Limits of Temperature Adaptation and Thermopreferendum

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Research

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Abstract

Background Managing the limits of temperature adaptation is relevant both in medicine and in biotechnology. There are numerous scattered publications on the identification of the temperature limits of existence for various organisms and using different methods. It was shown earlier that each cycle of synaptic exocytosis includes reversible phase transitions of lipids of the presynaptic membrane due to the entry and subsequent removal of calcium ions from the synaptic terminal. Violation of cyclic changes in membrane fluidity caused by a sharp increase or decrease in ambient temperatures will lead to the termination of synaptic transmission, which can be recorded by the loss of righting reflex.

Results The viability polygon for *Danio rerio* was determined by the minimum temperature of cold shock (about 6 °C), maximum temperature of heat shock (about 43 °C), and thermopreferendum temperature (about 27 °C). The ratio of the temperature range of cold shock to the temperature range of heat shock was about 1.3.

Conclusions The experimental values of the temperatures of cold shock and heat shock and the temperature of the thermal preferendum correspond to the temperatures of phase transitions of the lipid-protein composition of the synaptic membrane between the liquid and solid states. The viability range for zebrafish coincides with the temperature range, over which enzymes function effectively and also coincides with the viability polygons for the vast majority of organisms. The boundaries of the viability polygon are characteristic biological constants. The viability polygon of a particular organism is determined not only by the genome, but also by the physicochemical properties of lipids that make up the membrane structures of synaptic endings. The limits of temperature adaptation of any biological species are determined by the temperature range of the functioning of its nervous system.

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Figures

Figure 1

The dependencies of the heat shock temperature T_H and of the cold shock temperature T_C on the temperature of the long-term acclimation T_A in *Danio rerio*. Abscissa, T_A ; and ordinate, T_H , T_C , and T_A . Experimental values of T_C are shown by filled circles (●); values of T_H , by open circles (○), and values of T_A , by open triangles (△). Linear regression lines are drawn through temperature values in the range from 20°C to 30°C.

Figure 2

The adaptation kinetics of T_H and T_C upon sharp change of the water temperature from 20°C to 30°C of *Danio rerio*. Abscissa, the adaptation time, hours. Experimental values of the heat shock temperature, T_H , are shown by open circles (●) and the values of cold shock, T_C , by filled circles (●). Horizontal lines indicate the values of T_H and T_C after a prolonged acclimation at 20°C and at 30°C.

Figure 3

The kinetics of temperature adaptation of *Danio rerio*. Abscissa, adaptation time (t) in the logarithmic scale; ordinate, shock temperatures T_H (●), T_H (◇), T_C (●), T_C (◇). Experimental values of T_H are shown by open symbols (● and ◇) and values of T_C , by filled (black) symbols (● and ◇). The shock temperatures recorded after the transfer of the fishes into water with higher temperatures are designated with circles (● and ●) and shock temperatures recorded after the transfer of the fishes into water with

lower temperatures, with diamonds (◊ and ◆). Horizontal lines show the stationary values of TH and TC calculated on the basis of linear regression, with regard of the values of shock temperatures in the range from 20°C to 30°C: $TC = 0,70 TA - 4,12$, $TH = 0,53 TA + 24,20$. The letters A, B, C, D, E and F indicate the kinetics of adaptation in different temperature ranges.

Figure 4

Comparison of the viability polygon obtained for *Danio rerio* by means of the loss of righting reflex methodology (solid line) and the polygon of tolerable temperatures obtained by the methodology of the critical maximal and critical minimal temperatures (dashed line) [33]. Abscissa, T_A [°C] and ordinate, T_H [°C], T_C [°C] and T_A [°C].

Figure 5

The limits of temperature adaptation of various organisms. Abscissa, acclimation temperature T_A [°C], and ordinate, characteristic constants: $(T_C)_{\min}$ [°C], T_{PR} [°C] and $(T_A)_{\max}$ [°C].