THE EFFECT OF TEMPERATURE ON THE EXCITABILITY OF TURTLE MUSCLE

I. P. Suzdalskaya and M. B. Kiro

From the Laboratory of Histophysiology (Chief-Active Member of the USSR Academy of Medical Sciences Professor D. N. Nasonov), Physiological Institute (Director-Professor V. N. Golikov), Leningrad State University

(Received March 28, 1956. Presented by Active Member of the USSR Academy of Medical Sciences D. N. Nasonov)

The excitability of the conducting tissues of different animals has been the subject of many investigations carried out in D. N. Nasonov's laboratory [3, 4].

In one of these investigations a study was made of the excitability of the nerves of the turtle at different temperatures [1, 2].

In the present work we have tried to find to what extent the results found for the turtle nerve are applicable to the muscle. We used the turtle Emys orbicularis (L).

METHOD

The experiments were performed on the tonic head muscles (m. retractor capitis) and the tetanic muscles (m. puboischiotibialis) of turtles. The effect of cooling and heating between 5 and 26°C, 27 and 37°C, 30 and 41°C was investigated.

After the muscle preparation had been made, it was kept for 1½-2 hours at room temperature in Ringer's solution, and was then placed on silver electrodes in a chamber and covered with liquid paraffin, whose temperature could be measured. The thermometer was placed between the electrodes which were 15 mm apart. Stimulation was effected by discharging condensers of different capacities. In some experiments the whole of the voltage-duration curve was plotted, but usually, in order to avoid damage to the preparation from an excessive number of discharges, only the two constants a and b from Gorveg's formula $v = a/t + b$ were determined. The theobase (constant b), i.e., the threshold for a stimulus of long duration, was measured in volts; the constant a, which is the threshold value of short acting stimuli is measured in millivolt seconds.

RESULTS

Three sets of experiments were carried out to determine the excitability of the m. retractor capitis. In the first set, the excitability on cooling from 25° to 6-7°C and reheating to 25°C was investigated.

In all cases a change of temperature produced opposite changes of excitability according to whether the stimuli were long or short. Thus, on cooling, the excitability to short stimuli was reduced by 91.2%, while that to long stimuli was increased by 16.5%; on the other hand, warming increased the excitability associated with a by 46.1% and lowered that associated with b by 24.7%. These results were statistically significant, since the mean square root deviation was less than one third of the difference between the means.

Figure 1 shows a graph of log voltage against log stimulus duration for one of the experiments. The two curves intersect at a point representing 0.1 milliseconds.

In the second set of experiments we investigated the effect of high temperatures by warming from 27°C to 37°C and cooling again to 27°C.

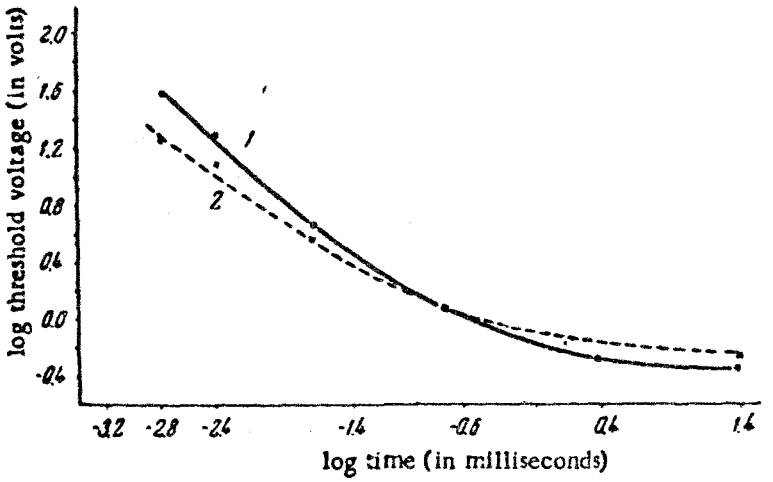

Fig. 1. Curves of log strength – log duration for the m. retractor capitis of the turtle. 1) at 6°C; 2) at 25°C.

All 11 experiments gave the same statistically significant result; heating always caused an increase of excitability to short stimuli (a was reduced on average by 23%), and a decrease of excitability to long stimuli (b increased by 52%). Cooling had the reverse effect and caused a 30% decrease and a 37% increase in excitability to short and long stimuli respectively.

In the third set, consisting of 5 experiments, the temperature was changed 30° to 41° and back from 41° to 30°.

The same results were obtained; on warming a was reduced by 20%, and b increased by 65%; on cooling 'a' increased by 31% and 'b' decreased by 38%.

Thus for any temperature change between 5°C and 41°C the two indices of excitability change in opposite directions, but the excitability of the muscle to stimuli of moderate duration, (about 0.1 milliseconds), remains unchanged and is independent of temperature.

Also when the temperature is changed from 6°C to 26°C the excitability, as indicated by the constant a changes more than does the rheobase value b , whereas in the range 27-41°C the opposite is the case.

Two sets of experiments were carried out to measure the excitability of the m. puboischiotibialis. In the first set the temperature changed from 5°C to 26°C and back to 5°C.

On heating to 26°C b increases by 41%, and a decreases by 51%. Cooling to 5° produces the reverse effect, and b decreases by 29% and a increases by 103%.

The strength duration curves from one of the experiments are shown in Fig. 2, and they can be seen to intersect at a point representing a stimulus duration of approximately 0.08 milliseconds.

In the next set of experiments, the m. puboischiotibialis was heated from 27°C to 37°C and cooled again to 27°C, just as in the case of the m. retractor capitis. The results however were not the same: this time the change of the index 'b' was very small, being between 3% and 10% which is not statistically significant, and the index 'a' decreased on warming by an average of 30% and increased on cooling by 53%. Therefore, instead of the two strength-duration curves intersecting sharply, they coincide for a considerable part of their length (Fig. 3). In other words for this temperature range the excitability of the muscle is independent of temperature for stimuli of almost all lengths.

Thus the only difference between the two muscles with respect to changes in excitability occur in the temperature range 27-37°C. Changes from 5°C to 26°C and back, affect tonic an tetanic muscles in the same way, and even the quantitative changes in the constants a and b are similar. Two strength-duration curves

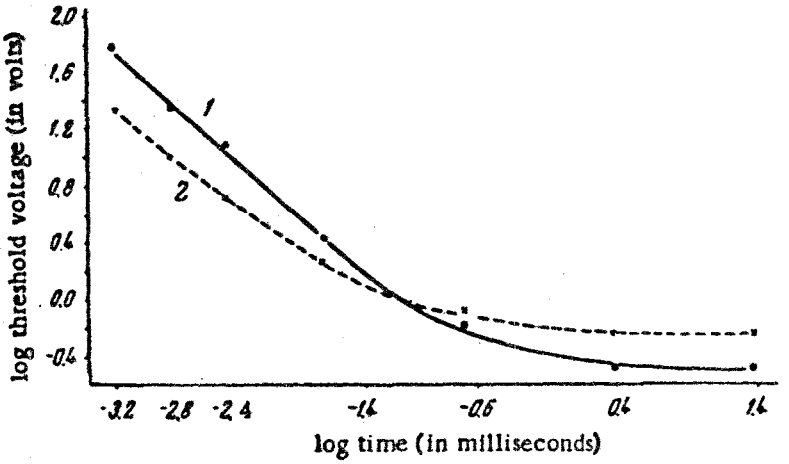

Fig. 2. Curves of log strength – log duration for m. puboischiotibialis of the turtle. 1) at 5°C; 2) at 26°C.

taken at different temperatures intersect each other, which demonstrates that the excitability to stimuli of physiological duration is independent of temperature. This reveals an adaptation of the cells to the maintenance of a constant level of excitability, unaffected by temperature changes.

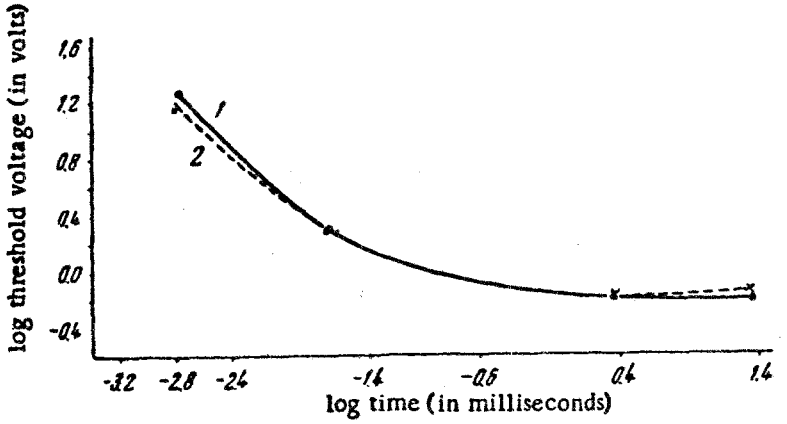

Fig. 3. Curves of log strength– log duration for m. puboischiotibialis of the turtle. 1) at 28°C; 2) at 38°C.

SUMMARY

The effect of cooling and heating of tonic and tetanic muscles of the turtle Emys orbicularis on the excitability caused by stimulation of various durations has been studied.

Cooling of muscles enhanced the excitability caused by prolonged stimulation and shortened that caused by brief stimulation. Heating caused a reverse effect. As a result, strength-duration curves cross at the area corresponding approximately to the duration of physiologic stimulus. In the zone where the curves cross the excitability is not altered by thermal changes, demonstrating an effective cellular adaptation, protecting muscular excitability from the effect of sharp thermal changes.

LITERATURE CITED

[1] D. N. Nasonov, and D. L. Rozental, Fiziol. Zhur. SSSR, 1953, 39, No. 4, 405-422.

[2] D. N. Nasonov and D. L. Rozental, Fiziol. Zhur. SSSR, 1953, 39, No. 6, 762-.

[3] D. N. Nasonov and I. P. Suzdalskaya, Fiziol. Zhur. SSSR, 1956, 42, No. 4, 415-425.

[4] D. N. Nasonov and I. P. Suzdalskaya, In the book: Theses and Summaries of Reports of the Conference on Problems of the Evolution of the Physiology of the Nervous System,* Leningrad, 1956, p. 111.

* In Russian.