PERIPHERAL THERMAL RECEPTORS

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I. INTRODUCTION

Thermal receptors as a rule do not provide an organism with the kind of detailed information one is accustomed to expect from sense organs for vision, hearing, or smell. The location of nest, brood, mate, foraging areas, and predators within a biotope is mediated largely by sensory systems other than thermal, though there are notable exceptions. The facial pits of crotalid vipers (Bullock and Diecke, 1956; Goris and Nomoto, 1967) enable their possessors to strike successfully at small warm objects in the dark. Similar pits line the mouth region of the Boidae (Haris and Gamow, 1971; Hensel, 1947b). *Melanophila*, a bupestrid beetle, has sense organs at the rim of the depressions where its middle legs join its mesothorax. Apparently the beetle employs these organs to locate the scene of forest fires (Evans, 1964, 1966a,b). There it seeks fairly intact stumps of freshly injured trees for its grubs to feed in. Fire damage affords access. Mosquitoes are another example. They are equipped with antennal thermal receptors which in combination with chemoreceptors presumably assist them in the search for their warm-blooded prey (Davis and Sokolove, 1975). But on the whole, thermal receptors tend to provide background information such as temperature internal to the organism, of its periphery and of the medium in which it is immersed, and also on the direction and rate with which these temperatures are changing. Such information is as important as it is general. At least in indirect form, it is prerequisite for thermal regulation.

The range of body temperature at which an animal functions effectively is quite narrow, often including little more than 4°C. Thus at least during those periods in which survival demands active
and successful competition, it becomes incumbent on the organism to match heat flow with heat production precisely in order to maintain its internal temperature within the range in face of variation in external temperature and its own activity. To make the match, control can be exerted on heat production, on heat flow, on peripheral or even on external temperature, and of course, on combinations of these parameters. Heat production is no great problem for desert jackrabbits forced to run in the cool early morning. But it the heat of the day locomotor activity can drive their internal temperature as high as 42 or 43°C. Then their running periods are much shorter. They must stop and do so, preferably in the shade (Shoemaker et al., 1976). Similarly on a hot day the thorax temperature of a bee may exceed 38°C during flight. But when the air streaming past is no longer enough to offset the rate of temperature increase, a drop of fluid appears in the mouthparts of the bee which it proceeds to smear over its thorax (Esch, 1976). Evaporating water is an effective coolant even when it is not pure. Moreover, the same heat production which becomes a problem at high ambient temperatures can be a solution when they are low. Sphinx moths employ prolonged bursts of muscular activity to elevate their thorax to flight temperature (McCrea and Heath, 1971; Heinrich, 1974). Shivering is commonplace in the cold, as it is also in animals emerging from hibernation. A more economical form of thermoregulation, however, is adjustable insulation. Birds ruff their feathers when they sit in the cold, and when it gets too hot pigeons increase the air gap between wings and body even to the point of extending a wing, the better to expose otherwise densely covered surfaces. Another alternative is to enhance or curtail peripheral blood flow, depending on the desirability in the circumstances of bringing core temperature blood to the surface where it can function as a heat exchange medium. Still another is to regulate external temperature by avoiding areas with extremes, as fish do in the neighborhood of a power plant dissipating waste heat into the water (Gift, 1977). An animal can move down the temperature gradient into a more suitable environment. When avoidance is impossible, however, a further alternative is to stop fighting to maintain a large temperature difference towards the outside. An animal may wait out a season in hibernation, in the inactivity of lowered temperature. Or in the extreme, it might leave the waiting to embryonic progeny in its eggs, and no longer able itself to regulate, simply die.

II. ADAPTIVE RADIATION

The preceding examples illustrate that thermoregulation is commonplace in the animal kingdom and that there is a variety of mechanisms which animals can make use of to achieve independence of ambient temperature. Wherever thermoregulation is accomplished through nervous control, the existence of thermal sense organs is strongly suggested. In many instances their existence has been de-