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Pinealectomy Increases Thermoregulatory Set Point Temperatures in the Lacertid Lizard *Podarcis sicula*

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The pineal complex (i.e., the pineal gland and the parietal eye if it is present) is involved in the mediation of thermoregulatory behavior in a number of lizard species. Pinealectomy usually causes a reduction in preferred body temperature or mean activity temperature, whereas parietalectomy, or simply covering the parietal eye, may cause increases in these temperatures (Firth et al., 1988; Phillips and Howes, 1988; Firth et al., 1989; Sievert and Hutchison, 1989). None of these studies involved lizards in the family Lacertidae. Shielding the parietal eye can cause decreases in mean body temperatures in the lacertids *Lacerta viridis* (Rismiller, 1987) and *Podarcis muralis* (Tosini and Avery, 1994). Since this is the opposite effect to that seen in other lizards, we investigated the effects of pinealectomy on a lacertid lizard. *Podarcis sicula* was used because this species was already the subject of investigation of the role of the pineal complex in mediating rhythmical and circadian behavior (Foà, 1991; Foà et al., 1993; Innocenti et al., 1993). All animals were adult males (N = 12; weight range: 10-12 g).

Lizards were captured in June 1992 on sand dunes along the coast near Pisa, Italy, and pinealectomized or sham operated with the procedure reported by Foa (1991). The lizards were then maintained for about one month in the laboratory at about 20 C in cages measuring 90 × 60 × 30 cm under natural illumination, i.e., the cages containing the animals were located near a window so that the animals were subjected to external illumination and photoperiod. Heat for thermoregulation was supplied from a 60 W tungsten bulb held 20 cm above the floor of each cage, and shone through a metal funnel so that only a small pool of heat and light, about 10 cm in diameter, was produced on the floor; this was called the 'basking

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spot.' While the bulb was switched on a lizard usually alternated periods of basking at the basking spot with periods of movement about the cage.

For experiments lizards were housed individually in an experimental arena as described by Tosini and Avery (1993). Temperatures of the dorsal surface of the body of basking lizards ($T_{surface}$) were determined using a pyroelectric vidicon camera (Avery and D'Eath, 1986). Methods for determining the sensitivity and accuracy of this equipment, and for calibration so that it could be used as a radiation thermometer, are given in Jones and Avery (1989). The $T_{surface}$ recorded when a lizard appeared at the basking spot is termed T_{bask}. Surface temperatures were subsequently recorded at 30 sec intervals and finally at the moment when the animal moved off after basking. This temperature is termed T_{move} (see Jones and Avery, 1989, for a more detailed rationale for this terminology). In small lizard species (body mass less than 20 g) the use of $T_{surface}$ may represent a good estimate of the internal temperature (Jones and Avery, 1989; Tosini and Avery, 1993). A series of 10 T_{bask} and T_{move} temperatures were then recorded in each of the experimental animals. In addition, we also measured the bask duration, subsequent period of movement about the arena before returning to the basking spot, and heating rate for each of the basking events. All measurements were carried out between 11:00 and 14:00 GMT; during this period of time food was not present in the arena.

Table 1 shows experimentally-determined values for overall mean T_{bask} and mean T_{move} for each individual tested. None of these means varied significantly among animals in the same group (Friedman tests; X^2 values are shown in Table 1; $P > 0.1$ in all cases). Values for T_{move} were significantly greater in pinealectomized lizards than in sham or unoperated lizards (multiple comparisons test, $P < 0.05$ [Siegel and Castellan, 1988]), while mean T_{bask} values, although higher in pinealectomized lizards, did not significantly differ among lizards of the three groups (Friedman test; $X^2_{11} = 11.8$, $P > 0.1$). Mean bask duration, mean heating rate and mean forage duration did not differ among individuals of the three groups (Friedman tests; $X^2_{11} = 8.5$, 10.1, and 4.26 for bask duration, heating rate and period of movement about the arena before returning to the basking spot respectively; $P > 0.1$ in all cases).

The increases in T_{move} that followed pinealectomy were small, but statistically significant in all individuals tested. Although T_{bask} values were not significantly higher in pinealectomized lizards they increased in all the animals after pinealectomy.

This finding contrasts with results of all previous studies on pinealectomy, in which body temperature either fell (e.g., Stebbins, 1960; Firth et al., 1980, 1988, 1989) or did not change (e.g., Firth et al., 1989). None of the lizards studied previously was a lacertid. However, Lacertidae respond to parietal eye impairment differently from other lizards (Rismiller, 1987; Tosini and Avery, 1994). The neural connections of the pineal are extremely complex (Engbretson, 1992). The pineal also produces the hormone melatonin in vertebrates (Gern et al., 1986). In *P. sicula* pinealectomy abolishes the daily rhythm in plasma of melatonin levels (Foà et al., 1992). It is tempting to speculate that the relative contributions of neural information and melatonin in mediating thermoregulatory behavior might differ among the lizard species previously studied (many of which have been iguanids) and the lacertids. One of the factors that will complicate an investigation of this hypothesis is that the pineal and the parietal nerve are associated; it has so far proved impossible to remove the former without also destroying the latter (and often the parietal eye, as in the present experiment). Although the pineal and the parietal eye operate in many respects as an entity, their precise functions are not identical (e.g., Engbretson and Hutchison, 1976; Bethea and Walker, 1978; Firth et al., 1988).

TABLE 1. Overall mean T_{bask} and T_{move} for each pinealectomized, sham operated and unoperated lizards (N = 10 in all cases). The values marked with an asterisk (*) differ significantly ($p < 0.05$) from the other values for the same variable (multiple comparisons test).

	T_{bask}		T_{move}	
	$\bar{x}$	SD	$\bar{x}$	SD
Pinealectomized				
Lizard 1	34.9	1.18	39.8*	0.38
Lizard 2	34.6	1.20	39.6*	0.32
Lizard 3	34.9	1.02	40.1*	0.22
Lizard 4	34.5	1.33	39.9*	0.35
	$\chi^2_3 = 3.8$		$\chi^2_3 = 5.4$	
Sham operated				
Lizard 5	34.1	0.66	38.6	0.33
Lizard 6	33.9	0.73	38.7	0.25
Lizard 7	33.8	0.70	38.6	0.31
	$\chi^2_2 = 3.1$		$\chi^2_2 = 4.1$	
Unoperated				
Lizard 8	33.6	0.75	38.6	0.21
Lizard 9	33.7	0.73	38.5	0.18
Lizard 10	34.0	0.71	38.9	0.26
Lizard 11	33.8	0.66	38.8	0.25
Lizard 12	33.7	0.64	38.7	0.31
	$\chi^2_4 = 6.2$		$\chi^2_4 = 4.9$	

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Natural Toe Loss in Southeastern Australian Skinks: Implications for Marking Lizards by Toe-clipping

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The use of toe-clipping as a method of marking lizards and amphibians is widespread (Swingland, 1978; Ferner, 1979; Dunham et al., 1988), yet few studies have been published on the incidence of missing toes in natural populations, or the effects of toe loss either from natural causes or by clipping. Toe loss is often assumed to have little or no effect on the subsequent fitness of the individual (Woodbury, 1956; Ferner, 1979; Dunham et al., 1988), although Clarke (1972) found that the probability of recapturing *Bufo woodhousei* decreased as the number of toes clipped increased. In lizards, toe-clipping has been shown to have no effect on the sprint speed of either *Sceloporus merriami* (Huey et al., 1990) or *Cnemidophorus sexlineatus* (Dodd, 1993).

The frequency of missing toes in natural populations may be indicative of the effect of toe loss on subsequent survivorship, and thus have implications for toe-clipping as a marking method. If the incidence of natural toe loss is relatively high within a population, the effect of missing toes on survivorship should be small, as it is unlikely that high frequencies of injury could persist in populations if those injuries had a severe effect on survivorship. Toe-clipping may be an appropriate method for marking such a population. Conversely, a low frequency of natural toe loss may indicate that the loss of toes significantly affects subsequent survivorship. Bustard (1968a, 1971) noted that no cases of natural toe loss occurred in the geckoes *Oedura monilis* and *Gehyra variegata.* Both species are arboreal, and both have elaborate toe pads which facilitate climbing (King and Horner, 1993). In these species, toe loss might have an effect on survivorship, and the high proportion (69%) of toe-clipped *O. monilis* individuals that were never recaptured was attributed to the effect of toe-clipping (Bustard, 1971). However, it may simply be that there are few or no cases of toe loss in these species, so that a lack of missing toes does not imply a fitness cost of toe loss. There were also no cases of natural toe loss recorded in *Heteronotia binoei,* a terrestrial gecko with padless toes (Bustard, 1968b).

The frequency of natural toe loss varies among sex-

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