The Evolution of Endothermy and Its Diversity in Mammals and Birds

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Abstract

Many elements of mammalian and avian thermoregulatory mechanisms are present in reptiles, and the changes involved in the transition to endothermy are more quantitative than qualitative. Drawing on our experience with reptiles and echidnas, we comment on that transition and on current theories about how it occurred. The theories divide into two categories, depending on whether selection pressures operated directly or indirectly on mechanisms producing heat. Both categories of theories focus on explaining the evolution of homeothermic endothermy but ignore heterothermy. However, noting that hibernation and torpor are almost certainly plesiomorphic (=ancestral, primitive), and that heterothermy is very common among endotherms, we propose that homeothermic endothermy evolved via heterothermy, with the earliest protoendotherms being facultatively endothermic and retaining their ectothermic capacity for "constitutional eurythermy." Thus, unlike current models for the evolution of endothermy that assume that hibernation and torpor are specialisations arising from homeothermic ancestry, and therefore irrelevant, we consider that they are central. We note the sophistication of thermoregulatory behavior and control in reptiles, including precise control over conductance, and argue that brooding endothermy seen in some otherwise ectothermic Boidae suggests an incipient capacity for facultative endothermy in reptiles. We suggest that the earliest insulation in protoendotherms may have been internal, arising from redistribution of the fat bodies that are typical of reptiles. We note that short-beaked echidnas provide a useful living model of what an (advanced) protoendotherm may have been like. Echidnas have the advantages of endothermy, including the capacity for homeothermic endothermy during incubation, but are very relaxed in their thermoregulatory precision and minimise energetic costs by using ectothermy facultatively when entering short- or long-term torpor. They also have a substantial layer of internal dorsal insulation. We favor theories about the evolution of endothermy that invite direct selection for the benefits conferred by warmth, such as expanding daily activity into the night, higher capacities for sustained activity, higher digestion rates, climatic range expansion, and, not unrelated, control over incubation temperature and the benefits for parental care. We present an indicative, stepwise schema in which observed patterns of body temperature are a consequence of selection pressures, the underlying mechanisms, and energy optimization, and in which homeothermy results when it is energetically desirable rather than as the logical endpoint.