (free from chorion) anterior to the vitalline arteries. The imme-

[1] McWilliam, J. A., *Proc. Roy. Soc. London,* 1884, **38**, 31.
[2] Mills, T. W., *J. Phy.*, 1886, **7**, 82.
[3] Bottazzi, F., *Cent. für Physiol.*, 1901, **14**, 665.
[4] Armstrong, P. B., *J. Exp. Zool.*, 1931, **58**, 43.
[5] Brinley, F. J., *Phy. Zool.*, 1932, **5**, 527.
[6] v. Brücke, E., *Winterstein's Hand. der vergl. phy.*, 1925, **1**, 1007.
[7] Izquierdo, J. J., *J. Phy.*, 1930, **69**, 29.

diate contraction of the melanophores on the dorsal surface of the embryo was a positive criterion of a successful injection. Injections were made into embryos at daily intervals from 4 days until hatching. Controls were conducted by injecting distilled water into the embryos and in no case did any change occur in the rate of contraction except when large amounts were given. The rate of cardiac contractions was determined by counting the number of beats per minute before and after injection of the drug.

Young embryo. Injections into embryos from 4 to 7 days old inclusive, do not produce any change in the rate or rhythm of the heart. This indicates that adrenalin has no visible effect on the rate of contraction of the embryonic cardiac muscle.



Graph showing the acceleration in the rate of heart beat following the injection of adrenalin chloride into Fundulus embryos 8 to 13 days after fertilization. Injections made at the time indicated by the arrow. The number of beats per minute is plotted as the ordinate and the abscissa indicates the time in minutes after injection.

Older embryos. Fig. 1 shows the results obtained by injecting adrenalin into embryos 8 to 13 days old inclusive. The heart of embryos 12 to 13 days old stops for several seconds immediately after injection which is due to a reflex stimulation of the vagus. Following this arrest and in all other cases the heart rate quickly

increases 10 to 20% above the rate prior to injection and gradually returns to its initial value. This marked acceleration seems to indicate that the heart is either innervated by augmentor nerves on the eighth day after fertilization or that the cardiac muscle of the older embryo is decidedly different physiologically from the younger embryos as no effect of the drug is shown on the cardiac muscle prior to the 8th day of incubation.

To test the above hypotheses, adrenalin was injected into embryos which had previously been immersed for 30 minutes or longer in nicotine solution, pure alkaloid 1 part in 1000 parts of 5/8 normal (isotonic) NaCl solution. Nicotine in general is considered to be a sympathetic ganglionic depressant and in this concentration nicotine did not produce any marked action on the contraction of the embryonic heart muscle.

The results of these experiments show that injection of adrenalin after nicotine does not produce any significant acceleration in the cardiac rhythm. Therefore, it seems apparent that the acceleration in rate of the older embryos after adrenalin injection is due to a stimulation of the accelerator fibers and not to a direct action on the cardiac muscle.

7024 C

Transudation Through Living Membranes.

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Gunn[1] has devised a mechanical system for transuding liquids through living membranes. The regulation and maintenance of a definite negative pressure in this system is based upon the method of Wade and Merriman[2] employing a variable air gap. Using this apparatus, Gunn tried the effect of the transudation of caffeine citrate and of Eschis venom on rabbit mesentery. The results were negative in that no change in rate was observed with these substances when compared with the rate obtained with Locke's solution itself.

The apparatus has been simplified and improved, and in its final form provided for a complete glass assembly. (Fig. 1.) Using this improved apparatus I have carried out experiments to determine

[1] Gunn, J. A., *J. Physiol.*, 1931, **71**, 412.

[2] Wade and Merriman, *J. Chem. Soc. London*, 1911, **99**, 984.