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A definition of homeostasis which links autonomic neurohumoral control to energy balance

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Constancy and stability of the internal environment, the internal homeostasis, are the necessary conditions for survival of the biological system in its environment. They have never been clearly defined and quantified, however. To this purpose the physical principles of equilibrium and non-equilibrium, reversibility, stationary steady state and stability (Lyapuonov, asymptotic, local and global) and non-equilibrium thermodynamics are taken as the frame of reference. On these basis the homeostasis of the internal variable may be defined as a spontaneous, time-independent, non-equilibrium stationary steady state of rest (X_S). Mathematically, the instantaneous state of a system ($X(t)$) is related to the time-independent steady state (X_S) through $X(t) = X_S + x(t)$, with $x(t)$ being the fluctuating or oscillating time-dependent state variable. In humans, two resting spontaneous homeostatic states are: (1) the conscious state of relaxed wakefulness during which time-dependent variables would display bounded oscillations around the mean time-independent steady state level, which thus is stable in the sense of Lyapuonov, and (2) the unconscious stable state of stages 3 and 4 of NREM sleep, during which the time-dependent variables would approach the lowest spontaneously attainable time-independent state of rest asymptotically, sleep becoming a globally stable and attractive state. While exercise may be viewed as a non-spontaneous unstable active state far away from equilibrium, bouts of hibernation of etherothermic mammals may be considered spontaneous, resting, time-independent steady states, very near or at the equilibrium with the external environment during which the residual neurohumoral control becomes a function of ambient temperature. In humans the range between sleep and exercise is neurohumorally regulated and may be expanded by both physical and mental training. Inside this range different behaviours will induce changes in autonomic and endocrine functions, metabolic rate and entropy production, moving the reference steady state towards or away from thermodynamic equilibrium. Emotions and action performance in the external environment entrain sympathetic activation, quicken metabolic rate and entropy production displacing the reference state away from equilibrium. Disengagement from the external environment induces a reinforcement of vagal drive to the cardiovascular system, withdrawal of sympathetic tone and deceleration of metabolic rate and is a necessary condition for spontaneous stable states of rest to occur. Thus it seems safe to conclude that amongst the numerous metabolic and neurohumoral contributing factors, homeostasis and stability are mainly under parasympathetic control.