Bee Language and the Waggle Dance

Part 1 - Video

Viewing Guide: http://video.pbs.org/video/2300846183/

Updated options: https://www.youtube.com/watch?v=aUCoLeI5Qxg
https://www.youtube.com/watch?v=AonV_MkUFSs

1. What is the 'waggle dance'?
2. What information do bees communicate with the waggle dance?
3. What is special about the waggle dance in terms of communication?
4. How do bees communicate direction and distance in the 'waggle dance'?
5. What does the duration of the dance indicate?
6. What constitutes a 'circuit' in the waggle dance?

Part 2 – Article Analysis

Each of the following **4 articles** describes bee behavior in terms of their ability to forage for food, and communicate the food's location to others in the hive. Your assigned group will be presenting the article to your classmates. Make sure each person in your group has an assigned role. One member of your group will be asked to present your article to the class

Complete each task for your assigned article:

1. Summarize the article in 2-3 bullet points.
2. Describe the role of the waggle dance and bee communication in the article.
3. Explain if the bee behavior is presented as innate, learned, or both in the article. (You may have to infer.)
4. Answer the questions specific to the article:
    - Honeybees and Monoculture: What is the author's argument concerning the effect of monoculture on honeybees? How does monocultural relate to bee foraging and waggle dance behavior?
    - Why Honey Bees Are Better Politicians Than Humans: How are bees 'democratic?' How does the waggle dance behavior relate to bee 'voting'?
    - How Honeybees Make Decisions: Describe how the headbutting and waggle dancing behavior combine to help bees make collective decisions. How does this relate to human decision making?
    - Nectar That Gives Bees a Buzz Lures Them Back for More: Describe the plant-pollinator relationship in the article. How are the plants 'encouraging' bees to pollinate them? What effect does this 'encouragement' on bee's brains?

Article 1
Honeybees and Monoculture: Nothing to Dance About
By Matina Donaldson-Matasci
June 7, 2013
http://blogs.scientificamerican.com/guest-blog/2013/06/07/honey-bees-and-monoculture-nothing-to-dance-about/?print=true

With all the talk of honeybee decline in the news, you may already know that honey bees don't just make honey. They also give us almonds, cherries, avocados, raspberries, apples … pretty much everything delicious. Of course, there are plenty of native pollinators that can also do that job. But domestic honeybees (first brought to the American continent in the 1600s) are great for large-scale agriculture for a couple of reasons.

First, they live in huge colonies of tens of thousands of bees: One colony can visit 50,000 blossoms in a single day. Second, those colonies can easily be picked up and moved around to wherever they're most needed. So the same bees that are used in February to pollinate almonds in California can be moved in April to pollinate cherries and apples in Washington State. Over a million honeybee colonies are moved around the US, going from crop to crop as they come into bloom.

The honeybees in a single colony can actually move among crops in a similar way, but on a much smaller scale. When a bee comes back to the hive with a full load of sweet nectar or nutritious pollen (food for bees), she'll do what's known as a "waggle dance"—pointing other bees in the direction of the flowers she found.

It's been more than 50 years since Karl von Frisch first figured out what bees were saying with the waggle dance, but we still don't know much about why. What does the colony as a whole gain from dancing—can they collect more food faster, or with less effort? When is the ability to dance most useful?

To figure this out, I decided to mess with the bees a bit, and make it so that when they danced, it came out gibberish. Then I asked how this affected how much food the whole colony could collect. What I found was that dancing was much more important for large colonies than it was for small ones. This is because a large colony can send out hundreds or even thousands of bees to search the landscape in parallel, getting lots of information very quickly. If any one of those searchers finds a lush patch of flowers, she can do a dance back at the nest and recruit plenty of other bees to help her collect pollen and nectar from those flowers.

I also found that dancing was most important when a wide variety of flowers were in bloom. So, particularly when there is a nice mix of different types of flowers available, the bees in one big colony can actually move themselves around among different flower patches as they come into bloom.

But the way agriculture is done these days, there doesn't seem much point to dancing. Why bother telling your hivemates about a great patch of almond flowers, when there are only almond flowers as far as the eye can see?
By planting crops in monoculture, we've increased the scale of flower patches so much that a honey bee colony can't effectively search across many patches: they're stuck in just one. That patch blooms for a short period of time, and then the bees have nothing else to eat. So instead of letting the honeybees move themselves around on a scale of several miles, we're forced to truck ailing colonies across states.

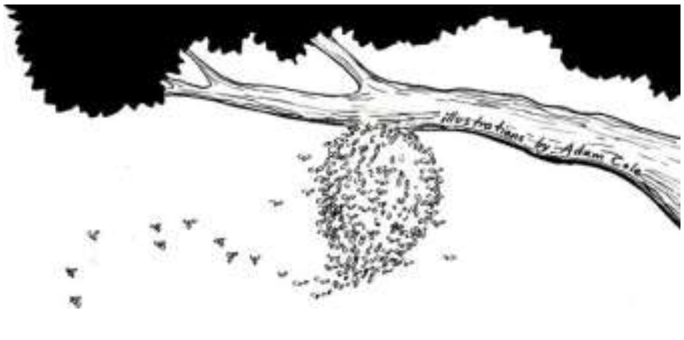
This is terrible for the bees: too much stress and poor nutrition make them more vulnerable to pesticides and diseases. As a result, we're losing around 30 percent of our bee colonies each year, and we may soon be at the point where there aren't enough bees to go around.

How can we fix this problem? A recent report released by the USDA and the EPA suggests we need to approach it from a number of angles, including better control of diseases and parasites and more research on the effects of potentially harmful pesticides. And—I think, crucially—we need to figure out how to quit moving so many bee colonies over such long distances.

Instead, we should let the bees make the most of their amazing capacity to search the landscape and go where the flowers are. That means making a broader diversity of flowers available to bees on a scale where they can really take advantage of them.

We've got to convince farmers to plant a wider variety of crops and let weeds grow on crop margins, and persuade landowners to maintain wild habitat near agricultural land. That's going to be hard. But if it means that beekeepers can maintain big, healthy colonies of honeybees—and that farmers can attract native bees to pollinate their crops as well—wouldn't it be worth it?

Article 2
Nature's Secret: Why Honey Bees Are Better Politicians Than Humans
by Robert Krulwich
May 24, 201112:01 AM
http://www.npr.org/blogs/krulwich/2011/05/24/136391522/natures-secret-why-honey-bees-are-better-politicians-than-humans

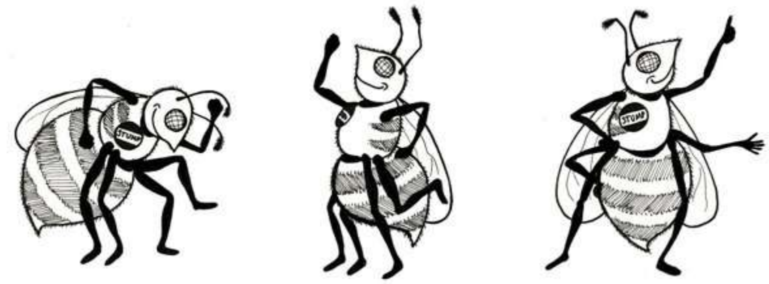


In the spring, beehives get so rich with honey, so crowded with baby bees, they often burst in two. Some bees stay in the original nest with a new queen, but a second group, led by the old queen, heads off to establish a new home. If there's a cloud of bees hanging by a tree branch in your back yard, that's them — the house hunters.

How do they choose a new home?

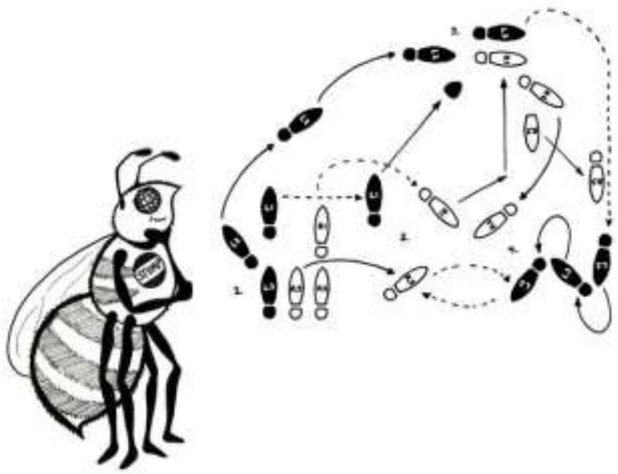
Ah, says Cornell professor Thomas Seeley, this is the beautiful part: The queen doesn't say, "Here's where we're going!" She's not in charge. The decision is made collectively, bottom-up, and it's done by "voting."

Bees are natural democrats. They've been shaped that way by evolution, *plus* they've got this spectacular, secret extra ingredient (which I'll describe in a minute). But first, here's the routine:
Ten thousand animals need a place to go. Three hundred of them form a kind of house-hunting "Senate." They're the older, more experienced bees. They fly off looking for options: How about that nice hole on the elm tree? Or how about this even nicer hole in the beech tree?



These scout bees announce their "finds" by dancing.

Each scout's dance tells the other bees how to fly to the site — this is done by "waggle dancing," a figure dance that gives bees directions. And if a bee *really likes the site,* she will dance her directions over and over and over, literally hundreds of times. That way, more and more of her sister scouts see the dance, know where to go, and can fly off and check for themselves.



If the site is ho-hum, the second wave of bees will do a ho-hum, say, 10-repetition dance. But if the site is spectacular — high off the ground, narrow opening, facing the right direction, lots of honey storage space inside — then they will give it a spectacular, say, 300-round dance, so more scouts will know where to go. If they like the site, pretty soon everybody is doing the same dance: Let's call it "The Elm Tree" dance.

This is how bees "vote;" they dance themselves into a consensus.

In my *Morning Edition* conversation with Professor Seeley, I asked him what happens if one of the bees is just so convinced that her choice is the right one, that she just keeps dancing and dancing, stubbornly advertising the Beech Tree — *not the elm tree.* How does the hive handle a stubborn bee?

Seeley says, "We haven't seen any bees like that."

They haven't?

Nope, he says. "In the world of scout bees, you don't have die-hard bees that just dance and dance and dance forever."

Why not?

Seeley thinks he's got an answer, and it's *so strange*: After careful observation and testing, he believes that once a scout bee has finished her dance — no matter how strongly she feels about her site — *she stops caring*.

He thinks there may be "an internal, neurophysiological process that causes every scout to gradually and automatically lose her motivation to dance for a site, even one that is high in quality."

So she's just finished dancing her heart out, telling the hive three times that this beech tree is absolutely, definitely, beyond question the place we need to go, and as soon as she steps back into the crowd, she loses her passion? It just ... dribbles away? And this is genetic? It's built in?

"[It's] built in," says Seeley. He calls this his Retire and Rest hypothesis. "And when you think about it," he says, "that works really well."

Well, it certainly helps things along if there are no fanatic bees, or insistent bees, or principled bees, gumming up the march to consensus. "Those fanatics," Seeley points out, "they're kind of gumming up the works."

True, true. I suppose our House of Representatives would find it a whole lot easier to reach consensus if everybody in the room was automatically drained of passion — and conviction. I'm not sure that's the best way to go about democracy, but it is the *bee way.*

Tom Seeley, in his book *Honeybee Democracy*, doesn't exactly admire this genetic "forgetting" in bees, but he does mention its obvious advantages. In science, for instance, eminent scientists often cling to bad ideas until they die.

One difference between aged scientists and aged [bee] scouts, though, is that the people tend to drop out of the debate reluctantly, sometimes not until death, whereas the bees do so automatically. I cannot help but wonder whether science would progress more rapidly if, in this regard, people behaved a bit more like bees.

Maybe "a bit more." But speaking not as a bee, but as me, I'm glad we have our Gandhis, our Lincolns, our Cézannes. Stubborn people with original ideas are what we've got that the bees don't.

Adam Cole/ NPR

Article 3

Head Butts & Waggle Dances: How Honeybees Make Decisions

Joseph Castro, LiveScience Staff Writer December 09, 2011 09:49am ET

http://www.livescience.com/17395-honeybees-head-butts-decisions.html

Honeybee swarms can include some 10,000 worker-bees and one queen. To make decisions in such a crowd, the bees use a process of head-butting and waggle dances. Honeybees choose new nest sites by essentially head-butting each other into a consensus, shows a new study.

When scout bees find a new potential home, they do a waggle dance to broadcast to other scout bees where the nest is and how suitable it is for the swarm. The nest with the most support in the end becomes the swarm's new home.

But new research shows another layer of complexity to the decision-making process: The bees deliver "stop signals" via head butts to scouts favoring a different site. With enough head butts, a scout bee will stop its dance, decreasing the apparent support for that particular nest.

This process of excitation (waggle dances) and inhibition (head butts) in the bee swarm parallels how a complex brain makes decisions using neurons, the researchers say.

"Other studies have suggested that there could be a close relationship between collective decision-making in a swarm of bees and the brain," said Iain Couzin, an evolutionary biologist at Princeton University, who was not involved in the study. "But this [study] takes it to a new level by showing that a fundamental process that's very important in human decision-making is similarly important to honeybee decision-making."

When honeybees outgrow their hive, several thousand workers leave the nest with their mother queen to establish a new colony. A few hundred of the oldest, most experienced bees, called scout bees, fly out to find that new nest.

"They then run a popularity contest with a dance party," said Thomas Seeley, a biologist at Cornell University and lead author of the new study. When a scout bee finds a potential nest site, it advertizes the site with a waggle dance, which points other scouts to the nest's location. The bees carefully adjust how long they dance based on the quality of the site. "We thought it was just a race to see which group of scout bees could attract a threshold number of bees," Seeley told LiveScience.

But in 2009, Seeley learned that there might be more to the story. He discovered that a bee could produce a stop-dancing signal by butting its head against a dancer and making a soft beep sound with a flight muscle. An accumulation of these head butts would eventually cause the bee to stop dancing. Seeley observed that the colony used these stop signals to reduce the number of bees recruited to forage from a perilous food source, but he wondered if the bees also used the head butts during nest hunting.

To find out, Seeley and his colleagues took honeybee swarms to Appledore Island in Maine, a treeless island with no natural nest sites, and observed how the bees chose from among the researchers' man-made nests. For each trial, they placed two identical nest boxes at equal distances from a swarm. When a scout would investigate a nest, the researchers painted a pink or yellow dot on the bee — this allowed them to quickly surmise which nest the scout was advertising back at the swarm.

They saw that after dancing for a while, a scout bee would take a break to walk around the swarm. She would then deliver a stop signal to another dancing bee, but only if that bee had checked out the opposite nest. "It turns out that they are quite discriminating," Seeley said. "That's pretty sophisticated."

The bees collectively chose a nest site when one of the nests accumulated 50 to 100 dancers, so the head-butting could help determine which site got enough waggling support. After that, the scouts changed their stop-signal tactics and began head-butting any bee that was still dancing, because the swarm had already reached a consensus.

With a computer model, the researchers learned that this discriminating inhibition is vital to bee decision-making. Without the signals, the bees would likely reach a stalemate when posed with equally suitable nests.

Couzin is curious to see if a similar inhibition mechanism exists in other animals that live in groups, such as flocking birds and schooling fish. "And I think it would be extremely interesting to look for it in other social insects," such as ants, Couzin said.

A critical aspect in our ability to make choices is neural inhibition, where neurons actively suppress the activity of other neurons, much like how the honeybees use their stop signals. Couzin thinks that further research into social insects decision-making may help us better understand our own decision processes.

Unlike the human brain, "one of the beautiful things about looking at social insects is that you can really see the individual components and really determine the mechanisms involved," Couzin said. The study was published online Dec. 8 by the journal Science.

Article 4
Nectar That Gives Bees a Buzz Lures Them Back for More
By JAMES GORMAN March 7, 2013
http://www.nytimes.com/2013/03/08/science/plants-use-caffeine-to-lure-bees-scientists-find.html?pagewanted=print&_r=0

Nothing kicks the brain into gear like a jolt of caffeine. For bees, that is.

And they don't need to stand in line for a triple soy latte. A new study shows that the naturally caffeine-laced nectar of some plants enhances the learning process for bees, so that they are more likely to return to those flowers.

"The plant is using this as a drug to change a pollinator's behavior for its own benefit," said Geraldine Wright, a honeybee brain specialist at Newcastle University in England, who, with her colleagues, reported those findings in Science on Thursday.

The research, other scientists said, not only casts a new light on the ancient evolutionary interaction between plants and pollinators, but is an intriguing confirmation of deep similarities in brain chemistry across the animal kingdom.

Plants are known to go to great lengths to attract pollinators. They produce all sorts of chemicals that affect animal behavior: sugar in nectar, memorable fragrances, even substances in fruit that can act like laxatives in the service of quick seed dispersal.

Lars Chittka, who studies bee behavior at Queen Mary, University of London, and wrote a commentary on the research in the same issue of Science, said that in the marketplace of plants seeking pollinators, the plants "want their customers to remain faithful," thus the sugary nectar and distinctive scents.

"The trick here," said Dr. Chittka, who was not involved in the research, "is actually to influence the memorability of the signal using a psychoactive drug. And that's a new trick in the book for plants."

Robert A. Raguso, who studies the interactions of plants and pollinators at Cornell and was not part of the study, said in an e-mail, "It makes the reader think twice about where natural products that have economic importance to humans actually came from before we 'discovered' and co-opted their biology."

Dr. Wright did not set out to investigate the evolutionary stratagems of plants. Rather, her goal was to use the honeybee as a model to study drugs that are commonly abused.

About eight or nine years ago, she said, "I ran across this paper on caffeine in floral nectar." And then, she said, she thought, " 'This could be quite interesting because there might be some ecological interaction between the plants and the pollinator.' That's how it started."

Several varieties of coffee and citrus plants have toxic concentrations of caffeine in leaves and other tissues, but low concentrations, similar to that in weak coffee, in the nectar itself. The toxic concentrations help plants fend off predators.

But Dr. Raguso pointed out a well-known axiom that "The dose makes the poison," a principle that Dr. Wright and her colleagues followed in lab experiments. She conducted learning experiments with bees to see if they associated a reward with an odor, the reward being either sugar water or a combination of sugar water and caffeine in the same concentrations found in the nectar of coffee and citrus plants.

The effect of caffeine was not obvious at first, but as Dr. Wright refined her experiments, it became more clear that the chemical had a profound effect on memory. "If you put a low dose of caffeine in the reward when you teach them this task, and the amount is similar to what we drink when we have weak coffee, they just don't forget that the odor is associated with the reward," she said.

After 24 hours, three times as many bees remembered the connection between odor and reward if the reward contained caffeine. After 72 hours, twice as many remembered. They then tested the effect of caffeine on neurons in the bee brain and found that its action could lead to more sensitivity in neurons called Kenyon cells, which are involved in learning and memory. Dr. Wright said that this was one plausible route for enhancing memory, but was not definitive.

Insect and human brains are vastly different, and although caffeine has many effects in people, like increasing alertness, whether it improves memory is unclear. But the excitation of the Kenyon cells was similar to the action of caffeine on cells in the hippocampus in a recent experiment on rats, Dr. Wright said.

Such similarities in neurochemistry that allow caffeine to affect mammalian and insect brains in similar ways may seem surprising, but insects like fruit flies and the nervous systems of even more primitive organisms like nematodes have been used to study learning at the level of individual cells and the chemistry that changes their activities.

Cori Bargmann of Rockefeller University, who studies the brain and behavior of a microscopic roundworm called *Caenorhabditis elegans*, said that the bee findings added more support to the idea that some very ancient behaviors like learning must have very deep evolutionary roots. Finding the common neurochemistry in such diverse creatures, she said, is like "learning the vocabulary of the brain."