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Metabolism

Winter torpor in a large bird

Torpor is a natural state in which animals show a substantial and controlled reduction of body temperature to conserve energy[1,2]. A few small birds (weighing less than 80 g) are known to use it as a survival strategy in winter, but we have discovered that a large bird, the Australian tawny frogmouth, which weighs 500 g, can also enter this state. This surprising finding increases the size of birds known to use natural torpor by almost tenfold, suggesting that avian torpor is more widespread than is commonly believed, enabling birds to stay in their territory throughout the year.

Small endothermic birds and mammals have enormous food requirements because of the fast metabolic rate that is necessary to regulate a high body temperature (T_b). When this high metabolic rate is unsustainable, for example in periods of adverse weather and/or food shortage, many small mammals (body mass 2–10,000 g) survive by entering a state of torpor[1–3]. The study of torpor in birds has so far been restricted to species weighing less than 80 g (refs 2,4,5), and rather than using torpor to overcome adverse conditions, birds may migrate to avoid them. However, many birds are sedentary and often rely on ephemeral, weather-dependent food sources — so how do they overcome periodic energy bottlenecks?

Figure 1 Tawny frogmouth (*Podargus strigoides*).

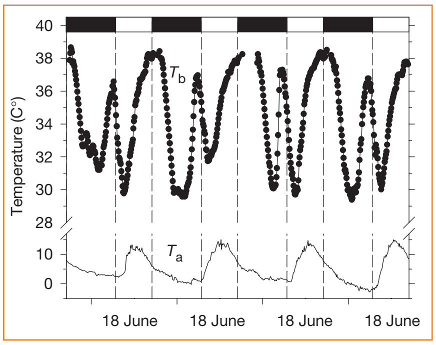

Figure 2 Fluctuations in body temperature of large Australian tawny frogmouth (T_b, filled symbols, measured by an internal transmitter) and in air temperature (T_a, solid line) over 4 days in June (winter). T_b was high at the beginning of the night (black bars), and then declined. The bird was aroused before dawn, after which it changed its roost and re-entered torpor. T_b increased from mid-morning to peak around sunset.

To answer this question, we investigated whether the Australian tawny frogmouth (*Podargus strigoides*; Fig. 1), a sedentary bird which feeds mainly on arthropods, uses torpor in the wild. The study was conducted from the Australian autumn to summer in an open woodland of *Eucalyptus* and *Acacia* at 1,000 m altitude in a cool temperate area near Armidale, New South Wales. We captured seven frogmouths and fitted them with temperature-sensitive transmitters (calibrated to the nearest 0.1 °C) weighing 3 g. All birds received an external backpack-style transmitter[4] (long range) to measure skin temperature (T_{skin}), and three birds had a second internal transmitter (short range), to measure core T_b and to determine $T_b - T_{skin}$ differentials, implanted under general anaesthesia. Transmitter signals were recorded at 10-min intervals for up to nine months[6].

All individuals entered torpor in winter: T_b fluctuated around 38–40 °C during activity and fell to about 36 °C during the rest phase, with a lower limit of 34 °C. On cold (less than 7 °C) winter nights in June–August, T_b fell below 34 °C on 202 of 462 observation days (44%). The minimum T_b recorded by an internal transmitter was 29.1 °C, the lowest T_b calculated from T_{skin} and the $T_b - T_{skin}$ differential was 27.2 °C, and the mean minimum T_b for the seven birds was 29.0 ± 1.0 °C. Birds usually entered torpor after a brief phase of activity in the evening (Fig. 2), became active again near sunrise and frequently entered a second bout of torpor after they had flown to their day roost. Dawn torpor was briefer (3.5 ± 1.2 hours) than night torpor (7.0 ± 1.2 hours) and was often terminated by passive rewarming in the sun.

Our study shows that the large frogmouth regularly enters torpor in winter. We argue that the use of torpor enables the bird to survive in a wide range of habitats and to remain resident in its territory throughout the year[7], despite feeding on arthropods. Because torpor occurs in this large bird and because birds are more diverse and smaller on average than mammals, we predict that avian torpor is much more common than is currently believed.

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Ageing

Cloning of mice to six generations

Mice have been cloned by nuclear transfer into enucleated oocytes[1–3], and here we describe the reiterative cloning of mice to four and six generations in two independent lines. Successive generations showed no signs of premature ageing, as judged by gross behavioural parameters, and there was no evidence of shortening of telomeres at the ends of chromosomes, normally an indicator of cellular senescence — in fact, these appeared to increase slightly in length. This increase is surprising, given that the number of mitotic divisions greatly exceeds that of sexually produced animals and that any deleterious effects of cloning might be expected to be amplified in sequentially cloned mice. Our results offer a new approach to the study of organismal ageing.

Founder clones (G1) of two lines, A and B, were generated using cumulus cells of adult female B6C3F1 mice (agouti coat colour) as nucleus donors, and oocytes from adult B6D2F1 (black) females as nucleus recipients. The cloning procedure