with the finding that the giant cell has a long time constant. A short duration pulse applied to a distant location on the cell (axon) would appear both lengthened and reduced in amplitude at the soma[5].

The results are of interest for 2 reasons: first, the presence of electrotonically conducted potentials, if undetected, can introduce a serious source of error in the analysis of complex responses observed in cells following stimulation of peripheral nerves. Second, in the specific case we have studied, the synaptic region of the gastro-oesophageal giant cell is dispersed along the main axon and along dendritic-like axonal branches which extend into the neuropile of the neighboring buccal ganglion[6]. We suggest that the extensive electrotonic conductive properties indicated by our results may have physiological significance by allowing synaptic events occurring at regions distant from the integrative center of the neuron to influence the activity of the cell without the involvement of all-or-nothing conducted activity.

Zusammenfassung. Nach Axon-Reizung eines Mollusken-Riesenneurons sind zweierlei Potentiale zu beobachten: eine antidromische Zacke und eine schnelle Hyperpolarisation, was bedeutet, dass das hyperpolarisierende Potential ein durch die Reizung induziertes und über das Axon geleitetes elektrotonisches Potential darstellt.

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Interaction of Spinal and Hypothalamic Thermodetectors in Body Temperature Regulation of the Conscious Dog

Thermosensitivity of the spinal cord has been derived from the findings that selective cooling within the vertebral canal causes shivering and cutaneous vasoconstriction[1], while selective heating is followed by suppression of shivering, vasodilatation and thermal panting[2]. These experiments have further shown that the diverse effector mechanisms participate in the thermoregulatory responses to varying extents, which are dependent on the general thermal state of the animal. Therefore, some cooperation between cutaneous, hypothalamic[3] and spinal cord thermodetectors must exist. To find out in what way this cooperation is achieved, the temperatures of the spinal cord and of the hypothalamus have been varied independently in unanaesthetized dogs at different ambient temperatures.

Methods. In 2 dogs weighing 14 and 19 kg, thermodes of polyethylene tubing and a thermistor probe were implanted chronically into the peridural space of the vertebral canal. Additionally, implantation of 6 thermodes of stainless steel tubing and of 1 thermistor probe into the anterior hypothalamus was performed stereotaxically under X-ray control after having filled the third ventricle with contrast medium[4]. After recovery from the surgical procedure, 21 experiments were carried out in the conscious animals at constant ambient air temperatures between 10 and 30 °C, in which the hypothalamic and vertebral canal thermodes were perfused with cold or warm water of constant temperatures between 20 and 48 °C. Temperatures in the rectum, in the anterior hypothalamus and the vertebral canal were recorded. To estimate heat production and evaporative heat loss, oxygen consumption and respiratory rate were determined. Skin temperatures of the paws and thermal conductivities of the skin at one ear and at the pastern joint of one hindleg were recorded to disclose variations of cutaneous blood flow.

Results. The Figure demonstrates 3 sections out of 1 experiment which was performed at an ambient air temperature of 20 °C. The first part contains the thermoregulatory responses of the animal to selective spinal cord cooling and to subsequent selective cooling of the anterior hypothalamus; both cooling periods were performed by perfusing the peridural thermode, and the hypothalamic thermodes respectively, with water of 25 °C at a rate of flow of 45–55 ml/min. Cooling of the spinal cord was followed by cold shivering and by increase in heat production which amounted, in average, to 80% of the precooling level. Cutaneous blood flow was reduced during spinal cord cooling, as indicated by the decreasing thermal conductivity of the skin of the hind leg.

Selective cooling of the anterior hypothalamus led to stronger shivering resulting in a mean increase in heat production for 140%. Additionally, cutaneous vasoconstriction of the ear is indicated by the decreasing thermal conductivity.

This part of the experiment shows that the thermoregulatory responses to spinal cord cooling and to hypothalamic cooling correspond to each other. From the greater responses to hypothalamic cooling it cannot be concluded safely that spinal thermosensitive structures play a minor role as compared with the hypothalamic thermodetectors. The distribution of the spinal thermodetectors is unknown; it must be taken into account that a considerable amount of thermally inert tissue is cooled by the peridural thermode.

The second part of the Figure demonstrates the thermoregulatory response to simultaneous cooling of the spinal cord and the anterior hypothalamus. The intensity of cooling was the same as before. Maximum shivering was elicited by this combined cooling. Oxygen consumption was elevated to an average value of 18.7 ml/min/kg, i.e. 210% above the resting level, with a peak value of 25 ml/min/kg. Cutaneous blood flow was markedly reduced, both on the ear and on the hindleg. Rectal temperature rose for 0.6 °C within 10 min. Apparently, the spinal and hypothalamic thermodetectors act together in pro-

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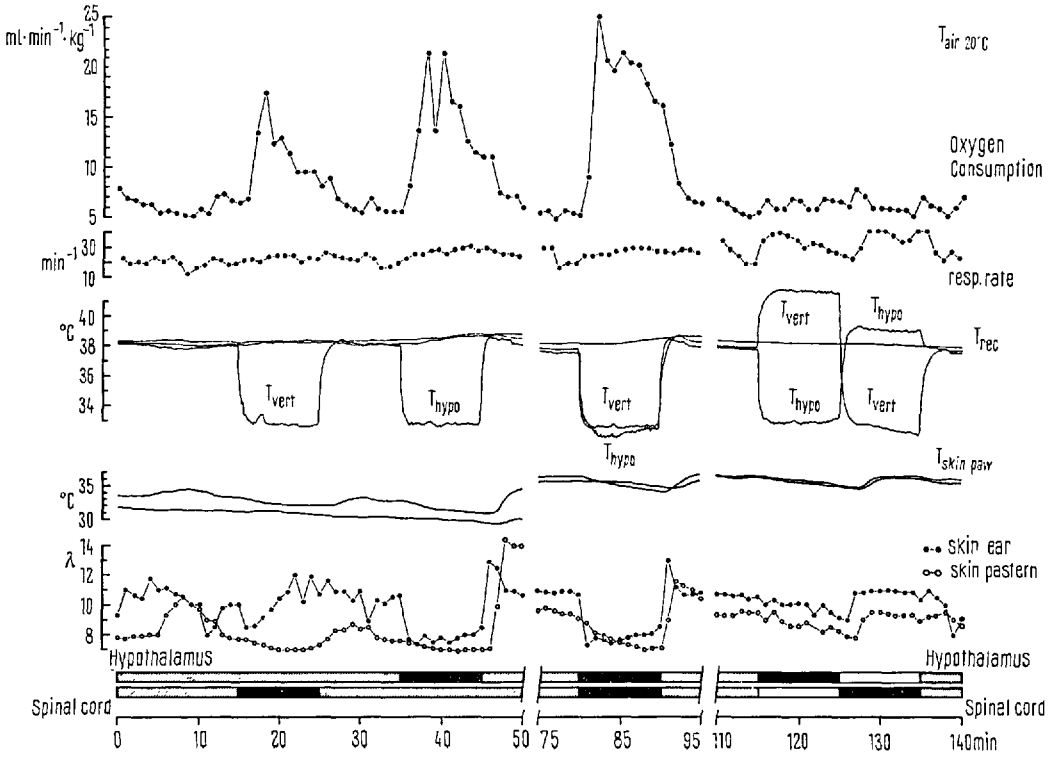

Selective changes of the temperatures of the anterior hypothalamus and of the spinal cord in a conscious dog. Localization and direction of experimental temperature changes are indicated by the bars at the bottom of the figure: black bars, cooling; white bars, heating. For further details see text.

voking this big response of the heat producing mechanism of cold shivering.

The third section demonstrates the result of antagonistic temperature changes applied to the spinal cord and to the anterior hypothalamus. At first, hypothalamic cooling was performed with the same cooling intensity as in the preceding periods, while the spinal cord was heated by perfusing the peridural thermode with water of 46 °C. In accord to the previous periods, hypothalamic temperature dropped to 33 °C, but neither shivering with increased heat production nor peripheral vasoconstriction occurred. Apparently, the thermoregulatory drive of hypothalamic cooling was counteracted by the elevation of vertebral canal temperature to 41.6 °C. At the 125th min of the experiment, cooling and heating of the anterior hypothalamus and of the spinal cord were reversed. While spinal cord cooling was performed again with the same intensity as in the preceding cooling periods, the intensity of hypothalamic heating was chosen so as to cancel out the thermoregulatory drive of the spinal cord stimulus. This was achieved fairly well by perfusing the hypothalamic thermodes with water of 42.5 °C, leading to a rise of hypothalamic temperature of 1.0 °C. No shivering occurred; hypothalamic heating seemed, however, to be slightly predominant, since a tendency towards increased cutaneous blood flow became obvious.

The experiment presented in the Figure was carried out at an ambient air temperature slightly below the critical temperature level for this animal. By several other experiments it was confirmed that, under such conditions, cooling of spinal and hypothalamic thermodetectors predominantly acted on the thermoregulatory effector mechanism of heat production. With increasing ambient temperatures, however, the responses were shifted towards the effector mechanisms governing heat loss. If, for example, cooling of the spinal cord or the anterior hypothalamus was performed at high ambient temperatures, only weak shivering was evoked. If thermal panting was present under these conditions, it was inhibited by cooling and was activated by heating of both central thermodetectors. With respect to thermal panting, thermal stimuli of the same kind applied simultaneously to the hypothalamus and to the spinal cord had synergistic effects. Opposed stimuli antagonized each other.

Conclusions. From the results of present experiments, the following conclusions may be drawn: (1) Thermal stimuli applied to the central thermodetectors of the spinal cord and of the hypothalamus parallel each other with respect to their influences on the various effector mechanisms of the temperature regulating system. (2) Temperature changes of the same direction have an additive effect, while opposite temperature changes tend to cancel each other. (3) This cooperation of spinal and hypothalamic thermodetectors is maintained under various external temperature conditions. (4) Thermal afferents of skin, hypothalamus and spinal cord are coordinated by the central nervous temperature regulating system to result in one uniform thermoregulatory response.

Zusammenfassung. An wachen Hunden wurden kombinierte thermische Reizungen von Rückenmark und Hypothalamus bei verschiedenen Lufttemperaturen durchgeführt. Die Untersuchungen führten zu dem Ergebnis, dass die thermischen Afferenzen aus Rückenmark, Hypothalamus und Haut in einem gemeinsamen Zentrum zu einer koordinierten effektorischen Leistung des temperaturregulierenden Systems verarbeitet werden. Die Funktion der hypothalamischen und der spinalen thermosensiblen Strukturen erwies sich dabei als völlig gleichartig.

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