Effect of Electric Fields on Mice

It has recently been postulated[1] that mice are sensitive to electric fields occurring in the Earth's atmosphere and may obtain "time cues" from the daily variations in this field, and further suggested that the field may be responsible for the 24 h rhythm exhibited by certain polar-dwelling animals. I find this untenable for the following reasons.

The electrical current passing through a high and low resistance connected in series is practically independent of the value of the smaller resistance. Similarly, because the electrical conductivity of air (about 10^{-14} Ω^{-1} m^{-1}) is much smaller than that of the earth (10^{-6} to 10^{2} Ω^{-1} m^{-1}) (ref. 2) and of any animal situated on it, the current through the animal is determined by the leakage current through the air (and not at all by the conductivity of the animal). If the animal is assumed to be hemispherical, the effect of the protuberance above the surface plane is to increase the current density flowing through it to about three times the undisturbed value[3]. This is about 10^{-12} A m^{-2} when the geoelectric field is 100 V m^{-1} (ref. 2). Most of the electrical energy dissipated in the animal will appear in the high resistance skin layers. Taking values of 10^{2} Ω m^{-2} and 10^{-2} m^{2} as extreme upper limits for the skin resistance and area for a mouse, the total energy dissipated is $(3\times10^{-12})^2$ 10^{2} 10^{-2}, or 10^{-23} W. This is an upper limit to the energy available from the field, and a more realistic estimate would be very much lower than this.

Such a low energy flux is unlikely to produce any significant stimulus in the animal; for comparison, the minimum energy flux required to stimulate the human eye is about 10^{-16} W (ref. 4) and the minimum energy required to induce the electric field response (galvanotaxis) in the unicellular protozoan Paramecium is 10^{-14} W (unpublished results of A. M. R.). It does not seem necessary to invoke a geoelectric response to explain the 24 h periodicity of reindeer in Alaska[5]; apart from a diurnal temperature variation of about 0·5° C at these latitudes, the altitude of the Sun in the sky during the Arctic summer varies considerably (being as much as 40° at latitude 70°) during the 24 h day. Both these stimuli are more energetically favourable than the postulated geoelectric effect. Interpretation, involving the measurement of spontaneous activity in mice[1], also seems questionable. The animals were most active during those periods of the day when their cage was charged to +500 V with respect to earth. This, however, can hardly be regarded as conclusive evidence for a direct electric-field interaction. The mice may have been responding to noise generated by the electrical equipment, or to corona discharges from the cage, which the mice (but not the experimenter) could hear. The electric field may have changed the relative concentrations of negative and positive ions inside the cage, and several investigators have claimed to have shown a clear relationship between ion density and spontaneous activity in animals[6]. Some examination of these possibilities is surely necessary if an unequivocal conclusion is to be drawn from the experimental results.

To summarize, it seems unlikely, on theoretical grounds, that any organisms are at all sensitive to atmospheric electric fields.

A. M. Roberts

Department of Physics,
Guy's Hospital Medical School,
London SE1.

Received May 19, 1969.

1 Dowse, H. B., and Palmer, J. D., *Nature*, **222**, 564 (1969).
2 *American Institute of Physics Handbook* (McGraw-Hill).
3 Page, L., and Adams, N. I., *Principles of Electricity* (Van Nostrand).
4 Pirenne, M. H., *Vision and the Eye* (Chapman and Hall, 1967).
5 Lutherer, L. I., Folk, G. E., and Essler, W. O., *Amer. Zool.*, **2**, 536 (1962).
6 Corrado, A. E., and Beckett, J. C., *Western Med.* 6 (1960).

Cellular Basis of Colour Vision in the Honey Bee

After exposure to light, the rhabdomeres[1,2] and cytoplasmic components[3,4] of the visual cells of invertebrates undergo structural changes. These changes are important, for they contribute to an understanding of the mechanism of perception of polarized light in arthropods[5], as well as to an understanding of colour discrimination in insects.

The retinula of the compound eye of the honey bee consists of eight (occasionally nine) visual cells[6–8] which can be classified into three types according to their fine structure[8]. The arrangement of these cells within the retinula is shown in Figs. 1 and 2*a*.

Colour vision in the honey bee is trichromatic[9,10], and the visual cells of different spectral sensitivity form a morphological basis for colour vision[11]. The sensitivity maxima of different receptors are those at 530, 430 and 340 nm. Although Autrum and Zwehl[11] found another type of visual cell with $\lambda_{max}=460$ nm, they failed to find more than two cells of this type, so it does not seem reasonable to consider the two cells as a fourth type of receptor.

I have been trying to establish whether there is a connexion between the "morphological" types of visual cells and the "physiological" ones. Light of a certain wavelength and high intensity was used routinely to illuminate the ventral region of the compound eye (the twentieth–thirtieth horizontal row of ommatidia counting from the edge of the eye), the λ_{max} of the light having been chosen in such a way as to stimulate the appropriate receptors[12] (an ordinary selective adaptation technique). Fixation of the compound eye for electron microscopy was carried out in the dark at 4° C for 2 h. To prevent undesirable adaptation to the dark in the course of fixation, the honey bee—while adapted to the light—was gradually cooled to the standard temperature of fixation. Fine structural changes of the rhabdomere provided the best criterion for evaluating the cell response after illumination with light of a certain wavelength.

Exposure to light of a wavelength greater than 480 nm (green–yellow) brought about marked changes in the rhabdomeres of the type II and type III cells, their rhabdomeric microvilli swelling and increasing in diameter when adapted to light. With high intensity illumination a number of large vacuoles appeared in the region where microvilli came off the cell. An extreme response—disintegration of the microvilli of the type II and type III cells—is shown in Fig. 2*b* (no changes occurred in this light in the microvilli of the type I cells). Similar changes occurred in the neighbouring ommatidia all around the section and in all regions of the retinula.

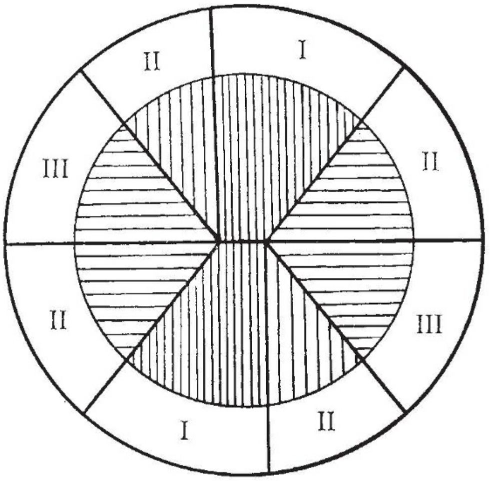

Fig. 1. Diagram of a rhabdom of honey bee compound eye, adapted to the dark. I, II and III represent the three types of visual cells.