THE EFFECT ON VASCULAR INTEROCEPTOR REFLEXES OF ANODIC AND CATHODIC POLARIZATION OF THE MEDULLA OBLONGATA

T. V. Popova

Laboratory of Pathological Physiology (Head, Prof. V. S. Galkin) and the Laboratory of the Physiology of Circulation and Respiration (Head, Prof. G. N. Konradi), I. P. Pavlov Institute of Physiology (Director, Academician K. M. Bykov) AN SSSR, Leningrad

(Presented by Active Member of the AMN SSSR V. N. Chernigovskii)

Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 50, No. 8, pp. 13-19, August, 1960

Original article submitted October 14, 1959

In our studies of interoceptor reflexes in different pathological conditions, we have assumed that the changes found depend to a certain degree on central functional changes, and in particular, on alterations in the excitability of the vasomotor center [9, 10].

In the present work we have studied the action of a direct current on the vasomotor medullary center in order to study changes in the interoceptor reflexes as related to the functional condition of the center.

METHOD

Acute experiments were performed on cats to study pressor reflexes following stimulation of the mechanoceptors of the stomach and urinary bladder. In some experiments, we studied blood pressure changes resulting from stimulation of the pressor region of the medulla. This region usually occupied the cranial third of the medulla, a result which agrees with results published by R. Alexander [15]. The electrodes were applied to the dorsal surface of the brain, lateral to the median sulcus of the rhomboid fossa on each side.

Part of the occipital bone was removed, and some of the cerebellum either excised or else pushed aside by means of a special spatula. The current was provided and controlled by storage cells or dry cells (BAS), a switch, wiper-arm, a resistance box, and a rheostat, which was used for gradually switching the current on or off; the current and voltage were measured by meters.

In the first ten experiments, the skin was not damaged, and the medulla was not exposed; the active electrode consisted of a chlorided cylinder 3 or 5 mm in diameter containing a nonpolarizable paste; it was attached to the skin over the occipital foramen. In the second set of 42 experiments, a nonpolarizable brush electrode ($Zn-ZnSO_4$) was used, and, according to the experiment, was placed at various positions between the middle of the rhomboid fossa and the obex.

When studying the "central pressor response," which develops when the pressor region is stimulated with an intermittent current from a stimulator, direct current was applied to the extreme caudal area of the brain. In the first set of experiments, the indifferent electrode was a plate measuring 4 × 3 cm, covered with silver chloride, and in the second, it was a zinc disk measuring 2.5 cm in diameter; it was fixed by a rubber band placed over a piece of gauze moistened in Ringer's solution beneath the jaw, or sometimes over the shoulder region. In the first set of experiments, the current varied from 0.5 to 100 ma, and in the second, from 0.025 to 16 ma.

The traces given below of the most typical experiments, performed with the direct current values reported in the text, are those of the second set of experiments.

RESULTS

In both sets of experiments, a marked phasic change in the interoceptor reflexes occurred when either the positive or the negative pole of a direct current supply was applied to the medulla.

As can be seen from Fig. 1, when the anode was first applied at a current of 0.2-0.6 ma, the pressor reflexes due to stimulation of the stomach and urinary bladder were increased (traces 3-7). Subsequently, the interoceptor reflexes were definitely suppressed at a current value of 0.8 ma, the effect being particularly marked at currents of from 3 to 5 ma (traces 10-15). The suppression was maintained for 20 minutes after the polarization was removed (trace 16, recorded after a 5 minute interval).

With these current values, a similar phasic response occurred in the "central pressor reaction." It can be seen from Fig. 2 that, when anodic stimulation is ap-

Effect on Interoceptor Reflexes and the "Central Pressor Reaction" of Cathodic Stimulation of the Medulla at a Current of 0.5-3.5 ma (Experiment of May 13, 1958)

Experimental procedure	Time from beginning of the procedure (in minutes)	Duration of cathodic stimulation (in minutes)	Magnitude of pressor reaction (in mm of mercury)		Remarks
			when pressure region of medulla was stimulated at 50 cps, 10 v, 0.05 msec	when pressure in bladder raised to 40 mm of mercury	
Initial conditions	–	–	23	–	–
	–	–	–	9	–
	–	–	–	8	–
	–	–	23	–	–
Cathodic stimulation of 0.5 ma	4	4*	–	19	
Cathodic stimulation of 2.5 ma	1	23*	34	–	
	4	26	–	17	First phase
	7	29	26	–	
	10	32	–	5	
	14	36	22	–	
Cathodic stimulation of 3.0 ma	4	42**	–	Pressor 1 Depressor 1****	
	7	45	18	–	
	13	51	11	–	Second phase
Cathodic stimulation of 3.5 ma	1	53***	–	1	
	4	56	7	–	
After switching off polarizing current	2	–	No reaction	–	–
	5	–	13	–	–
	9	–	–	Depressor 3****	–
	23	–	17	–	–
	28	–	–	8	–
	33	–	17	–	

*Before cathodic stimulation at 2.5 ma, cathodic current was applied for 11 minutes at 0.5 ma, and for 7 minutes at 1 ma.

**[14], p. 349.

*** A cathodic current of 3 ma had been applied previously for 1 minute.

**** Pressor-depressor change of blood pressure.

plied to the medulla for 22 minutes at 0.5 ma or 1 minute at 0.8 ma, there is a marked increase in the response to stimulating the pressor region of the medulla by a 25cps alternating potential of 10 v (traces 5-7). When the polarizing current is increased to 0.8 ma or to 3 ma, which causes a very marked effect, the "central pressor reaction" to the same stimulus is first reduced, and then completely suppressed (traces 8-10). After the constant current had been switched off for a few minutes, there was no response to the stimulus (trace 11), and not until 24 minutes after did a feebly shown pressor response develop interceptor reflexes.

The same phasic change in interoceptor reflexes, as well as the "central pressor reaction," was observed when cathodic stimulation was applied. The following experiment will serve as an example (see table). It

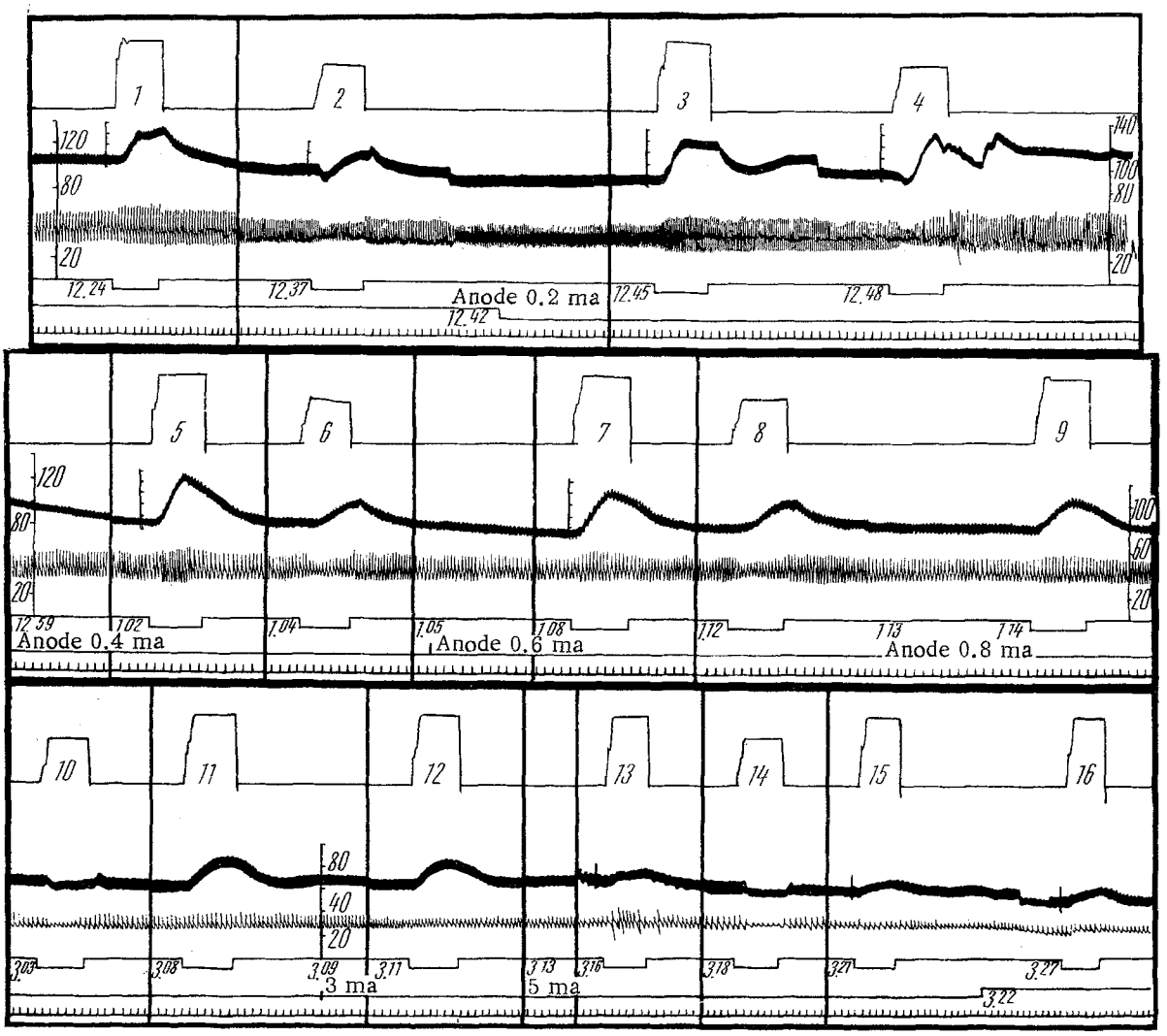

Fig. 1. Biphasic change of interoceptor reflexes in response to anodic stimulation of medulla at a current of 0.2-5 ma. Experiment of Mar. 29, 1958: 1, 3, 5, 7, 9, 11, 12, 13, 15, 16 – reflexes obtained in response to increasing pressure in urinary bladder to 60 mm of mercury; 2, 4, 6, 8, 10, 14 – reflexes in response to increasing pressure in stomach to 40 mm of mercury. Curves, from above downward: Pressure in organ; arterial pressure; respiration; zero line of arterial pressure (also stimulus marker); application of polarizing current; 5-sec time-marker.

can be seen that the first phase, consisting of an initial increase, and the second, comprising the subsequent suppression of interoceptor reflexes, took place at the same time as the corresponding change in the excitability of the part of the medulla which mediates the pressor response.

From the results obtained it follows that when the polarizing current is applied to the medulla, the phasic change in the interoceptor reflexes depends on an alteration of the condition of the central part of the reflex arc. The effects of anodic and cathodic stimulation are approximately the same, the difference being only in the relative strength of the action: Phasic changes of the interoceptor reflexes and their suppression developed more rapidly after cathodic,than after anodic, stimulation. For certain current values, it was, therefore, possible to observe a difference between the action of positive and negative poles. However, since the cathode reduces interoceptor reflexes, when it was replaced by an anode,an increased pressor response and a return of the reflexes previously suppressed by application of the cathode could once more be observed (Fig. 3; compare traces 6 and 7 with trace 9).

However, the restoration of the anodic action on the reflex excitability of the medulla during recovery from cathodic depression took place only for those values of current for which the anode itself exerted no depressive effect. For instance, after reflex depression had

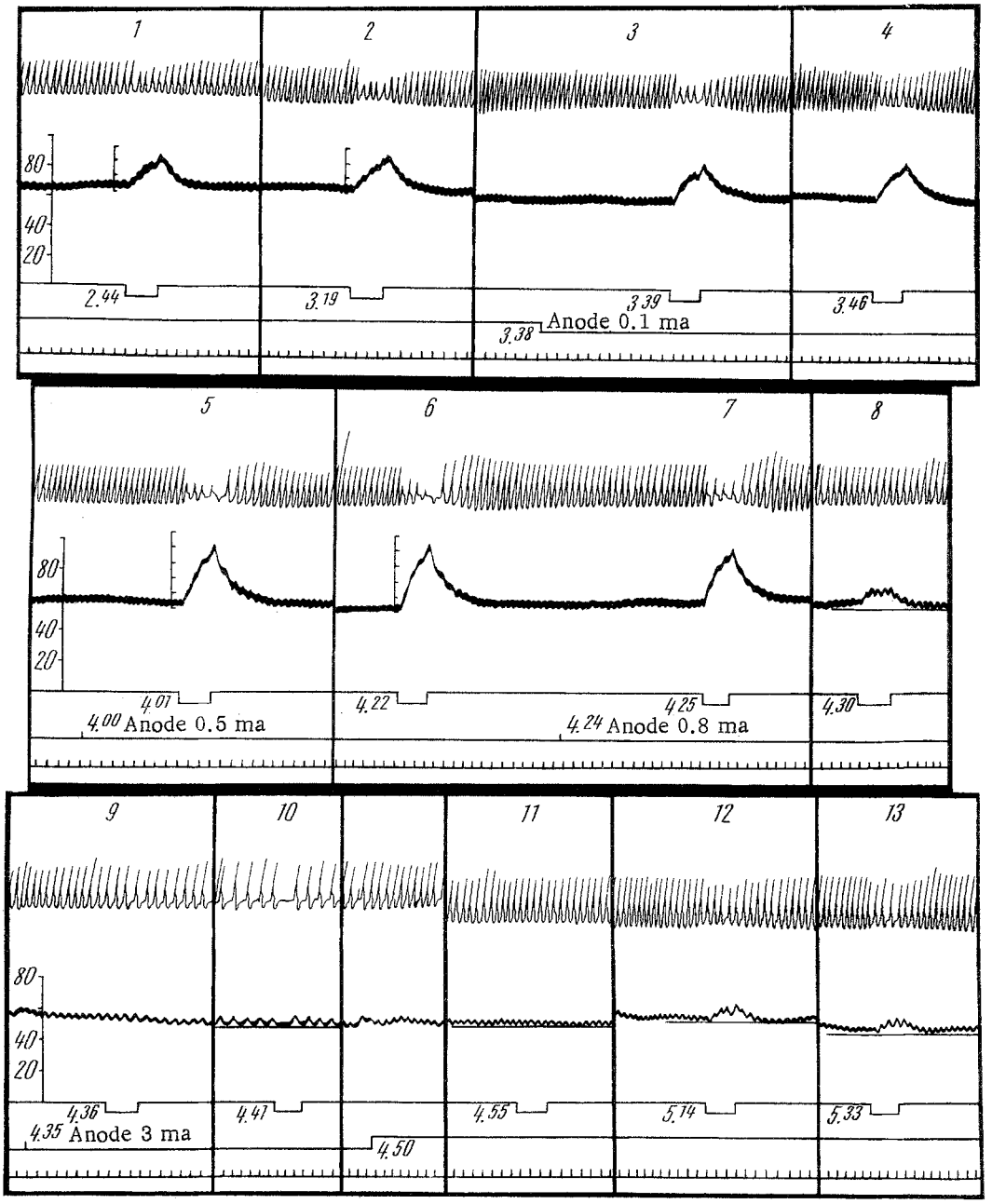

Fig. 2. Biphasic change of the "central pressor reaction" following the application to the medulla of direct current from an anode (0.1-3 ma). Experiment of Apr. 26, 1958. Curves, from above downward; respiration; arterial pressure (this line also represents stimulation of the pressor region of the medulla at 25 cps 10 v 0.05 m sec); 5-sec time-marker.

been induced by cathodic treatment, when using a current of 12 ma, it was not possible to restore interoceptor reflexes by application of the anode, although when polarization was withdrawn, the reflexes once more appeared, and gradually returned to their initial level.

It must also be added that the phasic changes in the interoceptor reflexes, which we have just described as following the application of either cathode or anode to the medulla, do not occur if strong currents equal to the higher values used are applied instantaneously. When this was done, both poles caused an immediate fall and subsequent elimination both of interoceptor reflexes and of the "central pressor reaction."

Since the time that Pflüger's law was published (1859), it has been usual to suppose that the cathode in-

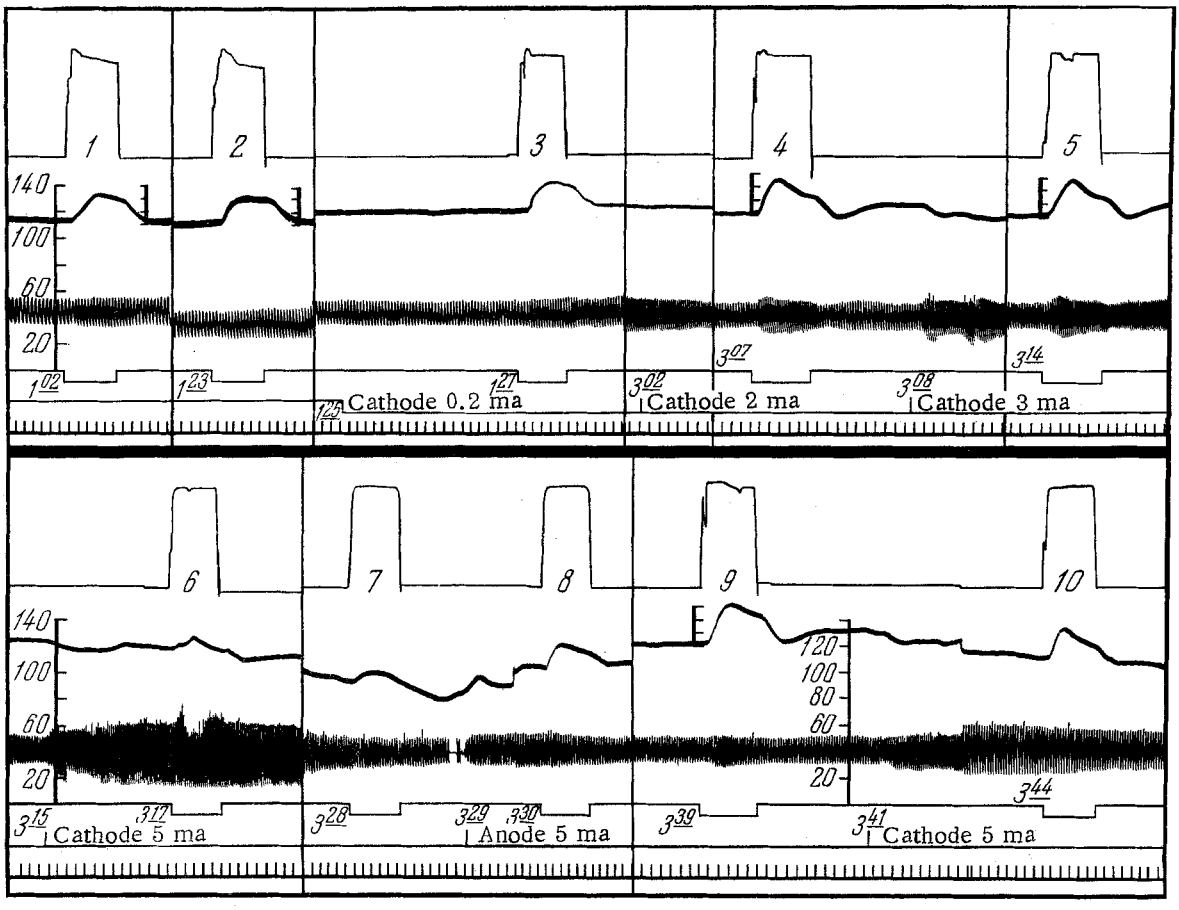

Fig. 3. Restoration of the effect of anodic stimulation with a constant current of 5 ma on interoceptive reflexes during the development of cathodic depression (0.2-5 ma). Reflexes recorded during increase of pressure in bladder to 80 mm of mercury. Curves as in Fig. 1.

creases excitability of nervous structures, while the anode depresses it. The results we have obtained do not fit into this framework of ideas. It must be emphasized that many authors have pointed out the error in Pflüger's conclusions. B. F. Werigo [3] confirmed that cathodic depression follows immediately after increase of excitability by a cathode, and later [4] he stated that "cat-electrotonus causes a gradual reduction in excitability which follows the course of the polarization,"* whereas, in the case of the anode, in all probability the excitability is raised.

B. F. Werigo saw that the reason for his disagreement with Pflüger was that the latter had not taken into consideration either the summation of the branches of the cathodic polarizing and stimulating currents or the reduction of the anodic test current where the ascending direct current is in the opposite direction to the stimulating current (it is known that an intermittent current exerts a stimulating action only at the point of exit from the nerve). Werigo's conclusions were confirmed by B. I. Khodorov, who found that "true changes in the excitability of the nerve at the poles, as our experiments have shown, were the reverse of those reported by Pflüger." † Werigo and Khodorov's refutation of Pflüger's statements has been discussed in detail by D. N. Nasonov [8], who has shown the necessity for reconsidering the classic assumptions regarding the action of positive or negative poles.

Pflüger's explanation of the reverse changes of excitability of nerves after cessation of a constant current has also been criticized, on the grounds that he confused the time of recovery of the initial level of polarization with the duration of postcathodic depression [16]. We must also note reports in which emphasis has been placed on phasic excitability changes following anodic or cathodic stimulation of nervous structures [2, 5, 6, 7, 12, 14]. In experiments by N. V. Golikov and V. L. Merkulov [5], and by B. P. Ushakov and his co-workers [12], in which small currents were applied at extremely short time intervals, there was found to be a similar-

*[4], p. 213.

†[14], p. 349.

ity in the phasic excitability changes following the action of either an electrotonus or catelectrotonus on the nerve.

The absence of any qualitative difference between the action of anode and cathode under certain conditions has also been pointed out by other authors [1, 13, 18]. There are many reports that the cathode has a stronger effect than the anode [5, 7, 11, 12, 17]; for this reason all cathodic phasic changes take place more quickly and at smaller current strengths than do those produced by the positive pole [5, 12, and others]. According to N. V. Golikov and V. L. Merkulov, this clear-cut quantitative difference between the action of the positive and negative poles has been the reason why several authors have concluded that the actions were opposed, and that the cathode exerted a parabiotic, and the anode, an antiparabiotic effect.

The results which we have obtained agree entirely with those of authors who observed the same type of phasic change of excitability in response to the action of either pole, the effect from the cathode being stronger. It must be noted that, in our experiments on the interoceptor reflexes, there could be no summation of the polarizing and the stimulating currents, because the stimulus used was that of a reflex. The similarity in the changes in the interoceptor reflexes and the "central pressor reaction" indicates that experimental conditions were such that there was no physical reaction between the constant current and the stimulus applied to the medulla. The same conclusion is indicated by the fact that in our experiments restoration of the "central pressor reaction" and interoceptor reflexes always took place gradually. In the first moments after switching off the constant current, these reactions, as a rule, remain the same as at the end of polarization.

The course of the changes of the interoceptor reflexes which followed alteration in the functional condition of the central portion of the reflex arc is similar to those which we have described previously in certain general pathological conditions [10].

SUMMARY

Acute preparations of cats were used for a study of interoceptor reflexes involving blood pressure changes, and of the pressor reaction which developed in response to polarization of the medulla oblongata. It was found that both cathode and anode elicited essentially similar phasic blood pressure changes. Because of its relatively weaker effect, the anode restored reflexes (within certain limits) which had been depressed by previous cathodic stimulation.

LITERATURE CITED

1. V. Babkova, The Effect of Galvanic Stimulation of the Brain on the Functional Condition of the Nervous System: Author's abstract of candidate's dissertation [in Russian] (Leningrad, 1953).
2. L. L. Vasil'ev, in: Advances in Reflexology and the Physiology of the Nervous System [in Russian] (1925) pp. 1-14.
3. B. F. Werigo, Pflüg. Arch. 31, 417 (1883).
4. B. F. Werigo, Dissertation for doctorate: The Problem of the Action of Galvanic, Intermittent and Continuous Current on the Nerve (an attempt to explain the physiological phenomena of electrotonus) [in Russian] (St. Petersburg, 1888) pp. 1-338.
5. N. V. Golikov and V. L. Merkulov, Transactions of the Society of Naturalists, Physiology Section [in Russian] (Leningrad-Moscow, 1935) p. 304.
6. I. E. Kamnev, Izv. AN SSSR, Ser Biol. No. 4, 437 (1948).
7. I. A. Medyanik and Ya. V. Oleinik, Fiziol. Zhur. SSSR 43, 400 (1957).
8. D. N. Nasonov, The Local Response of Protoplasm and the Spread of Excitation (Izd. AN SSSR, Moscow-Leningrad, 1959).
9. T. V. Popova, Byull. Éksp. Biol. Med. 37, 3, (1954).
10. T. V. Popova, Transactions of the Conference on the Physiology and Pathology of the Circulation [in Russian] (Kiev, 1959).
11. N. Ya. Pérna, Reports of the Physiological Laboratory, Petersburg University, 1913, 6, 1911, Yur'ev, p. 35.
12. D. P. Ushakov, M. S. Averbakh et al., Fiziol. Zhur. SSSR 39, 218 (1953).
13. K. S. Figurina, Problems of the Physiology and Pathology of the Nervous System, Theses, AN SSSR (I. P. Pavlov Institute of Physiology, 1958) p. 36.
14. B. I. Khodorov, Uspekhi Sovr. Biologii 29, 329 (1950).
15. R. S. Alexander, J. of Neurophysiol. 9, 205 (1946).
16. J. Bogue and H. Rosenberg, J. of Physiol. 82, 353 (1934).
17. Grünhagen, Ztschr. f. ration. Medizin. 31, 43 (1868).
18. W. S. Holobut, Rozprawy wydzialu lekarskiego 1, 1 (1931).
19. E. Pflüger, Physiologie des Electrotonus (Berlin, 1859) pp 1-502.