THE AMAZING LIFE OF BEES - OUR INDISPENSABLE PARTNER ON EARTH

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ABSTRACT

The great physicist Albert Einstein once said that:
"If the bee disappeared off the surface of the globe then man would only have four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man"[1] This hopefully may never come to pass. But it is a great way of emphasizing the importance of the indispensable symbiotic relationship between us and the bees. For millions of years bees have evolved to perform an essential role in pollinating trees, flowers, and food crops on which both animals and humans depend. The bees need to eat protein from the pollen of flowers, carbohydrates from floral nectar, and we need the bees to pollinate our plants. While sucking nectar, pollen is brushed onto the bees' body and is carried from one flower to another for fertilization. Of 100 crop species that provide 90% of our global food supply, 71% are bee-pollinated.

The value of pollination of food crops by bees in the U.S. alone is estimated at $16 billion and insect pollinators in general contribute $29 billion to U.S. farm income. [2]

Here we describe the fascinating social organization the bees have evolved in finding pollen and nectar for food and make honey, how a foraging bee finds nectar and returns to the hive to communicate to the others in the hive where to find her trove by a set of dances. It is an amazing exposition of social organization for an insect which is not supposed to have intelligence and 'brains'. The direction of the flowers is given by the orientation of the figure 8 waggle dance, the distance to the find is conveyed through the speed and length of the dance, the amount and size depends on how vigorous and how long is the dance and finally the oder of the flowers is used to help a contingent of bees to find the trove in case more bees are needed if the find only lasts for s short time [3].

Tragically, bees today are dying at an unprecedented rate. This does not augur well for the future supply of food for our planet—in fact this problem deserves to be much better known and discussed among the most serious facing the world—an impending crisis that demands urgent mitigation. The main cause is our intensive agriculture driven by the ever increasing global overpopulation resulting in the use of toxic insecticides such as the neonicotinoids[4]. This article examines what bees contribute to the world, how they perform their work, the threats they face, and

how readers at all levels—from politicians and farmers to ordinary citizens, in particular futurists—can directly help preserve bees and, in the process, save humanity.

INTRODUCTION

How much of bees' action is all instinctive?
The evolution of the bees has a long history. Scientists have long believed that bees first appeared about 120 million years ago. But the discovery of a bee fossil embedded in amber in Myanmar [5] showed bees appeared 100 million years ago. From the study of the bees' DNA, there is some link between the bee and the wasp. Much interest has been focussed on the relationship between bees and flowering plants - a most diverse organism - 'an abominable mystery' - according to Charles Darwin! [6]

Back in 330 BC, the Greek philosopher Aristotle noticed some sort of organization exists with the bees:
"*Each bee on her return is followed by three or four companions . . . how they do it has not yet been observed*"
Aristotle, Historia Animalium, IX [7].

On the discovery of the dance language of bees. Karl von Frisch said [3]: "In the summer of 1944 a few very simple experiments led to a result that was just as

unexpected as it was thrilling". He was awarded a Nobel prize in 1973 for his work on bee communication.

SOCIAL ORGANIZATION OF THE BEES

The intricate society of the bees consists of 3 kinds of bees: the queen, the worker and the drones, each with different functions. The worker bees take up different jobs throughout their lifetimes. They are in turn guards, builders, cleaners, nurses, heating and cooling technicians (See NOTE 1 below), scouts, honey makers, pollen stampers, and finally as well as foragers, collectors of nectar, pollen, water, and resin. They build complex hives with beautiful honeycombs of perfect hexagons. They accomplish great feats of navigation. They see more colors and smell more scents than humans do. They even see and use the polarization pattern in the sky which we do not. And they communicate information in a complex symbolic language without match in the animal kingdom: the bee dance.

Author Note #1 The temperature of the hive is very carefully kept, between 32 - 35 C. Whenever the temperature in the hive is too high, the worker bees ventilate the hive by fanning the air out with their wings. When the temperature is too low, the workers generate metabolic heat by relaxing

and contracting their flight muscles. The resulting vibration generates heat.

There are different kinds of bees with different functions: [8]

1) Queen bee: there is only one queen in a colony which may number 60,000 or more. Larva destined to become a queen bee is fed royal jelly for the entire larval stage. The queen only develops from fertilized egg in the largest cells in the hive and can live up to 3-4 years. Her sole function is to lay eggs up to 2500 eggs per day.

2) Worker bees are all female and make up about 85 percent of bees in a hive. They may live up to few months and have three life stages during which they have specific roles to fill. Young workers (1 to 12 days old) clean cells, nurse the young, and tend to the queen. Middle-aged workers (12 to 20 days old) build the comb, store pollen and nectar which are brought back by forager bees. They also ventilate the nest. Older workers (20 days to 30 days or more) are primarily foragers who supply nectar and provide the enzymes needed for converting it to honey. Forager bees can fly at a speed of about 24 km per hour. This bee has been known to travel more than 5 km from home on a single flight (See NOTE #2 below).

Author NOTE #2. it may be surprising that bees can fly so far. But if we think of the birds, who can fly half way across the globe, even over the Himalayas, there are truly wonders in the animal world

3) Drones are male bees developed from unfertilized eggs which are laid in larger cells. Drones are also fed royal jelly for three days and are then fed on beebread. Unlike the female worker bee, drones do not have stingers and do not gather nectar and pollen. A drone's primary role is to mate with a fertile queen. He dies after mating.

While workers select which fertilized eggs to feed and make into queen or worker, the queen decides the sex of her young. Fertilized eggs will become female offspring, while unfertilized eggs will become males. This is a mechanism of sex determination known as haplodiploidy,

HOW DO BEES COMMUNICATE?
THE DANCES

The bees are economical with way they find food. Only a small number of forager bees fly around to look for pollen and nectar. These bees go to flowers of the same kind and then take it back to the hive. They never visit a flower of a different kind before returning to the hive to dump their

find. This way the scent of the particular flower is preserved for the others.

This social organization in bees has a number of advantages. One of the most important of these is the ability to quickly mobilize a large number of foragers to gather floral resources that may only be available for a short period of time. The ability to communicate location with such precision is simply amazing. It is one of the most remarkable behavior of a very interesting insect which we consider has limited 'thinking' abilities. How do they do it? (see Author Note #3 below)

Author Note #3:

For detailed information on how bees use round and waggle dances to convey information to their hive, see [3].

A worker bee becomes a forager when she leaves the hive and finds a source of nectar on some flowers and returns to the hive engorged with nectar and pollen on her body to communicate the find to those in the hive. Her dance begins when she has attracted the attention of enough bees in the hive. She begins by spending 30-45 seconds regurgitating and distributing nectar to bees waiting in the hive. While collecting nectar, the pollen spores dust the bee's back and this dust is now also deposited in the hive. Then she starts dancing. There are various ways a forager bee communicates her information: the direction and distance of the trove, the scent of the nectar. Also the

quality and quantity of the source is conveyed through how vigorous is the presentation. If the nectar source is of excellent quality, a foragers will dance with enthusiasm and for a longer time. Food sources of lower quality will produce fewer, shorter, and less vigorous dances; this would recruit fewer new foragers.

Four different types of bee dance: [9][10]

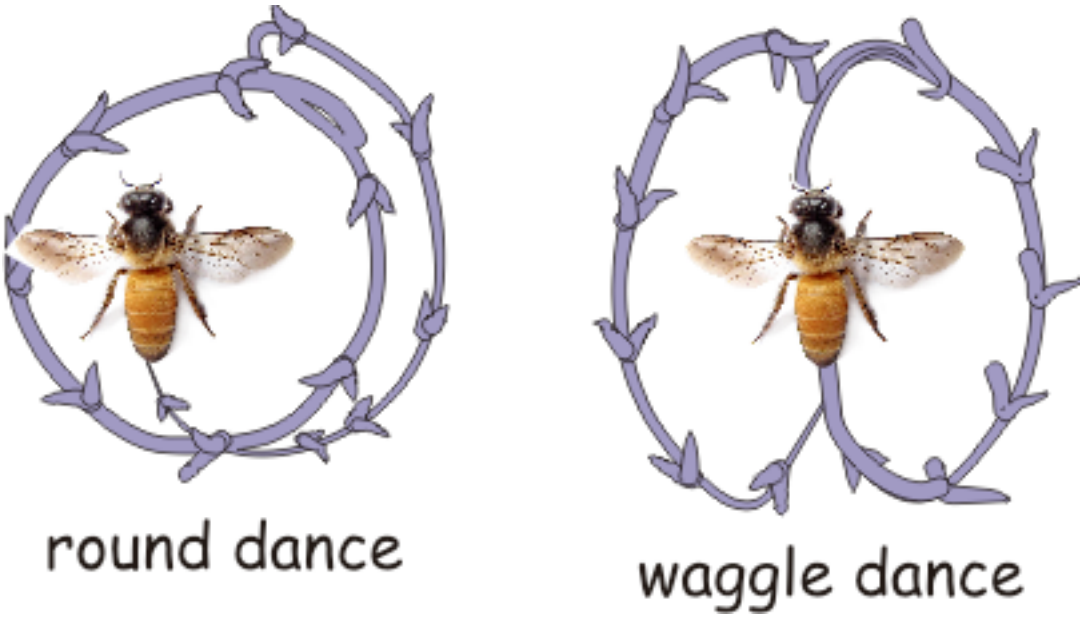

Figure1 Schematic diagram of the round dance and waggle dance

A) ROUND DANCE

The round dance does not communicate any specific direction. See figure 1

The round dance is used for food sources 25-100 meters away from the hive or closer. After distributing some of her new-found nectar to waiting bees the forager will begin running in a small circle, switching direction every so often. After the dance ends food is again distributed at this or some other place on the comb and the dance may be repeated three times, though rarely more.

The path of the round dance is shown in figure 1. This is not a very useful dance as it does not give information on distance and direction of the source of nectar The forager bee turns in circles alternately to the left and then to the right. And it also runs in a sickle shaped path. The richer the food source, the longer and more vigorous the dance.

B) WAGGLE OR TAIL WAGGING DANCE

As the food source becomes more distant and more plentiful the round dance is replaced by the waggle dance with the bee waggling her tail in a zig zag fashion to the right and to the left. There is a gradual transition between the round and waggle dance, taking place through the sickle shaped pattern.

Figure 2 The figure 8 pattern of the Waggle dance

The waggle occurs on a special dance floor, which is conveniently located near the entrance to the hive facilitating quick entry and exit of foragers so as to waste no time during the foraging period in the day. Only bees with news of highly profitable sources of nectar execute the dance. Arriving back at the nest, a bee with news to share immediately proceeds to the dance floor, where other bees waiting for news gather around her. During the waggle, she dances a figure-eight, 8, pattern. See Figure 2. In between the loops there is a straight zig zag path

connecting the loops. At the same time she flutters her wings sporadically.

Important information is encoded in the waggle dance:

1) The bee waggles its tail following a figure 8 pattern. The direction of the straight part of the run in the middle of the figure 8 communicates the direction of the trove of food in relation to the sun. As an example, if she waggles at an angle 60 degrees to the right of the sun the food source may be found 60 degrees to the right of the sun.

In general the hive lies in the vertical direction to the ground. If the trove of nectar lies in the same direction as the midday sun, the foraging bee dances with the straight portion of the waggle dance facing the sun straight 'UP'. If the source lies in the opposite direction of the sun, the bee dances with the straight part of the waggle dance straight 'DOWN'. If the source, the flower, is to the right, the bee dances at the appropriate angle to the right. The angle is marked by 'α' in figure 3.

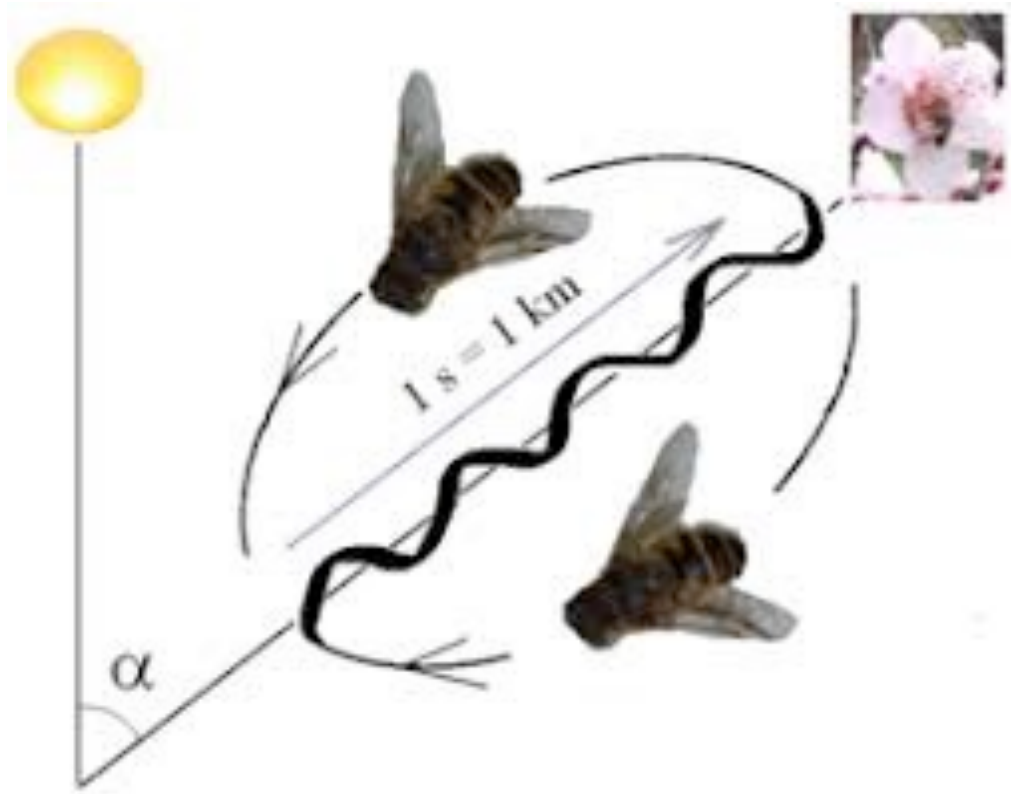

Figure 3 Diagram showing the direction of the waggle dance. in relation to the sun and the flower

Now modern beehives consist of a set of vertical boards enclosed in a wooden box. There is no sun and under these circumstances, gravity takes over. The reference, the sun, is replaced by the ‘UP‘ direction. For example, if the bee points to 70 degrees clockwise to the vertical sun then it points at 70 degrees to the vertical line ‘UP’. Since in general bee foragers spend time under the overhead sun, using gravity is probably not too bad an approximation.

In addition, if there is a patch of blue sky visible through the enclosed box, the bee will use the information on its

polarization for orientation because the amount of polarization depends on the position of the sun. How does the bee use this additional inference of the sun's position? it is absolutely amazing! For example they can maintain course under the shadow of a mountain, at twilight or when only small patch of sky are not clouded.

2) The distance between the hive and this flower source is encoded in the speed of the waggle runs. The farther the target, the slower the waggle phase.

For example :

a) If food source is around 200 meters away, the dance is fast and may last 8 to 9 circuits in 15 seconds

b) If food source is around 1000 meters away, the dance may last in general 4 to 5 circuits in 15 seconds

c) If food is 2000 meters away, the dance may last only 3 circuits in 15 seconds

The farther the flower patch lies from the hive, the longer is the dance. For every additional 100 meters, she prolongs the dance roughly by 75 milliseconds.

3) The information on how rich the source is conveyed by how long and how vigorously she dances through waggling of the tail and fluttering of the wings. In all cases the quality and quantity of the food source determines the

liveliness of the dances. If the nectar source is of excellent quality, the forager will dance long and enthusiastically each time on returning from foraging. Food sources of lower quality will produce fewer, shorter, and less vigorous dances; recruiting fewer new foragers.

The larger the find the more excited the bee is about the location, hence the faster and longer it will waggle so as to grab the attention of the other observing bees waiting in the hive, and try to convince them. When excited she will flutter her wings to produce a vibration sound. If multiple bees are doing the waggle dance, there is a competition to convince the observing bees to follow their lead. Competing bees may even disrupt other bees' dances or fight each other off. What a human like behavior! The longer the forager waggles - typically bees make between one and 100 waggle runs per dance - the richer the source.

4) The scent of the flower.
In general the forager bee stays on a given type pf flower and returns to the hive to dump her find before going to another species of flower. In this way the scent is preserved for the other bees in the hive, who sample it with their antennae. This is necessary in the case a larger contingent of bees is needed to go and collect the nectar which may be plentiful for only a short period of time. It is

useful for them to know the scent especially if the sunlight is dim.

When the bees are flying or rubbed together, they accumulate an electric charge. Bees emit constant and modulated electric fields during the waggle dance. Both these low and high-frequency components emitted by dancing bees induce passive antennal movements in stationary bees.

C) SHAKE DANCE

Arriving back from a good foraging run, a forager bee does the "shake" dance when nectar sources are so rich that more foragers are needed. First the shake dance encourages these non-foragers to make their way to the waggle dance floor and observe the dances. She will move throughout the hive and shake her abdomen back and forth before the brood for one to two seconds before moving onto more non-foragers at the rate of between one and 20 bees per minute.

D) TREMBLE DANCE

The forager bee does the "tremble" dance when she has brought so much nectar back to the hive that more bees are needed to process the nectar into honey. Walking slowly around the nest, the dancer quivers her legs,

causing her body to tremble forward and backward and from side to side. Lasting sometimes more than an hour, the tremble dance stimulates additional bees to begin processing nectar.

SUMMARY OF LIFE OF BEES:

Honeybees have evolved an extraordinary form of communication known as the dances. First comes the activity that grew out of discovering a nectar source. And then the activity that will spur other bees to go to that nectar source. When a forager bee discovers a good source of nectar or pollen, the pollen spores will dust this bee's back, then she will return to the hive to perform a waggle dance to let her nest mates know where it lies.

What is most astonishing she indicates the direction of of the source by the angle her waggling walk deviated from an imaginary straight line drawn from the dance floor to the sun at its current position. She also shows how rich the source is by how long and how vigorous she dances. In addition, the dancer shares the odor of the flowers with the other bees, who sample with their own antenna. And finally the richness and size of the find is conveyed by the length and how vigorous the dance is.

WHY ARE BEES DISAPPEARING?

The importance of bees in our food cycle cannot not be over-emphasized. More than 2/3 of the worlds crop species rely on bee pollinators. Honeybees and wild bees are the most important pollinators of many of the fruits and vegetables we eat. Examples include not only familiar fruits and vegetables, but also many of the herbs we use to season our foods, as well as nuts, berries, cotton for clothing, and even clover and alfalfa which provide the main feed for cattle.

Yet despite their economic importance, for over a decade now bees have been dying at an unprecedented rate. In the United States alone, nearly 44% of bee colonies had collapsed by 2016 [11][12]. Honeybee colonies are dying at frightening rates. Since 2007, an average of 30% of all colonies have died every winter in the United States. This loss is about twice as high as what U.S. beekeepers consider economically tolerable. 29% of all colonies died in Canada and 20% died in Europe. In the winter of 2012, 30% bees died in US, in Canada 29% and in Europe, 20%. In China, the scarcity of bees is so acute that fruit farmers have resorted to human pollination by brushes[13].

The main reasons d for their disappearance are[14]:

1) **Overuse of insecticides.**

Worldwide, the intensive agriculture necessary to provide food for Earth's ever growing population has led to the wider and more intensive use of insecticides. One of the most deadly, and most widely used of these, the neonicotinoids, are sprayed directly on the leaves or coated on the seeds of major crops including corn, from where they infiltrate flowers and their nectars. This can have a devastatingly toxic effect on the bees' immune systems and make them vulnerable to pests, also damage the bees' ability to navigate back to the hive. Although another extremely toxic new insecticide, chlorpyrifos,[15] has been found to effect human brains, it has not yet been banned and is still being used as a pesticide.

2) **Loss of habitat:** Here too global overpopulation is posing a threat to bees**.** As rural areas become urban, the patches of green space that remain are often stripped of all weeds and their flowers, which bees rely on for food. Lack of fresh water in urban areas can cause bee distress.

3) **Climate change:** Drought, storms and inclement weather can destroy the habitat for flowers. Unusually warm winters have caused plants to shift their schedules. When bees come out of hibernation, the flowers they need to feed on have already bloomed and died. Largely as a result of global warming, bees have lost nearly 300 km off the southern end of their historic wild range in both the US and in Europe, a trend that is continuing at a rate of about 8 km every year.

4) Disease: Increasing transport from different countries brings pathogens like mites which weaken bees and make them more susceptible to pesticide poisoning. The most destructive is the varroa destructor mite which can hitch a ride on a bee into the hive. Then they lay eggs which will feed on the young bees, especially the drones, and ultimately wipe out the entire hive. To control mite infestation early detection is important. A product called Apistan is a strip which can be hung in the brood nest area of the the colony for 4 weeks to kill the mites.

5) **Radiation**
Although not yet definitively proven, scientists suspect that growing radiation used by communication towers for mobile phones can interfere with the bees' ability to navigate through their antennae. More research is required in this area.

WHAT CAN WE DO TO HELP?

We must not be afraid of these lovely insects because of their stings. They only sting when provoked.

It is easy to feel sympathy for endangered species when they look helpless (like baby seals) or majestic (like lions or eagles). But many people in today's largely urbanized world, never think of bees as valuable but simply consider them nuisances and potentially dangerous. Honey comes from a jar on the store shelf, wax from a sealed container or a spray can, and the

pollination process takes place out of sight—far away from where most of us live and work. When we do encounter bees, we tend to shy away or panic, fearful that they may sting us without provocation. But the truth is they won't. Wild bees are few and far between in most urban areas, and domesticated bees are no more liable to attack a casual passerby than a cow to chase you through a field, or a pig to bite your leg for entering its sty.

Professional bee keepers manage many hives and interact with thousands of bees using only a few simple rules and equipment that has not changed greatly for centuries. And now amateurs, too, are becoming more interested in keeping bees for fun and profit. Like most animals, bees are not naturally aggressive but will defend themselves if they feel threatened. Sadly, the greatest threats bees face today come from forces against which they have no natural defense. Instead, humans must act for them; and here are some of the things we can do:

* Take political action by urging our governments to regulate or ban toxic insecticides and replace them wherever possible with effective organic substitutes.

* Help diversify our farms and urban landscapes by planting flowers along crop borders, in land unprofitable for crop production, along roadsides, power line corridors, in city lawns and on urban roof top gardens. In these locations, lay out beds of native flowering plants from your region. It is important to plant flowers of the same kind

together in blocks, as bees, when they find a trove, always report its exact size and location to others in their hive.

* Homeowners, plan a garden, watch the bees pollinate it and get the pleasure of seeing them while you reward yourself and the world with healthy food and beautiful flowers.

* Provide a water source such as a shallow bird bath with rocks in it.

* Finally, consider being proactive and start our own hive! I am glad to say that my son in Philadelphia has just done that in his own garden.

Even though, as individuals, we may only contribute a little, the aggregate of our efforts can lead to a decisive change for the better in the bee environment. It is time for all of us to act.

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