1.4 The Location and Function of Different Skin Thermoreceptors

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1.4.1 Introduction

In the continuing endeavor to understand the fundamental principles of homeothermy, the classical theories must be reassessed in the light of new findings and the interpretations that can be placed upon them. One long-standing theory is that the direction and density of heat flow through the skin of homeothermic organisms may selectively activate thermoreceptors lying at varying depth within the skin, and that a spectrum of different impulse frequencies in the thermosensor afferent nerve fibres may provide the central nervous system with information on the direction and rate of heat flow through the skin (Ebbecke 1917). In 1953, Hensel established that the latencies of changes in discharge frequency of skin thermoreceptors are not the same when a thermal stimulus is applied. The reason for these differences, and their physiological significance, remain unestablished. Whether the latencies in the responses of skin thermoreceptors to thermal stimulation can be correlated with the position of the receptors in the skin has now been investigated.

Ivanov et al. (1976) have found a regular delay in the change of discharge frequency of some cold thermoreceptors when skin temperature was caused to change. The delay was practically equal to the time lag of temperature changes measured at depths of about 2–2.5 mm below the skin surface. On the basis of this observation, the conclusion was made that some of the cutaneous thermoreceptors are situated in the deeper layers of the skin near to the subcutaneous fat.

A comparison of the effects of superficial and deep skin temperature changes on cutaneous thermoreceptors activities presents some new evidence in support of this hypothesis.

1.4.2 Experimental Techniques

The arrangement of water-perfused thermodes inserted into the skin of upper lip of a rabbit is illustrated in Fig. 1. One of the thermodes was inserted between the cutis vera and the subcutaneous fat. The other was placed just over the cutis vera. A
thermocouple (copper-constantan) of 0.1–0.2 mm diameter was inserted under the skin parallel to the skin surface for a distance of 1 cm at the depth 0.2–0.4 mm from the skin surface. Another thermocouple was inserted at the depth of 2–2.5 mm.

1.4.3 Experimental Results

1.4.3.1 Temperature Changes in the Skin and Responses of Thermoreceptors

Figure 2 shows the temperature shifts in surface and deep skin layers in response to the increase and decrease of temperature of one thermode or the other. The continuous line represents the temperature in the surface skin layers; the dotted line represents the temperature in the deeper layer. Changes in the temperature of the more superficial thermode gives rise to rapid and large temperature changes at depths of 0.2–0.4 mm from the skin surface, and to a slower and smaller shift in temperature at depths of 2–2.5 mm. Changes in the temperature of the more deeply placed thermode gave rise to rapid and large temperature shifts in the deep layers of the skin and to a slow and small shift in the surface layers.

Figure 3 illustrates the effects of such induced skin temperature changes upon thermoreceptors activities. In seven out of ten thermoreceptors (the first group), the sudden decrease in the temperature of the surface thermode produced a transient overshoot in discharge frequency followed by adaptation to the new static frequency level (Fig. 3a). The sudden increase in the temperature of the surface thermode produced in this group of thermoreceptors a quick decrease in discharge frequency followed by its very slow increase (Fig. 3b).

The same extent and rate of temperature changes in the subcutaneous thermode produced, in this same group of thermoreceptors, only a gradual increase in discharge frequency on cooling without any obvious change on warming (Fig. 3c,d).

The other three thermoreceptors (the second group) gave converse responses to the same sudden temperature shifts of both thermodes. Temperature shifts in the surface thermode were followed by only slow gradual changes in discharge frequency (Fig. 3e,f), while the thermoreceptors showed an overshoot or undershoot in the discharge frequency on colling or warming, respectively, of the subcutaneous thermode (Fig. 3g,h). The results of individual experiments can be seen in Fig. 4.