# [Science Round-Up: The Language of Bees](http://www.beesource.com/point-of-view/adrian-wenner/science-round-up/)

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*A 1937 paper by Karl von Frisch has received very little attention since its publication. We believe that Bee World readers will find it interesting and we reproduce it below, with an introduction by Adrian Wenner, Emeritus Professor of the University of California.*

**Introduction**

Karl von Frisch delivered a lecture ‘The language of bees’ in March 1937, at University College in London. The summary of his research findings up to that time was published in the same year as an article in English(2). The Smithsonian Institution later reprinted that article, verbatim, in their 1938 Annual Report(3).

The article is of considerable historical interest in that von Frisch indicated very clearly therein that the ‘language’ of bees during recruitment of naive bees to food sources was to him a matter of odour. His statements(2) (e.g. ‘[Recruits] did not know where the food was. They flew out in all directions and looked for it.’; ‘I succeeded with all kinds of flowers with the exception of flowers without any scent. And so it is not difficult to find out the manner of communication.’; ‘It is clear from a long series of experiments that, after commencement of the dances the [recruited] bees first seek in the neighbourhood, and then go farther away, and finally search the whole flying district.’) support an ‘odour-search’ model of bee recruitment.

This 1937 article can be considered a presentation of von Frisch’s well-developed ‘odour-search’ hypothesise(6, 7).

Later experiments(4) convinced von Frisch that odour was far less important during recruitment to food sources than he had earlier believed. Instead, he concluded that recruited bees could use direction and distance information contained in the dance manoeuvre and fly directly out to the food source visited earlier by dancing bees – using odour cues only when close to the ‘target’ food source. That conclusion clearly differed from his 1937 position.

We can consider his 1946 paper(4) to be the inception of von Frisch’s ‘dance language’ hypothesis.

What neither von Frisch nor anyone else noticed was that results published in different sections of his classic 1946 ‘dance language’ paper(4) were inherently contradictory. Results from the direction experiments section of his paper were not compatible with conclusions drawn in the section that reported results from distance experiments, and vice versa.

It is an under appreciated truth that hypotheses always remain just that – hypotheses. Recent reviews(6, 7) document the fact that both of these von Frisch hypotheses (odour vs. ‘language’), have been with us for centuries in one form or another – it is only our perception about them that has changed.

In the late 1960s my co-workers and I published experimental results that conformed more closely with von Frisch’s 1937 odour search hypothesis than with his later dance language hypothesis. Appearance of these papers led to a storm of protest that persists in some quarters to this day. Few realized that all we had really done was to stumble on to the conclusions presented by von Frisch so eloquently in 1937.

Unfortunately, in the 1960s we did not know of the existence of that 1937 article – von Frisch did not refer to it in his 1946 paper. Neither did he include coverage of his early position nor a citation of that 1937 paper in his 1965 [1967] review volumes; nor does it appear in the list of contributions published at the time of his death. Neither is that article (or his stance in 1937) mentioned in review volumes written by others. One can only wonder whether the dance language controversy would have become as intense as it did, if von Frisch’s 1937 contribution had been kept in circulation these past 55 years.

Since von Frisch first published his dance language hypothesis, experimental results – gathered by both advocates and challengers – have been accumulating, many of which are at variance with expectations of his ‘language’ model but in conformance with his odour-search model. It is only fitting that Bee World now publishes the original text of von Frisch’s charming 1937 article. Readers can then compare for themselves the fit of all available evidence (and their own bee handling experience) to the two competing hypotheses.

**References**

1. AUTRUM, H (1982) Karl von Frisch. *Journal of Comparative Physiology* 147:417-422.

2. FRISCH, K von (1937) The language of bees. *Science Progress* 32(125): 29-37.

3. FRISCH, K von (1939) The language of bees. *Annual Report of the Board of Regents of the Smithsonian Institution [showing the operations, expenditures, and condition of the institution for the year ended June 30, 1938]*. United States Government Printing Office; Washington, DC, USA.

4. FRISCH, K von (1947) The dances of the honey bee. *Bulletin of Animal Behaviour* 5:1-32 (translated from Die Tanze der Bienen (1946) *Osterreiche Zoologie Zeitschrift* 1:1-48).

5. FRISCH, K von (1967) *The dance language and orientation of bees*. Harvard University Press; Cambridge, MA, USA (translated from the 1965 German edition by Leigh E Chadwick).

6. WENNER, A M; MEADE, D E; FRIESEN, L J (1991) Recruitment, search behavior, and flight ranges of honey bees. *American Zoologist* 31: 768-782.

7. WENNER, A M; WELLS, P H (1990) *Anatomy of a controversy: the question of a ‘language’ among bees.* Columbia University Press; NY, USA; 399 pp.

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**The Language of Bees**

By PROFESSOR K von FRISCH

To understand the language of bees it is first necessary to know something about the senses of bees. The senses of bees are of special interest for biologists, because bees are flower-visiting insects. Since the time of the German naturalist Chr K Sprengel, more than 140 years ago, we distinguish two main types of flower in the higher plants. A great many plants have small, scarcely visible, blossoms without any scent, and their pollination is effected by the wind. Such blossoms have plenty of pollen, which is spread by the wind and comes by chance to other blossoms of the same species. The other plants have conspicuous, brightly coloured blossoms, or a striking scent, or both colours and scent. We call them flowers. Such flowers produce honey, and they are therefore visited by feeding insects, which effect the pollination quickly and surely by flying from one flower to the next one of the kind. It seems probable that the flowers have their colour and scent to make them more striking for the visitors. In this way, the insects can more easily find them and get their food, and the pollination of the flowers is guaranteed.

Sprengel’s view was not accepted by all naturalists. There was a controversy on this subject for many years, especially concerning the function of the colours of flowers. Even twenty-five years ago Professor Hess asserted that bees and all other insects are colour-blind. If this is true, the colours of flowers cannot be of the biological significance that Sprengel thought. I tried therefore to find out whether bees can distinguish colours.

The honey bee is a social insect. It lives in a beehive. In such a hive there are about 70,000 bees, only one of which is a fully developed female, the queen, the only egg-laying insect of all the inhabitants of a beehive. The males are plumper, and very stupid and lazy. Most of the inhabitants are worker bees. They are not able to produce eggs under normal circumstances. But they do all the work in the hive, they feed the larvae, they build the wax combs, they are the charwomen in the hive, and only the worker bees fly out to get honey and pollen as food for the inhabitants.

Such food-collecting worker bees we take for our experiment. We use the scent of a little honey to attract some bees to our experimental table, and feed them, for instance on a blue cardboard. They suck up the food and, after homing, give it to other bees in the hive. Then they return to the good feeding-place they have discovered. We let them do so a while, and then we take away the blue cardboard with honey and put a new clean blue cardboard on the left, and a red one on the right of the feeding place hitherto existing. Should the bees remember that they found the food on a blue cardboard, and should they be able to distinguish between blue and red, they would fly to the blue colour. That is exactly what happens.

This is an old experiment, already carried out by the English naturalist John Lubbock. It proves that bees can distinguish colours. But it does not prove that bees have colour-sense. It is not the same thing. There are (very rarely) totally colour-blind men. They see all things in much the same manner as we see them in an ordinary photograph. They can distinguish between red and blue, for red is very dark to them and blue much lighter. From our experiment we cannot conclude whether the bees have distinguished red and blue by the colours or by the shades, as a colour-blind man does.

For a colour-blind human eye every colour is a grey of a distinct degree of brightness. What the brightness may be for the eye of a colour-blind insect we do not know. We therefore make the following arrangement.

We place a blue cardboard on a table, and beside it and around it grey cardboards of all shades from white to black. On each card there is a little watch-glass, but only the glass dish on the blue cardboard contains food (sugar water). In this way we train the bees to the colour blue. Bees have a very good memory for place. We therefore change the respective positions of the cards very often. But the food is always placed on the blue cardboard, and the colour therefore indicates invariably where the food is to be found.

After some hours or after some days we can make the decisive experiment. The cardboards and glass dishes soiled by the bees are taken away. We put on the table a new, clean series of differently shaded grey cardboards, and anywhere between them we put a clean blue cardboard with an empty glass dish. The bees remember the blue colour and alight only on the blue cardboard. They distinguish it without hesitation from all degrees of grey. They therefore have a colour sense.

Training to orange, yellow, green, violet, or purple gives the same good results. But bees trained to scarlet red alight not only on the red paper but in the same manner on black and all dark papers in our arrangement. Red and dark are the same for bee’s eyes. Bees are red-blind. That is very interesting. We understand why scarlet red bee-blossoms are so rarely found. There are very many red flowers in America, for instance, but only in bird-blossoms. Bird’s eyes are very sensitive to red. In Europe there are some plants with red flowers, but their pollination is – with few exceptions – effected by certain butterflies. These butterflies are the only insects which are not red-blind. There is an exception to the rule – the poppy, the flowers of which are visited by bees although they are scarlet red. But these flowers reflect many ultra-violet rays. Bees are able to perceive ultra-violet rays. Ultra-violet is a special colour for them, distinguishable from blue and all other colours. It is evident that the colours of flowers have been developed as an adaptation to the colour-sense of their visitors.

One more thing is of interest to biologists. We make the following experiment. We train bees to blue, and then we put all the different-coloured cardboards on the table. The bees seek the blue colour, but are unable to find it with certainty; they confuse it with violet and purple. Bees trained to yellow confuse the yellow with orange and green. It is important to notice that they cannot distinguish as many colour shades as we can.

Bees restrict their visits to certain flowers. A given individual on its trip always visits definite species of flowers. That is of advantage for the bees, which on all flowers of the same kind meet with the same mechanism of blossom and save time through being acquainted with it; it is also of advantage for flowers, for their pollination depends on bees coming from other flowers of the same species. If the bees specialize in certain flowers, they must be able to distinguish the different kinds of flowers. Biologists formerly thought that it was the difference of colour shade which enabled bees to distinguish them. Now we hear that bees cannot distinguish so many different shades of colour as we can. They must therefore have other means of distinguishing the different kinds of flowers. It might possibly be the scent of flowers. Such considerations led me to my work about the sense of smell in bees.

The result was that we found that the scent of flowers is the most important factor that enables bees to recognize the different flowers. We can train bees to scent just as we trained them to colour. On a table we place some cardboard-boxes, each of which can be opened from above. There is a hole in the front of the box. In only one of the cardboard-boxes is there a feeding-glass, and into the same box we drop a little essential oil. The other boxes are without scent and without food. We change the position of the food-box frequently in order to avoid a training to place. The scent guides the bees to the food. After some hours we put away all the boxes soiled by the visiting bees, and make a new arrangement with boxes not yet touched by bees. In one of them, we drop a little of the scent we have adopted for training purposes, but there is no food in it. The bees fly to the boxes, smelling around the hole, but they only enter the scent box. It is therefore clear that they can smell this scent, and that they use it as a guide to the food place.

The sense of taste is a very closely allied sense. It is also a chemical sense. But for taste it is necessary that the mouth parts should come in contact with a solution. If it is a sweet solution, the bees suck it up. Indeed, the bees are rather fastidious about sweetness. If it is a solution containing 20% saccharose, they suck it up. If it contains 10% we can see that in bees as in men there is an individual difference in taste. Some bees drink, others hesitate, and others refuse it. If it contains 5%, they taste it and refuse to accept it. In this connection it is interesting that nectar in bee blossoms is always a solution with a high content of sugar; on an average nectar contains about 40% sugar.

Training to taste is impossible. Either they drink the solution, or they refuse it. Nevertheless, it is possible to find out something about the quality of their sense of taste. But I cannot explain the methods in a few words. Let me only say that bees can distinguish the same qualities as we can – sweet, bitter, sour. salty. But not all substances we consider sweet are sweet for bees. Many sugars very sweet for us are tasteless to bees, e.g. lactose, cellobiose, raffinose, etc. And the artificial sugars saccharin and dulcin are not sweet but are tasteless to bees.

It is much easier to find out more facts about the quality of the sense of smell in bees, because we can train to a certain scent. Thus, for example, we provide all the boxes with different scents. The bees trained to a certain scent are able to pick out the training scent from 30 or 40 different scents. Furthermore, we can dilute the training scent more and more, and the result is that for the sense of smell in bees the limit is quite the same as for human beings. The scent of most flowers therefore cannot attract from a great distance. The colour of flowers has the advantage of attracting bees from a greater distance. Scent has the advantage of being perfectly distinct for each species of flower. And so the scent permits the definite recognition of flowers from nearby.

In earlier times biologists thought that the function of scent of flowers was to attract insects and to enable them to find the flowers. I think this is true of such bees as fly out to seek new feeding-places; for scout-bees. Another function of scent is to enable the collecting bees to recognize certain flowers to which they are true and to distinguish them from other kinds of flowers. But there is one more function of scent – perhaps the most important. To explain it I must speak about the language of bees.

They have something like a language. That is clear from the following observation: when I want some bees for experiments, I place some sheets of paper smeared with honey on the experiment table in the open air. Then I have to wait many hours, many days even, until finally a bee discovers the feeding-place. But as soon as one bee has found the honey, very many will appear, perhaps several hundred, within a short time. They all come from the same hive as the first discoverer. The latter must have announced its discovery at home. How is that possible? How could it communicate its discovery?

To clear up the matter two conditions must be fulfilled. First, a hive allowing one to watch all events taking place on the wax combs in the interior of the hive. For this I constructed observation hives in which the wax combs are not arranged one behind the other, but one beside the other, all together forming a large wax comb, the surface of which can be observed through glass windows. Second, every experimental bee must be numbered to enable it to be recognized personally at first sight in the mass of other bees on the wax combs. I succeeded in painting them with coloured spots in five different colours. A white spot on the fore part of the thorax is number 1, a red spot 2, orange 3, yellow 4, green 5. A white spot on the hind part of the thorax is number 6, red 7, orange 8, yellow 9, green zero. Now it is possible to write two figure numbers. The hundreds we paint on the abdomen. Thus we can number them up to 599. The coloured numbers can be read as easily as written ones, and can be recognized when the bee is in flight, so that at our feeding-place we can see from a considerable distance – here comes No. 17, etc.

Now a bee which has discovered the feeding-place is marked with colour and observed after homing in the observation hive. First, it delivers the honey or sugar water, found and sucked up on our table, to other bees in the hive. Then it begins to dance. On the same spot it turns round and round in a circle with quick, tripping little steps, once to the right, once to the left, very vigorously, often half a minute or a full minute on the same spot. The dance is then often repeated on another spot. It is not possible to give a good description in mere words. The dance finishes just as suddenly as it began, the bee hurries to the hole of the hive and returns to the feeding-place.

The bees on the wax comb around the dancing bee become greatly excited by the dance, they trip behind the dancer, following all its turning movements.

They turn their heads to it and keep their feelers as closely as possible to its body, and it is evident that they are highly interested. Suddenly one of the following bees and then another turns away, cleans its wings and antennae, and leaves the hive. Soon afterwards these new bees appear at the food-place. After homing, they dance also and the more bees there are dancing in the hive, the more appear at the feeding-place. It is clear that the existence of the food is communicated by the dance in the hive. But it is not clear how the bees which have been communicated with can find the feeding-place. How can they know where it is and where they have to fly?

The simplest assumption would be that when the discoverer returns to the feeding-place the new bees fly behind it. But that is not the case. The new bees do not fly behind our marked discoverer, they appear at the feeding-place quite independently.

I could not understand it, till I made the following experiment: I fed some of the numbered bees of the observation hive at a feeding place 40 feet to the west of the hive. In the meadow round the hive to the north, south, west and east, I put glass dishes with sugar water and a little honey on the ground. If the dancer bee dancing in the hive reported where the feeding-place was, the new bees would all fly to the west feeding-place. As a matter of fact, a few minutes after commencement of the dance new bees appeared at the same time at all the little dishes to the north and south, to the west and east. They did not know where the food was. They flew out in all directions and looked for it. When there were no dances in the hive, the little glass dishes in the meadow were not visited by any bee for many days. As soon as there were dances in the hive, the dishes in the neighbourhood were all found within the shortest time.

But not only in the neighbourhood! In further experiments I left the feeding-dish, visited by some numbered bees, at a short distance from the hive. And I put some other dishes farther and farther away in the meadow, observing whether they would be found or not. The farther they were the longer time it took till they were found by the bees sent out by the dancer. In the last experiment they were found after four hours in a meadow a full kilometre from the hive, with hills and woods lying between them. It is clear from a long series of experiments that after the commencement of the dances the bees first seek in the neighbourhood, and then go farther away, and finally search the whole flying district.

So the language of bees seemed to be very simple. But feeding from glass dishes is not natural for bees. If we make the conditions more natural, we get a new riddle at once.

We put the glass dish away, and feed the numbered bees at the same place on flowers, e.g. on cyclamen. Into the flowers we drop sugar water to provide plenty of food. The collecting bees dance after homing. New bees fly out seeking – but seeking something definite. In the vicinity we put a larger dish with cyclamen on the ground, and a similar dish with phlox. The new bees are only interested in cyclamen. They take no notice of phlox. Now we change the flowers at the feeding place and put food in phlox blossoms. After 5 or 10 minutes the situation at the observation place changes, the new bees now are not interested in cyclamen, they only alight on phlox and search through the flowers, examining them as if they were convinced there must be food there. Everywhere in neighbouring gardens where phlox plants are we can observe questing bees – a curious sight for everybody aware that bees cannot get honey from phlox blossoms and therefore never visit phlox under normal circumstances. The dancer bee has not only reported that there is food, but also in what kind of flowers it is to be found.

In performing this experiment I succeeded with all kinds of flowers with the exception of flowers without any scent. And so it is not difficult to find out the manner of communication. When the collecting bee alights on the scented flowers to suck up the food, the scent of the flower is taken up by its body-surface and hairs, and when it dances after homing the interested bees following the movements of the dancer bee, and holding their antennae against its body, perceive the specific scent on its body and know what kind of scent must be sought to find the good feeding-place announced by the dancing bee. That this view is correct can be proved easily. We feed some numbered bees, giving them sugar water in a glass dish, on a cardboard on which some essential oil has been dropped. Then, in the neighbourhood on the ground, we put some card-boards with drops of various essential oils on them. The bees sent out by our dancer bees are only interested in the scent of the essential oil dropped on the feeding-cardboard, and alight on every place and everything provided with scent. They take no notice of card-boards provided with other essential oils.

It is thus seen that there is a biological function of flower-scent not known before. The dancing bee can communicate a message about all kinds of scented flowers by means of scent adhering to its body.

But the language of bees is still more perfect than has been shown up to now. A little variation of our experiment makes this clear. At the feeding-place we put sugar water in the glass dish, and we renew all sugar water taken away by the collecting bees. There is plenty of food. The collecting bees dance after homing, and new bees continually come out, and more and more discover the feeding-place. Now we remove the full glass dish and we put in its place a glass dish provided with some sheets of filter-paper moistened from beneath with a little sugar water by means of a syringe. Now there is a scarcity of food. It is troublesome to suck it up, and takes a long time. Now the bees do not dance after homing. They deliver the food to other bees and return to the feeding-place, they continue to collect the food no less industriously, but they do not dance, and so they do not attract new worker bees to their feeding-place. Just the same is true of flower-visiting bees. They only dance if they find plenty of food. As soon as the flowers are visited by so many bees that all nectar produced by the flowers can be easily collected and taken away, there is no longer plenty of food, the dances stop, and no more worker bees are attracted. This makes it possible that there is always a correct proportion between the number of collecting bees and the quantity of food offered by a certain kind of flowers.

But one more thing still – the dances depend not only on the quantity of food but also on its sweetness. If we feed the bees with sugar water of a very high concentration the dances are very vigorous. If the concentration is diminished, the dances are continued but less vigorously. If the concentration is still further diminished to a certain point, the collection of food is still continued, but there are no dances in the hive, although there is plenty of food. In natural conditions this is very important. For when various kinds of flowers with different concentrations of nectar begin to bloom at the same time, and are discovered by scout bees belonging to the same hive, the bees discovering the flowers with the best nectar dance most vigorously, and attract the largest number of worker bees for the best flowers. That is the role of the sense of taste in the language of bees.

But there is a word in the bee language not yet mentioned. The bees have a scent organ on their abdomen located in a pocket of skin containing glands. Usually the scent organ is closed and cannot give out scent. But bees which have discovered a good feeding-place put out the scent organ on returning to the place, and thus give out a scent that is very attractive to other bees. It can be concluded from special experiments that the scent of this scent organ is much more intensive for bees than for us. It tells the questing bees with special emphasis where the good place is, as soon as they are in the vicinity, and attracts them from quite a considerable distance.

It may be that some of my statements seem to be a little hypothetical. But all the results I have mentioned have been obtained from long series of experiments. To deal more thoroughly with the experimental methods here is impossible.

To sum up: if a new kind of flower begins to bloom in a certain region, it is discovered after some time by scout bees. The first bees find the flowers full of nectar. They find plenty of food and after homing they report the discovery by dancing, and in addition indicate the species of flowers by means of the scent adhering to their bodies. The bees communicated with fly out and look for the flowers with this specific scent. Flying out in all directions, they find out in the shortest time the plant which has commenced to bloom, wherever it is in the entire flying district. Where there are already collecting bees, the scent of the scent organ makes it easier for fresh questing bees to find the good feeding-place. When the number of bees has become sufficient to collect the amount of nectar in these flowers, the flowers are no longer full of nectar, the nectar becomes scarce, there is no more dancing and the number of bees does not increase. If different plants begin to bloom at the same time, the flowers with the sweetest nectar cause the most vigorous dancing and, incited by the scent adhering to the body of the dancer bee, the largest number of bees fly to the best feeding-plants.