Citation:

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Physiology. — "*Are contractility and conductivity two separate properties of the skeleton-muscles and the heart?*" By Dr. S. DE BOER. (Communicated by Prof. G. VAN RIJNBERK).

(Communicated in the meeting of September 29, 1917).

In 1888 BIEDERMANN made experiments on skeleton-muscles, from which he concluded that under special circumstances these muscles are still irritable and have still retained their conductivity, whilst the contractility has ceased to exist. He placed the sartorius of frogs over a certain length in water. When it had lain in it for some time he stimulated the end of the sartorius that had been in contact with the water. The result was, that the stimulated part of the muscle that had been in the water, did not contract, but the other part did. ENGELMANN repeated the experiment, and obtained the same result. ENGELMANN applied this experiment likewise to the heart. He plunged the auricles of frogs' hearts for some time into water, thereupon he stimulated the auricles, and saw after doing so that the ventricle contracted, whilst the auricles did not show any contraction at all. ENGELMANN communicates his results in the following phrases: "Von der Richtigkeit der Thatsache hatte ich mich durch eigene Versuche am Sartorius curarisirter Frösche überzeugt. Die Bestätigung ist so leicht, wie das Resultat überraschend. Der Muskel wird in der ganzen Ausdehnung, in welcher das Wasser ihn seiner Contractilität beraubt, gleichsam zum Nerv. So nun auch die Muskelbündel der Vorkammern: sie verlieren im Wasser ihren Charakter als Muskeln, und behalten ihre Function als motorische Nerven der Kammer". Further: "dass die Muskelfasern der Vorkammer auch nach vollständiger Aufhebung ihrer Contractilität doch den Bewegungsreiz für den Ventrikel noch fortzupflanzen im Stande sind, und zwar mit einer Geschwindigkeit durchaus derselben Ordnung, wie wenn das Verkürzungsvermögen erhalten wäre".

It has now appeared to me, that the conclusions made from their experiments by BIEDERMANN and ENGELMANN, are entirely incorrect. This may appear from the following experiments which I made with regard to this problem. In the first place about the skeleton-muscles. I attached a m. Gastrocnemius of a frog to a lever and plunged the muscle into a solution of RINGER. Then I induced the muscle to contraction by direct stimulation, and registered it by means of a stationary drum covered by smoked paper. Then I substituted water for the fluid of RINGER. After 5 minutes the point of the lever had already distinctly risen, then the drum is turned round a little way, and by direct stimulation another contraction is brought about and registered. In this way the drum is turned a little way by the hand every five minutes, and afterwards a contraction is registered on the stationary drum. The result is reproduced in Fig. 1. We see that after every five minutes the point of the lever has risen, and that after 25 minutes the point of the lever has mounted over the top of the first registered curve. Then on a stimulation the muscle no longer reacts with an abbreviation. This experiment can be explained as follows: Because the muscle has been so long submerged in water, it becomes saturated with water, swells and assumes rather a globular form. This causes the ends of the muscle to come nearer to each other, and an inflation-abbreviation is the consequence. As soon as this inflation-abbreviation surpasses the height of the "Zucking", the mechanical proportions have assumed such a character that an abbreviation can no more become manifest after a stimulation. The irritability and conductivity are intact, and the abbreviation exists already on account of the inflation. The active abbreviation of the fibrils no more approaches the ends of the muscle nearer to each other, because the inflation has already approached them at the smallest possible distance. What is decisive in this respect is the fact, that such a swollen muscle can no more dilate.

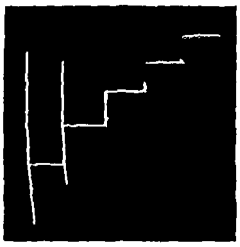

Fig. 1.

I arranged my experiments on the frog's heart in the following manner. I fastened a canula of KRONECKER through the sinus venosus in the auricles, after I had destroyed the septum atriorum and the atrioventriculary-valves. Then I imbibed the heart with the solution of RINGER under the pressure of a column of water 9 mm., and registered the heart-curves by means of suspension on a drum covered by smoked paper. Then I substituted by water the fluid of RINGER. Within a short time the heart stood still and indeed at a level with the tops of the formerly registered curves (vide Fig. 2). If thereupon the heart is again imbibed with the fluid of RINGER, we can make the heart pulsate again, after the inflation-abbreviation of the heart-muscle has first diminished. The heart has, like the skeleton-muscles, sustained a rather important inflation by the imbibition with water, and the distance from the basis to the point of the ventricle has decreased. Here also the mechanical proportions have consequently assumed such a character that an active abbreviation of the heart-muscle cannot express itself. After the substitution of the water by the fluid of RINGER the restoration of the systoles sets in, but first an allongation of the heart-muscle has occurred again on account of a decrease of the inflation.

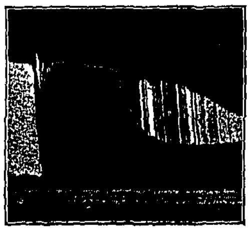
Time 1 min.

Fig. 2.

Fig. 2 shows these proportions distinctly. The restoration of the systoles is not complete here, because the stagnation has lasted rather long. A complete restoration of the systoles of the ventricle can however easily be obtained by imbibing the heart for a short time with water.

Consequently the disappearance of the contractility, whilst the conductivity and irritability continue to exist, as BIEDERMANN and ENGELMANN supposed to be the case for the skeleton-muscles and the heart, are only an apparent phenomenon. In order to show, that the processes that are the causes of the contraction really take place in the heart that is swollen by water, I had recourse to the string-galvanometer. After having placed 1 unpolarisable electrode on the point of the heart and 1 on the atrioventricular limit I registered the action-currents from the imbibed (with the solution of RINGER) suspended frogs' hearts. When now I imbibed the heart with water, it stood soon still in the maximal abbreviation-state on account of the inflation. The action-currents continued for some time in the beginning of the stagnation. (vide fig. 3). In this way it was ascertained, that during the stagnation in the maximal abbreviation-state the automation and the conductivity of the heart had remained intact.

I may be allowed to devote a single word to the criticism that KAISER thought necessary to pronounce with regard to BIEDERMANN's and ENGELMANN's experiments. This physiologist attributed the results of BIEDERMANN and ENGELMANN to currentloops that should have induced to contraction from the stimulator the part of the muscle (of the heart) that had been in contact with the water. They do not deserve this criticism. My experiments, in which the stagnating imbibed frogs' hearts produced still electograms, teach us, that in reality the processes that cause the contraction and the conductivity can continue to exist. The experiments of BIEDERMAN and ENGELMANN remain consequently unimpeachable.

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Time $^{1}/_{5}$ sec.

Lever electrogram.

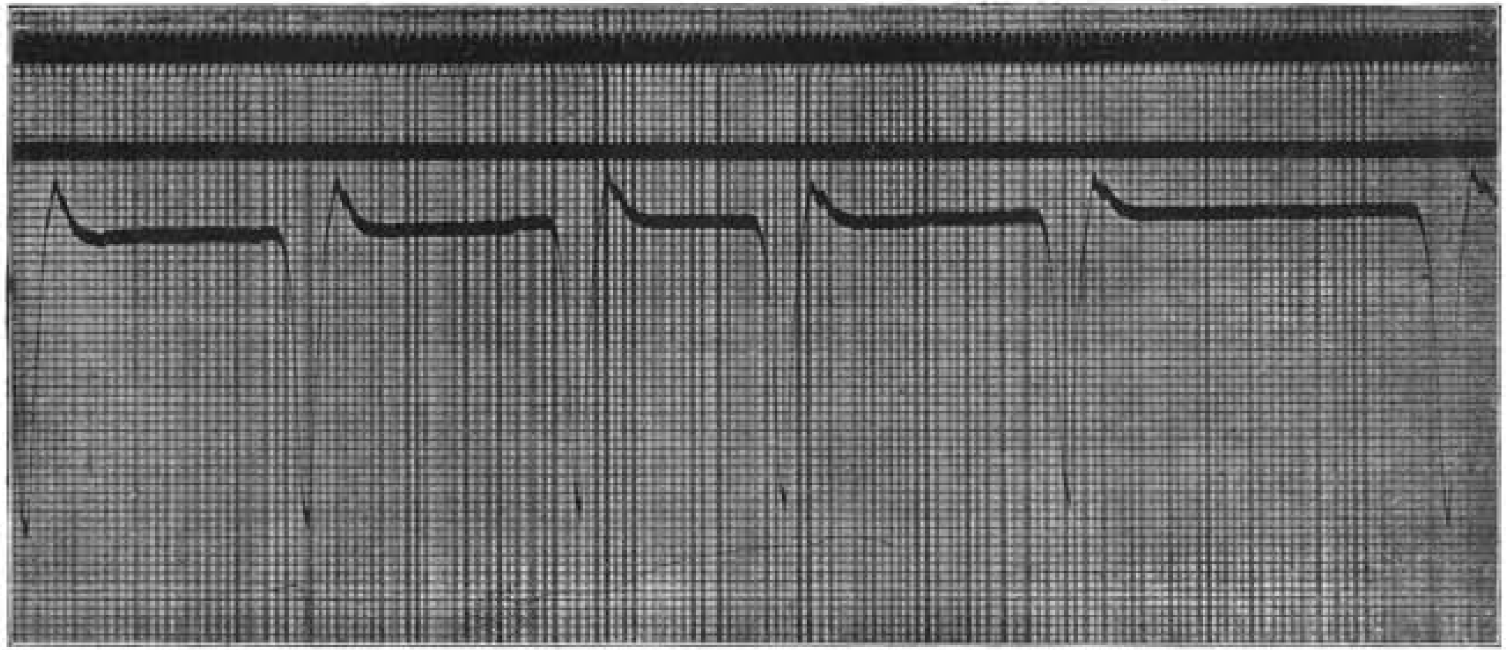

Fig. 3.

Their far-going conclusions, however, which have connection with important generally physiological problems are not justified. Their experiments do not furnish the proof that conductivity and contractility are 2 separate properties, because the muscles (heart) swollen by water are already maximally abbreviated, and consequently an active abbreviation cannot become manifest.

In this short preliminary communication I wish to desist from far-going conclusions and considerations, but I observe only that no more than the contractility and the irritability, the contractility and the actioncurrent may be separated.

Last year EINTHOVEN[1]) has moreover pleaded in one of his essays for the connection between contractility and impulse-currents.

[1]) Pflügers Archiv Bd. 166, Seite 109, 1916.