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

Communication II. On the Application of the Concept of Molecular Substrate Regulation in the Resting Muscle

A. A. Gurvich

Mitogenesis Office of the Institute of Normal and Pathological Physiology
(Dir.-Active Member AMN SSSR V. N. Chernigovskii),
AMN SSSR, Moscow

(Presented by Active Member AMN SSSR V. N. Chernigovskii)
Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 50, No. 10, pp. 82-86, October, 1960
Original article submitted June 30, 1958

Investigating the resting state of the neuromuscular system as an "active background" in the introduction to our first report [1], we related this idea to the concept of interacting processes, occurring in the molecular substrate of the system. The resulting state is characterized by uninterrupted molecular regulation, maintained in an unequilibrated condition [2, 3, 4, 6]. Thus, we may state that at every given moment the state of each individual system, mentally separated from the "whole," is, to a considerable degree, "tied-up" with the actions of the other systems.*

But the concept of unequilibrated molecular regulation is, by its nature, dynamic. The order of the molecular substrate is uninterruptedly and incompletely broken down and built up again; with slight exaggeration we can speak of this as the uninterrupted renewal of the "organization" of the substrate, or, drawing on a more common biological concept, we may describe it as an uninterrupted "regulation." The principle of "regulation" of the substrate in the resting stage may be regarded, then, as a completely tangible question, and its analysis serves as the goal of this and subsequent reports.

The muscles of mammals and cold-blooded animals in situ are subjects on which a study of the molecular substrate, from the aforementioned point of view, is not only completely accessible but also presents special interest. A number of signs make it probable that the "resting" radiation of the nervous and muscular systems represents a "physiological" degradation radiation [1, 2, 3, 6].

A comparison of the relative radiation intensity in the resting state and with degradation caused by chilling, and a study of the spectra under these same conditions, made it possible to draw several conclusions on the regulation of the muscle substrate in the resting state.

EXPERIMENTAL METHOD AND RESULTS

Total radiation of the calf muscle, M. gastrocnemius, in the frog under different temperature conditions. The basic purpose of these experiments consisted of comparing the radiation intensity of a muscle at normal temperature (15-16°) and with significant chilling of its surface (to 2-3°). The conditions were standardized as much as possible: the radiating surface of the upper part of the muscle was constant–10-12 mm², and the distance from the detector was also kept the same–10 mm. The experiments were carried out in the Fall and Winter on Rana temporaria and Rana ridibunda (males). The muscles were chilled by intense streams of cold physiological saline or by direct insertion of a small thin icicle of frozen physiological saline into the muscle.† In both modifications the chilling was begun immediately before the exposures. The intensity of radiation was determined according to the relation Jt=const.

Thus, judging from the marked drop in the plate exposure, the radiation of the muscle following chilling was approximately 3 times more intense than the radiation at 15-16°.

On the basis of these data the following general conclusion may be made. A resting muscle exists at a high energy level; the energy output in this case (in the form of radiation, for example) is very small, but it is easily elevated by artificial intervention, e.g., chilling, which is evidence of its high potential energy. This latter fact also shows that the energy state of the muscle is maximal-

* In the strict sense, one should speak of the "interlaced" character of the substrate in each microvolume of each system.

† The physiological saline was cleared for the radiation.

TABLE 1. Radiation of the Calf Muscle in the Resting State (in percentages)*

Exposure (in seconds)	At normal temperature (15-16°)	With chilling (to 2-3°)
3	-7, -8,6	31 ± 8***, 10, 42, 66, 35
5	4, 6	—
8	35 ± 12**, 63,52,33,39,60,65	—

*Here and in the following table the effect in % is calculated according to the formula $\frac{O-K}{K} \cdot 100$, where O is the experimental value and K is the control.

**The probable error, calculated for the average trials (at the height of the effects), illustrates their reliability.

***Footnote indicated but omitted in Russian – Publisher.

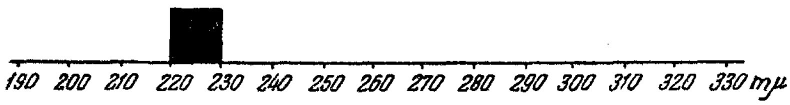

Fig. 1. Radiation spectrum of the calf muscle of the frog in the resting state.

ly labile, i.e., unequilibrated, and, in addition, makes the converse inference probable: doubtlessly, the uninterrupted utilization of energy, occurring in the physiological resting state, is accomplished very economically. In such a general form this inference is not directly linked to the concept of the unequilibrated molecular order, but any attempt to ground the inference more strongly leads to this concept, since spatial propinquity of the molecules at the moment of their excitation is the most adequate mechanism for the economic accomplishment of a series of processes.

Spectral analysis of muscle radiations. The value of mitogenetic spectral analysis is especially clear in work on the organism as a whole. By studying the spectra of degradation radiation and of radiation from the system in the resting state we were able to come to a certain opinion on the "preciseness" or on the "degree" of reproducibility of the structural status of the substrate. Unquestionably, the barren appearance of the spectra, i.e., the limited number of spectral bands, is directly related to the monotypic nature of the molecular arrangement—that is, the more or less strict reproducibility and recurrence of the molecules' orientation and deformation. In these experiments we employed a relatively crude spectral analysis of the radiation, but, in so doing, were able to cover a number of spectral areas simultaneously, which is important in studies of the physiological state in situ.

We studied the spectrum of the calf muscle in the resting state at both normal temperature (15-16°) [5] and during the cooling of the muscle to 3-4°. As in the case of the previous experiments, we laid bare the standard surface in the upper portion of the muscle, and the frog was secured in such a fashion that the bared segment was situated in front of the inlet aperture of the spectrograph. Metal discs (so called templets) were alternately inserted in the focal plane of the outlet aperture. These discs bore sets of windows calculated to lie in such a way that the entire effective range of mitogenetic radiation (1900-3200 A) was analyzed in regions of 100 A.‡ The spectral maximum for the resting state radiation was observed at 8-10 seconds. With cooling the plate exposure was decreased to 5-6 seconds.

The results of the experiments showed that the effective spectral range was the same for both modifications of the investigation. The spectrum was very limited. A clearly manifested radiation intensity was observed only in the 2200-2300 A range (Table 2). The entire band of wave lengths to the right and left of this segment, even examined with increased exposure, did not produce a positive reading, i.e., it could be regarded as a significantly reduced background in comparison to the maximum segment.

A radiation spectrum as unusual as this requires further study. It was necessary to clarify whether such a barren spectrum was characteristic for the resting radiation of muscles in general or only for certain types of muscles. From this point of view, we studied the spectra

‡An independent biodetector was placed against each window.

TABLE 2. Radiation Spectrum of the Calf Muscle (in percentage)

Wave length (in A)	At normal temperature (15-16 deg)			With cooling (to 3-4 deg)	
	I	I	II	III	III
1900—2000	—7	5	—6	—2	5
2000—2100	4	—	—5	—3	8
2100—2200	—	—	5	12	—
2200—2300	34	48	45	53	48
2300—2400	—8	—	—5	11	8
2400—2500	—	—	2	—4	0
2500—2600	10	—2	—11	16	6
2600—2700	—8	—	3	—11	10
2700—2800	—	—	—2	4	—
2800—2900	—8	0	11	10	5
2900—3000	—2	—	10	—3	—1
3000—3100	—	—	5	13	—
3100—3200	—3	10	—6	—10	11

Note: I–8-second exposure; II–16-second exposure; III–5-second exposure (Fig. 1).

It is naturally necessary to take into consideration that ranges of 100 A yield arbitrary boundaries for the spectral maximum. For example, breaking up the 2200-2300 A range into 20 A bands showed that the maximum effectiveness was situated in the first 60 A, and that the intensity fell in the last 40 A. In the investigations necessary for our problem, however, such arbitrary division into 100 A bands is still sufficient.

of the resting and degradation radiations from the m. semimembranosis and the considerably smaller m. tarsalis anticus.

The data obtained affords the opportunity of making the following conclusion. The spectrum of the semimembranosis muscle in the resting state—at both normal and decreased temperatures—is principally close to the spectrum of the calf muscle. An intense maximum, appearing when the exposure was 8-10 sec, was also characteristic of its spectrum. But differences did exist: the maximum radiation occupied a different spectral range—2000-2100 A; in addition, when the exposure was approximately doubled weaker spectral bands appeared. The most intense of these was the range 2500-2600A, and the considerably weaker ranges 2200-2300 A and 2700-2800 A (Fig. 2).

Thus, in comparison with the calf muscle the spectrum of the semimembranosis muscle is less limited.

The spectrum of the m. tibialis anticus differed from the spectra of both the calf muscle and the semimembranosis. The intense radiation (approximately of the same order as for the other two muscles) fell in the range 1900-2000 A; in addition, a wide swatch of the wave length spectrum, 2800-3200 A, was unquestionably active (Fig. 3).

It is necessary to take note of the fact that, in contradistinction to the two previous muscles, whose radiations were constant at different times of the year, the radiation of the anterior tibial muscle was more intense in the spring than in the fall and winter (the latter two seasons were when these data were obtained).

The following general conclusions are possible from a comparison of the spectra. Muscles at rest possess a clearly expressed "spectral individuality". This concept

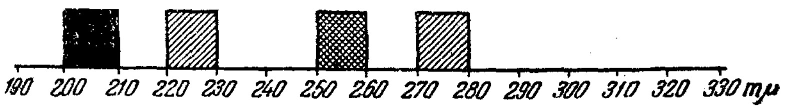

Fig. 2. Radiation spectrum of the semimembranosis muscle of the frog in the resting state. The depth of shading of the bar is proportional to the intensity of the radiation.

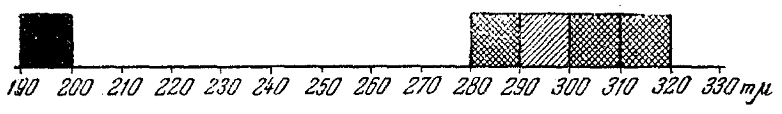

Fig. 3. Radiation spectrum of the m. tibialis anticus of the frog in the resting state. The depth of shading of the bar is proportional to the intensity of the radiation.

may be regarded as a rule, since there is no basis for believing that the observed phenomenon is limited to the muscles studied. The highly delimited spectrum strikingly manifested in the analysis of the calf muscle did not occupy a wide portion of the wave length band. The possibility that this limitedness is more marked in the coarser muscles has not been excluded. This question, which we regard as highly important, continues to be studied. But as far as the calf muscle is concerned, we can freely state, in all cases, the opinion advanced above, i.e., that the monotypic nature of the molecular substrate structure of this muscle is more impressive than in other muscles.

These conclusions make it possible to go somewhat further and formulate the following inferences. The resting state of the different muscles, uniform from a functional point of view, is attained by dint of the different variations in their molecular substrates. This can mean only one thing: in order to appraise the resting state of a muscle one can never be limited to describing it as a localized system; it is absolutely necessary to bring in the concept of the "adequacy" of its state as pertains to the state of another system, perhaps even isolated from it but nevertheless interdependent upon it. The resting state is itself a functional manifestation of such adequacy, but the means by which it is attained may be different, and, correspondingly, the resulting natures of the molecular substrates may also differ from one another.

Working with the idea of the molecular substrate, we start from the statistical molecular multitude and characterize any state from the point of view of statistical laws, i.e., we speak of their probability. But in this case it is very important to remember the dynamic facet of all phenomena and to regard the probable state of the substrate, not as the manifestation of a stable condition, but rather as a reflection of the fact that the particular "type" or "character" of the interacting processes arises more often than the other variants.

In other words, we see our main problem specifically in analyzing the continuous accomplishment of a given or many given states. From this viewpoint, we are studying the principle of substrate regulation in muscles at rest, and we are attaching principal importance to the application of this concept in the study of phenomena observed in the nervous and muscular systems.

SUMMARY

Data are presented which permit regarding the mitogenetic muscle radiation in vivo at the state of rest as a "physiological" degradational radiation. The radiation spectra of the frog muscles (m. gastrocnemius, m. semimembranosus, and m. tarsalis anticus) differ in the quantity and distribution of the active bands. The least amount of the latter is present in the spectrum of gastrocnemius muscle, whereas m. tarsalis ant. contains the largest quantity of the bands. The regulation of the muscle's substrate at the state of rest is envisaged on the basis of these results.

LITERATURE CITED

1. A. A. Gurvich, Byull. Éksp. Biol. Med. 49, No. 5 (1960).**
2. A. Gurvich and L. Gurvich, in: Mitogenetic Radiation [in Russian] (Moscow, 1945).
3. A. Gurvich and L. Gurvich, in: Preface to the Studies on Mitogenesis [in Russian] (Moscow, 1948).
4. V. F. Eremeev, Byull. Éksp. Biol. Med. 45, 6, 95 (1958).**
5. M. A. Lipkind, Byull. Éksp. Biol. Med. 45, 6, 65 (1958).**
6. A. G. Gurwitsch and L. D. Gurwitsch, Die mitogenetische Strahlung (Jena, 1959).

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