MITOGENETIC RADIATION SPECTRA OF MUSCLES AS AN INDICATOR OF THE DYNAMIC MOLECULAR ORGANIZATION OF THE SARCOPLASM

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In earlier papers [2-4,9], facts relating to the mitogenetic radiation of skeletal muscles have been described. The radiation spectra of resting muscles of intact animals are characterized by predominance of wide bands, which most probably indicate the orderly state of the molecular substratum of the muscle fibers. Probably, the orderliness, for which an extremely labile (unbalanced) state is specific, is maintained and regulated by the continuous action of the nerve centers.

The object of the present investigation was to continue the experimental studies of these ideas and, in particular, to make a much closer study of the radiation spectra of the gastrocnemius muscles of the frog and rabbit (in the latter at different age periods).

EXPERIMENTAL METHOD AND RESULTS

Experiments were carried out on the exposed muscles of frogs and rabbits. For the spectral analysis of the radiation, the animals were fixed horizontally on a frame and placed slightly below the collimator of the spectrograph, and the radiation from a localized area of the muscle surface was directed to the entrance slit by reflecting it from an aluminum mirror tilted at an angle of 45°. The detector of the radiation was a yeast culture, and the method of working with this has been described previously [6-8].

The radiation of the gastrocnemius muscle of the frog and rabbit at rest, when studied in experiments on the whole organism, showed an extremely simple type of spectrum consisting of one wide band lying in the region 2200-2300 A (Fig. 1a) [2,4]. Because of this simplicity of the spectrum, the character of its changes could be studied during the fall in the general level of metabolism of the animal and the evolution of the spectrum in the early period of postnatal development.

Previously published data [2,3] show that the resting (spontaneous) radiation of a muscle arises in association with disturbances of the established molecular orderliness, i.e., it is directly associated with the dynamics of the unbalanced substratum. A parallel can be drawn with the concept of degradation mitogenetic radiation [6-8], widely used in the mitogenetic literature, arousing during artificial disturbances of orderliness (for example, a lowering of metabolism by cooling the object), and we can define the resting radiation of the muscle as physiological degradation radiation.

The need for a fully effective metabolism for maintaining an unbalanced, orderly state of the substratum and, consequently, for maintaining the character of the spectrum associated with it, a spectrum consisting of one wide band only, suggested that during a prolonged and general lowering of the level of metabolism, persistent and considerable changes would be observed in the spectrum.

Accordingly, the radiation of the gastrocnemius muscle was studied after prolonged generalized cooling of the frog (kept on ice for two days). Gradual and profound lowering of the metabolism in this way may be associated not only with quantitative changes in the energy level, but also with changes in the character of the processes taking place — a smaller chance of profound dissociation of molecules, fewer opportunities for synthesis, and so on.

The results obtained showed considerable changes in the radiation spectrum of the muscle, as shown by the appearance of several new spectral regions (Fig. 2b). Judging from the detailed analysis of the spectrum, which is not yet complete, most of the bands were considerably narrowed.

Mitogenesis room, Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR, Moscow. (Presented by Active Member of the Academy of Medical Sciences of the USSR V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 8, pp. 53-56, August, 1966. Original article submitted August 1, 1964.

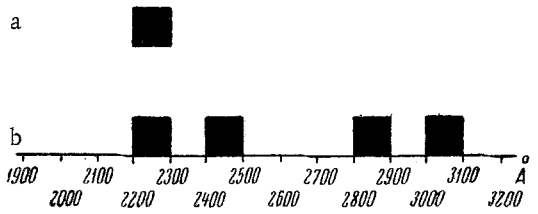

Fig. 1. Spectrum of mitogenetic radiation of the gastrocnemius muscle of the frog and rabbit at rest (a) and of the frog after prolonged, general cooling (b).

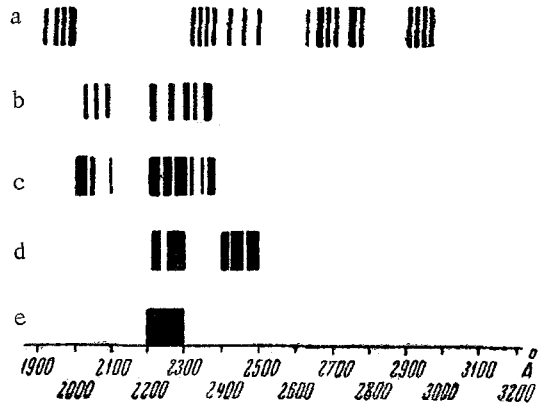

Fig. 2. Spectra of radiation of the gastrocnemius muscle in a rabbit at different age periods: a) 1 day; b) 2 days; c) 6 days; d) 9 days; e) 16 days.

This marked reactivity of the radiation spectrum of the muscle made it necessary to investigate still more closely the relationship between the width of the bands and, consequently, the unbalanced orderliness of the substratum and the influence of the nerve centers. The continuous character of these influences is assumed here, being an essential condition for the maintenance of muscle tone. One way of approaching the solution of this problem was to study the radiation spectra of the muscle in very young animals, i.e., during the gradual formation of a fully effective innervation.

Experiments were carried out on rabbits (aged from 1 day to 2 weeks). The conception of rest cannot be applied to the muscle in rabbits during the first days after birth in the sense in which it is understood in relation to the muscles of adult animals. This is confirmed by the almost continuous mobility of the tiny rabbits and also by electrophysiological findings. For that reason, the length of the exposures during which the radiation was recorded had to be so short that the animals immobilized on the frame could be considered at rest during that period, at least in their outward appearance.

Previous investigations [8] showed that the intensity of the spontaneous radiation of the muscle, which is strongest during the first days of postnatal development, falls as the animal grows, and becomes approximately stable after two weeks. Conversely, the appearance of degradation radiation, caused by local cooling of the muscle, and superposed on the spontaneous radiation, is not observed until several days after birth; its intensity increases and by the age of approximately two weeks it becomes constant in character.

These results clearly show that during the first days the radiation of the muscle consists mainly of a component of pure chemiluminescence, arising on account of the energy of enzymic processes, and later, with the development of the structural components – the unbalanced orderliness of the substratum – the component of the radiation associated with reconstruction (destruction and subsequent restoration) of the molecular constellations becomes predominant. For that reason, the parallel study of the evolution of the spectra was of particular interest. A detailed analysis of the spectrum undertaken on several animals at the age of 1, 3, 6, 9, and 16 days gave the following picture. The large number of narrow bands characteristic of the first days of development gradually diminished and the new bands arising at the same time in the short-wave region became wider. By the age of two weeks, the spectrum had acquired the typical character of the adult animal, i.e., one wide maximum in the region of 2200-2300 A (see Fig. 2).

The results obtained thus agree well with the group of facts recently observed indicating that the width of the spectral bands in the radiation of the muscular and nervous system of the intact organism may be regarded as an index of the unbalanced-orderly state of the molecular substratum. This unbalanced-orderly state is formed gradually during the animal's growth, and the organization of the unbalanced molecular orderliness procedes parallel with the development of the myoneural synapse, and the assumption of the standing posture, and it ends approximately when the animals have reached the level of maturation corresponding to the development of a fully effective functional state of the higher centers*.

The fact that unbalanced molecular orderliness exists leads to the following conception. "Rest" of a muscle or of any system forming part of a functional whole, must be regarded as a continuous "process of organization" of the dynamic molecular whole, i.e., the continuous establishment of general energy levels [11] within the framework of the functional whole. It is evident that the links connecting the centers with the conducting pathways and the periphery are chain processes, characterized by definite spatial (steric) principles.

*It is interesting to compare these results with those previously obtained in the laboratory directed by Professor I. A. Arshavskii [1,10].

The fact that the spectrum of resting radiation of the gastrocnemius muscle is limited to one band and in other muscles to a small number of wide bands suggests that several (few) types of unbalanced molecular orderliness exists. This seems important because the approximate reproducibility of one type (or of several types) or orderliness may favor one or several directions of development of the processes while inhibiting others, i.e., it may be a factor limiting or "standardizing" the variations between the processes. By this I imply a possible analogy with the principle of steric hindrances, so important to the understanding of the specific course of chemical processes. At the same time, this ability of unbalanced molecular orderliness to undergo spatial reconstruction, proceding in the same direction as, and perhaps even outstripping, the changes in functional states, raises the question of the "actual" limitations of the variation of the processes while still retaining extremely wide "potential" powers of variation [5,6-8]*.

In the author's opinion, the arguments described above confirm the importance of the concept of excitability, i.e., the production of "intermediate" states associated with successively developing changes in the molecular substratum.

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*This can be illustrated by the example of acetylcholine [9].