FACULTATIVE NONSHIVERING THERMOGENESIS IN REGULATION OF BODY TEMPERATURE IN ENDOTHERMS

Summary

Facultative (regulatory) nonshivering thermogenesis (NST) is a very effective way to generate heat, especially in small animals exposed to cold. It is energetically much cheaper response to cold than shivering thermogenesis or the increase in maximum metabolic rate. The thermogenic capacity of NST undergoes seasonal changes, being the highest in winter and the lowest in summer. The main cues for seasonal improvement of the capacity for NST are short photoperiod and low ambient temperature. However, not only seasonal but also daily variations in the NST capacity are possible. The latter depend on the circadian rhythm of body temperature.

The NST is very important for heterotherms since it plays a fundamental role during the arousal from torpor (daily or seasonal), allowing for rapid elevation of body temperature. In placental mammals, the major source of NST is the brown adipose tissue (BAT). Thermogenic capacity of BAT depends on the species, the ability to enter torpor, photoperiodic and thermal history of animals and ambient temperature. The mechanism of NST in BAT requires a special and unique feature of BAT mitochondria, i.e. the presence of the uncoupling protein UCP1, that uncouples — under the control of fatty acids — oxidative phosphorylation from ATP synthesis.

Nevertheless, not only placental mammals but also marsupials and birds are able to increase heat production by means of NST. They need extra heat to maintain a constant body temperature in the cold or during arousal from torpor. However, most of these animals lack functional BAT (it was found only in a few species of marsupials) and their mechanism(-s) of NST is (are) entirely different. NST here is attributable to skeletal muscles and may involve other members of the UCP family, like UCP2 or UCP3 or avian UCPS. Another possible mechanisms are based on the translocation of Ca^{2+} between the lumen of sarcoplasmic reticulum (SR) and the cytosol, mediated by the SR Ca^{2+}-ATPase. The energy derived from a Ca^{2+} gradient may be converted into heat.

Independently of BAT- or muscle-origin, NST is an important source of heat in the face of cold. Different mechanisms could evolve concomitantly as a response to changes in the environment, mainly due to a decrease in ambient temperature. Both, seasonal and daily changes in the capacity of NST reflect different demands for heat dependently on the time of the year and time of day.