MITOGENETIC RADIATION OF THE NEUROMUSCULAR SYSTEM AS A METHOD OF ANALYSIS OF ITS MOLECULAR SUBSTRATE

REPORT I. Analysis of the Interacting Antidromic (Antibathic) Processes and the Degree of their Propagation

A. A. Gurvich

Cabinet on Mitogenesis of the Institute of Normal and Pathological Physiology
(Director—Active Member of the AMN SSSR V. N. Chernigovskii) of the AMN SSSR, Moscow
(Presented by Active Member of the AMN SSSR V. N. Chernigovskii)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny
Vol. 49, No. 5, pp. 67-71, May, 1960
Original article submitted June 30, 1958

In foregoing publications [1, 2] it was shown that the concepts of A. A. Gurvich on the unequalibrated state of the molecular substrate of living systems—the "physiological" theory of protoplasm— are completely applicable to neuroplasm and myoplasm. Spontaneous radiation of the nervous system and of muscles is regarded from the point of view of a degradation radiation that is physiological in character [2-6].

The structural organization of the unequilibrated, extremely labile substrate is subjected to the constant interaction of the centers and the periphery, among which great importance is held by the influence demonstrated by the muscles on the entire system. This influence, along with sporadic proprioceptive impulsation, manifests itself in the form of continuous activity, spreading centripetally and along motor fibers, i.e., it has an antidromic character [1].

Preliminary data [6] showed that the muscle action permits the genesis of the coarse state in the proteins and peptide chains of the neural fibers, at the same time that the action of the centers can be characterized as a reversing disperser. In other words, regarding the physiological understanding of the interactions of the centers and the periphery, from the points of view of structurochemical relationships, we could speak of the interaction of processes of a reverse—antibathic—character, and we saw our subsequent problem in the study of the connection of these phenomena with the unequilibrated state of the molecular substrate of the nervous system and of muscles.

The present work is related to the further study of the character and degree of propagation of the processes in the nervous system arising under the influence of the muscles.

EXPERIMENTAL METHOD AND RESULTS

The investigation was carried out by studying the mitogenetic radiation of the sciatic nerve and several of its branches in experiments in vivo on frogs. Spectral analysis was used in the series of experiments. In the form of an auxiliary series of experiments, spectral analysis was carried out on the radiation of models containing a well-regulated distribution of protein molecules (running protein solution).

The method of detection of the radiation was based, as in all the foregoing laboratory investigations, on the principle of its biodetection [3, 4, 6].

The determination of intensity of radiation necessary for the clarification of the character of the interacting processes was based on the dependency, studied in special investigations, of the binding intensity of radiation I on the threshold exposure $t(I \cdot t - \text{const}$ [6]).

Determination of the degree of coarsening and dispersion was based on the possibility of estimating the amount of free peptide terminal groups by the intensity of their respective spectral bands [6].

However, for further study of these processes in the substrate of the nervous system, a preliminary study was necessary of this phenomenon on models , comparable in labile regulation of molecules to the unequilibrated state of the substrate in the neural fiber. The simplest model of this type is a slow current of a weak solution of protein in a narrow pipe, connected to a source of molecules of known orientation in regard to the direction of flow. The flowing solution can thus be regarded as a molecularly regulated system of unequilibrated character.

The entire representation in the illustration (Fig. 1) of the system was filled with a weak solution of egg albumin. The wide U-shaped tube was provided with a quartz window. In the low siphon was placed a section of quartz pipe. A closed clamp was used to stop the motion of the solution, and by its use the varying speed of flow was regulated. The left window of the U-shaped tube was irradiated with ultraviolet light from a physical source. The collimator of the quartz spectrograph was centered against the quartz pipe of the lower siphon.

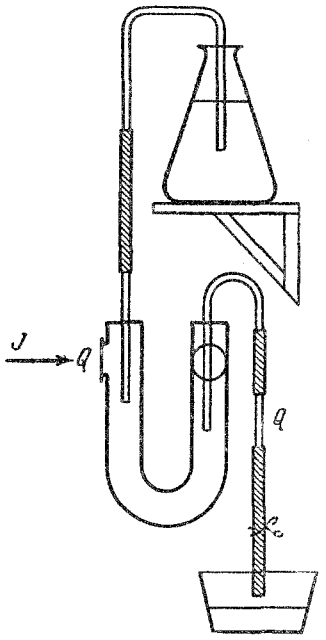

Fig. 1. Scheme of the assembly for the determination in a model of the state of the substrate of a neural fiber. Explanation in the text.

TABLE 1

Radiation Spectra of the Amino Groups in the Protein Solution

Lines of the amino-groups	Solution	
	stationary	flowing
2065–70 Å	27 ± 3.0	0.3 ± 1.58
2260–70 Å	25 ± 3.4 (Average of 8 trials)	4.2 ± 1.81 (Average of 8 trials)

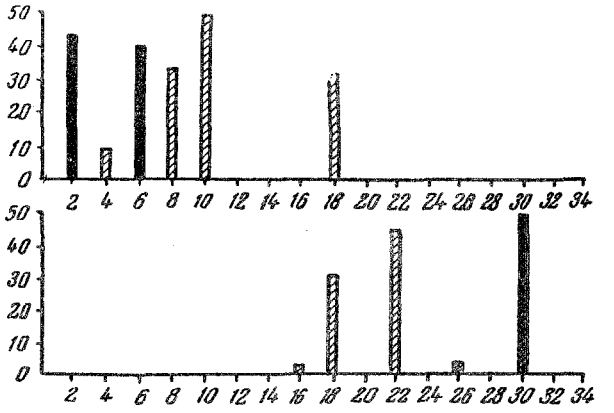

Fig. 2. Distribution of intensity of the radiation of amino groups along the length of the sciatic nerve. Upper series Radiation of spectral lines characterizing the amino group at the proximal end of the nerve; lower, same, at the distal end; crosshatched bars, radiation of the nerve in the resting state; black, the same on stimulation. Exposure is plotted on the abscissae (in seconds); on the ordinates, results (in percent.

Irradiation of the solution with ultraviolet light caused a photochemical chain reaction throughout its entire volume, accompanying the ultraviolet luminescence of mitogenetic intensity with a selective spectrum expressing the molecular composition of the solution [3, 4, 6].

Evaluation of the intensity of the spectral bands, characterizing the terminal peptide groups in the stationary and flowing solutions, showed a greater intensity of radiation, i.e., a larger amount of free terminal groups in the stationary solution in comparison with the flowing solution. In other words, the orientation of the protein chains in the direction of flow already leads to a certain interaction of the terminal groups (the number of free amino groups as though decreasing), which can be observed by the spectral method.

The model experiments thus explained the orientating data obtained by us on the nerve, and permitted making them more precise, thanks to a more detailed spectral analysis of the processes taking place in the unexcited nerve. The frog was placed in front of the spectrograph in such fashion that the proximal or distal portion of the sciatic nerve was centered, in turn, in front of the inlet window. In a comparison of the spectra of these portions a clearly manifested difference in the intensity of radiation was observed; the small exposure necessary for detection of the amino group lines in the proximal end had to be increased by 2–3 times in order to detect the corresponding lines in the distal part. The results were identical by spectral analysis of the radiation at rest and by analysis using the method of selective diffusion (Fig. 2).

Thus, it can be accepted that a continuous activity of the muscles causes a tendency toward coarsening of the peptides in the nerve fibers and that impulses sent by the spinal cord centers counteract this.

It seems probable that the stimulated state, in the presence of which the potential complexity of the system, is in fact realized, would be connected with the clearer manifestation of the processes. Thus, in a series of experiments, the receptor zone of an afferent cutaneous femoral nerve was stimulated with a weak acid solution. The results obtained fortified the hypothesis: exposures in the proximal portion of the nerve were still less than in the resting state; the necessary exposure in the distal portion, on the other hand, lengthened (see Fig. 2).

The results described afforded the possibility of making the general concept on the interaction of anti-

bathic processes more concrete. Its physiological sense may be closer to a complete formulation in the following manner: the "functional" concept of the "connections" of the individual systems with each other entering into a neuromuscular system as a whole should be regarded from the point of view of a distribution of counteracting (and, thus, also interacting) molecular processes.

Significant propagation of interacting processes was already shown in a series of data [1, 3, 6]. The facts presented here are related to the radiation of an afferent cutaneous femoral nerve, and reflect the reaction of that nerve to an action being endured by a segment of the sciatic nerve distant from it.

TABLE 2

Radiation of an Afferent Cutaneous Femoral Nerve (results in %)

Experimental conditions	Before transection of the distal portion of the sciatic nerve	After transection (within a half hour)
Without application of additional stimulation	22, 25, 32, 33*	18, 21, 30, 35
With skin stimulation	N/5 H_2SO_4—25, 22, 24, 40	8, 8, -2, -6
	Pressure on the skin in the region of branching of the nerve (20 g weight) 35, 45	-12, 13
	Pinching of the skin in that region	-3, -15, 9, 4

* Threshold exposure from 15 to 20 sec. Each number represents the results of a single trial.

From Table 2 it is apparent that in "at rest" radiation of an afferent cutaneous femoral nerve transection of the sciatic nerve is not reflected.

The cutaneous nerve radiates in the presence of stimulation, in contrast to the resting state, only with retention of the entire system of the sciatic nerve intact.

The preceding data showed that transection of the sciatic nerve at the distal portion disrupted the regularity (coordination) of the reflex radiations from the semimembranosus and semitendinosus muscles of the thigh in the presence of irritation of the skin in the region of an afferent cutaneous femoral nerve, and, as follows from the data in Table 2, simultaneously disrupts the capacity of the cutaneous nerve to radiate. Definite interest is aroused by the fact that in those comparatively rare instances where the full character of the reflexes was preserved, the capacity of the cutaneous nerve to radiate was likewise preserved [1].

Another reaction of the cutaneous nerve was observed after transection of the motor roots on the same side.

With this latter transection of the roots there appeared a loss of the capacity of the cutaneous nerve to radiate both in the resting state and in the presence of irritation.

In other words, one can state that for the nerve's radiation at the moment of irritation it requires activity on the part of all or almost all of the muscles innervated by the sciatic nerve. For resting radiation the activity of a portion of the muscles is sufficient.

TABLE 3

Radiation of an Afferent Cutaneous Femoral Nerve (results in %)

Experimental conditions	With preservation of the anterior roots intact	After their transection
Without the application of additional stimulation	33, 43, 20, 25,	0, 12, 9, -10
With skin stimulation	40, 33, 25	10, -2

The results presented must be regarded from two points of view. The single fact of the reaction of the cutaneous femoral nerve to disruption of the integrity of a distant nerve trunk clearly shows not only a large degree of spread of muscular activity in the norm, but also its effectiveness in relation to such various elements as synaptic connections, nerve cells, etc.

But the range and complexity of this generally self-propagating reaction are great, and, in the meantime, permit discussing only the following general considerations: Comparatively light disturbance of the regularity of the reflex muscle acts showed that the potency of the regular responses is not connected with a readily accomplishable, i.e., probable, state of the substrate, and that this potency must be regarded as the manifestation of an extremely labile, unequilibrated state. Along with this, only in the presence of this condition is the intensive development of sufficiently energetic chain processes ensured, accompanied by radiation and yielding coordinated reactions. In other words, the "resting" state appears to be the basic "active" background, determining, to a known degree, the character of the uprising deviation—the stimulated state.

SUMMARY

The general conception of the antidromic character of processes on the sciatic nerve is concretized by the method of mitogenetic spectral analysis. Determination of the relative quantities of peptide-free terminal amino-groups demonstrates the prevalence of the prepolymeric processes in the distal portion of the nerve (muscle action)

and of the processes dispersive in character in the proximal area (the action of the centers). Their continuous interaction creates the resulting inequilibrated state of the molecular substrate, also spreading to the afferent paths of the spinal cord system, distant from the muscular connections.

LITERATURE CITED

1. A. A. Gurvich, Byull. Éksp. Biol. i Med. 19, 11 (1945).
2. A. A. Gurvich, Byull. Éksp. Biol. i Med. 19, 3 (1945).
3. A. G. Gurvich and L. D. Gurvich, Mitogenetic Radiation [in Russian] (Moscow, 1945).
4. A. G. Gurvich and L. D. Gurvich, Introduction to the Study of Mitogenesis [in Russian] (Moscow, 1948).
5. V. F. Eremeev, Byull. Éksp. Biol. i Med. 45, 95 (1958).*
6. A. G. Gurvich and L. D. Gurvich, Die mitogenetische Strahlung [Russian translation] (Jena, 1959).

* Original Russian pagination. See C.B. Translation.