TEMPERATURE ANALYSIS OF PROPERTIES OF THE HEART

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The temperature coefficient (Q_{10}) for various properties of the heart within the temperature range 35-25° was determined simultaneously in dog heart-lung preparations. For automatism (heart rate), duration of excitation (electrical systole), and time for recovery of excitability (duration of the refractory period), Q_{10} exceeds 2, while for conductivity and contractility (using the contraction velocity as parameter) it is less than 2. It is suggested that physical processes predominate in production of the properties of conductivity and contractility, while chemical properties predominate in the production of automatism and recovery of excitability.

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In a homoiothermic organism at a normal temperature the properties of the heart – automatism, excitability, conductivity, and contractility – are combined harmoniously, ensuring the functioning of the organ as a single entity. The temperature coefficient (Q_{10}), the ratio between the velocities of a process at temperatures differing by 10°, provides an objective means of comparing the degree of inhibition of individual properties during cooling. For chemical reactions this coefficient has a value over 2, while for physical reactions it usually does not exceed 1.2. Credit for using the temperature coefficient in analysis of a complex physiological process is due to Samoilov [3], who long before the discovery of mediators predicted the existence of a chemical link in the transmission of excitation from nerve to muscle and the predominantly physical mechanism of spread of excitation in a nerve.

The index Q_{10} provides a concrete, numerical measure of the degree of inhibition of each property of the heart relative to temperature. At the same time, the temperature coefficient can provide an insight into the nature of processes lying at the basis of formation of each property of the heart, although such analysis has largely been confined to the study of physiological processes [1].

Data for the temperature coefficient of certain electrical [18, 13] and mechanical [9, 12] parameters of cardiac activity have been published in the literature. However, no investigations could be found in which composite determinations were made of the temperature coefficient for all properties of the heart of a homoiothermic organism under conditions completely excluding the possibility of involvement of the heart in a thermoregulatory protective reaction.

EXPERIMENTAL METHOD

To rule out neurohumoral thermoregulatory effects, experiments were carried out on dog heart-lung preparations. Altogether 24 experiments were performed.

Synchronized recordings were made on the N-106 oscillograph of the ECG and the pressure within the left ventricle and aorta, on the basis of which a phase analysis was made of left ventricular systole and the velocity of contraction was obtained by differentiation of the pressure curves. The minute volume was recorded by Starkov's volumetric method [4, 5]. Excitability was determined by the method described by Medelyanovskii and co-workers [2], the test pulse being triggered by the R wave of the ECG. Q_{10} was calculated within the temperature range of 35-25°.

EXPERIMENTAL RESULTS

The results are given in Table 1, showing that the value of Q_{10} for conductivity and contractility (using the contraction velocity as parameter) was less than 2. Conversely, for automatism (based on the heart rate), the duration of excitation, and also the time taken for recovery of excitability of the myocardium, the

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TABLE 1. Q_{10} and μ for Various Properties of the Dog's Heart (M ± t)

Index	Q_{10}	μ (in kcal/mole)
Conductivity	1.77 ± 0.05	10,409 ± 494
P–Q	1.71 ± 0.04	9,788 ± 408
QRS		
Contractility		
Maximal velocity of increase in intraventricular pressure	1,83 ± 0.06	10,951 ± 574
Mean velocity of increase of intraventricular pressure	1.66 ± 0.13	8,712 ± 572
Volume velocity of ejection	1.63 ± 0.08	8,621 ± 542
Excitability (time for recovery of excitability)		
Duration of absolute refractory period	2.26 ± 0.15	14,329 ± 1,076
Duration of total refractory period	2.52 ± 0.14	16,029 ± 771
QRST		
Electrical systole	2.37 ± 0.07	15,675 ± 548
Heart rate (automatism)	2.65 ± 0.10	17.773 ± 475

temperature coefficient was higher than 2. Correspondingly, the value of μ, denoting the activation energy of the sum of the various reactions [6], was maximal for automatism.

These results demonstrate differences inthe nature of the processes lying at the basis of individual properties of the heart. It may be suggested that chemical processes predominate in the production of automatism and restoration of myocardial excitability, while physical processes predominate in the production of conductivity and contractility. This conclusion is in agreement with modern views concerning the chemical basis of automatism [7], the predominantly physical character of the spread of excitation [11], and the role of the physical component of sliding of actin and myosin filaments in muscular contraction [10]. The discovery of differences in temperature coefficients for excitation, for its conduction in the heart, and contraction of the myocardium shed light also on the temperature limits of complete inhibition of these properties in the heat of warm-bloded animals at low temperatures. During deep cooling of a heart working under the conditions of a heart-lung preparation without a considerable hemodynamic load, automatism of the sinus node is inhibited initially at a temperature of 22-17°. The arrested heart is able to respond by contraction at temperatures down to 7° to direct electrical or mechanical stimulation applied after a sufficiently long time interval to allow restoration of myocardial excitability. This offers the possibility of maintaining cardiac activity at low temperatures by means of rhythm binding.

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