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the hive is too heavy to lift, first remove supers and set them aside with covers and/or screens underneath and on top of them.

b. Place another hive on the old stand with empty frames (and foundation or starters if desired), and preferably one frame with honey and pollen, but no brood from the troublesome colony.

c. Undertake manipulations during the next day or two, when the foragers have returned to the old location, leaving young nurse bees (less disposed to sting) in the hive.

d. Either requeen the hive at the new stand, or provide a new queen at the old stand.

e. If it is necessary to keep colonies that are difficult to manipulate, there are benefits in using a bee house.

f. Use a cage round the hive, to prevent the access of robber bees during manipulations; this is also useful for public demonstrations.

g. If you do get stung, scrape the sting out immediately with the finger nail, without squeezing the poison sac; while this continues to contract venom is pumped into the wound. In the event of an anaphylactic reaction, adrenalin or other treatment must be administered without delay. Such reaction is fortunately very rare.

h. In exceptional circumstances, so many bees become alerted that effective operation is no longer possible. If a colony gets out of control in this way, reassemble the hive as quickly as possible, leaving no gaps by which robbers can enter. Leave the apiary, removing any uncovered combs, and do not open other hives there until the next day.

EFFECTS OF ELECTRIC CHARGES ON HONEYBEES

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Introduction

The fact that insects can carry an electrostatic charge is neither surprising nor new. A paper on the electrical properties of insect hairs was published as early as 1929[9]. The subject was not pursued further for a long time, seeming to be without importance, but when proof was obtained that bees and other insects in electric fields show changes in behaviour and metabolism, the electrostatic charges on them acquired a new significance. For this reason we tried, first of all, to measure the electric potential on the body surface of bees and then to ascertain the various factors that influence it[14].

From the measurements, which were initially purely physical, a physiological interest emerged which had not previously been recognized. A large number of new viewpoints came to light for discussing the perception of electric fields and also intraspecific communication of social insects, and for "weather sensitivity" and orientation[15]. Any working hypothesis had to be based on the fact that insects evolved relatively early in the history of the earth. Since then, electric fields in the atmosphere, and electromagnetic oscillations and atmospheric ions, have become established as meteorologically correlated factors in the insects' habitat. It seems unlikely that they should have remained unused as sources of information, especially by animals at a primitive evolutionary stage.

Charges on the body of an individual bee and on the colony

The body surface of a bee can be divided roughly into two areas as far as its electrical behaviour is concerned. All the membranous and glandular surfaces of the cuticula show great variations in potential, whereas the rest of the surface is at a low potential, up to +1 v. Over fairly short distances, there may be fairly high intensities of electric field, 25v/0·2cm. These measurements show certain peculiarities:

(*a*) Static potentials can be measured only from the antennae; elsewhere on the body there is an effect analogous to the discharge of a condenser.

(*b*) A bee is able to change the polarity of an antenna, completely or partly, in less than a second (Fig. 1). The change usually occurs just before flight take-off, suggesting perhaps that this change of polarity has some function in orientation. It may be brought about by an active stretching or compression of the cuticula (piezoelectric effect, electrostriction).

(*c*) The bee is insulated electrically from any underlying surface by the claws of its tarsi, but it can make electric contact with the surface by means of the electrolyte secreted from the arolium. According to the sign and magnitude of the potential of the underlying surface, the bee then becomes either charged or discharged.

Every colony as a whole shows a level of charge which is characteristic of it, depending on its strength and the amounts of brood and honey in it. The alighting board immediately in front of the hive entrance is within the electrical influence of the colony.

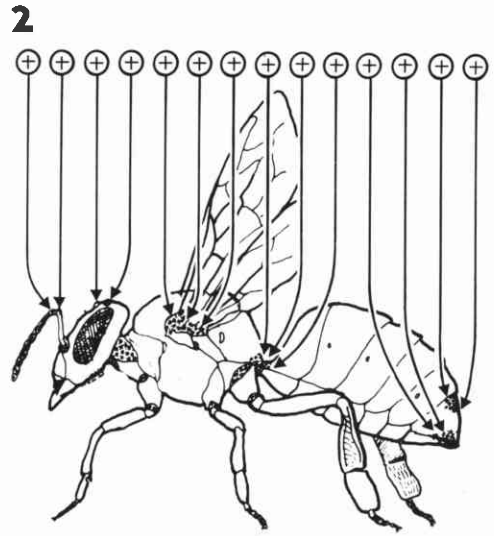


Fig. 1. Diagram illustrating the dipole effect of a bee's antennae. The bee is able to change the polarity of an antenna (e.g. from positive to negative) within seconds. The dotted lines give a stylized indication of the lines of the electric field.

Fig. 2. Diagram showing the lines of the electric field originating from the spatial charges; they are concentrated in cuticular areas of high electrical conductivity.

In the first place, the wood of the alighting board acts as a potential-distributor for currents originating in the hive. Secondly, when bees are fanning (either ventilating or scenting) charged particles are whirled out of the hive.

Beyond a (measurable) distance from the entrance, the electrical influence of the colony ceases. On days when a colony has a negative potential, positively charged bees returning to it change their potential from positive through zero to a negative value during flight. On other days (when its potential is positive) those bees that have a small positive potential increase this more and more as they approach the colony (Fig. 3). It is possible to record the arrival or departure of an individual bee, within a suitable distance of the hive entrance, by recording the change in the potential of the colony with a sufficiently sensitive instrument.

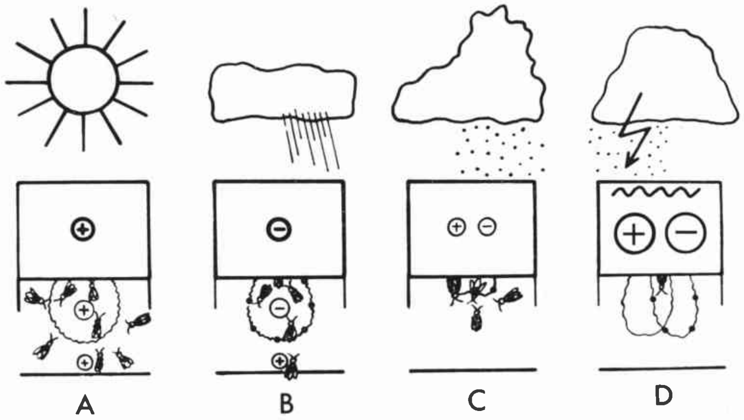


Fig. 3. Charges on bees and colonies in relation to the weather.
A. In fine weather the colony and the bees are positively charged.
B. In rain the charges are mainly negative, under the influence of the polarity of the clouds. The polarity of bees returning from foraging is changed.
C. Before a thunderstorm breaks, the high relative humidity causes discharge of bees on the ground, and a high bipolar concentration of atmospheric ions discharges bees in the air.
D. During the discharge of lightning, very high variations in electric potential occur in the colony.

Environmental influences

Electric field

Under the influence of an external electric field, a bee and all electrolytic pathways in it (haemolymph, epidermal secretions) are affected. The lines of the electric field are concentrated towards those areas of the cuticula which have a higher electric conductivity (due to ion pollution or local precipitation of moisture), or which present a pathway of lower electric resistance to the inner organs via the haemolymph (membranes, parts of the integument which act as sensors); see Fig. 2. The cuticula of antennae of live bees shows higher potentials than the rest of the body surface. Comparing

individual bees, the antenna potential of a queen is approximately twice that of a worker. This difference is due to the paired ovaries of the queen, which present an extensive electrolytic surface capable of being affected by an electric field.

Atmospheric ions

The amount of electric charge on a bee that is "whirring" its wings [German *schwirren*] depends on the number of unipolar ions per unit volume of air. The charge originates from the friction of the wings against the air.

Humidity and temperature

In relatively humid air, the surface of a bee's body is covered with a conducting film of fluid. Once there has been discharge to earth, subsequent charging of the bee is impossible.

Light irradiation

The incidence of light on the cuticula increases its surface conductivity. The results of recent experiments also indicate a photoelectric effect, i.e. emission of electrons from the cuticula under the influence of solar radiation.

Changes in behaviour brought about by electric parameters

An applied low-frequency field of 1–10 kv/m increases the metabolic rate of bees above that of bees screened electrically[1,4]. The hyperactivity of colonies in electric fields such as occur under high tension wires has already been described[11,18]. Recently we have obtained new results from controlled laboratory experiments, and have made a film which demonstrates them[16]. Bees in a strong electric field became aggressive, stinging each other to death; communication was disturbed. At still higher fields, the bees tore out the brood from the cells, and no new brood was produced. The bees left their hive if they could, or otherwise they sealed themselves inside it with propolis, closing not only any crevices and holes but also the entrance. Lack of oxygen led to intensive fanning, as for ventilation; abnormally high temperatures were produced, and the bees died.

Colonies subjected to electromagnetic oscillations (10–30 kHz, 800 v/m) produce a changed pattern of sounds, and their temperature increases[5,17]. Given a choice, bees will evade such oscillations[13].

Increased concentration of atmospheric ions increases motor activity and also affects the water balance of the bees[2]. Extensive electric screening of bees by a Faraday cage reduces general activity and results in a pathological loading of the rectum[2].

Human beings—often with a high electrostatic charge, as when they wear clothing of synthetic materials—can subject bees to considerable electric shocks, which may make them aggressive.

Mechanics of these effects

Experiments have provided clues to some of the mechanisms which release the effects of electric parameters. A direct electric field (or an alternating field of low frequency), in which a bee is situated, undergoes a displacement at the body surface of the bee. It is to be expected that the force brought about by the field would produce a distortion of mechanosensilla. Corresponding experiments on the human epidermis, using an electro-optical method, have shown rhythmic bending of hairs keeping time with the changes in a direct electric field. In the presence of electromagnetic oscillations (about 20 kHz, 800 v/m) the petiole of a bee becomes warmer, perhaps indicating muscular activity or the concentration of current through a smaller area. If the ion concentration of the air is high, peak discharge currents of about 10×10^{-8} A may occur at the antennae; these are sufficiently high to produce physiological excitement.

Weather sensitivity of bees

This is a well recognized phenomenon. It is particularly apparent when a thunderstorm is approaching: bees that have been foraging return to the hive in large numbers, and a considerable time before the storm breaks the bees show increased "irritability" and readiness to sting[12]. Some types of behaviour can be correlated with atmospheric electrical factors. The level of the electric potential affects the ability of bees to imbibe food[12]. It also affects the onset and course of the flight of young bees from the hive[10], and also aggressivity[14]. The fact that the bees' ability to return to their home or hive varies from time to time can be attributed to atmospheric disturbances (electromagnetic oscillations in the long-wavelength range)[6].

Changes in weather and cloud formation are associated with changes in electric potential, which produce local changes of charge both in the individual bee and in the colony (Fig. 3), and this could account for the bees' "recognition" of the dynamic course of weather changes. Corona discharge due to high atmospheric field intensities (for example from the tips of grasses and leaves) must also be taken into account: they might produce a UV pattern visible to the bees which, being unstable in time, could confuse their orientation.

Electrocommunication

All modes of behaviour in which the wings produce a current of air (e.g. scenting), or movement by the bee (flight), create an alternating field in the bee's immediate neighbourhood[3,15] (Fig. 4). An influence on nearby bees (induction) inevitably occurs. The same is true of rhythmical movements of parts of the insect's body, such as all forms of dance (Fig. 5) and antennal contact.

If two bees at different potentials make contact through their antennae, a current will flow from one to the other, its strength depending on the bees' internal resistances and the resistance of the underlying surface. If one accepts the findings of Gałuszka and Lisiecki[8] that different colonies have different internal resistances, then it seems

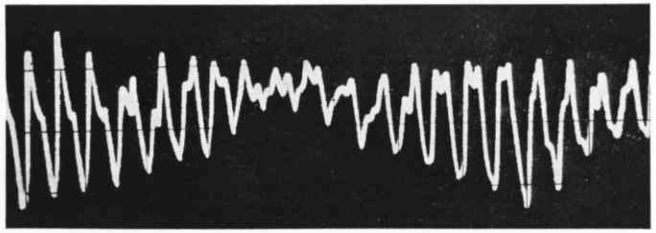


Fig. 4. Oscillogram of the electric field of a bee "whirring" its wings (*schwirren*). The field shows amplitude modulation, and inevitably affects neighbouring bees.

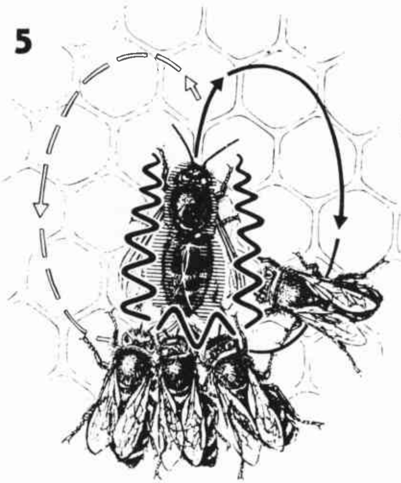
possible that a bee may make antennal contact with another bee and recognize whether it belongs to the same colony by the decrease of internal potential resulting from the contact (Fig. 6).

Electronavigation

Looked at from a physical point of view, a flying animal constitutes a moving charge, i.e. an electric current (convection current). Provided a bee does not fly parallel to the earth's magnetic field, a small force is exerted on it—which is proportional to the flight speed (Lorentz effect). This force produces an electric potential (Hall effect).

Calculations on the charging of insects by natural electrical factors show that insects become discharged a considerable time before a thunderstorm breaks, whether they are in the air or on the ground. If an electric charge is basically important for the orientation of insects, their discharge would be followed by disorientation and possibly increased aggressiveness.

This series of conjectures could be extended, but the first thing is to obtain further experimental results. It is hoped that this article will encourage scientists to include investigations of effects of electrical factors in their future researches on bees.



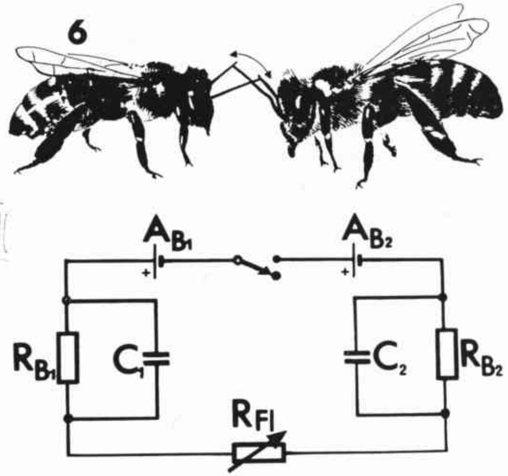


Fig. 5. The wagtail dance. Communication of information by means of the alternating field produced? *Diagram modified from von Frisch.*

Fig. 6. Antennal contact between two bees produces a discharge current if the antennae had different polarities. The current is large enough to produce physiological stimuli.
In the circuit diagram:
A_{B_1}, A_{B_2} represent the two bees as sources of electric energy.
R_{B_1}, R_{B_2} represent the internal resistances of the bees' bodies.
C_1, C_2 represent the capacities of the two bees.
R_{F_1} represents the resistance of the alighting board.

References

Reference numbers such as 208/61 indicate entries in *Apicultural Abstracts*. Almost all publications are in the BRA Library.

1. ALTMANN, G. (1959) Der Einfluss statischer elektrischer Felder auf den Stoffwechsel der Insekten. *Z. Bienenforsch.* 4(10) : 199–201 [208/61
2. ALTMANN, G. & WARNKE, U. (1971) Einfluss unipolar geladener Luftionen auf die motorische Aktivität der Honigbienen. *Apidologie* 2(4) : 309–317 [573/74
3. ——— (1973) Registrierung von Tierbewegungen mit Hilfe der Körperoberflächenladung. *Experientia* 29 : 1044
4. ——— (1976) Der Stoffwechsel von Bienen im 50 Hz-Hochspannungsfeld. *Z. angew. Ent.* 81 *In press*
5. ALTMANN, G., WARNKE, U. & PAUL, R. (1975) Der Temperaturgang im Bienenvolk als Störungsindikator. *Z. angew. Ent.* 79 : 617–625
6. BECKER, L. (1958) Untersuchungen über das Heimfindevermögen der Bienen. *Z. vergl. Physiol.* 41 : 1–25 [185/59
7. BUTTEL-REEPEN, H. VON (1900) Sind die Bienen Reflexmaschinen? *Biol. Zentralbl.* 20 : 97–109, 130–144, 177–193, 209–224, 289–304 Also English translation
8. GAŁUSZKA, H. & LISIECKI, I. (1969) Certain reactions in honey bees to the flow of electric current of different parameters. *Zoological Pol.* 19(2) : 197–211 [352/71
9. HEUSCHMANN, O. (1929) Über die elektrischen Eigenschaften der Insektenhaare. *Z. vergl. Physiol.* 10 : 594
10. HÜSING, J. O. & STAWOWY, P. (1959) Zur Frage der Auslösung des Jungbienenfluges. *Wiss. Z. Univ. Halle, Math. Nat.* 8(6) : 1121–1122 [see 365/61
11. HÜSING, J. O., STRUSS, F. & WEIDE, W. (1960) Über Reaktionen der Honigbiene gegenüber starken elektrischen Feldern. *Naturwissenschaften* 47(1) : 22–23 [163/61
12. SCHUÀ, L. (1952) Untersuchungen über den Einfluss meteorologischer Elemente auf das Verhalten der Honigbiene. *Z. vergl. Physiol.* 34 : 258–277 [310/57
13. ——— (1954) Die Wirkung von luftelektrischen Feldern auf Tiere. *Verh. dt. zool. Ges., Tübingen Zool. Anz. Suppl.* 18 : 435–440
14. WARNKE, U. (1973) Physikalisch-physiologische Grundlagen zur luftelektrisch bedingten "Wetterfühligkeit" der Honigbiene (*Apis mellifica*). *Diss. Math. Nat. Fak. Univ. Saarlandes*
15. ——— (1975) Vögel und Insekten erzeugen elektrische Felder. *Umschau* 75(15) : 479
16. WARNKE, U. & PAUL, R. (1975) Bienen unter Hochspannung. *Umschau* 75(13) : 415–417
17. WARNKE, U. & HEINE, H. W. (1975) Reaktion der Honigbiene auf Wechselfelder im VLF-Bereich. *In press*
18. WELLENSTEIN, G. (1973) Der Einfluss von Hochspannungsleitungen auf Bienenvölker. *Z. angew. Ent.* 74 : 86–94 [350/75

SOLITARY BEES AND WASPS

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The most familiar bees and wasps are the honeybee, the bumble bees and the ordinary jam-loving wasps. All these have a well known social structure, with queens, males or drones, and a population of workers which are imperfect females. These species, however, constitute only a small minority of the bees and wasps. In Britain there are about 250 species of solitary bees, and more than 300 solitary wasps. These are called solitary because they have no social structure comparable with that of the better known social insects. Each female makes her own nest and provides for her own offspring. Yet many females may make burrows within a limited area which happens to be favourable. We may thus see, on a sand-bank, very populous colonies of so-called solitary bees. Some solitary bees are not unlike honeybees, though most are smaller. Some, such as species of *Hylaeus, Lasioglossum* and *Halictus*, are only a few millimetres long. Many solitary wasps are equally small.

Bees, wasps and ants belong to a very large Order, the Hymenoptera or membrane-winged insects. The most primitive of these are the sawflies, which have no constriction between thorax and abdomen like that of bees and wasps. Then there are the ichneumons and other parasites, many with long protruding ovipositors in the female, and varying in size in different groups from a few centimetres to something almost microscopical. We are interested here in the Aculeates, in which the female ovipositor has been modified to form a sting. They differ from other Hymenoptera in the arrangement of the wing-veins and in a number of other ways. Ants differ from bees and wasps in having 1 or 2 differentiated nodes between thorax and abdomen; also in having wingless worker castes.

The most obvious way in which bees differ from wasps is in their hairiness. In most bee genera the females have scopae or regions of brushlike hairs adapted for collecting pollen. Many of the hairs are branched. These scopae are most frequently on the hind tibiae but may be on the ventral surface of the abdomen. Some bees which have adopted parasitic habits have lost their scopae and look more like wasps, especially as they may be banded with black and yellow. Even these will be found to possess a few branched hairs. It is generally believed that the Parasitica arose in the course of evolution from the more primitive sawflies, the wasps from the parasitic orders, and the bees from the wasps.

Where to watch bees and wasps

Anyone who is observant must have seen plenty of solitary bees and wasps in the countryside, although he or she may fail to realize what they are. Perhaps the best areas to watch are sandy commons. All the insects under discussion need a good source of food—plenty of suitable flowers for bees, available prey for wasps—and all need convenient places for nest building. Vertical banks in sand-pits are among the best, although I have watched a bee, *Andrena barbilabris*, diving to find its nest beneath loose sand; I wondered how it knew where to dive. The sandy commons round Woking and Chobham, south-west of London, were favourite hunting grounds for the early entomologists and are probably quite good today. In my youth I lived near Hampstead Heath and found many species there in numbers I have never seen since.