MOLECULAR ORGANIZATION OF SKELETAL MUSCLE SARCOPLASM IN DIFFERENT FUNCTIONAL STATES

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The study of mitogenetic radiation of muscles has led to the formation of views on the structural and energetic state of the muscle fiber sarcoplasm. The sarcoplasm has not only stable structures (sarcoplasmic reticulum, actin and myosin filaments, nuclei), but also a molecular organization of unbalanced character, maintained by the energy of metabolism — unbalanced molecular constellations (UMC) [2]. This ordered state of the molecular substrate is favorable for the spread of chemical and structural chain processes. As a result of this, local changes arising under the influence of certain factors lead to structural and energetic changes in the substrate as a whole and to the onset of new functional states in the muscle fiber and in the muscle as a whole.

The object of this investigation was to study changes in the molecular substrate of the frog gastrocnemius muscle by comparing the intensity of radiation in different functional states: at rest, in response to indirect above-threshold stimulation, and in a state of fatigue. The comparison was made at normal and reduced temperatures (down to 2-3°C), which reveals the dynamics of UMC more clearly.

EXPERIMENTAL METHOD

Male winter frogs (*R. temporaria* L.) were used. The gastrocnemius muscle and a small segment of the sciatic nerve were exposed and the latter placed on electrodes. The duration of the stimulating pulses was 10 msec, the frequency of stimulation 2 Hz, and the voltage for each experiment was above threshold (0.2-5 V). During indirect stimulation the gastrocnemius muscle worked under isotonic conditions with a load of 2 g. The contractile effect was recorded by means of a strain gauge. The signal was led to an electrocardiograph. In all experiments mitogenetic radiation was recorded on a yeast biodetector with exposures of 3, 5, and 8 sec. By comparison of these exposures it was possible to obtain a relative estimate of the radiation [1, 2]. The emitting surface of the muscle (3 × 3 mm^2) and the distance to the biodetector (8-10 mm) remained constant.

TABLE 1. Radiation of Frog Gastrocnemius Muscle, Experiment in Percent of Control (M ± m, n = 6)

Exposure, sec	Radiation of muscle, %					
	resting state		indirect stimulation		fatigue	
	18—20 °C	2—3 °C	18—20 °C	2—3 °C	18—20 °C	2—3 °C
3	24,2±1,3	31,0±2,7	32,0±5,5	—10,0±2,9	12,0±7,3	11,0±4,1
5	26,0±7,3	29,0±2,4	18,5±3,1	4,0±2,5	11,8±4,8	32,0±3,4
8	27,7±7,1	35,0±3,4	23,0±4,6	4,0±5,6	20,0±4,3	37,0±6,7

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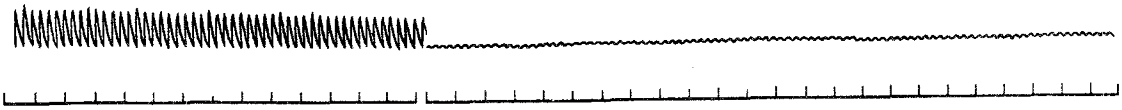

Fig. 1. Kymogram of single contractions of frog gastrocnemius muscle: a) contraction during first minutes of indirect stimulation, b) fatigue of muscle developing.

EXPERIMENTAL RESULTS

The data given in Table 1 show that the intensity of radiation of the frog gastrocnemius muscle on the addition of physiological saline at room temperature was comparable for all three exposures. Radiation of the muscle during cooling was rather more intensive. These results indicate that continuous energy-linked discharges and restoration of UMC take place in muscles at rest. During temporary cooling (inhibition of metabolism) the probability of the discharges is increased, and this explains the small increase in the intensity of radiation.

During above-threshold stimulation of the sciatic nerve, evoking active contraction of the contractile elements of the muscle fibers during the first few minutes, the relationship between radiation and temperature changed. Radiation at room temperature was preserved or even strengthened (judging from the exposures), but during cooling it disappeared. It can be postulated that above-threshold pulses giving rise to abrupt structural changes in the molecular constellations in nerve and, muscle fibers, lead to massive energetic discharges ("mechanical" degradation), and for that reason cooling ("temperature" degradation) is no longer effective.

Continued stimulation leads gradually to a decrease in the amplitude of contractions, to fatigue of the muscle. The slow development of fatigue points to gradually cumulative changes in the substrate, i.e., that the reversibility of the molecular states in the intervals between stimuli is only partial. Radiation of the muscle recorded at minimal amplitudes (compare Table 1 and Fig. 1) was weak at room temperature, but stronger during cooling.

The experimental results thus indicate preservation of UMC and the acquisition of new parameters by them. Structural changes in the molecular substrate and deviations from normal are consequently possible.

The following general view can be expressed on the basis of the facts described above. The sarcoplasm is a highly reactive unbalanced molecular system interacting both with the more balanced macrostructures of the muscle fiber, including its contractile elements, and with the molecular substrate of nerve fibers [3]. The resting state is characterized by active maintenance of the unbalanced molecular organization, combining substrates of nerve and muscle fibers into a single functional entity. The first phases of the active reaction to the stimuli are connected with transient repetitive disturbances of functional integrity and imbalance, during recovery from which the structural and energetic parameters of the substrates develop gradually increasing abnormalities. It can be tentatively suggested that these deviations from normal are manifested clearly in synaptic regions, where they reduce the probability of interaction between acetylcholine receptors and the mediator [4].

It is this sequence of gradually developing processes, lowering the levels of energy metabolism and the corresponding structural changes in UMC in the synaptic regions and in the sarcoplasm of the muscle fibers which, we may suppose, lead to fatigue of the muscle. The sarcoplasm is thus an important component in the regulation of coordinated changes in different structural elements of the muscles.

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