nected with the taking of food, is hardly to be expected to be among the results of stimulation of starving cells.

In studying the effects of drugs it will be useful to consider the relation of these various effects in order to understand the special mode of action of the agent employed.

By these observations we have also obtained indications of the ways in which cells can be placed in different states of activity, so that, by the administration of drugs at various times after a meal, we can study more accurately what accelerating, restraining, or otherwise modifying, influences the drug may have.

We have been driven to consider, incidentally, some other problems, such as the relations which exist between contractility and secretory activity, but such things cannot be considered fully in this communication.

V. "On the Electromotive Phenomena of the Mammalian Heart." By W. M. Bayliss, B.A., B.Sc., and Ernest H. Starling, M.D., M.R.C.P., Joint Lecturer on Physiology at Guy's Hospital. (From the Physiological Laboratory, University College, London.) Communicated by E. A. Schäfer, F.R.S. Received October 23, 1891.

(Abstract.)

Methods of Research.—The heart being exposed, two points of its surface were connected by means of non-polarisable electrodes with the terminals of a capillary electrometer. An image of the meniscus was thrown on to a moving photographic plate, on which were also recorded the contractions of the ventricle, a time tracing (8 or 100 per second), and in many cases the time of stimulation (when artificial stimuli were used), or the period of excitation of the vagus (when it was desired to slow the heart). In nearly all experiments we used dogs.

We have also made experiments on the excised heart. In these, the heart, immediately after the chest was opened, was placed in a warm moist chamber. The wires of the electrodes and the tube going to the tambour recording the heart beats passed through holes in the sides of the chamber.

Results.—As to the wave of negativity in the ventricle, we find that in animals whose hearts are in as normal a condition as possible the variation is always diphasic, the negativity at the base preceding that at the apex. The result is the same whether the pericardium be intact or opened, or whatever points of the ventricular surface are led off.

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The character and direction of this variation, however, is exceedingly sensitive to slight changes in the temperature of the various parts of the heart, so that in order to obtain a constant result in animals with opened chest it is necessary to use warmed air for artificial respiration.

The following experiment illustrates the sensitiveness of the direction of the electrical variation to changes in the temperature of the respired air:—

June 27, 1890.—Dog: Operation as already described; artificial respiration with warmed air. Base of right ventricle (anterior surface) to acid, apex of left ventricle to capillary.

Direction of variation—

(*a.*) Before opening pericardium: diphasic—base, apex.

(*b.*) After opening pericardium: diphasic—base, apex.

The hot water was now poured out of the vessel surrounding the spiral, and this was filled with ice. After five minutes another photograph was taken of the variation—

(*c.*) Triphasic—base, apex, base.

(*d.*) (After another five minutes.) Diphasic—apex base.

(*e.*) The ice was now replaced by hot water.

After ten minutes more, the variation was found to be once again diphasic, the base becoming negative first.

Cold air was then used again, with the same result as before.

The same reversal of the variation can be obtained in the tortoise's heart by warming the apex and cooling the base simultaneously.

If we may regard the electrometer tracings as reliable, that is to say, if the variation—apex, base—with cooled base is the real variation, and it is not really a triphasic one with a first phase too small to be read on an electrometer, the only conclusion we can draw from our experiments is that the excitatory wave in the ventricle is a different thing from the wave of negativity, and precedes it (since in the hearts with cooled base, although the ventricles were beating in normal sequence to the auricles, the negativity began at the apex before the base).

Possibly, in the ventricles, the excitatory state is not transmitted directly from one muscle cell to another, but by the intervention of the intermuscular network of nerves shown by Dogiel, Openchowski, and others, to be universally present in the ventricular walls.

Time Measurements.—Some point of the auricles or ventricles was stimulated three times a second by means of an induction shock. In this way an artificial rhythm is induced, the heart contracting to every stimulation. This is the only method by which it is possible to get time measurements in the mammalian heart, since we cannot put this organ into a prolonged standstill, as we can the frog's heart by means of the Stannius ligature.

The latent period of electrical response of auricular and ventricular muscle to direct electrical stimulation is so short that we could not measure it accurately with the means at our disposal. It is certainly less than 0·01″.

We have sought to measure the rapidity of propagation of the wave in the mammalian ventricle in the same way as Engelmann and Sanderson and Page estimated it in the frog's heart, namely measuring the time interval between the beginning and the culmination of the initial phase.

In the exposed heart of a dog, breathing warmed air, the rate is generally about 30 mm. in 0·01″, *i.e.*, about 3 metres per second. But the sensitiveness of the form and direction of the variation to slight changes in temperature of different parts of the heart surface must make us hesitate in taking these figures as the correct ones.

There is a long period of delay in the passage across the auriculo-ventricular groove. A mean of eight observations gave 0·15″ as the time elapsed after stimulation of the auricles before the development of negativity at the base of the ventricles. Nearly the whole of this time is taken up in the passage from auricles to ventricles, since it makes very little difference to the time interval, whether the stimuli be applied to an auricular appendage, or the auricles close to the auriculo-ventricular groove.

Lastly, we have obtained no evidence of the supposed tetanic nature of a cardiac contraction (Fredericq), all our results pointing conclusively to the contraction being a single wave, starting at the base and passing thence to the apex of the heart.

The conclusions arrived at by Sanderson and Page in their work on the heart of the frog and tortoise hold good also for the mammalian heart.

Appendix.

On the Electrical Variation of the Heart of Man and the Intact Dog.

We have also photographed the electrical change of the heart of man and of the dog, with chest unopened, and, in opposition to Waller, we find that the variation is of such a nature as to show negativity always commencing at the base. The greatest effect was obtained by leading off from the apex beat and the right hand, but we found the same character of variation from whatever points on the surface of the body we led off, *i.e.*, the electrode nearest the base became negative first.

The photographs show what the eye could not distinguish clearly, viz., that each beat is accompanied by a triphasic variation, consisting of 1st, a "spike" (basal negativity); 2nd, a more prolonged excursion in the opposite direction (apical negativity); and 3rd, a large and prolonged movement in the same direction as the "spike" (basal nega-

tivity). Hence we conclude that the *base becomes negative before the apex*, and that its negativity overlasts that of the apex.

We do not feel able as yet to explain the triphasic nature of the variation ; it shows, however, that normally the excitatory state at the base lasts longer than at the apex.

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