7.4 Adaptive hypothermia

7.4.1 *Hibernating mammals*

Hibernation (winterschlaf, winter dormancy) may be defined as a periodic phenomenon in which body temperature falls to a low level, approximating to the ambient, and in which heart rate, metabolic rate and other physiological functions fall to correspondingly minimal levels. Spontaneous arousal is possible at any time during hibernation.

Hibernation is an adaptation to overcome periods of climatic stress associated with food shortage and is practised by certain species within three mammalian orders: *Rodentia*, *Insectivora*, *Chiroptera*. Hibernators are homeothermic during the summer, although the precision of temperature regulation is less than in non-hibernators.

During the winter, when food is scarce, the low environmental temperature would require a higher metabolic rate to maintain core temperature; under such conditions, the hibernator becomes virtually poikilothermic. It spends its time in an inactive, torpid state and supports its much reduced metabolic requirements by the energy stores it laid down in preparation for hibernation.

THE HIBERNATING STATE During hibernation, the metabolic rate falls to as little as 1/70 of the basal non-hibernating rate and the core temperature falls to within 1–2 °C of the environmental temperature (it should be noted that hibernators tend to retreat into burrows or nests in which the microclimate is somewhat more favourable than in the outside environment).

If the local environmental temperature falls to dangerously low levels, where there would be danger of the tissues freezing, hibernators have two safety mechanisms which tend to prevent this occurrence: the metabolic rate may increase without the animal waking up, a relic of homeothermy, or the animal may undergo complete arousal.

The heart rate during hibernation may fall to as low as 5-6 beats per minute, but, despite this, intense vasoconstriction together with an increase in the viscosity of the blood ensures that the blood pressure remains adequate. The respiratory rate may decline to one respiration per minute and kidney function is much reduced. There is still formation of some urine and the animal may undergo periodic arousal for purposes of micturition. There are profound changes in the endocrine system. Many

glands, such as the thyroid, adrenals, pituitary and gonads show signs of regression and inactivity, and cold no longer stimulates the thyroid and adrenal glands. However, despite extensive research on the endocrine system, it is still not clear what is the precise significance of specific endocrine changes to the induction and maintenance of the hibernating state.

ENTRY INTO HIBERNATION There are two main patterns for entering into hibernation. Some species, such as the ground squirrel (*Citellus beecheyi*), enter hibernation gradually over several days. The nocturnal core temperature falls progressively lower over several successive nights in a series of 'test drops' until a critical point is reached where the temperature fall becomes non-reversible and the animal enters prolonged hibernation. In other species such as the woodchuck (*Arctomys* spp.), there is a single relatively rapid entry into hibernation which occupies only a few hours.

The trigger for hibernation is not well understood but it is clearly related to environmental temperature, lighting regime and the extent of the food stores deposited in the body. Some interesting recent work has indicated that a blood-borne substance may trigger hibernation in certain species. Thus the injection of a small volume of blood taken from a hibernating ground squirrel into a non-hibernating individual induced hibernation within 48 hours. Such hibernation could be induced in March, when ground squirrels are not normally prepared for hibernation, and was maintained throughout the summer. The factor or factors in the blood responsible for inducing hibernation have not yet been characterized.

AROUSAL FROM HIBERNATION Although most hibernating species remain in their burrows for many months, most awaken from dormancy several times during this period. These periods of arousal may last a few hours or several days. During this time metabolic waste products are eliminated and some species, such as the dormouse, may eat some of the food previously stored in the burrow.

Arousal is a complex and highly coordinated process. There is a sudden increase in heat production and oxygen consumption which can be almost entirely attributed to shivering, to the activity of the heart and to the metabolism of brown fat. The heat produced is distributed via the circulation to particular organs in turn. The heart, lungs and brain, together with other less vital structures in the head and thorax, are warmed before the abdomen and extremities. This circulatory coordination is organized by the action of vasoconstrictor nerve fibres of the sympathetic system and means that in early arousal there may be as much as 20 °C difference in temperature between the thorax and abdomen. Changes in heart and brown fat temperature and rectal temperature are illustrated in Fig. 7–4.

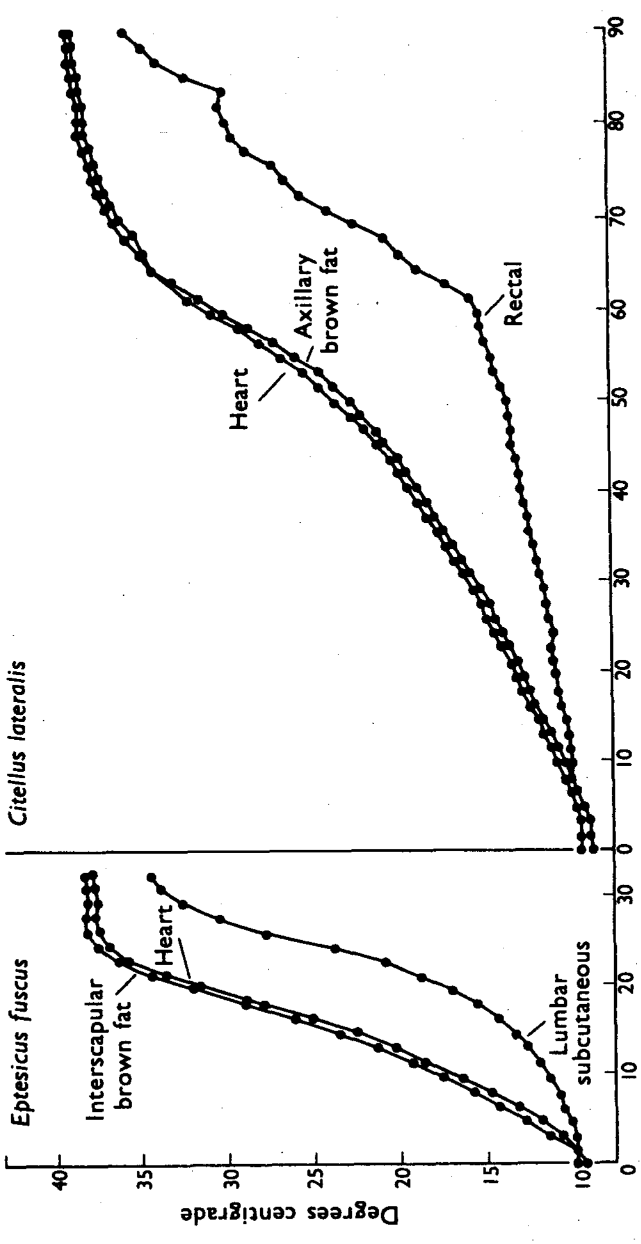

Fig. 7-4 Patterns of body temperature during arousal in the big brown bat (*Epesicus fuscus*) and the golden-mantled ground squirrel (*Citellus lateralis*). Environmental temperature, 6 to 8 °C. (From HAYWARD, J. S. et al., (1965). *Ann. N.Y. Acad. Sci.*, **131**, 441).

7.4.2 *Dormancy in poikilotherms*

Many poikilotherms overwinter in a state of dormancy with a much decreased metabolic rate and a body temperature very close to that of the environment. This is not comparable with true hibernation as defined on p. 53 first because arousal is not possible until the animal has been *passively* warmed and secondly, there is no 'fail-safe' device as in mammalian hibernators, who will increase their metabolism or wake up if the body temperature approaches freezing point. Under such conditions poikilotherms freeze.

Conclusion

We have seen in this book how homeothermic animals have evolved means of regulating their internal temperature in such a way that they are able to function efficiently throughout a wide range of environmental temperatures. Poikilotherms, on the other hand, have not escaped from the thermal limitations of their environment and are, in consequence, severely limited in their ecological potential.

However, homeothermy cannot simply be dismissed as an evolutionary trick calculated to allow the exploitation of thermally difficult habitats, because it has perhaps even greater significance as a prerequisite for physiological sophistication. For without homeothermy, the development and functioning of intricate biological mechanisms such as the human brain would be inconceivable.