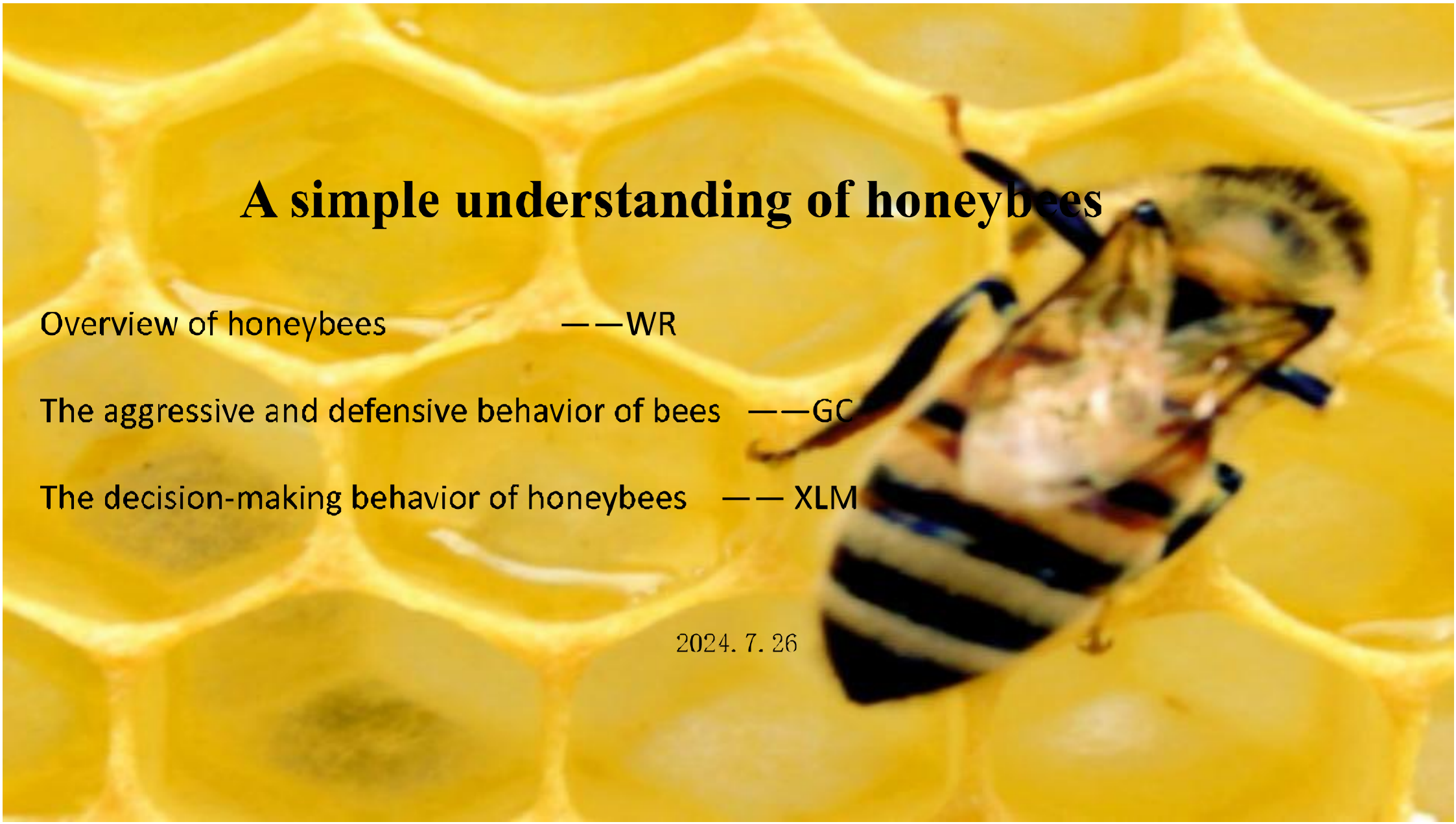
A simple understanding of honeybees

Overview of honeybees ——WR

The aggressive and defensive behavior of bees ——GC

The decision-making behavior of honeybees —— XLM

2024. 7. 26



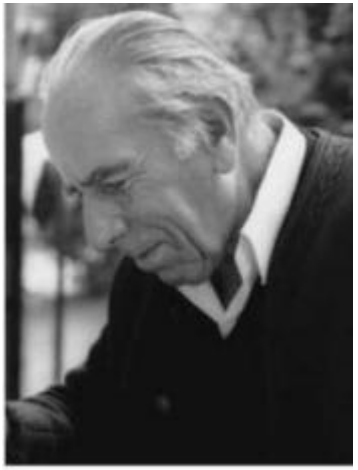
Part1: Overview of honeybee

- What are the social divisions of labor of honeybees?
- Why are honeybees "selfless"?
- How do bees communicate with groups?

Leading representative of researchers of honeybees

Karl Ritter von Frisch (November 20, 1886 – June 12, 1982) was an Austrian ethologist who received the **Nobel Prize in Physiology or Medicine in 1973**, along with Nikolaas Tinbergen and Konrad Lorenz.

Research: **Bee Perception ; Dances as languag ; "Dialects" ; Pheromones** .



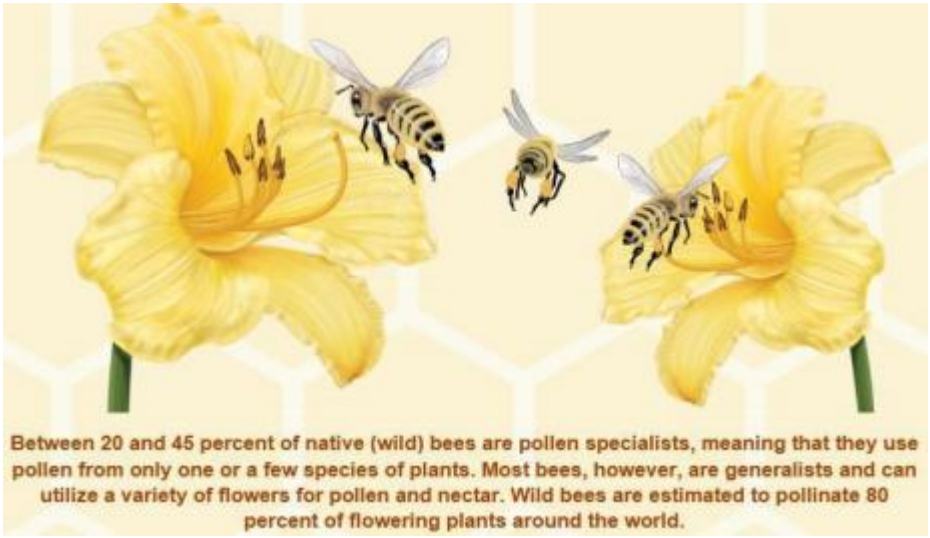
Martin Lindauer (1918–2008), Prime mover in behavioural physiology and sociobiology

Research: **how honeybees communicate and learn, sense the world, find their way, and live in societies**

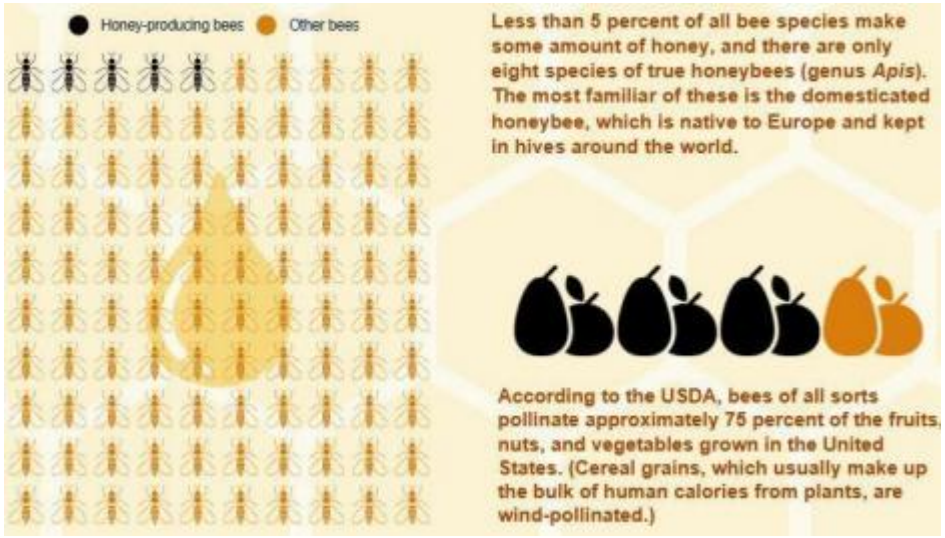
The definition of *honeybee*

Honeybees*(tribe Apini)*, any of a group of insects in the **family Apidae** (**order Hymenoptera**) that

- in a broad sense includes all bees that **make honey**.
- in a stricter sense, honeybee applies to any one of **seven members of the genus Apis**—and usually only the single species, **Apis mellifera,** the domestic honeybee

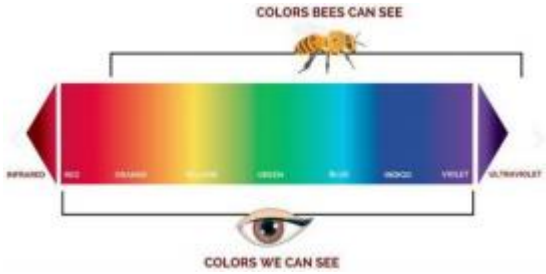


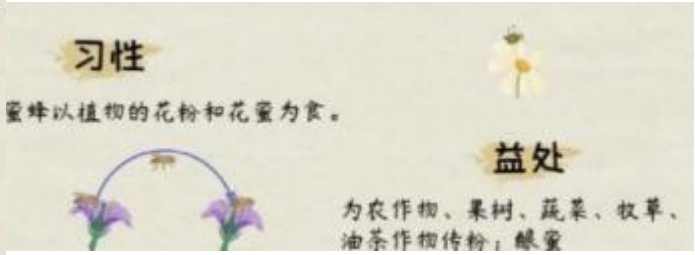
Between 20 and 45 percent of native (wild) bees are pollen specialists, meaning that they use pollen from only one or a few species of plants. Most bees, however, are generalists and can utilize a variety of flowers for pollen and nectar. Wild bees are estimated to pollinate 80 percent of flowering plants around the world.



Diversity facts of bees

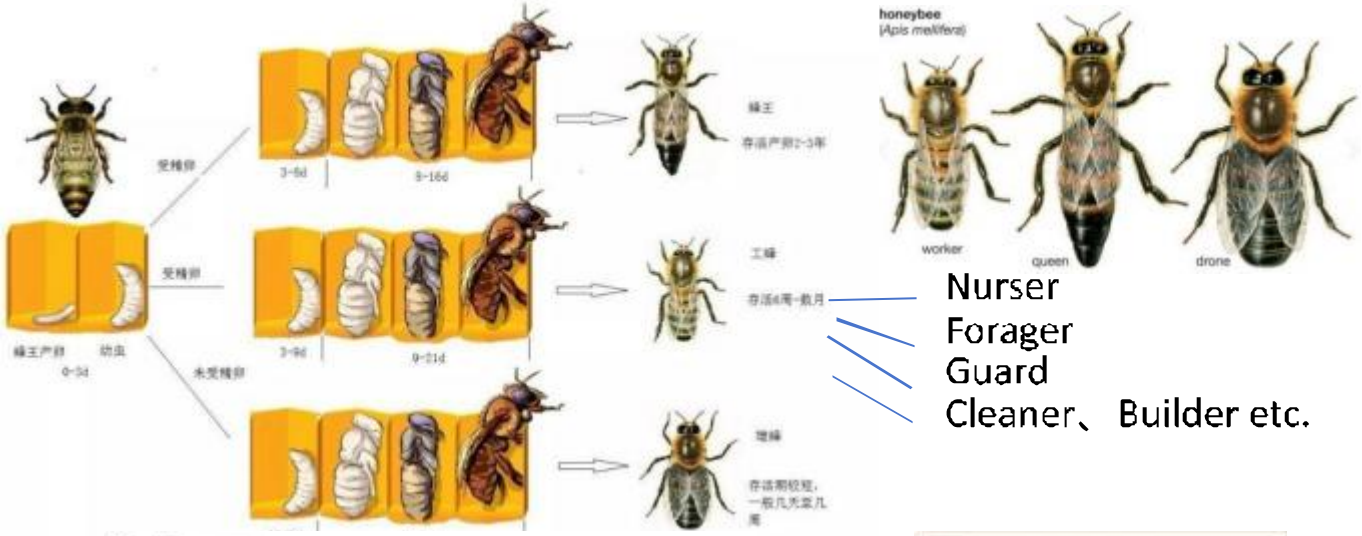
BEE FAMILY	APPROXIMATE NUMBER OF SPECIES	COMMON TYPES
Andrenidae	3,000	mining bees
Apidae	5,700	bumblebees and honeybees
Colletidae	2,700	plasterer bees
Halictidae	4,500	sweat bees
Megachilidae	4,000	mason bees and leaf-cutter bees
Melittidae	200	

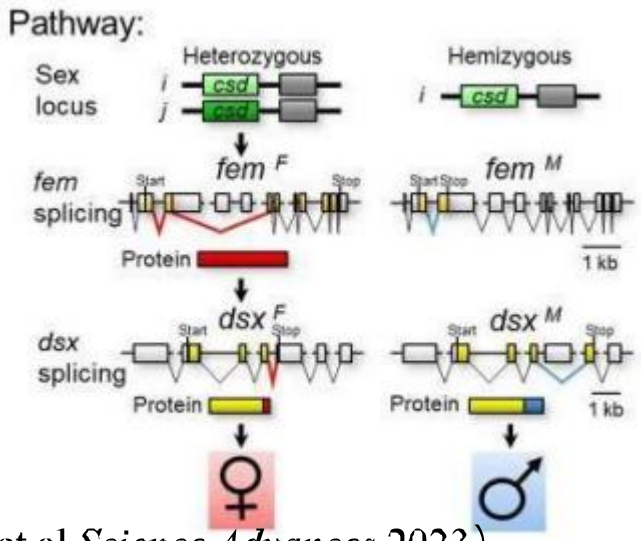




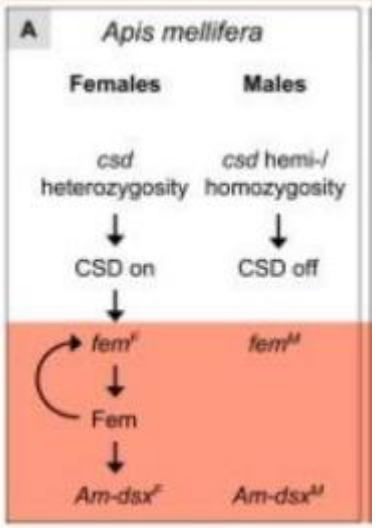
What are the social divisions of labor of honeybees?

Social composition and sex determination of honeybees





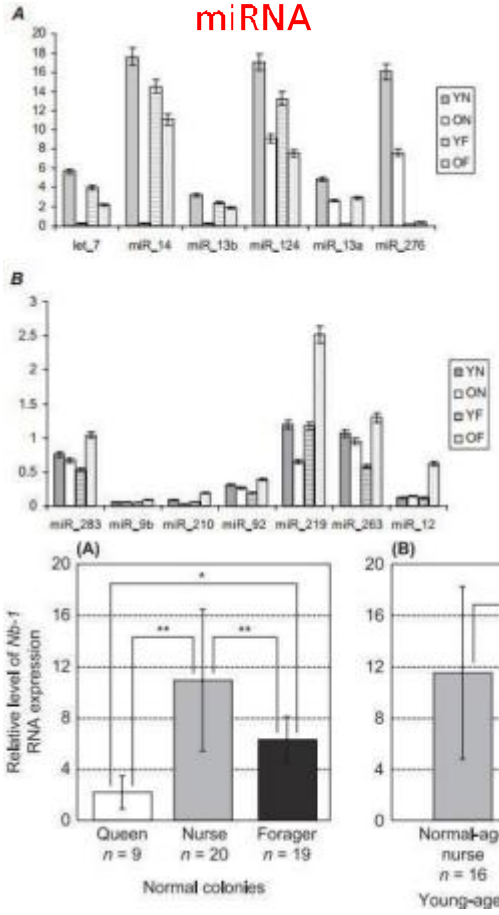
(Marianne Otte et al.*Science Advances*.2023)



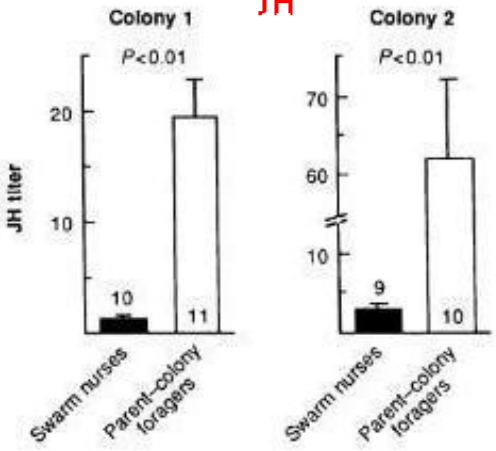
(Tanja Gempe. et al.*PLoS Biology*.2009)

Possible regulatory mechanisms of social division of labor in bees

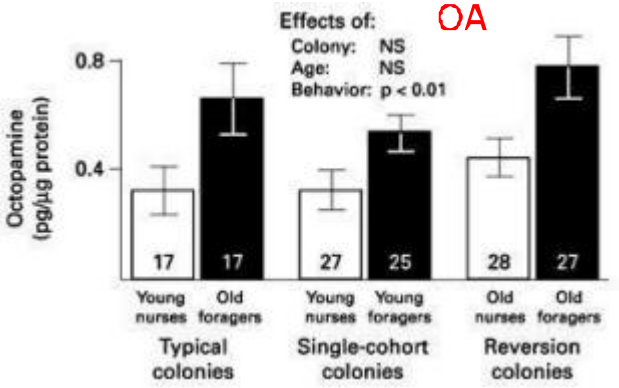
miRNA



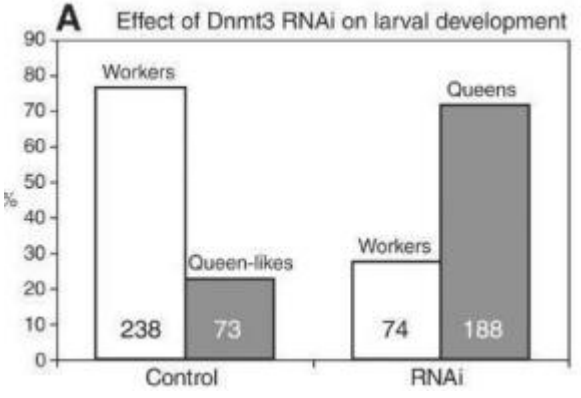
JH



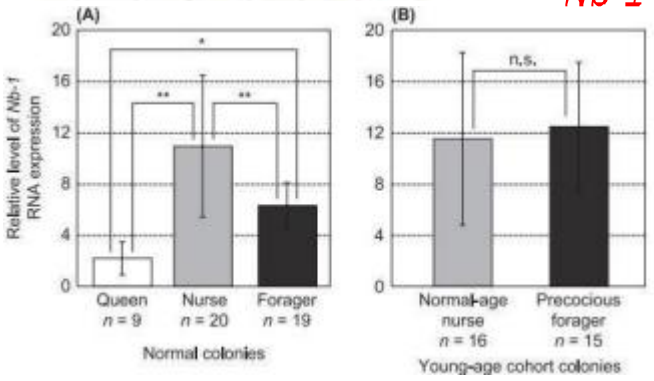
OA

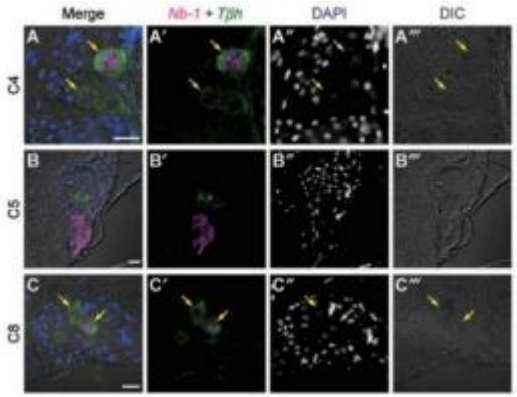


Dnmt3 DNA 甲基转移酶



Nb-1





(S. K. Behura and C. W. Whitfield.*Insect Molecular Biology*.2010)

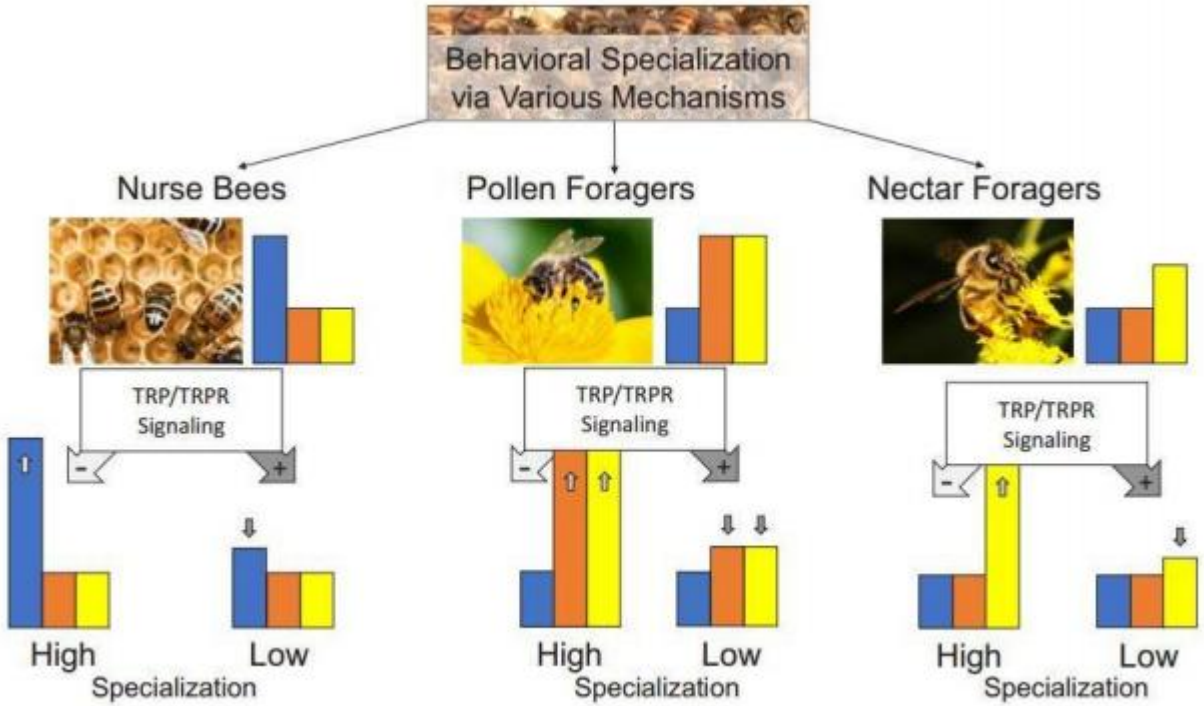
(H. Tadano et al.*Insect Molecular Biology*.2009)

(Gene E. Robinson et al.*Science*.1989)

(David J. Schulz et al.*Brain Behav Evol*.2002)

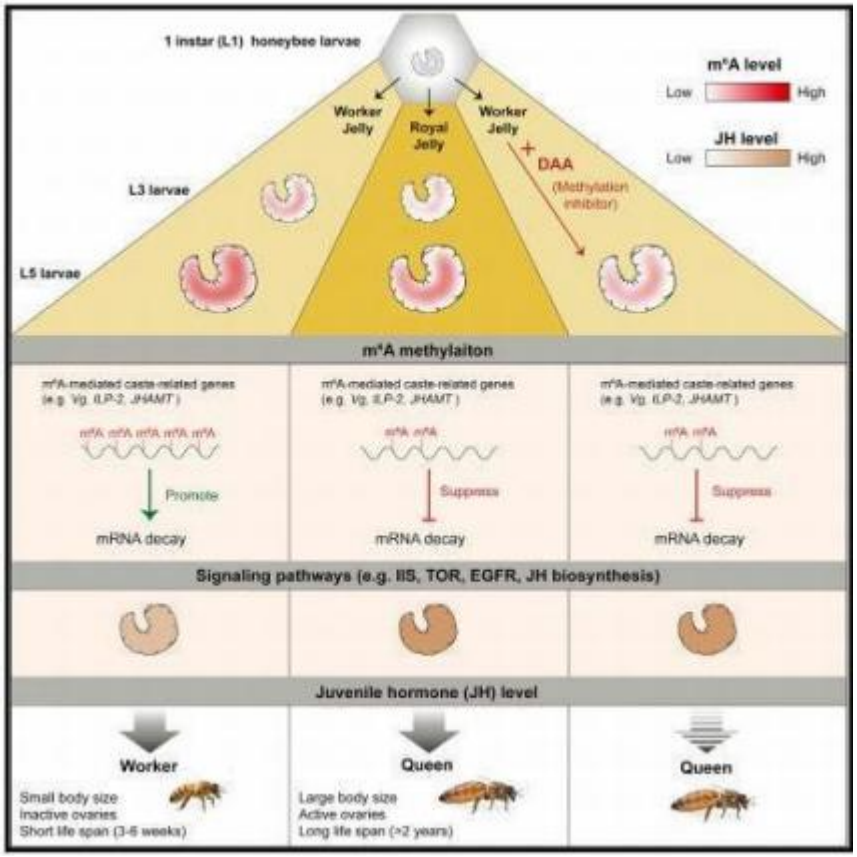
(R. Kucharski et al.*SCIENCE*.2008)

Tachykinin signaling inhibits task-specific behavioral responsiveness in honeybee workers



（Bin Han et al.*eLife*.2021）

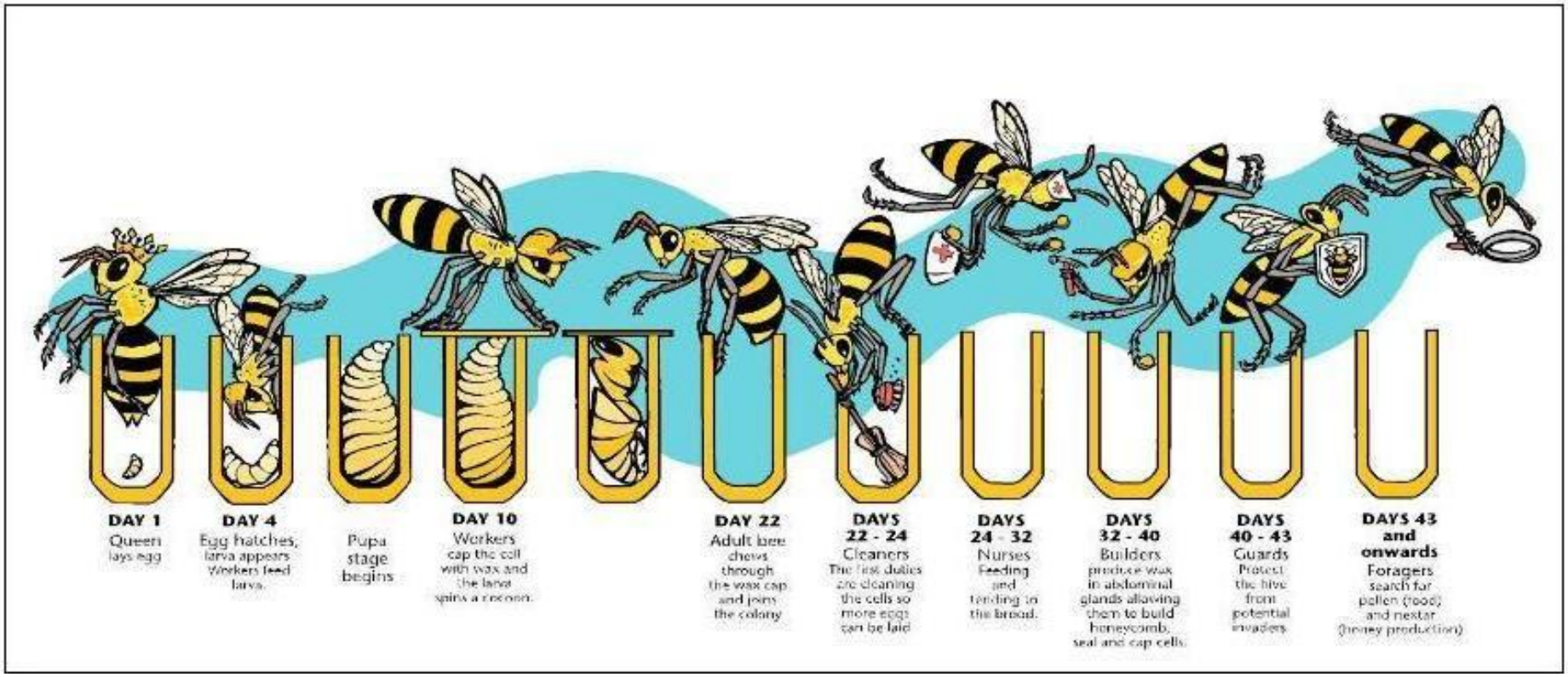
RNA m^{6}A modification functions in larval development and caste differentiation in honeybee(*Apis mellifera*)



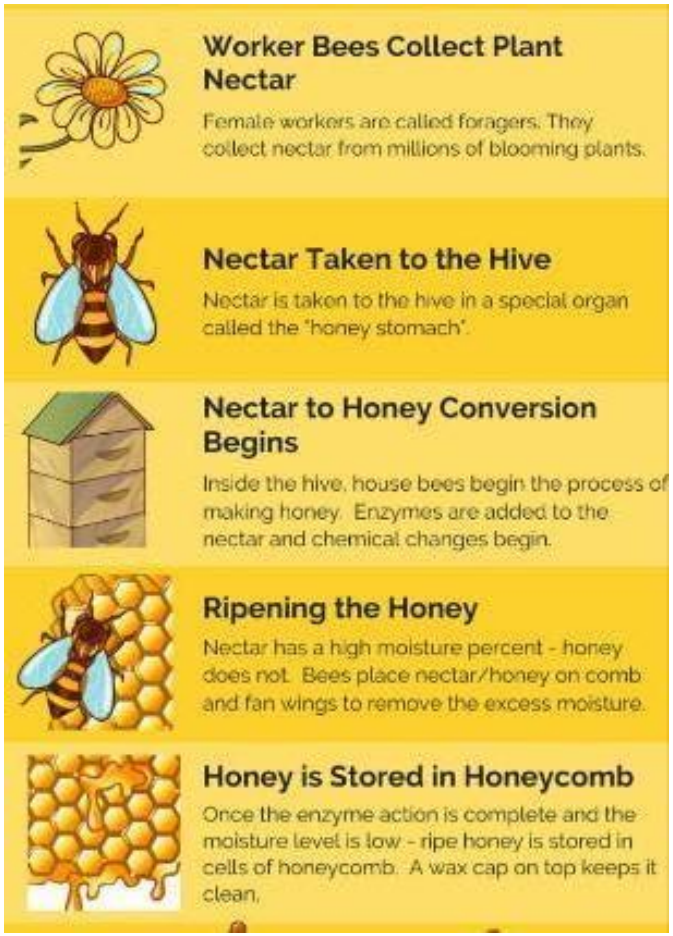
（Miao Wang et al.*Cell Reports*.2021）

Why are honeybees “selfless”(worker bees)?

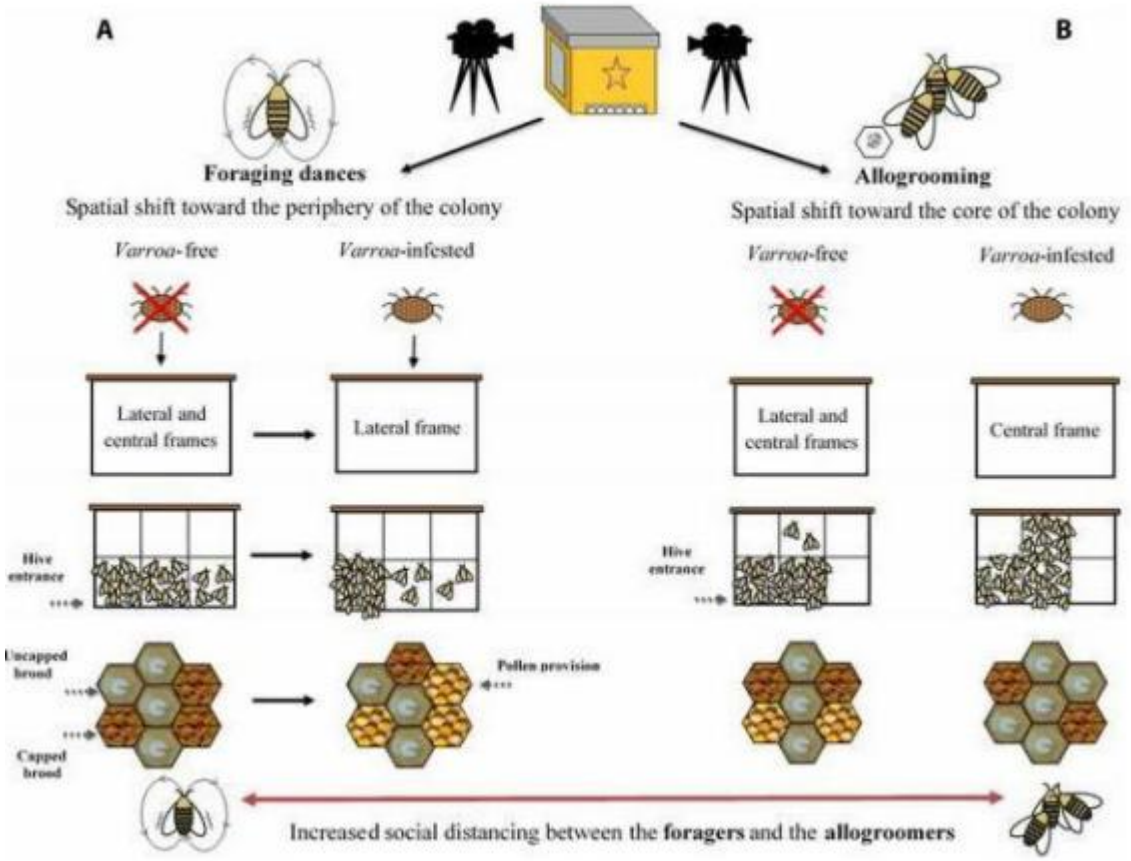
The life of a worker bee



The process of honey making by bees



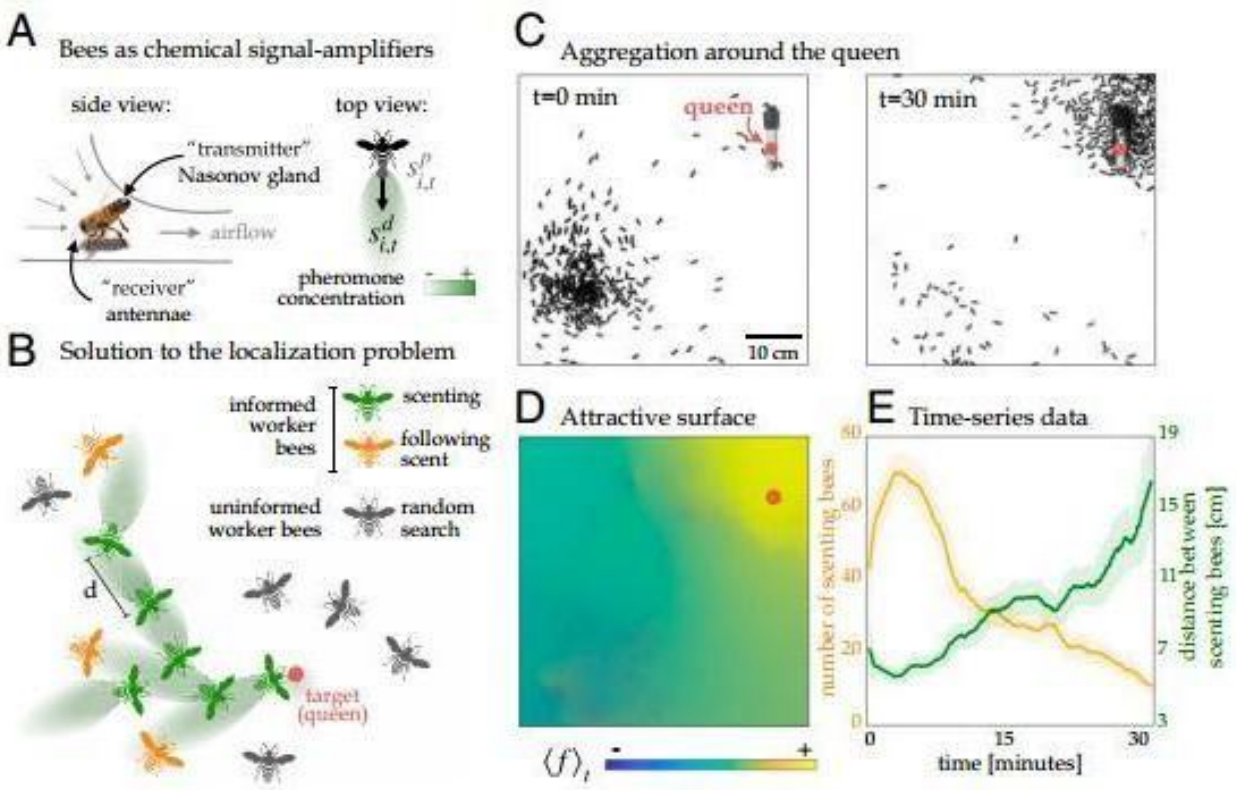
Honey bees increase social distancing when facing the ectoparasite Varroa destructor



(Michelina Pusceddu et al.*Sci. Adv.*2021)

Brief introduction——How do bees communicate with groups?

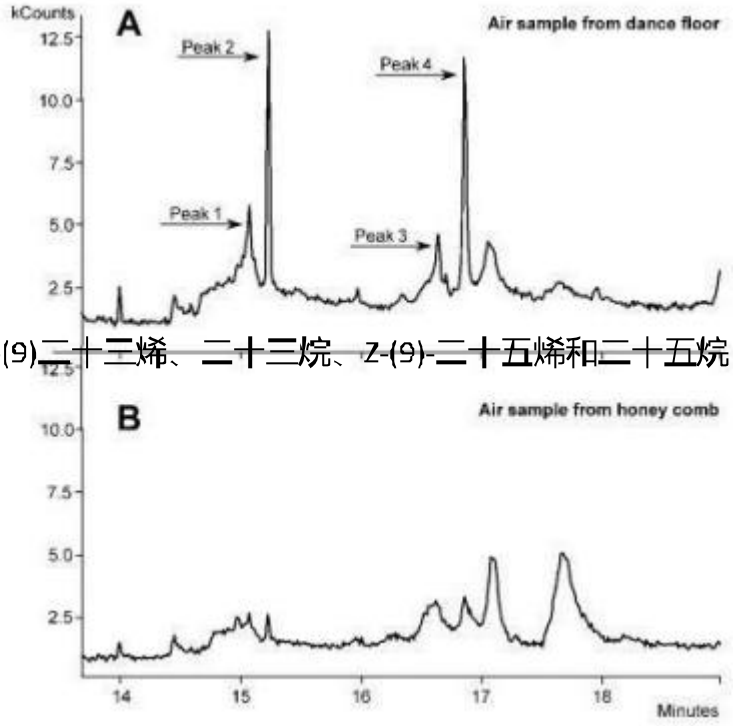
I.Honeybees use directed volatile communication to locate their queen



(Dieu My T. Nguyen et al.*PNAS*.2021)

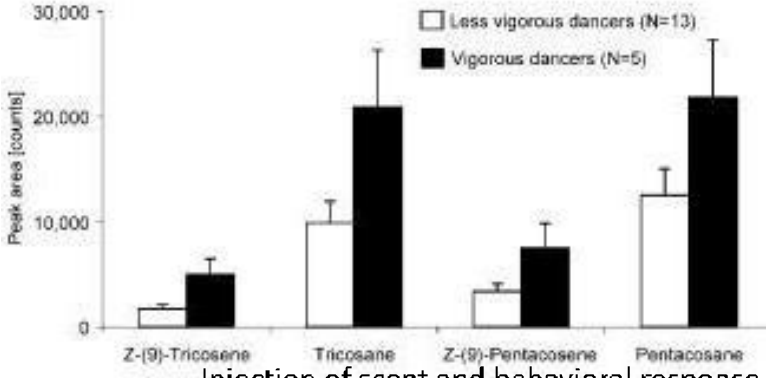
The scent of the waggle dance

Comparison of air samples above waggle dancers and nondancing bees

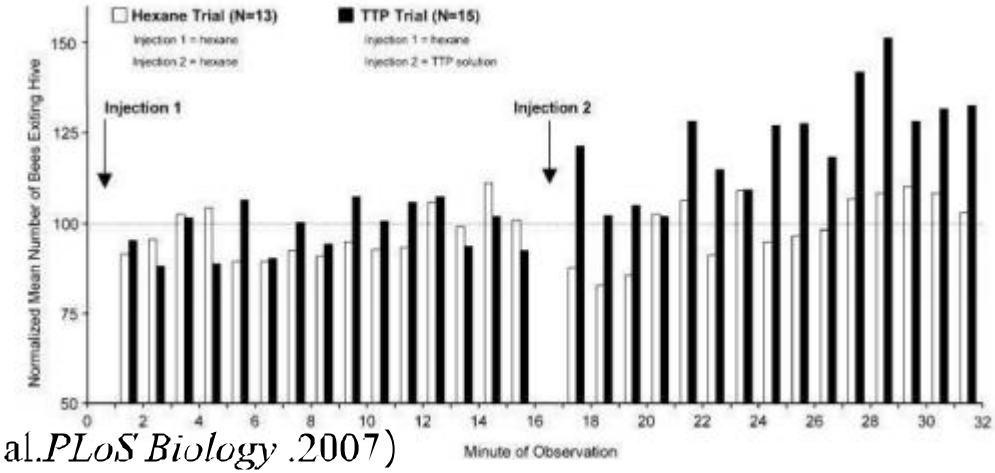


Z-(9)二十三烯、二十三烷、Z-(9)-二十五烯和二十五烷

Comparison of vigorous and less vigorous dancers



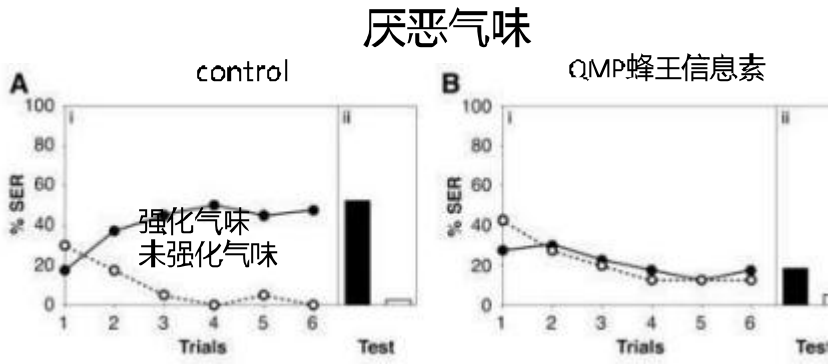
Injection of scent and behavioral response



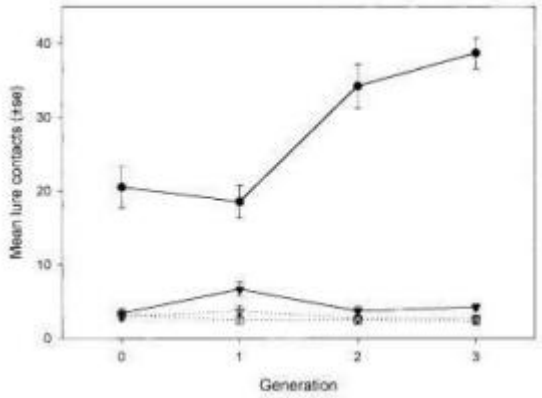
（Corinna Thom et al.*PLoS Biology* .2007）

Effects of queen pheromone on worker and drone bees

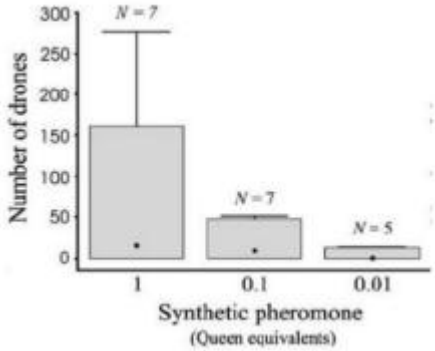
Queen pheromone blocks aversive learning



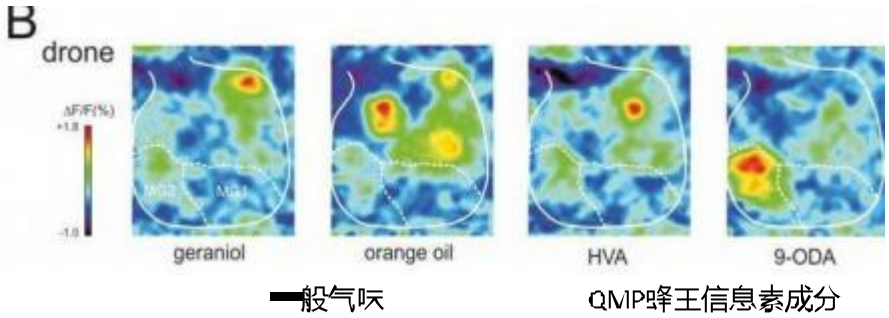
The Retinue responses to queen mandibular pheromone(QMP)



（Vanina Vergoz et.al.*Science*.2007）



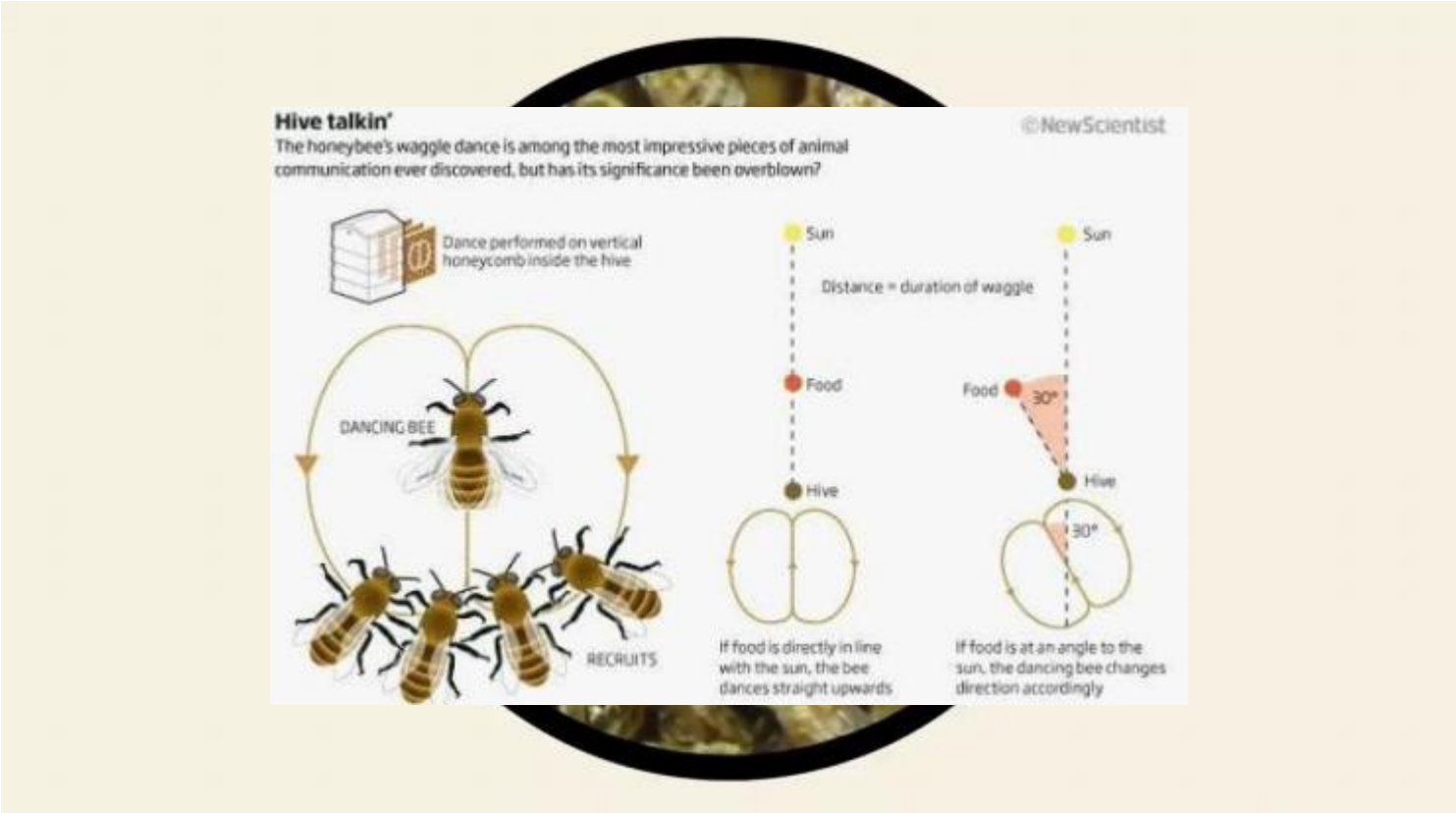
The attraction of queen pheromone to drones



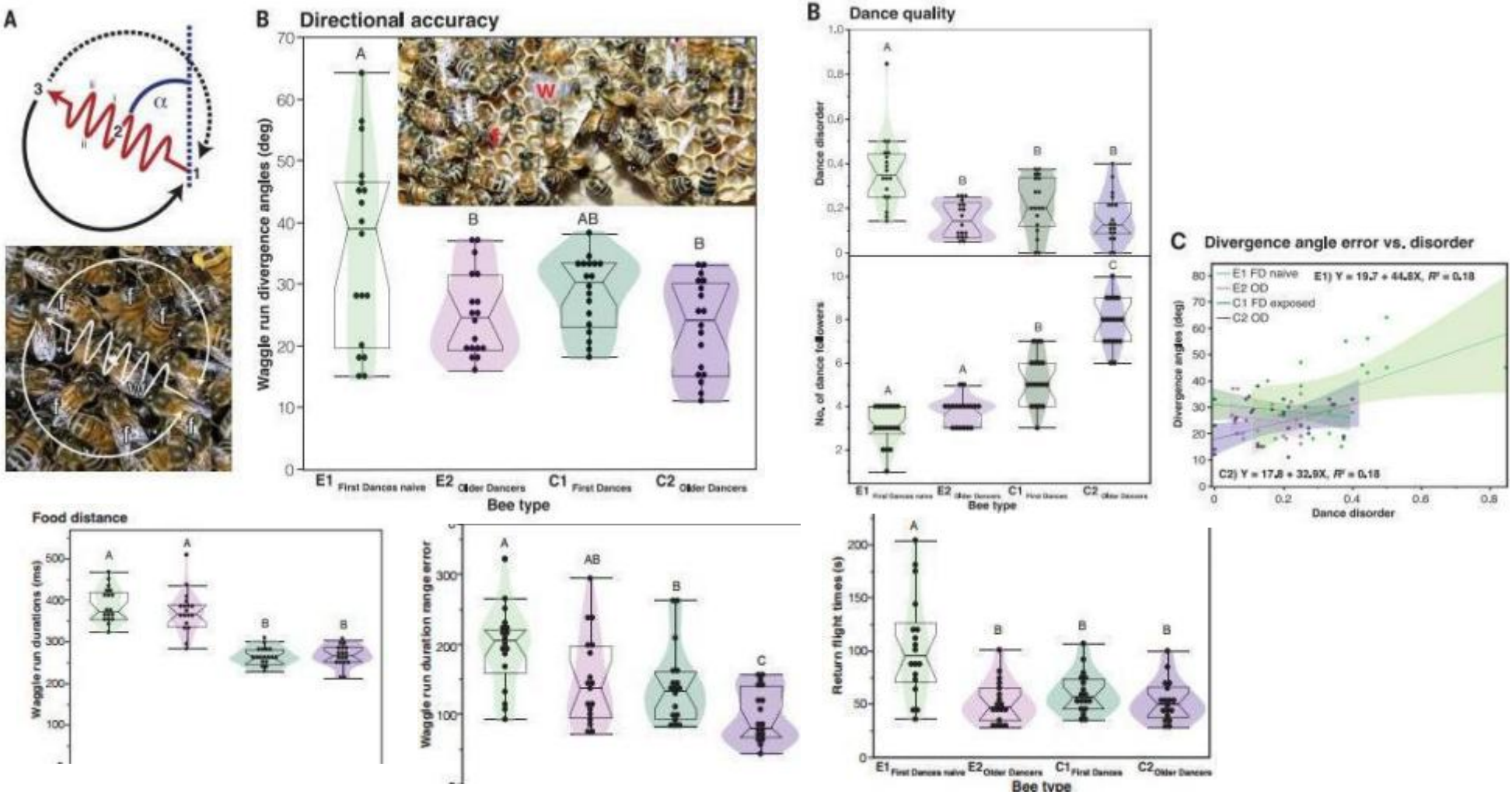
（Jean-Christophe Sandoz et.al.*Frontiers in Behavioral Neuroscience*.2007）

（Tanya Pankiw et.al.*Naturwissenschaften*.2000）（Johannes Spaethe et.al.*Journal Chemical Ecology*.2006）

II.The dancing behavior of honeybees

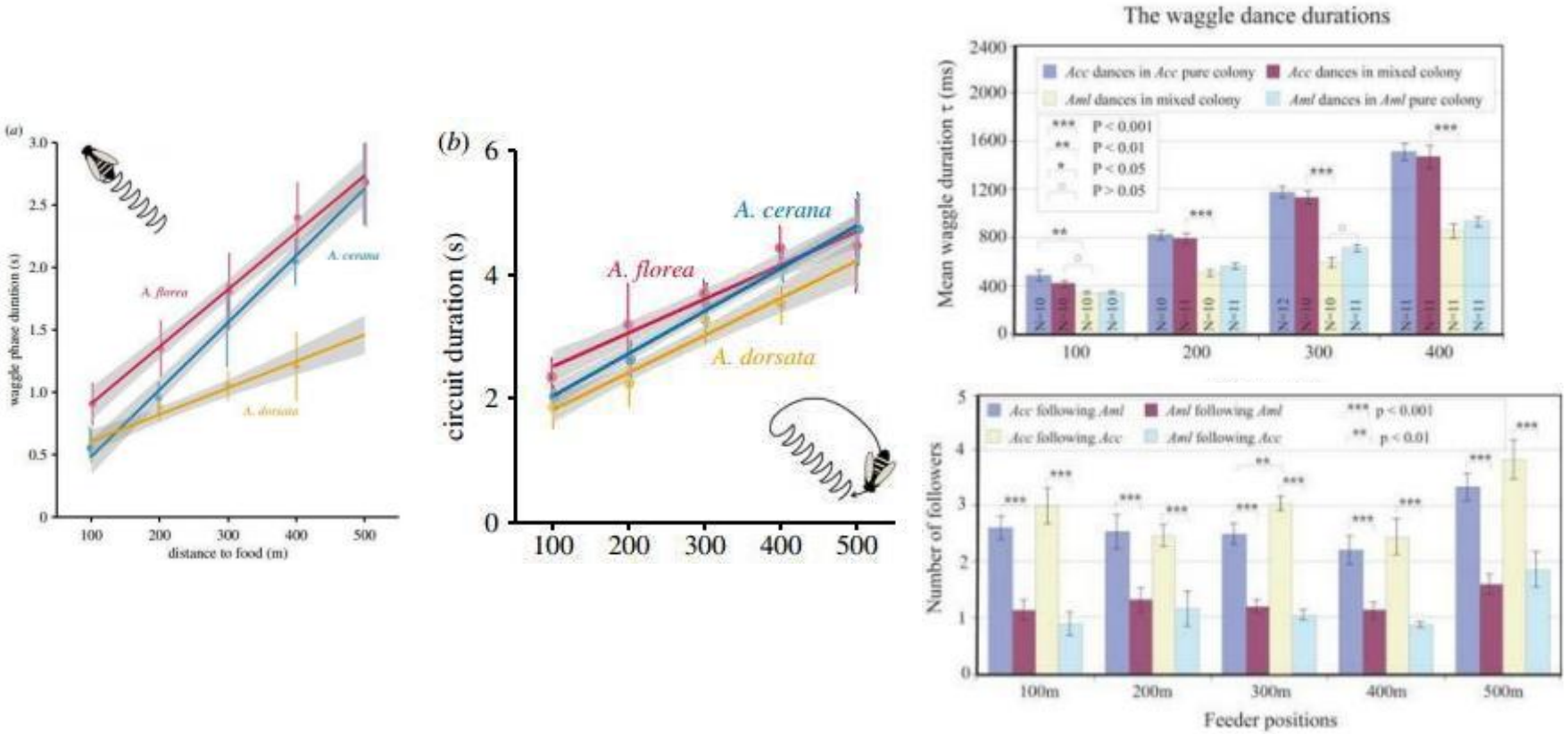


Social signal learning of the waggle dance in honeybees



(Shihao Dong et al.*Science*.2024)

Different species of honeybees can understand “dialects”

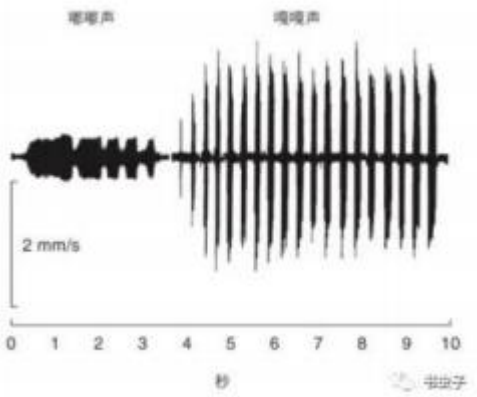


（Patrick L. Kohl et al.*Proc. R. Soc.*2020）

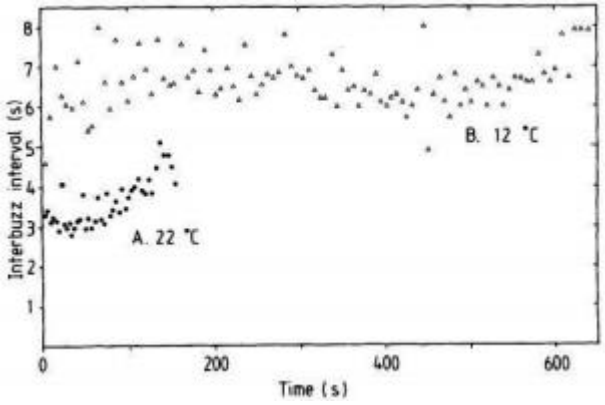
（Songkun Su et al.*PLoS ONE*.2008）

III.Physical communication between bees—sound

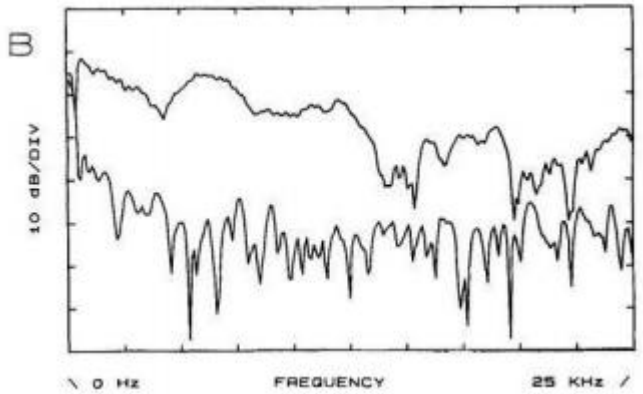
The whistles of two virgin queens were recorded as the vibrations of the hive



Emission of copulation buzzes by *Collefes* males



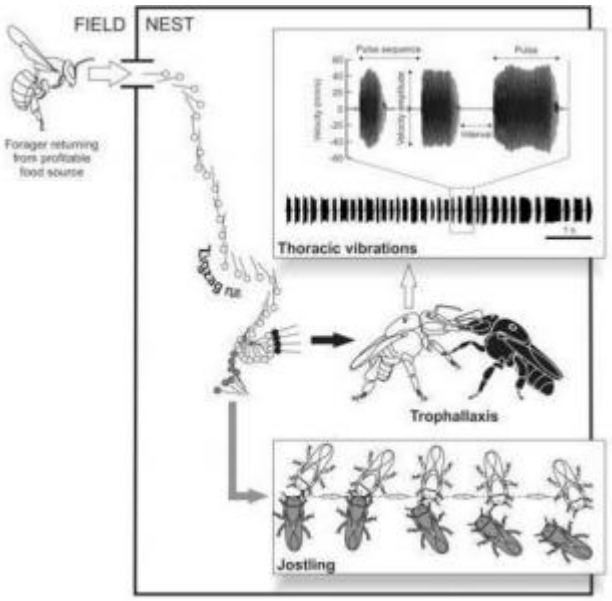
Sounds made in the face of danger of a *Colletes* male



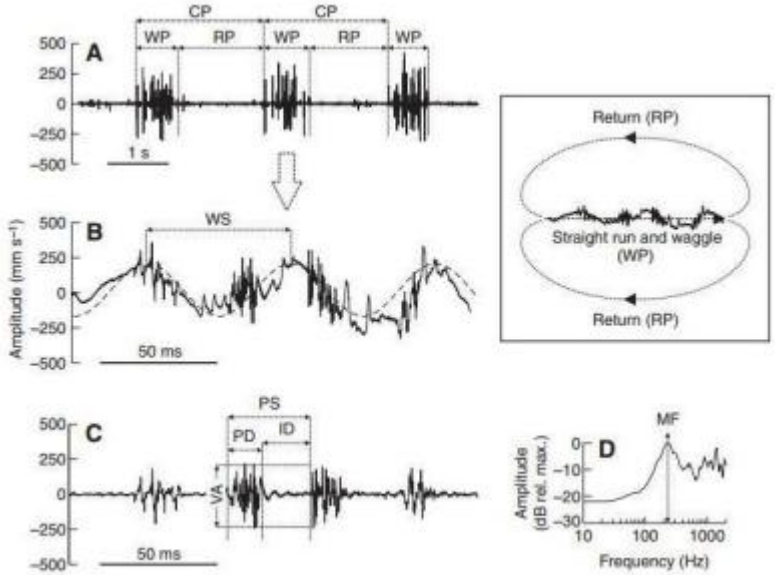
（Ole Nesbye Larsen et al.*Physiological Entomology*.1986）

Thoracic vibrations in bees can transmit information

Vibratory communication in stingless bees (*Meliponini*)



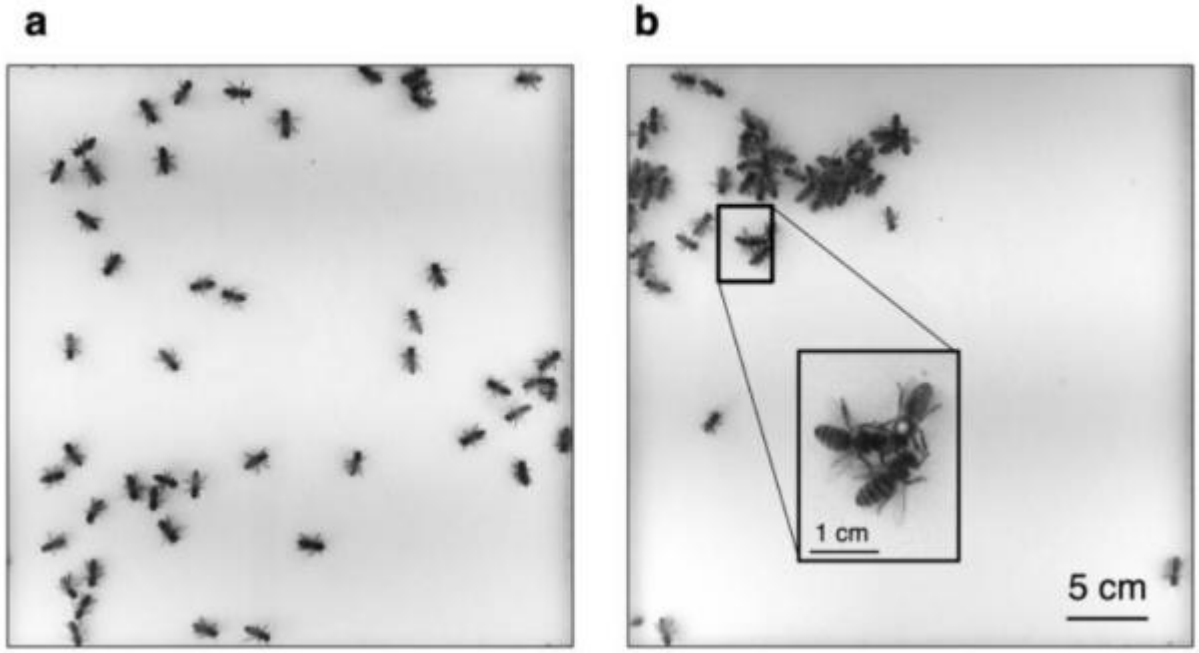
The honey bees' waggle dance



two vibratory pulses per waggle movement

（Michael Hrncir and Friedrich G. Barth.2014）

Physical communication between bees—Trophallaxis



（Golnar Gharooni-Fard.*Nature*.2024）

Take home message

1、Honeybees are typically social insects, with a colony consisting of a queen bee, a few drones, and a large number of workers and sex determination in Apis mellifera is controlled by heterozygosis at a single locus carrying complementary sex determination genes (*csd*);

2、The average life span of a worker bee is only about 45 days, when eclosion, they rarely rest and undertake different kinds of work to keep the whole colony functioning;

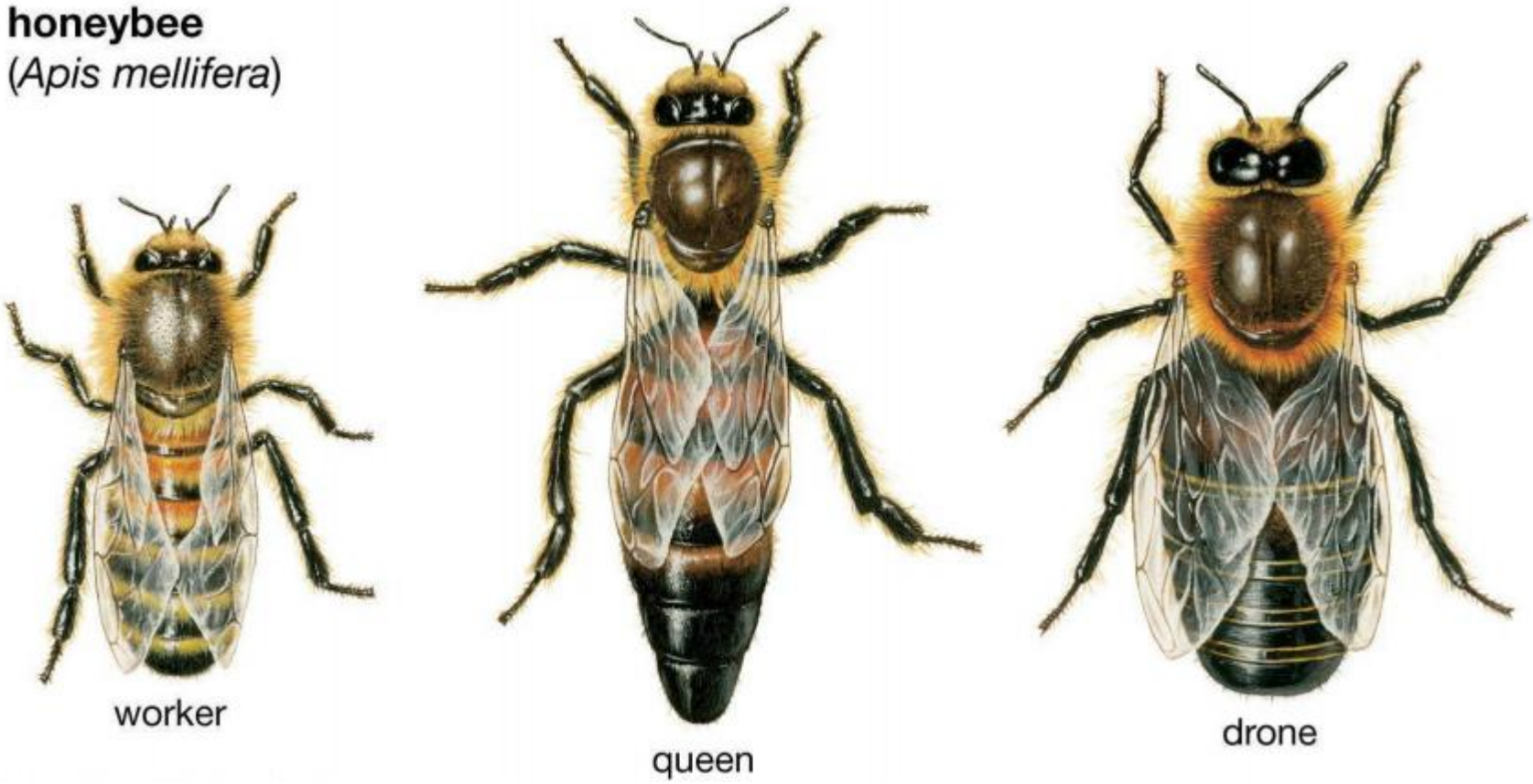
3、Honeybees communicate with their species through pheromones, dancing, and physical contact.

- The pheromones of bee colonies include QMP, worker pheromones, drone pheromones and larval pheromones and different pheromones are used to transmit information in different social division of labor;
- Honeybees dance to convey information about food :direction of the food source——angle of the direction of waggle and the direction of gravity ; the distance——duration of waggle;
- Honeybees can send messages by thoracic vibrations or wing vibrations, and they transmit food by trophallaxis.

Defense & Fighting Behavior of Honeybees

Gao Can

Which one can exhibit fighting behavior?



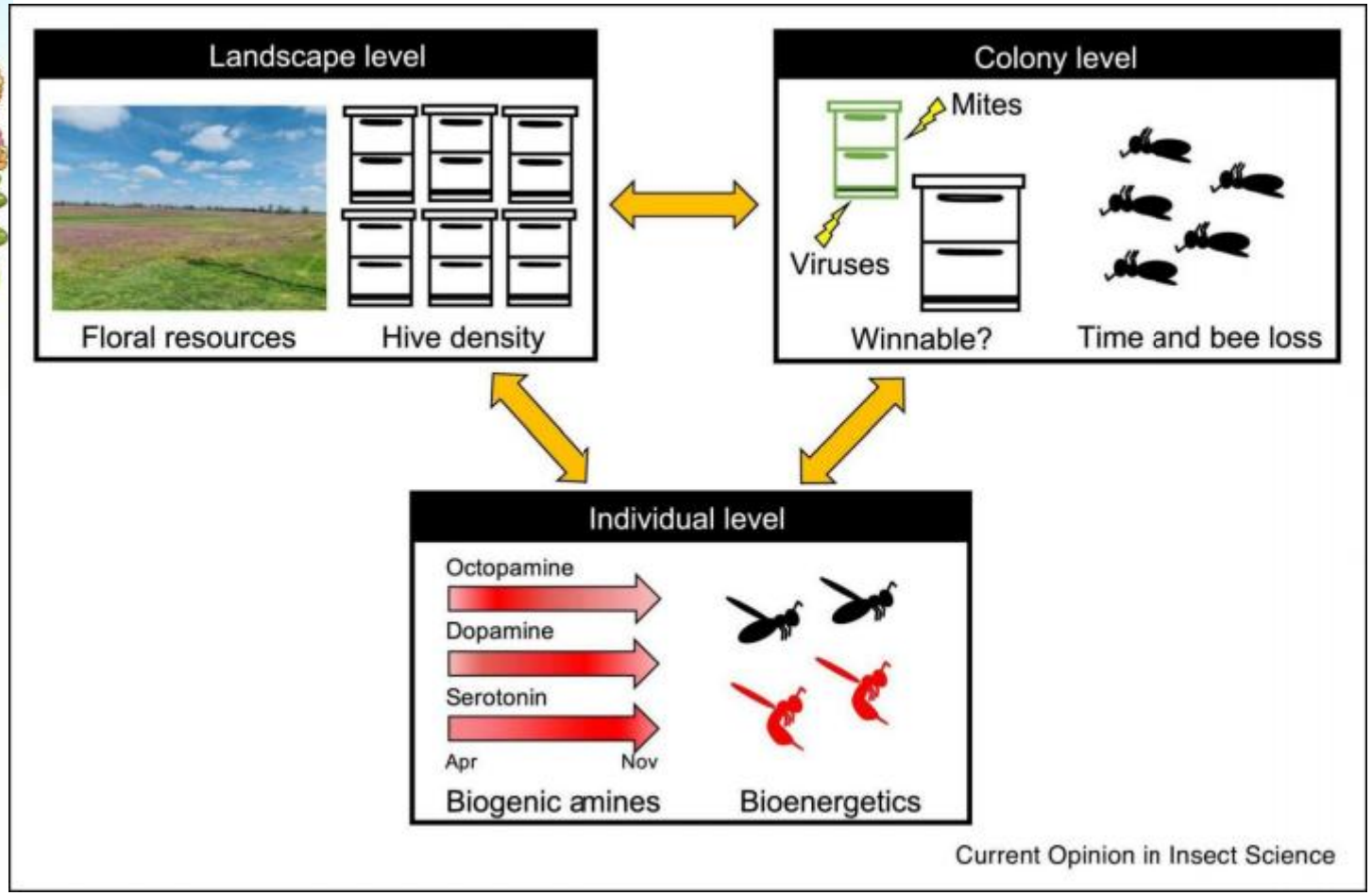

Two queen bees emerge
at the same time
B2U

时尚蜂衣

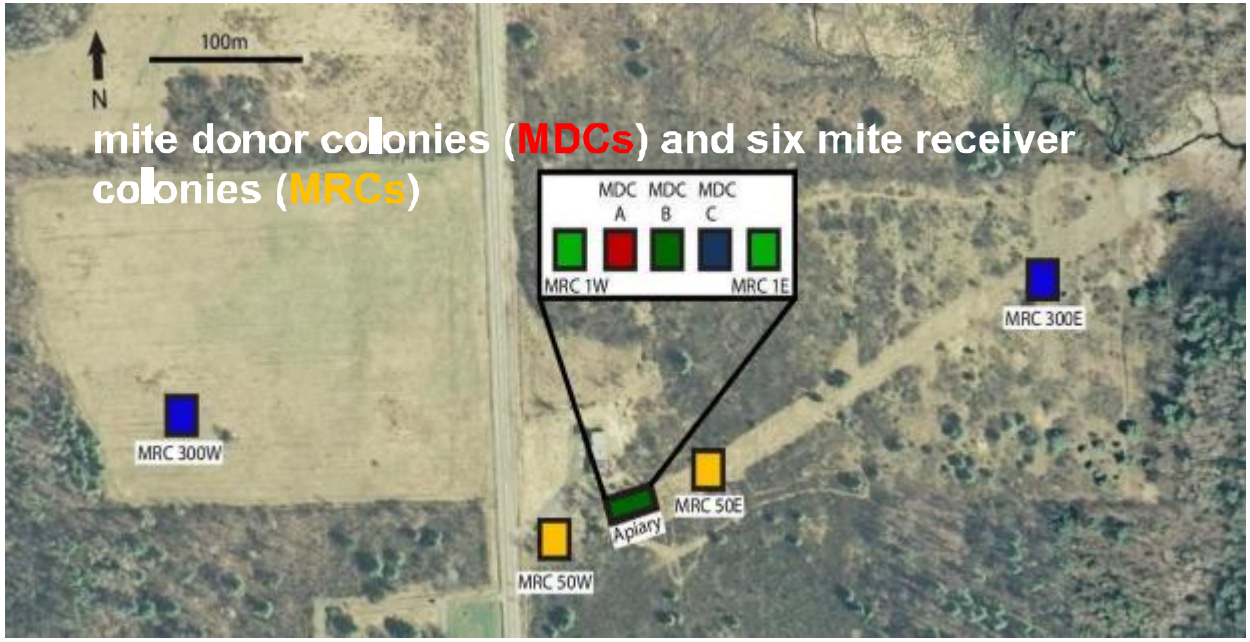
Why do bees exhibit fighting behavior?

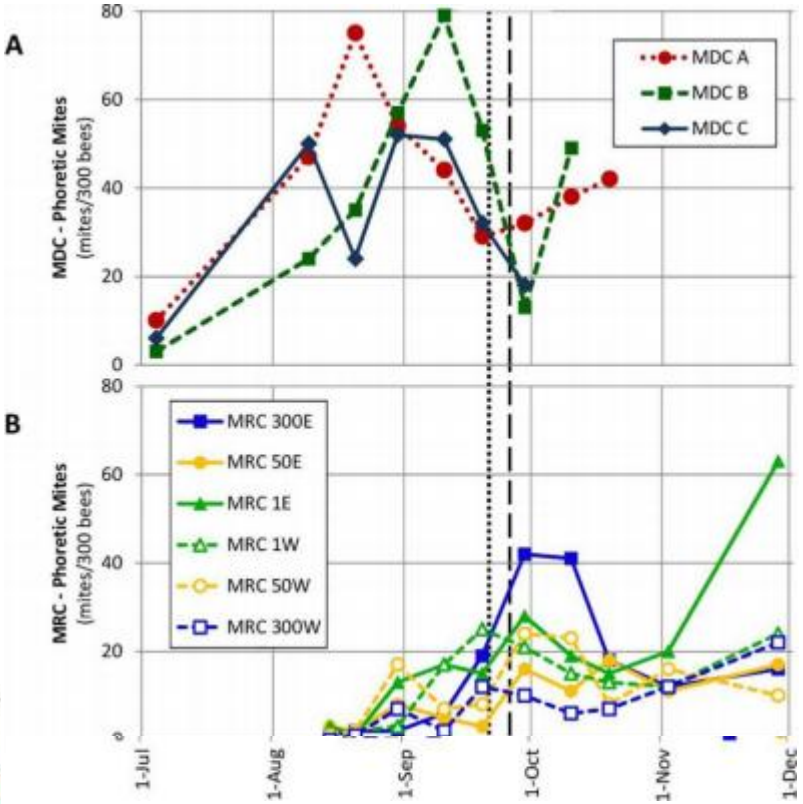
- Lack of food/protecting stores
- Compete for the throne
- Feeling under threat

Honey Robbing



Mite bombs or robber lures?



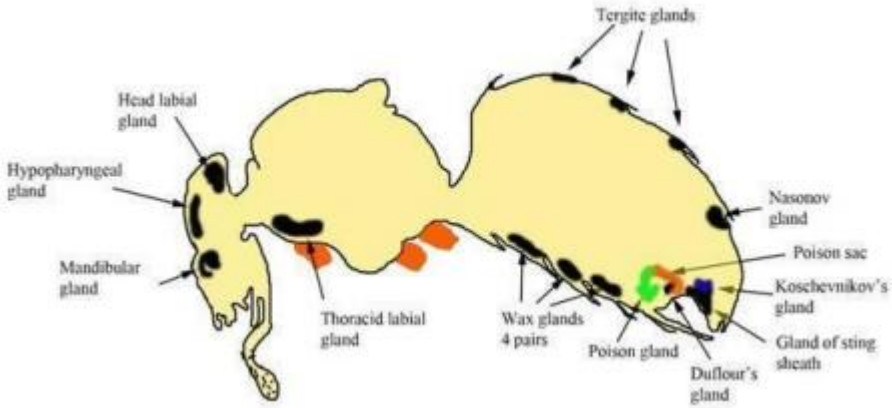


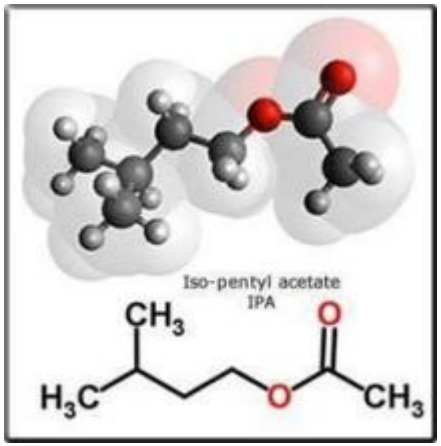
David Thomas Peck, 2019

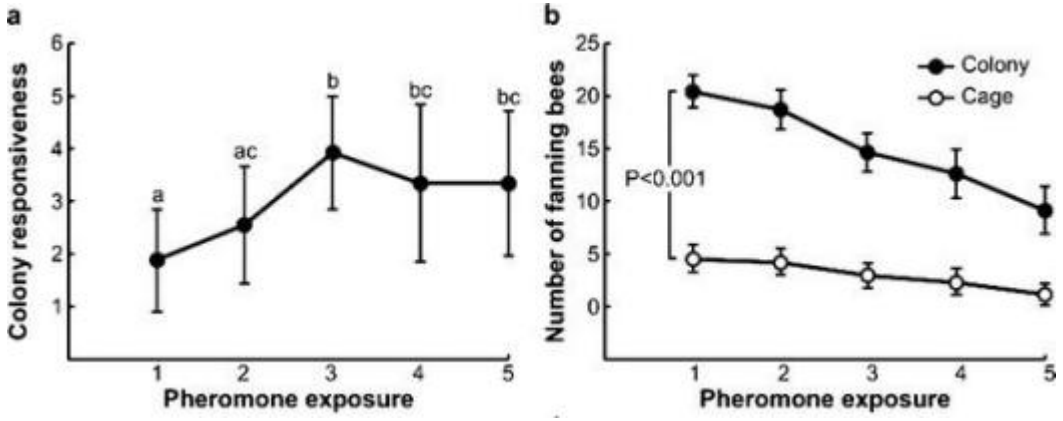
Alarm pheromones are closely related to the fighting or defensive behavior of honeybee

Alarm pheromones

are produced by honey bee workers in the mandibular gland and through the Koschevnikov gland, over 40 chemical compounds have been identified.







Cédric Alaux, 2007

PLOS BIOLOGY

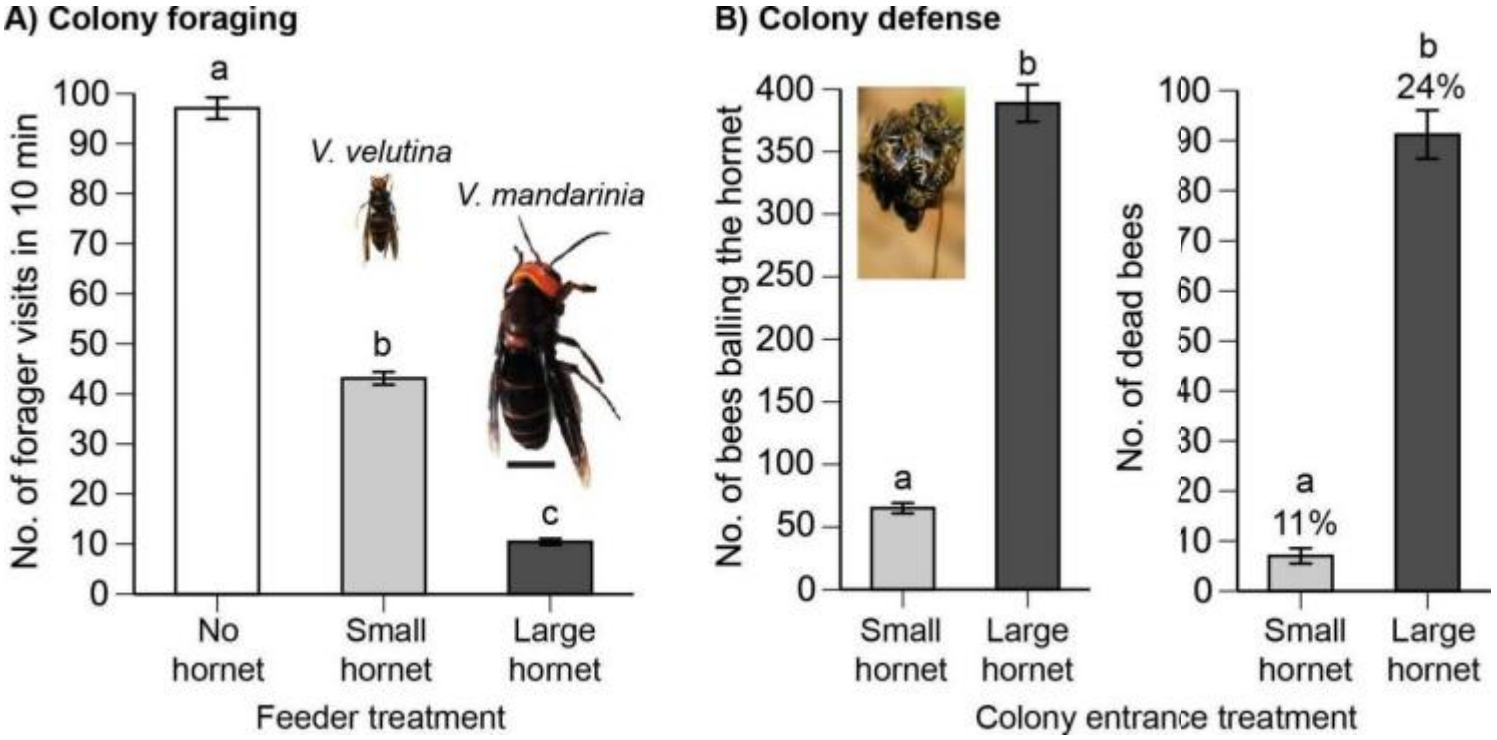
OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Honey Bee Inhibitory Signaling Is Tuned to Threat Severity and Can Act as a Colony Alarm Signal

Ken Tan, Shihao Dong, Xinyu Li, Xiwen Liu, Chao Wang, Jianjun Li, James C. Nieh

Effects of hornet attacks upon colony foraging allocation and defense

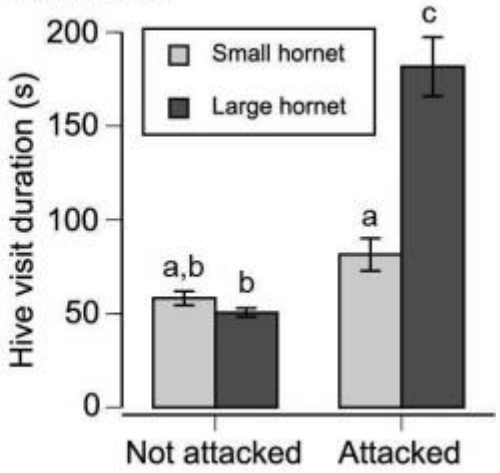


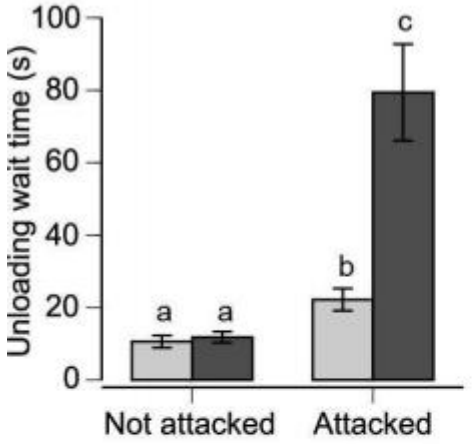
What is STOP signal?

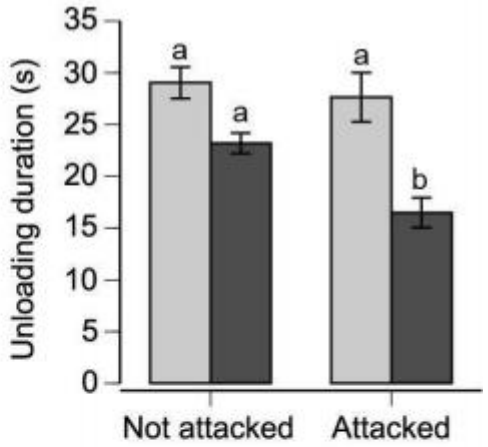
The stop signal is "beeping" sound produced when the signaler heat-butts the receiver, usually another forager.

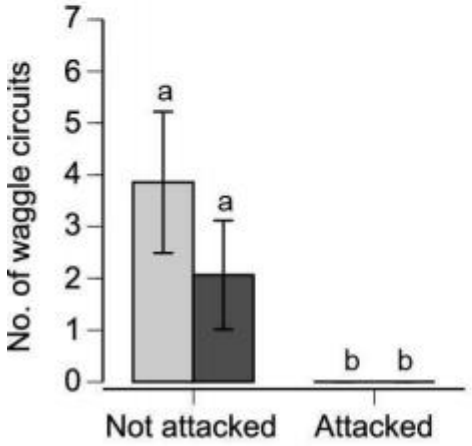
Foragers that were attacked reduced waggle dancing and produced stop signals

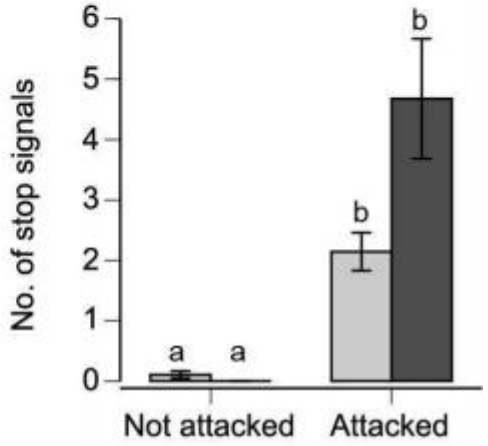
Individual forager responses to hornet attacks



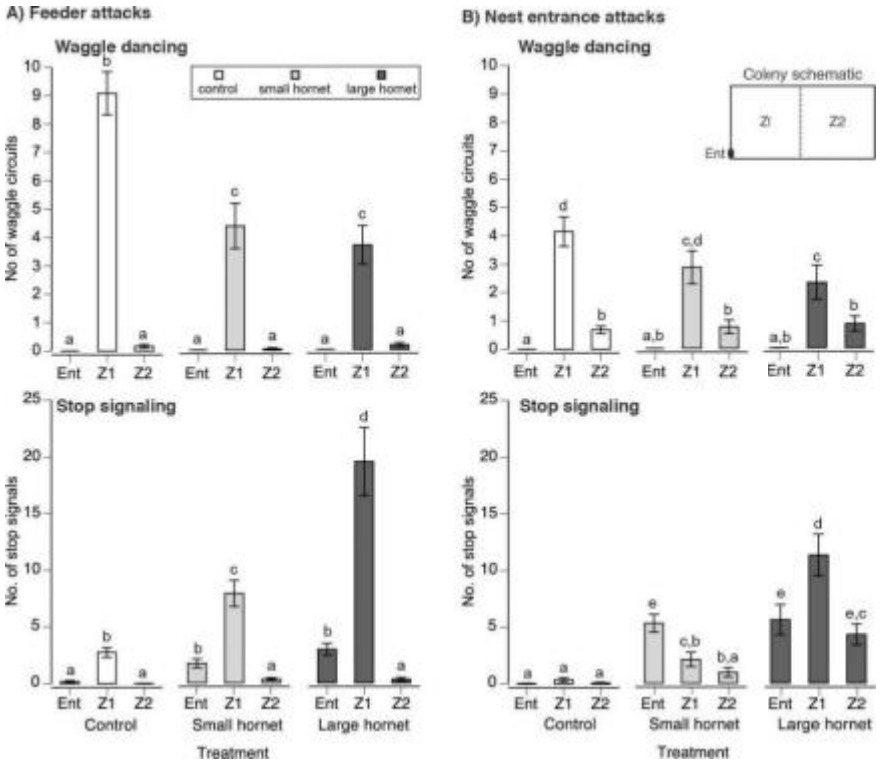


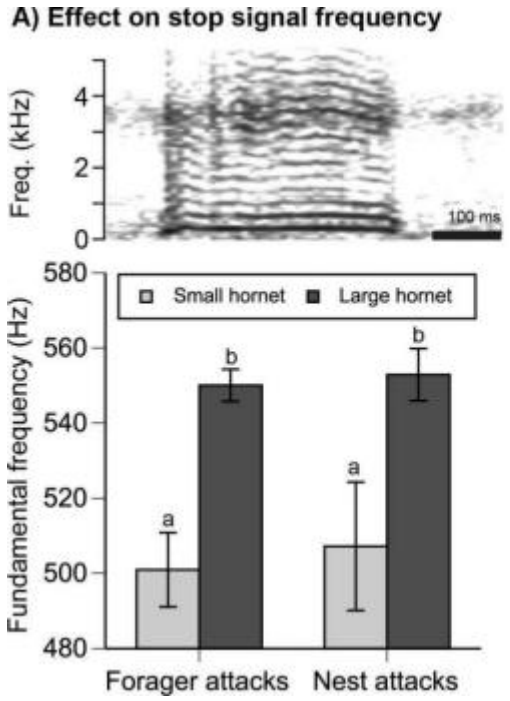


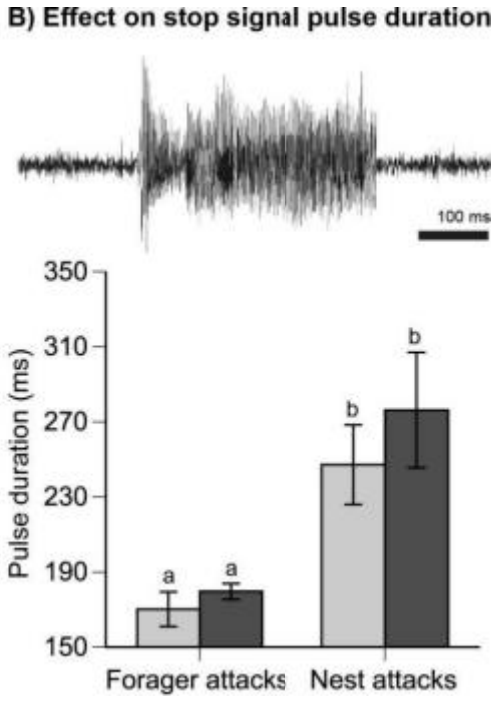




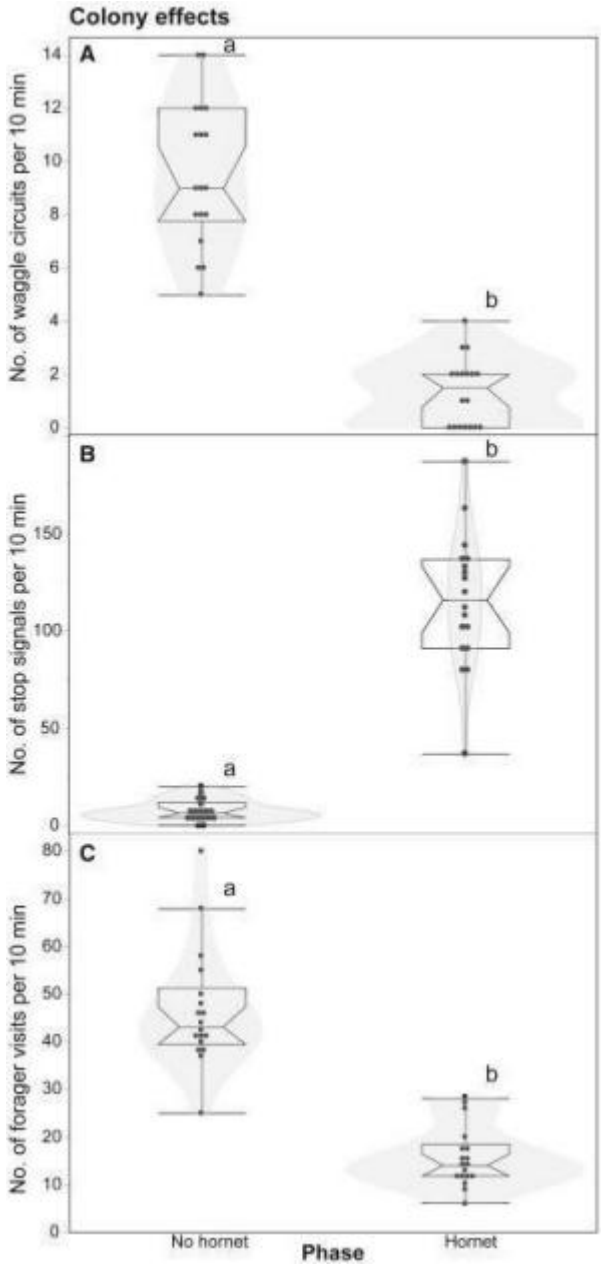
Colony stop signaling increased according to predator size



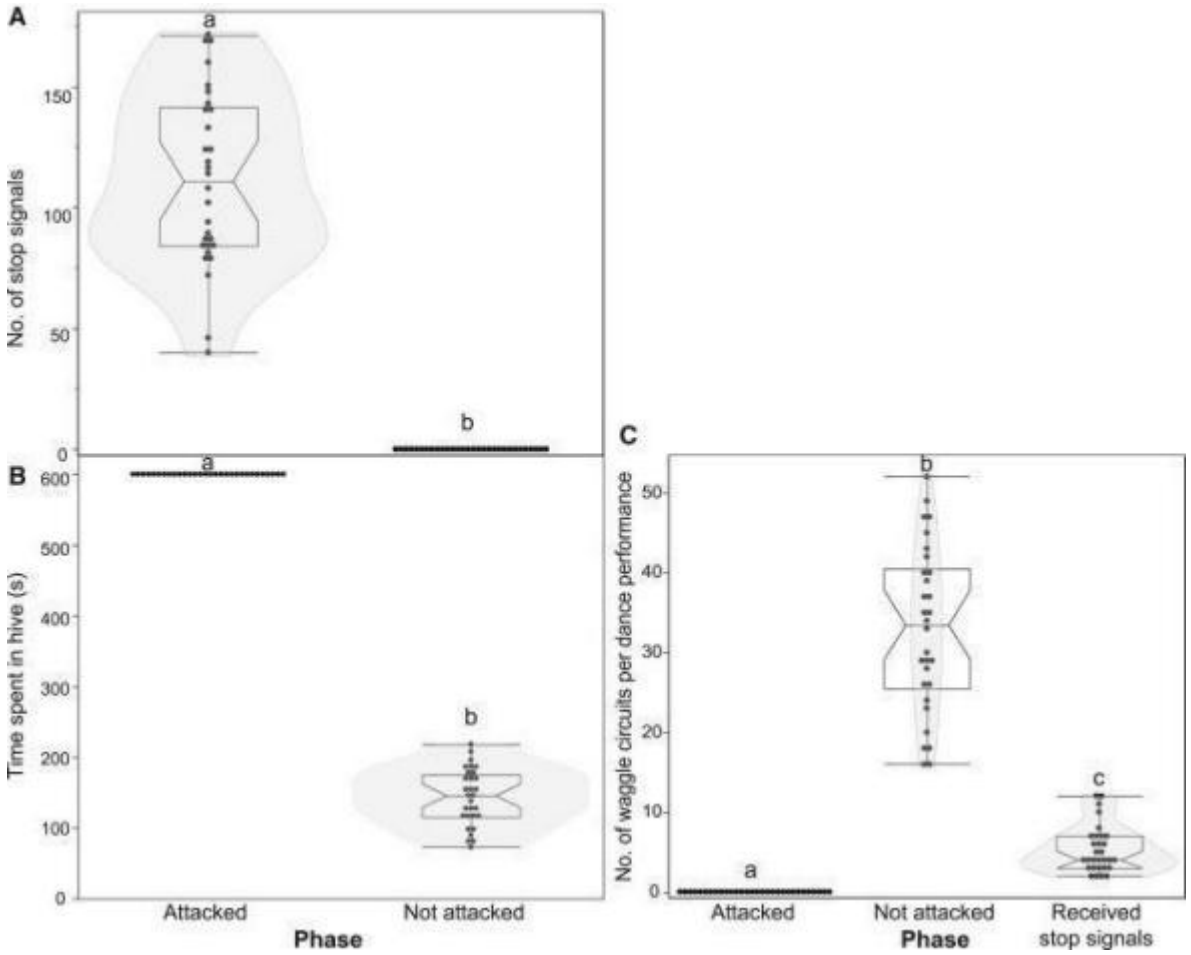




Hornet attacks decreased waggle dancing and increased stop signaling at the colony level

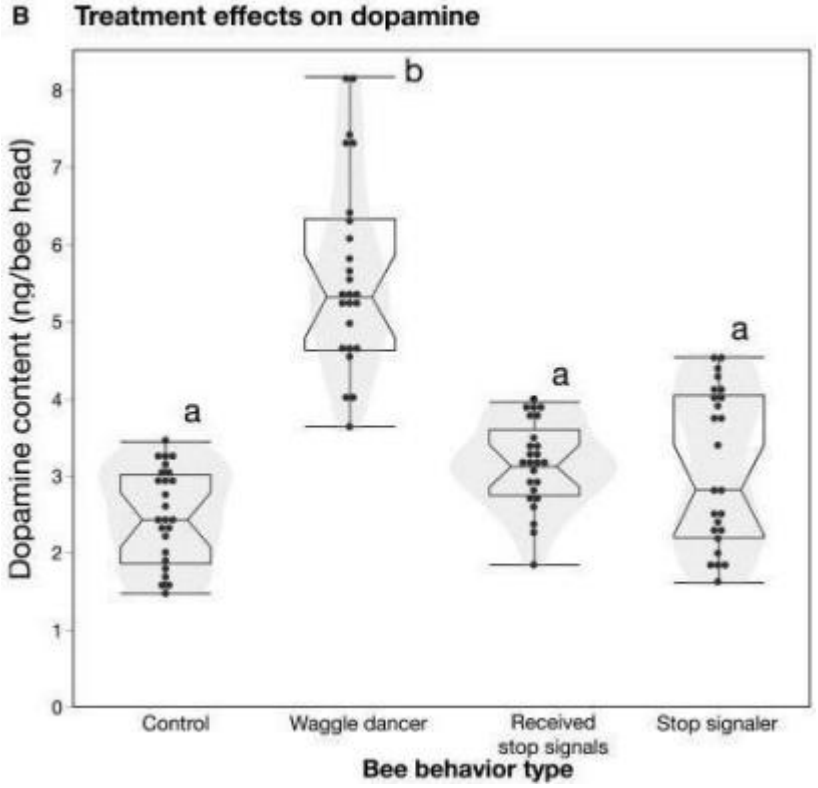


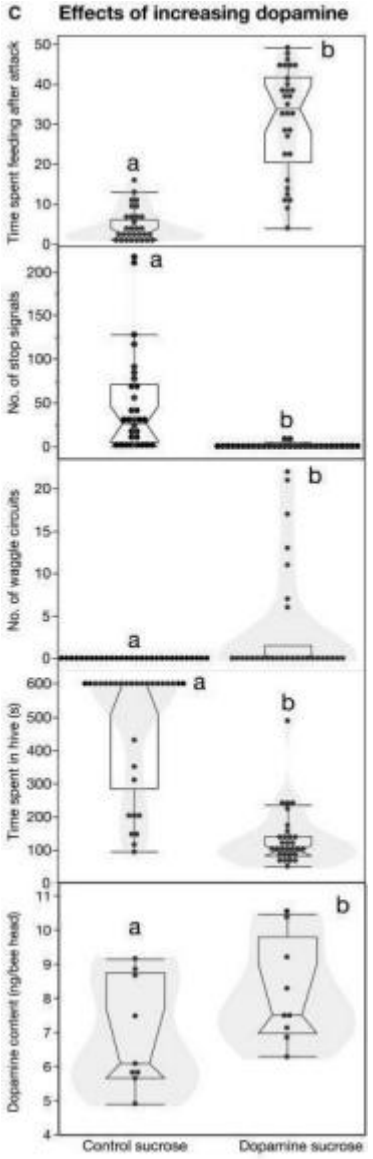
Hornet attacks increased stop signaling and decreased waggle dancing by individuals



Attacks by hornets and stop signals reduced bee dopamine levels, but increasing dopamine reduced the aversive effects of attacks

A *Vespa mandarinia* attacking a honey bee at a feeder





Honeybee Don‘t Care!

(dopamine boosted bees ignore giant hornet)

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RESEARCH ARTICLE | SOCIAL LEARNING

Social signal learning of the waggle dance in honey bees

SHIHAO DONG, TAO LIN, JAMES C. NIEH, AND KEN TAN Authors Info & Affiliations

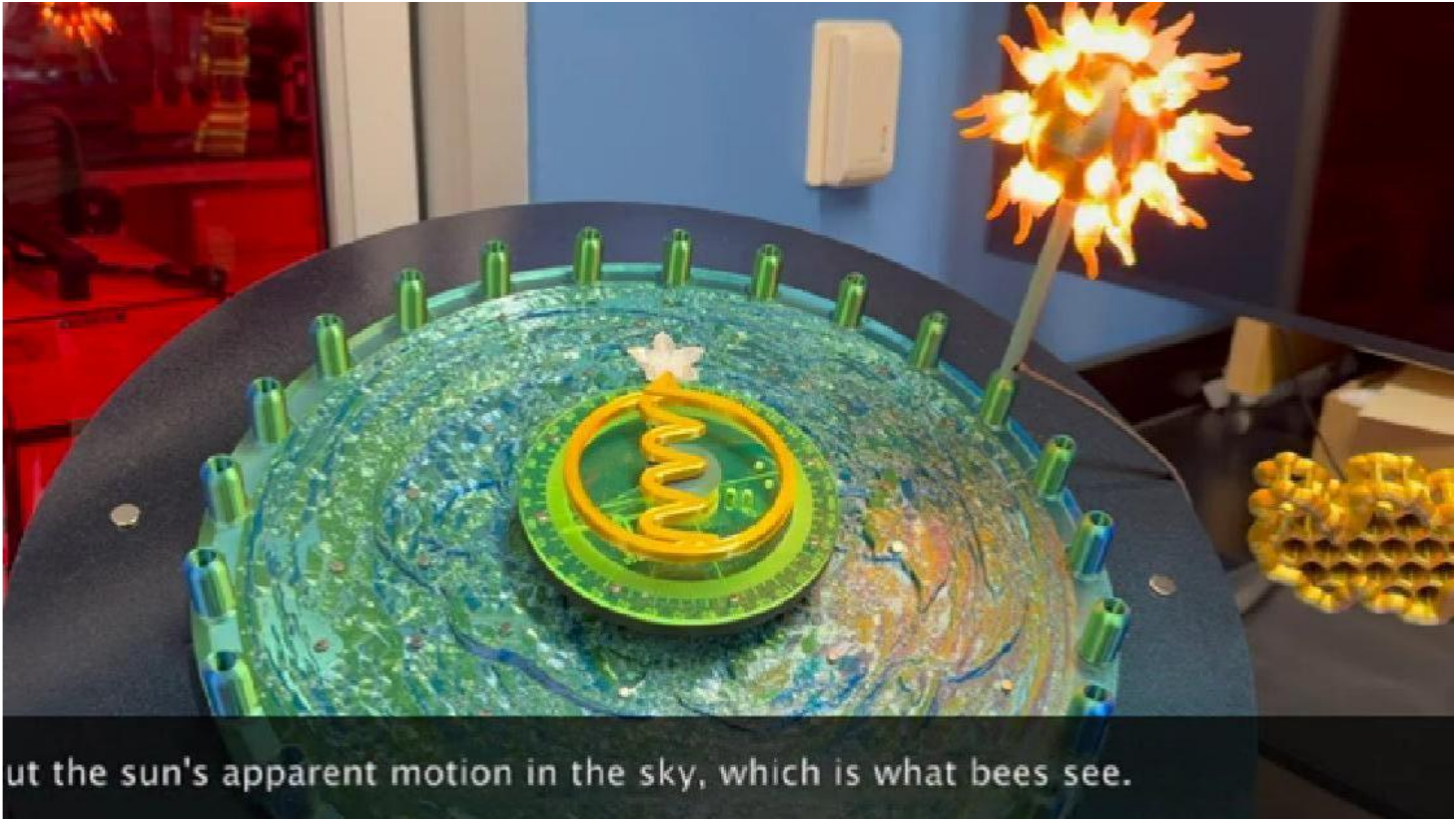
谭垦

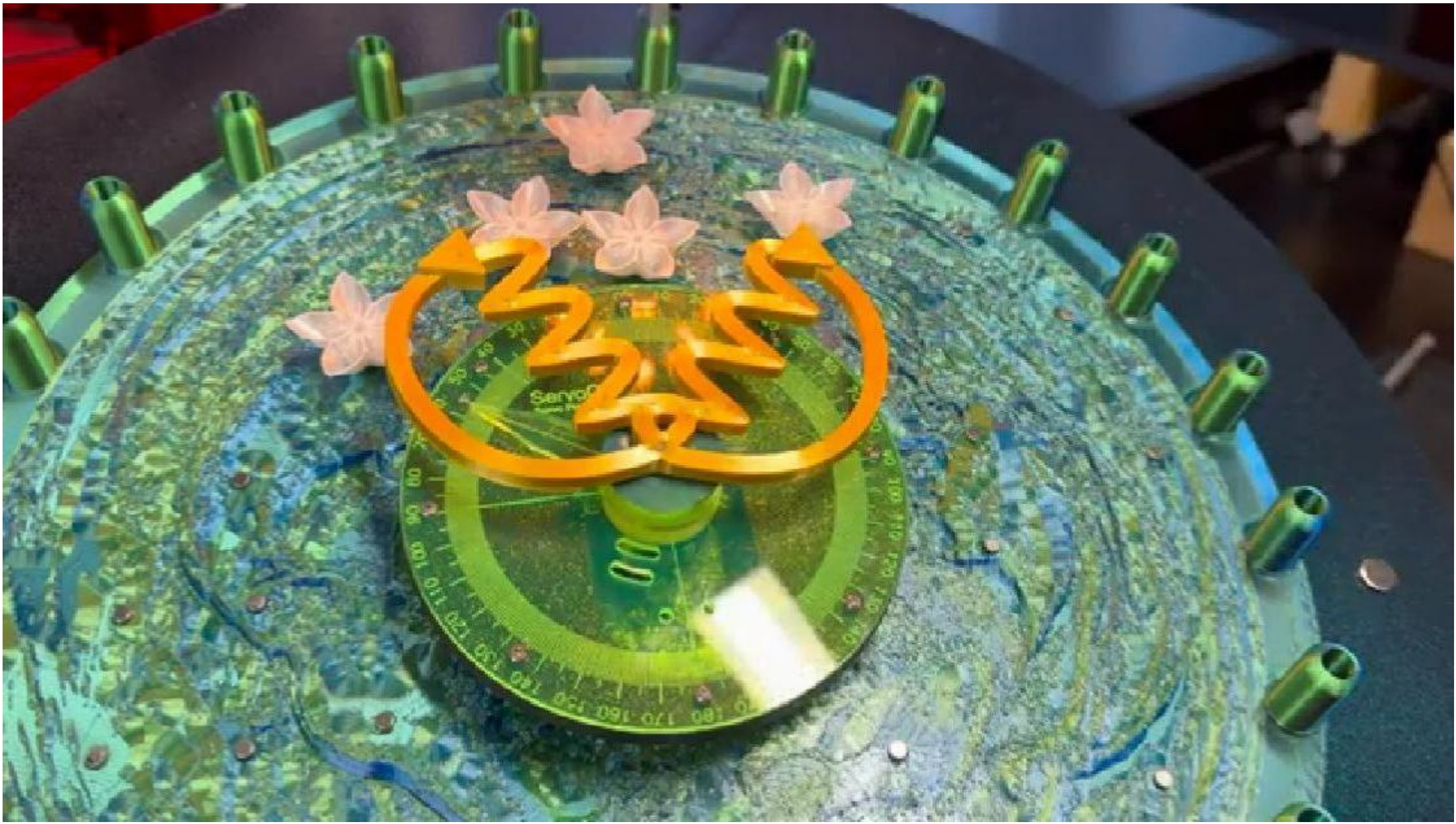
中国科学院大学
University of Chinese Academy of Sciences

James Nieh

UC San Diego

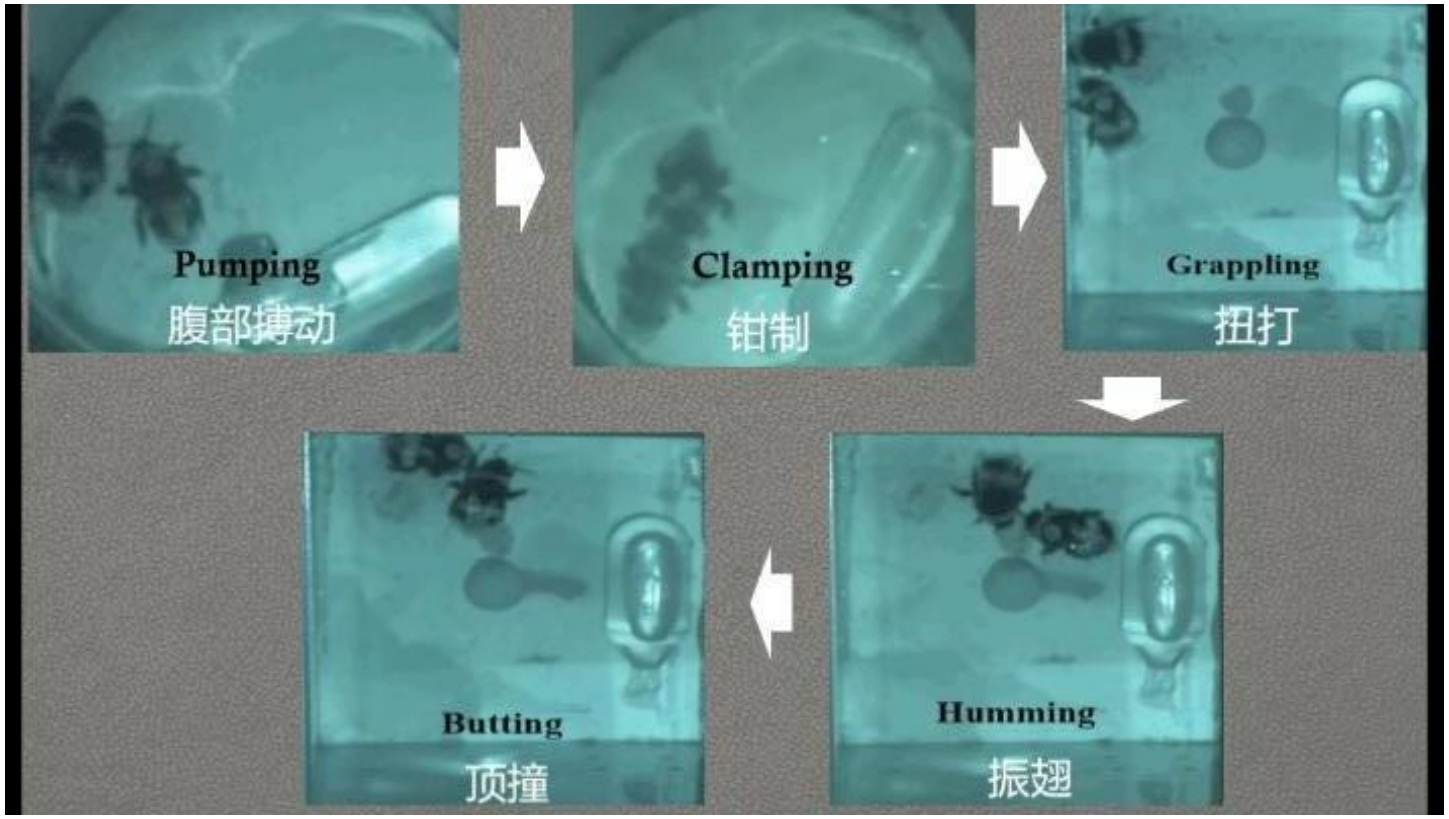

Here you see the waggle dance pattern that a bee makes on her comb

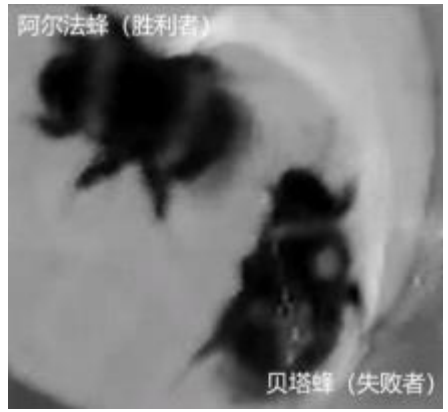

ut the sun's apparent motion in the sky, which is what bees see.

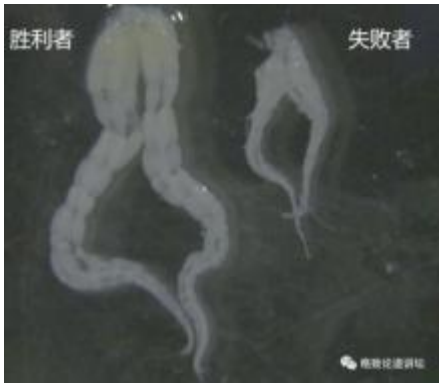


Fighting behavior between bumblebee workers

葛瑨

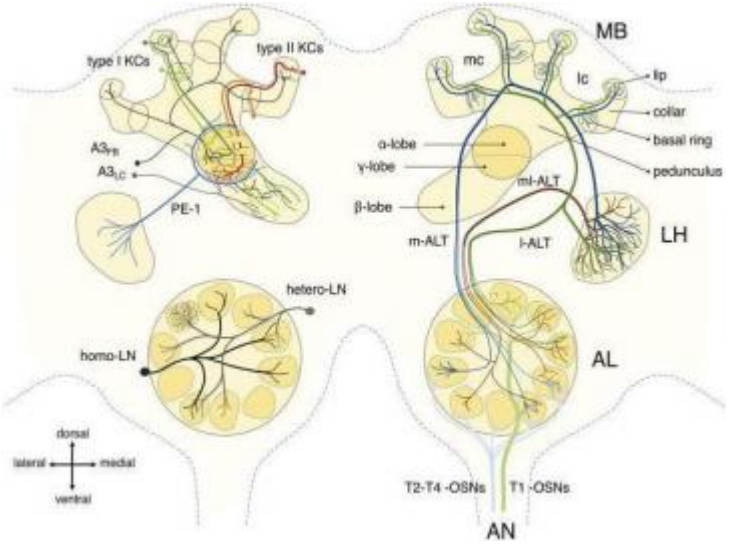




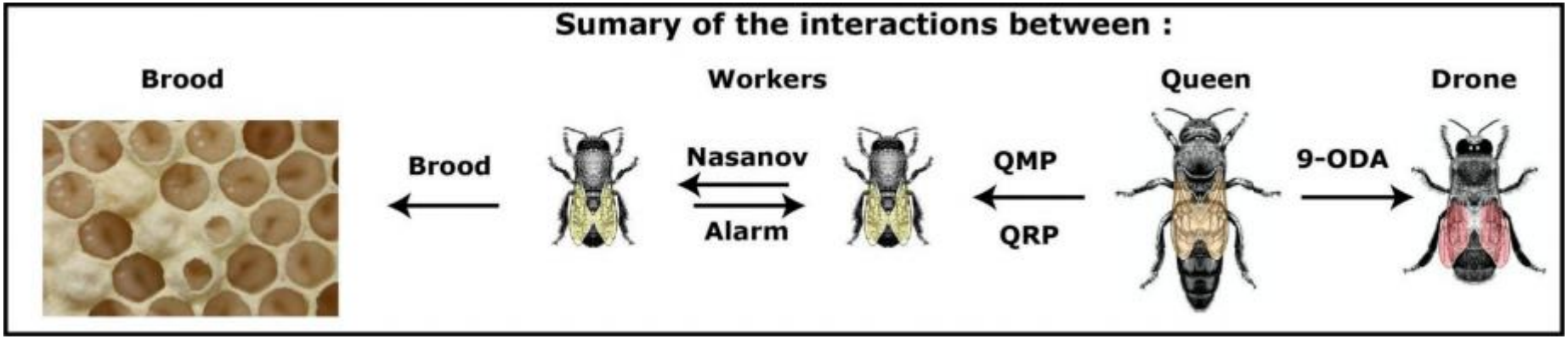


https://mp.weixin.qq.com/s/r8x56_TxYvNOFw_0eM3wXg

Honeybee olfactory system and pheromones



- Brood pheromones
- Workers' pheromones
- Queen's pheromones
- Drones' pheromones



https://www.kirkowen.com/index.html

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HOME > SCIENCE > VOL. 317, NO. 5836 > QUEEN PHEROMONE BLOCKS AVERSIVE LEARNING IN YOUNG WORKER BEES

REPORTS

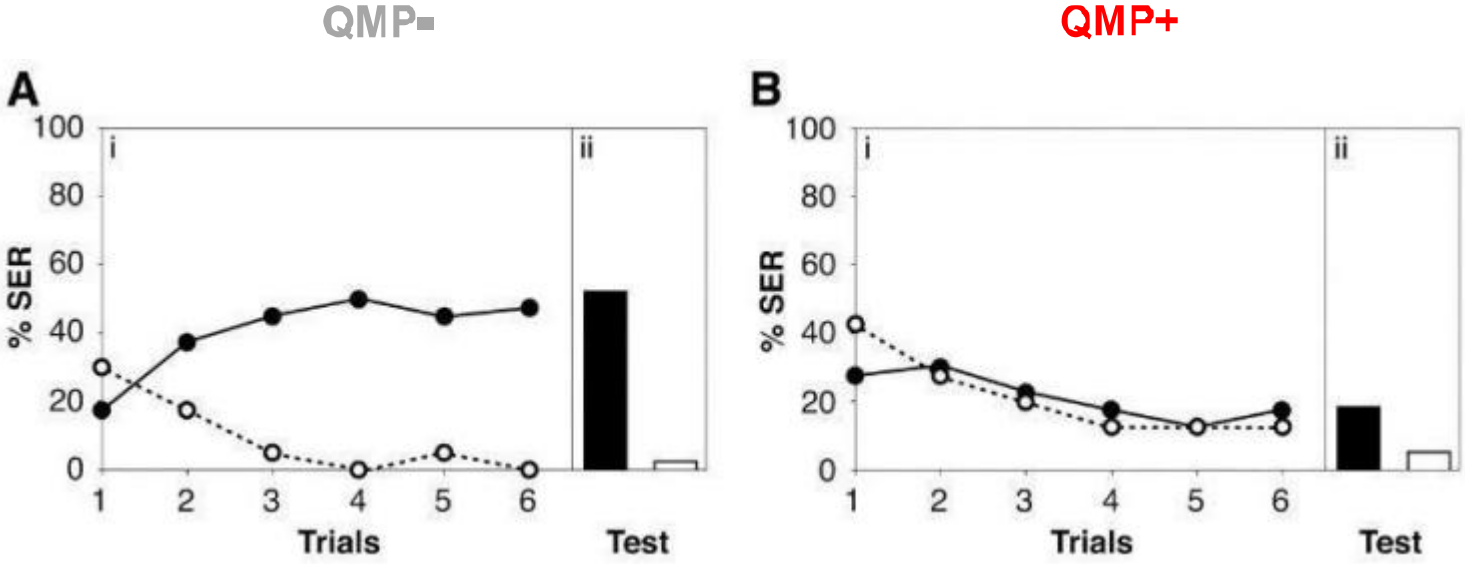
Queen Pheromone Blocks Aversive Learning in Young Worker Bees

VANINA VERGOZ, HALEY A. SCHREURS, AND ALISON R. MERCER Authors Info & Affiliations

SCIENCE • 20 Jul 2007 • Vol 317, Issue 5836 • pp. 384-386 • DOI: 10.1126/science.1142448

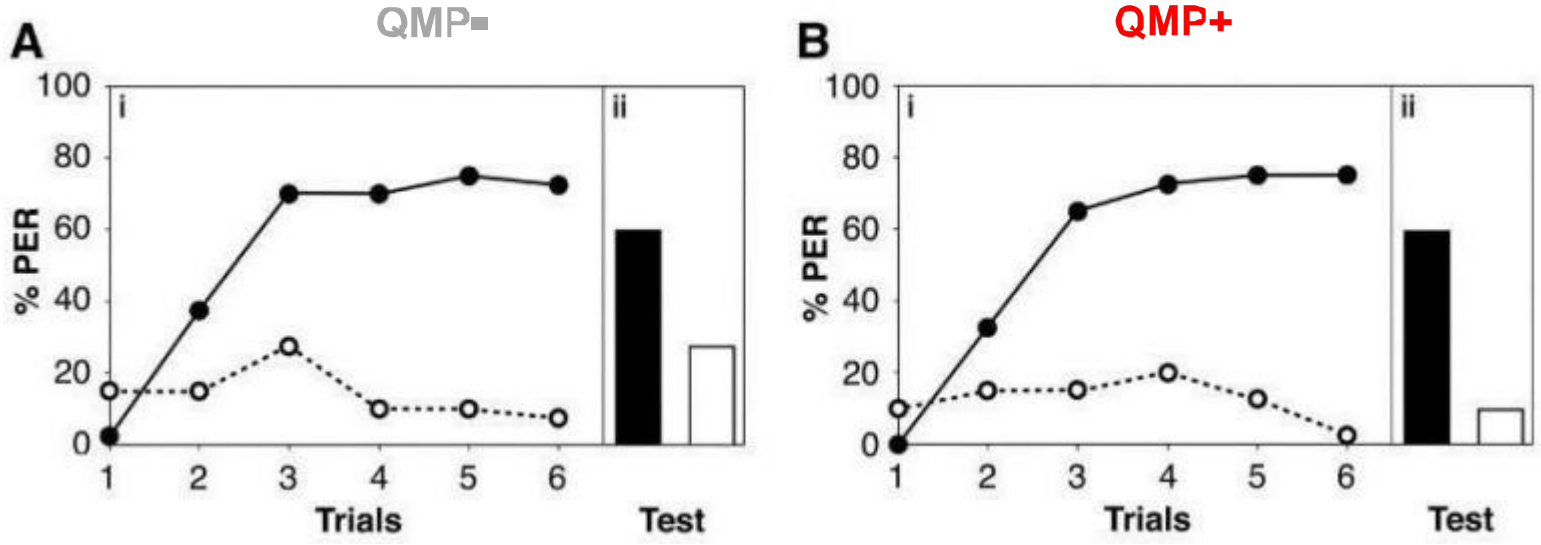
289 85

Queen mandibular pheromone (QMP)



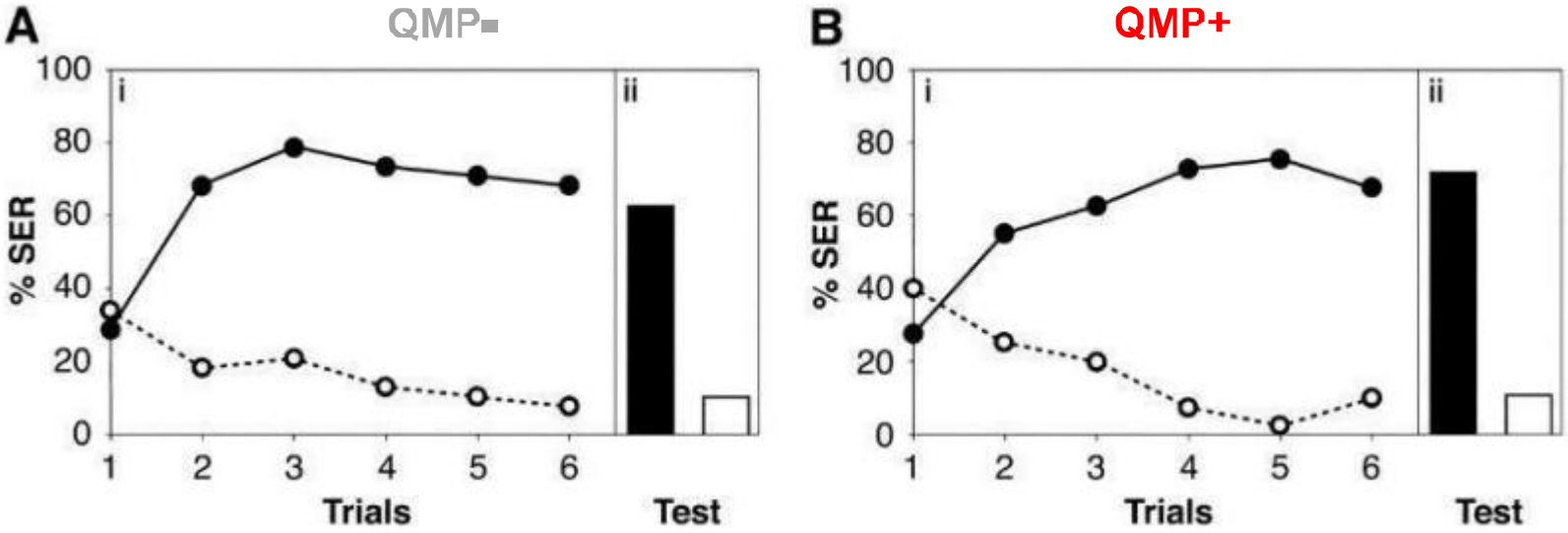
Effects of QMP on aversive learning in 6-day-old workers

QMP have no effect on appetitive learning in young workers



Effects of QMP on appetitive learning in 6-day-old workers

QMP have no effect on aversive learning in old workers



Effects of QMP on aversive learning in 15-day-old workers

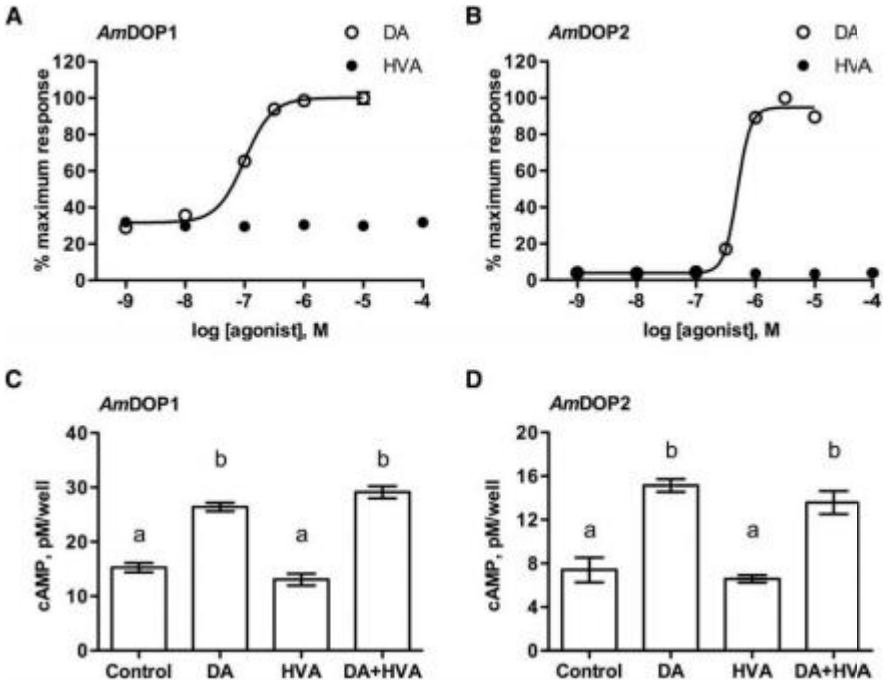
Current Biology

Volume 19, Issue 14, 28 July 2009, Pages 1206-1209

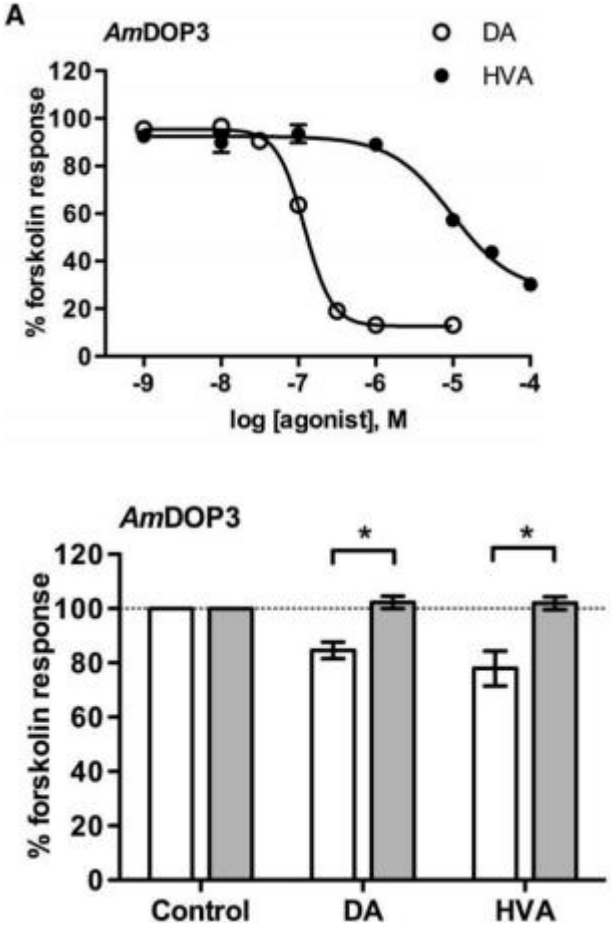
Report

Dopamine Receptor Activation By Honey Bee Queen Pheromone

Kyle T. Beggs [1], Alison R. Mercer [1]



HVA Acts as an Agonist at the D2-like Dopamine Receptor AmDOP3



*Take home message

Why honeybees fight?

Protecting food, compete for the throne, feeling under threat.

How bees repel hornets?

Make a "Hot Defensive Ball".

What is alarm pheromone and queen pheromone?

Alarm pheromone is produced by workers, it allows bees to develop defensive behavior.

"QMP" : classic queen pheromone, can inhibit dopamine signal and young workers aversive learning.

THANKS
FOR
LISTENING
&

BEE
HAPPY

PART3:

Decision-making behavior and regulatory factors in bees

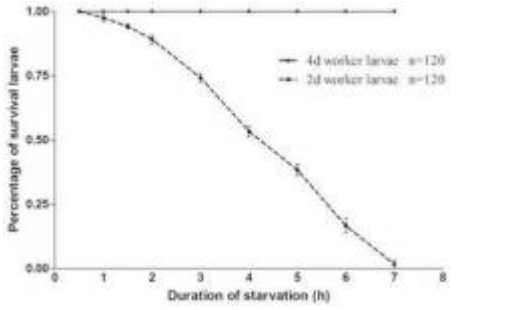
XLM

- At the individual level, what decisions bees make?
  When to foraging? Which flower to choose?

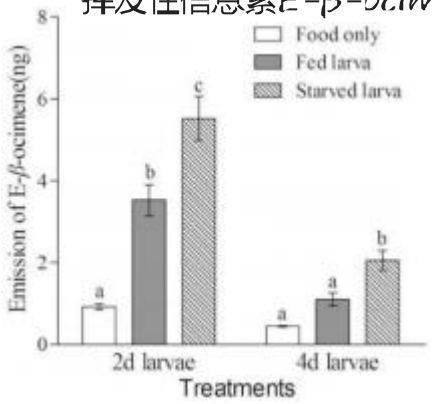
- As a typical group animal, do bees have group decisions and how to regulate them? (e.g. nest splitting behavior, nest choosing behavior)

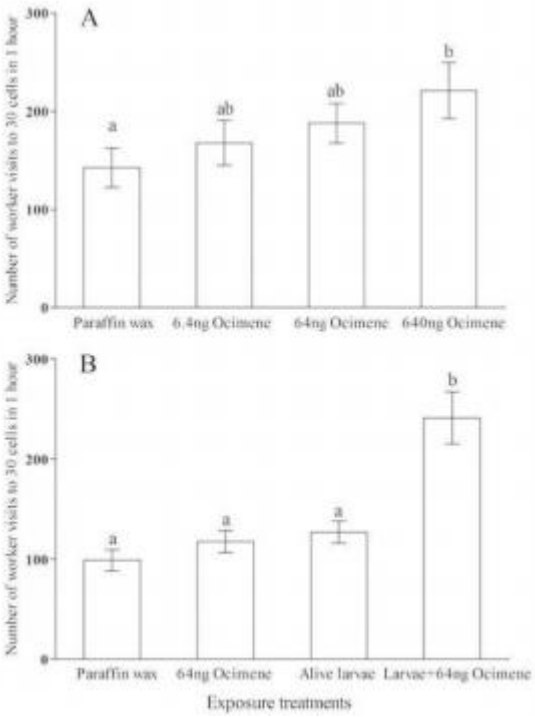
When to foraging?

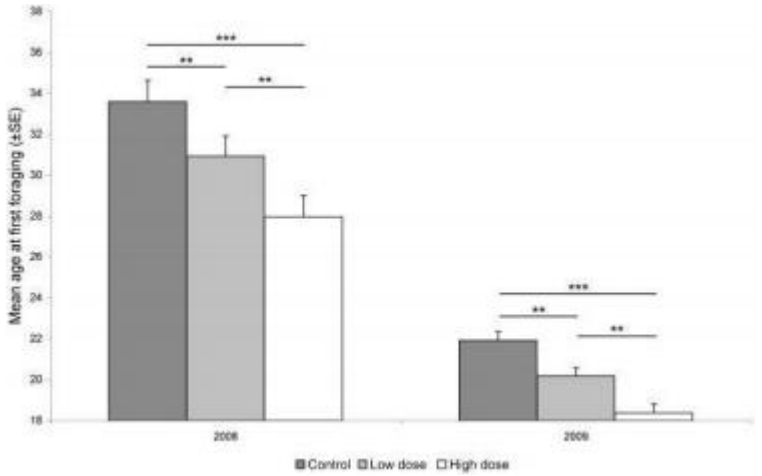
Starving honey bee larvae encourage worker bees to forage by releasing pheromones



挥发性信息素E-β-ocimene







He XJ, et al., *Sci Rep*, 2016　　Masonnasse A, *et al. PLoS One*, 2010

How do bees quickly decide which flowers are right for honey?
(e.g. vision, olfaction, taste?)

Visual (color) perception of bees

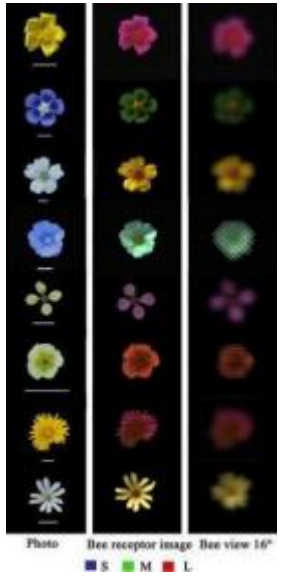
+

Lubbock J (1882)

Grey card experiments

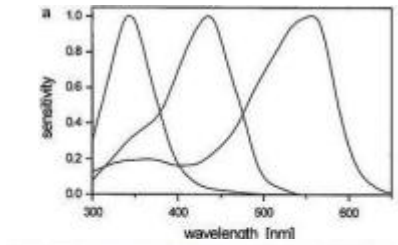
Honeybees were the most significant ones proving the existence of colour vision in non-human animals.

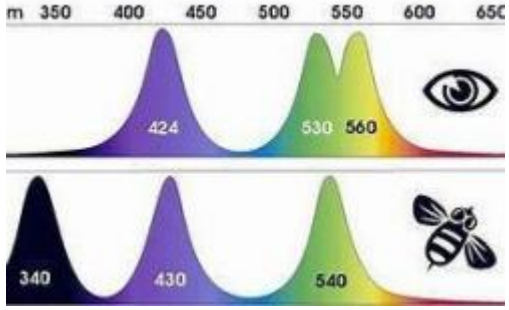
Karl Ritter von Frisch (1914)



The spectral range of bees' vision includes ultraviolet (UV)

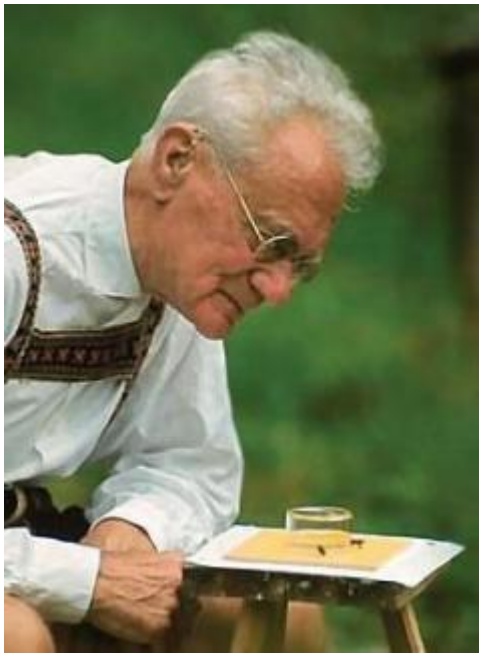
Kühn (1924)





Karl Daumer (1956)

在短波长、中波长和长波长区域确定了三种原色，提出蜜蜂具有三色视觉，在后来的光感受器细胞的细胞内记录中被证实

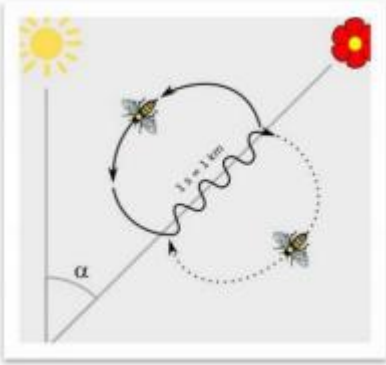


Karl Ritter[a] **von Frisch**, ForMemRS[1] (20 November 1886 – 12 June 1982) was a German-Austrian ethologist who received the Nobel Prize in Physiology or Medicine in 1973, along with Nikolaas Tinbergen and Konrad Lorenz.[2][3]

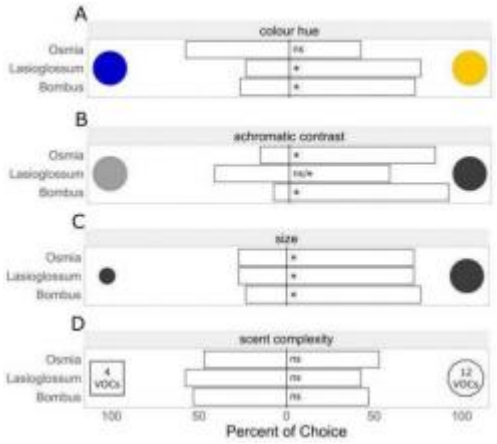
His work centered on investigations of the sensory perceptions of the honey bee and he was one of the first to translate the meaning of the waggle dance. His theory, described in his 1927 book *Aus dem Leben der Bienen* (translated into English as *The Dancing Bees*), was disputed by other scientists and greeted with skepticism at the time. Only much later was it shown to be an accurate theoretical analysis.[4]

Frisch's investigation of a bee's powers of orientation were significant:

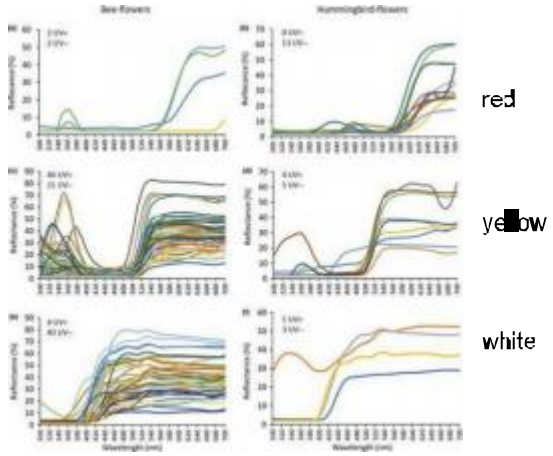
1. by the Sun,
2. by the polarization pattern(偏振模式) of the blue sky,
3. by the Earth's magnetic field



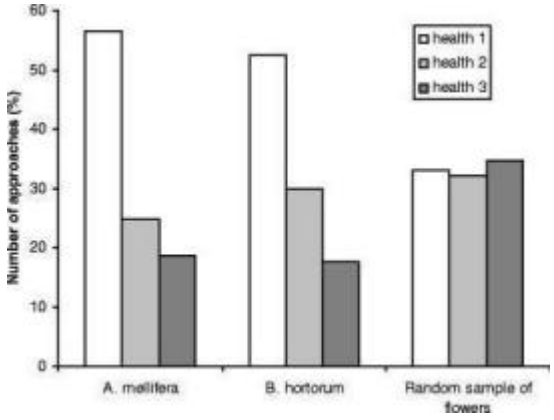
The color and completeness of the flowers will influence the bees' choice



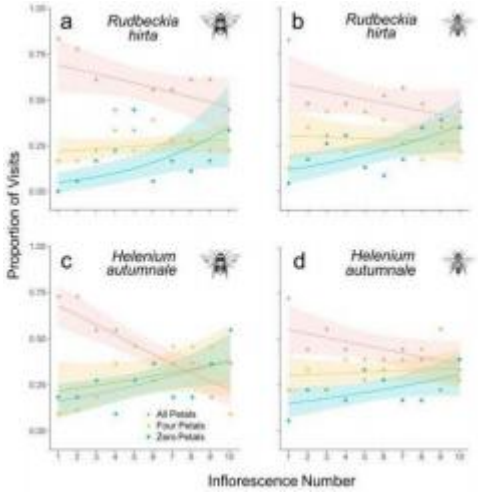
Heuel KC, *et al. Insects*, 2024



de Camargo MGG, *et al. New Phytol*, 2019



Goulson D, *et al. Behav Ecol Sociobiol*, 2007



Balfour NJ, Ratnieks FLW, *Insects*, 2023

The quality of food is very important to the colony

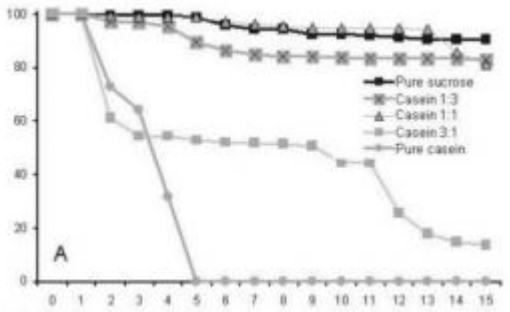
Nectar primarily contains carbohydrates, while most other macronutrients are provided by pollen

花蜜：碳水化合物
花粉：属于蜂群中蜜蜂获得蛋白质和脂质的主要来源，是蜂群中蜜蜂幼虫的主要食物

Honeybees have shorter life spans when fed a diet high in proteins (Pirk *et al.*, 2010; Archer *et al.*, 2014).

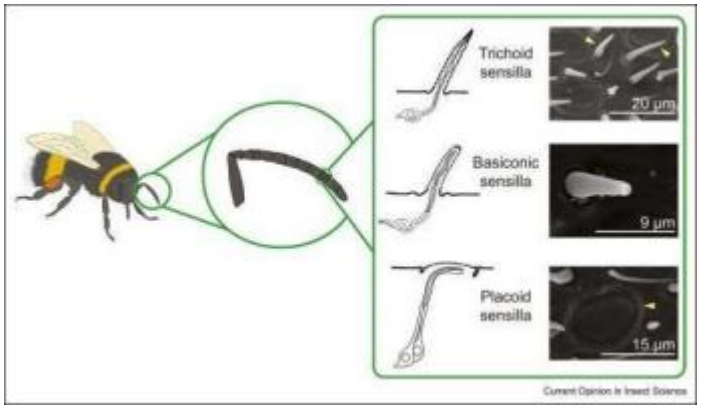
Pollen of comparatively higher protein content was found to benefit larval growth and development (Herbert *et al.*, 1977; Herbert, 1992; Tasei and Aupinel, 2008)

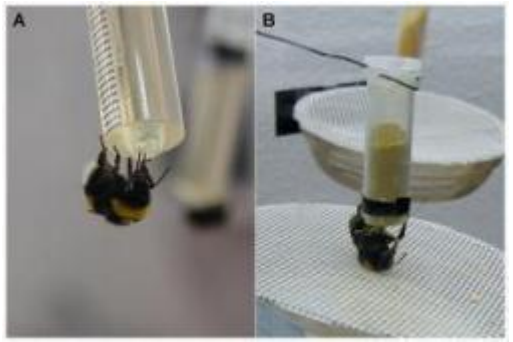
Adult bees and larvae performed better on higher sugar concentrations (Kaftanoglu *et al.*, 2011).

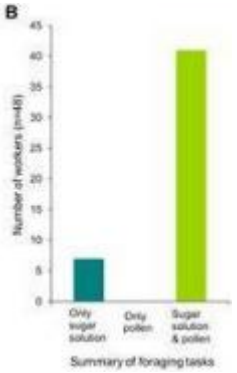


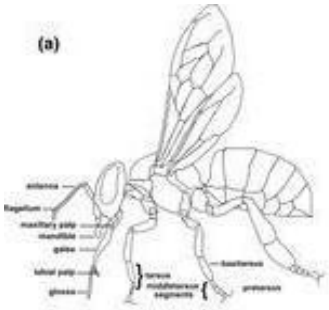
How do bees further assess pollen quality (e.g. protein content)?

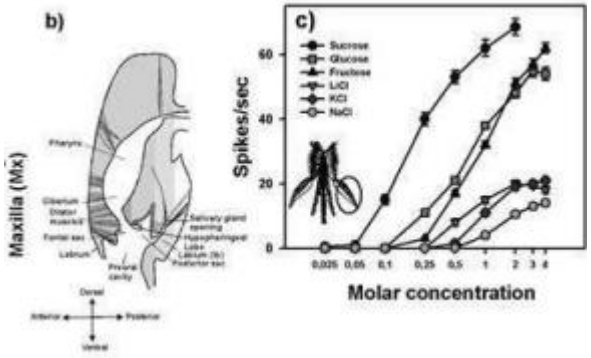
Involvement of smell and taste in pollen foraging

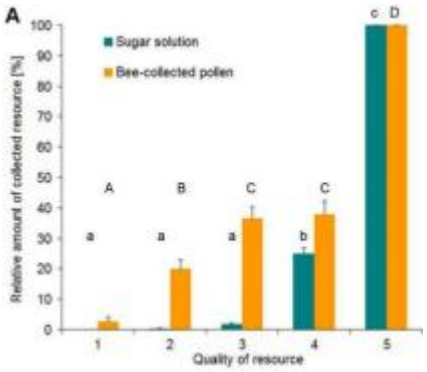


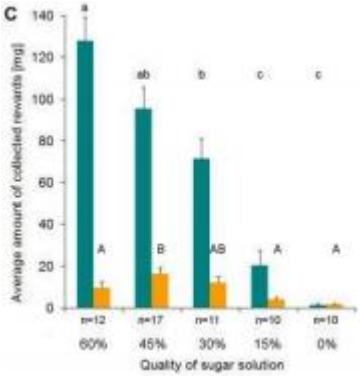






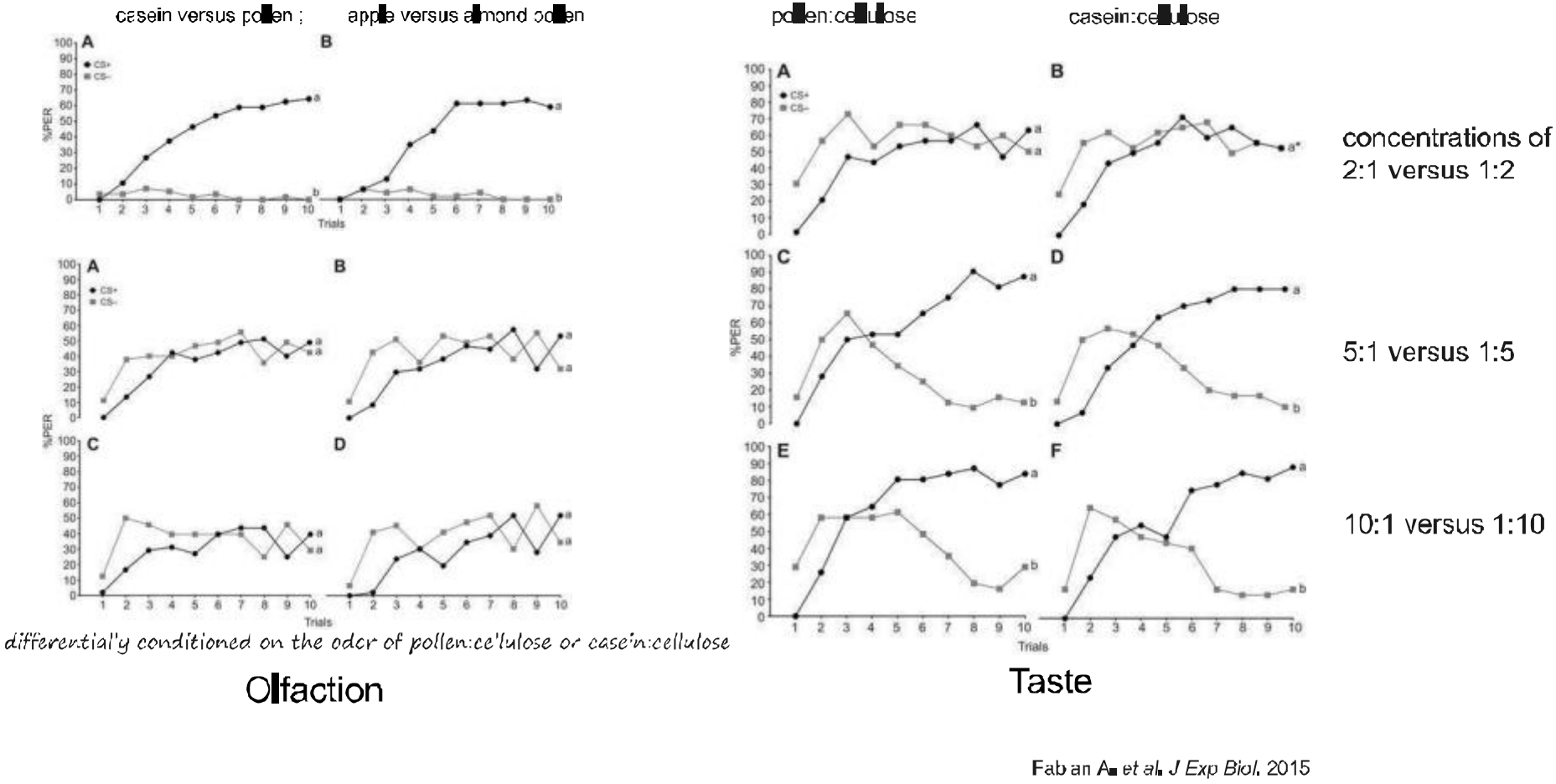






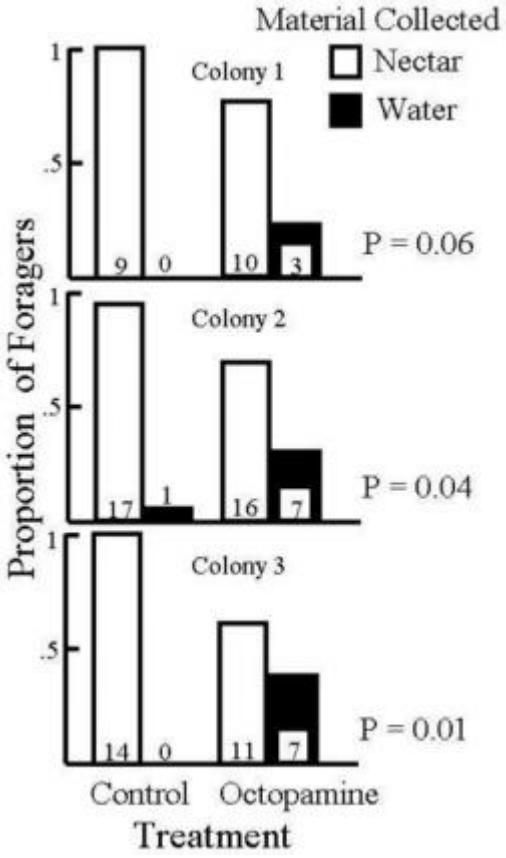
Konzmann, S. and Lunau, K. *PLoS ONE*. 2014

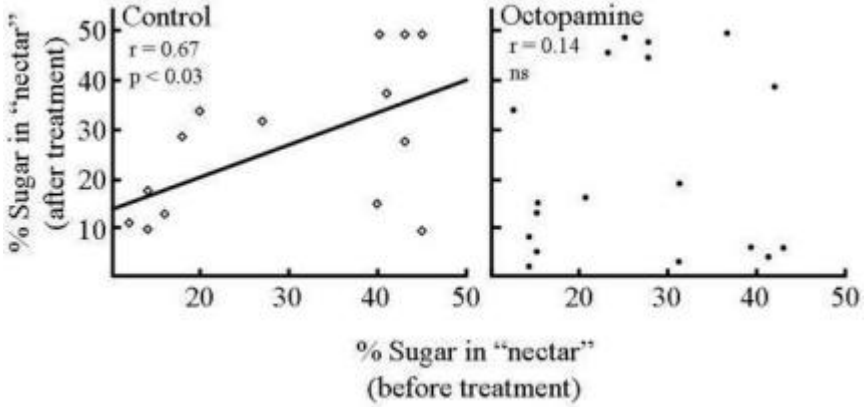
Olfaction and taste were involved in the detection of pollen composition and concentration, respectively



Fabian A. *et al. J Exp Biol.* 2015

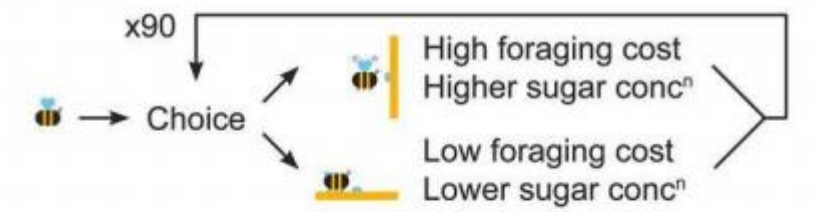
Octopamine influences honey bee foraging preference to sugar





Giray T. *et al. J Insect Physiol.* 2007

Bumblebees negotiate a trade-off between nectar quality and floral biomechanics

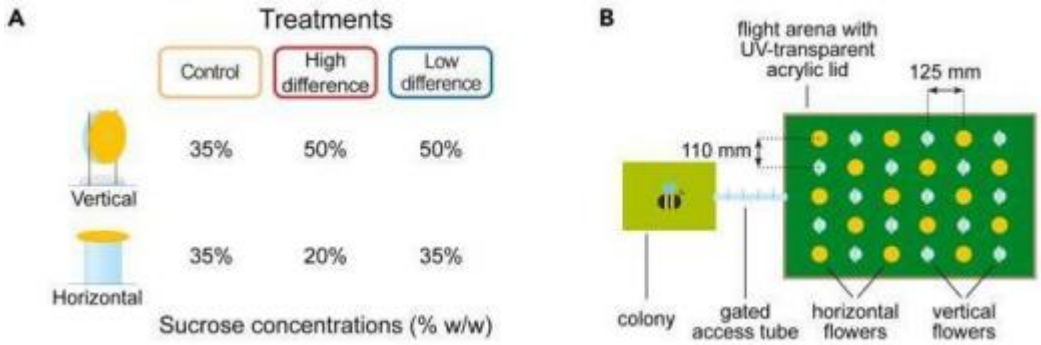


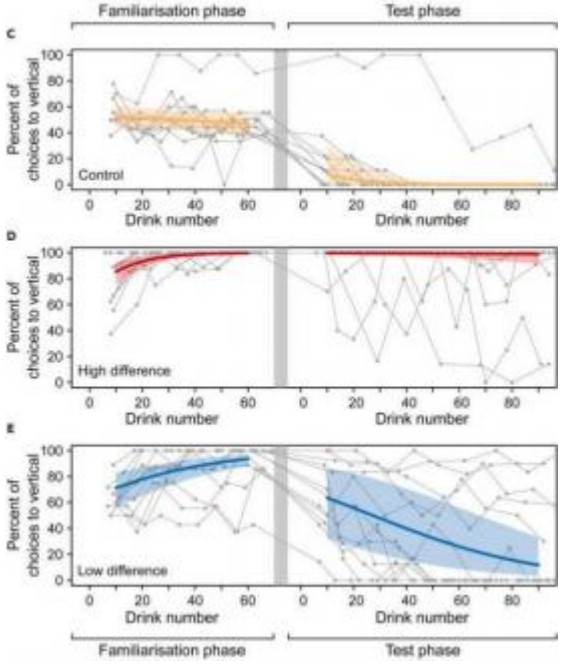
Experimental treatments & bee behaviour

	Same sugar conc^{n} on both	High conc^{n} difference	Low conc^{n} difference
Bee behaviour			
Maximizes energy efficiency?	✓	✗	✓
Maximizes rate of energy return to the nest?	✓	✓	✓

Pallrick JG, *et al.* *iScience*, 2023

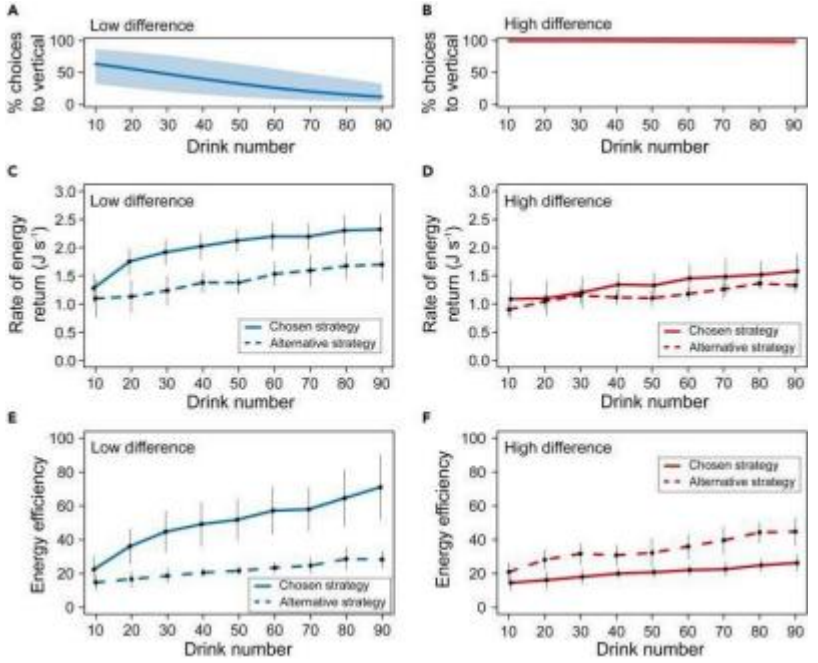
Bumblebees prioritize immediate carbohydrate flow to the nest





$$RER = \frac{energy\ intake - energy\ expenditure}{time} \quad (公式1)$$

$$EE = \frac{energy\ intake - energy\ expenditure}{energy\ expenditure} \quad (公式2)$$



bumblebees are maximizing the currency of RER rather than maximizing EE.

Pattrick JG, *et al.* *iScience*. 2023

The influence of acquired factors on decision making in bees

Home > Naturwissenschaften > Article

Honeybees learn floral odors while receiving nectar from foragers within the hive

Short Communication | Published: 05 October 2006

Volume 94, pages 55–60, (2007) Cite this article

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Research

Young bumblebees may rely on both direct pollen cues and early experience when foraging

Fabian A. Ruedenauer[1,3], David Sydow[1], Johannes Spaethe[2] and Sara D. Leonhardt[1,3]

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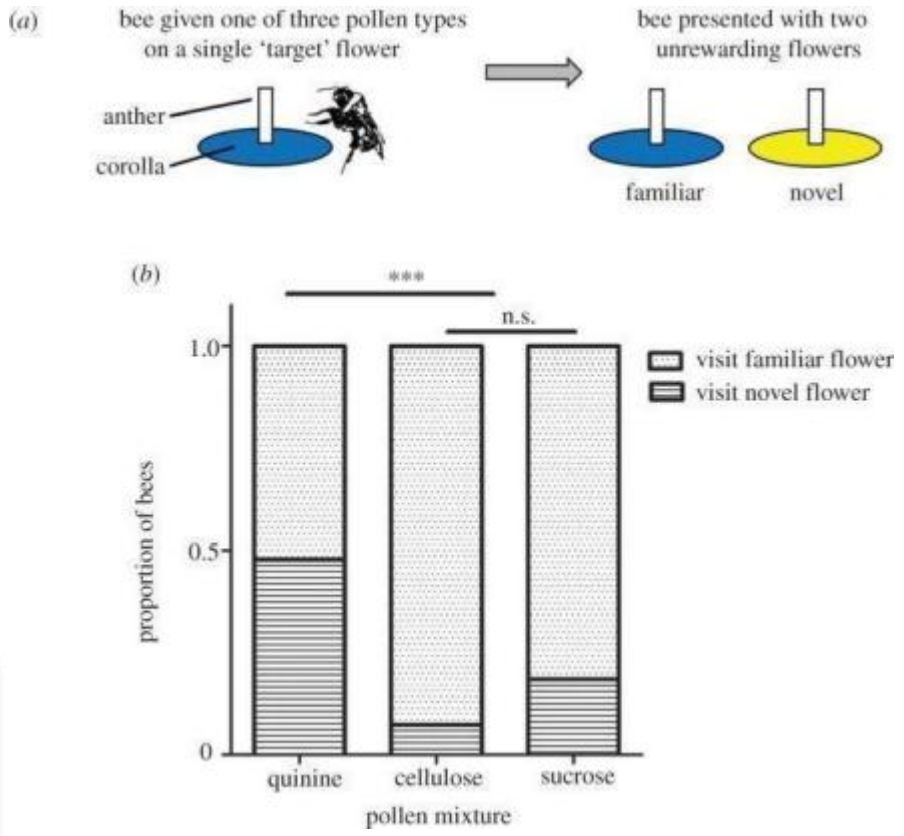
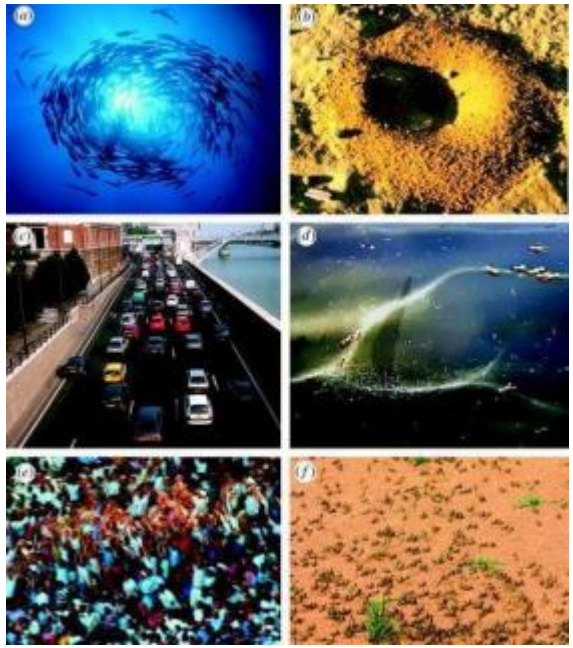
Bias to pollen odors is affected by early exposure and foraging experience

A. Arenas *, W.M. Farina



Muth F, *et al. Biol Lett.* 2016

Collective decisions in bees



As a typical group animal, do bees have collective decisions?
And how to regulate?

The choice of nest design groups takes into account many aspects

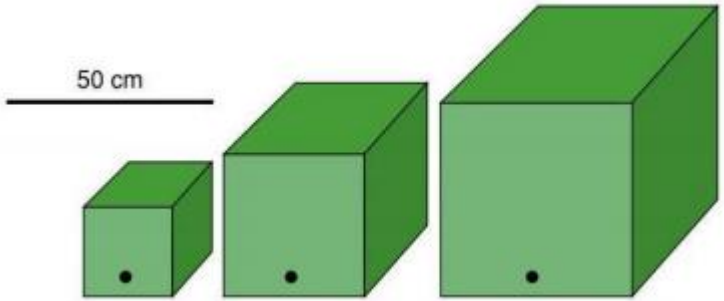


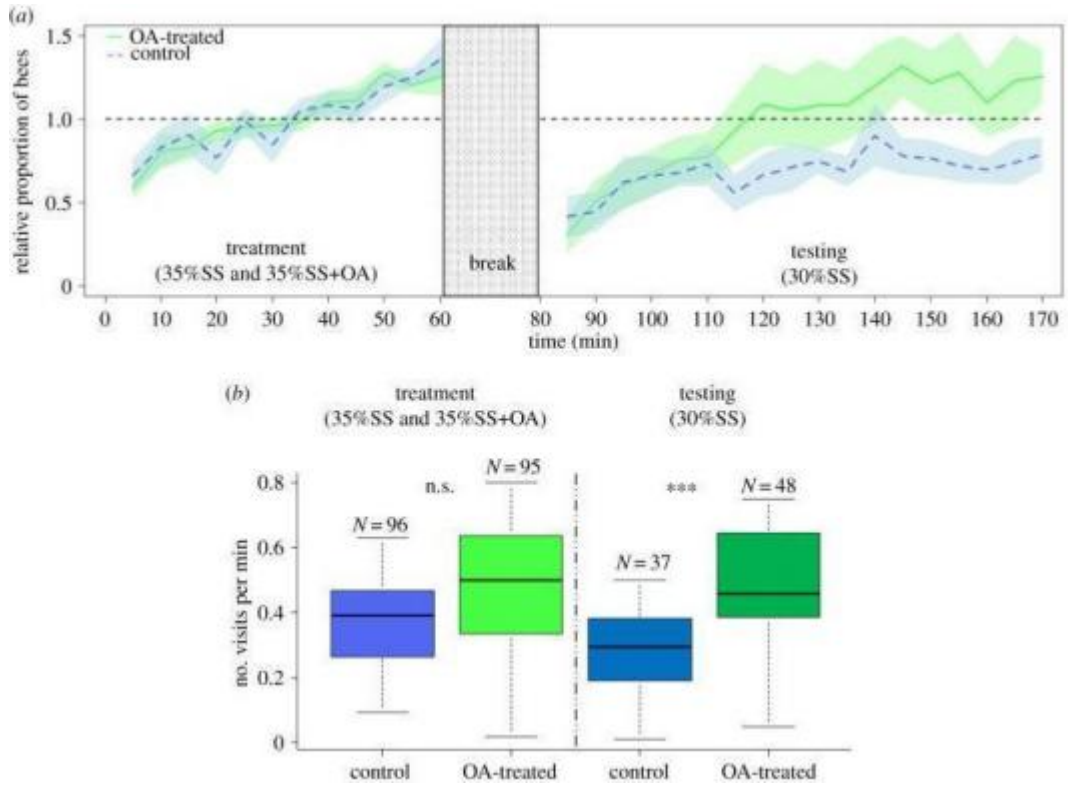
Table 1 Properties of nest sites that have been tested in choice tests with honey bees and ants, and the preferences shown

Nest-site property	Frequency of occupation, given choice[a]	Reference(s)
Apis mellifera		
Nest height from ground	5 m > 1 m	82
Nest exposure/visibility	Visible > hidden	82
Distance from parent nest	No preference (?)	33, 34, 66, 81, 82
Entrance area	12.5 cm^2 > 75 cm^2	82
Entrance location	Bottom > top	82
Entrance direction	Southward > northward (?)	33, 34, 82
Cavity volume	10 liters < 40 liters > 100 liters	82
Previous occupancy	Previously used > new	67, 100
Nasanov pheromone	With pheromone > without pheromone	39, 69, 70
Cavity dryness	Damp sawdust = dry	82
Cavity soundness	Walls with holes = sound walls	82
Presence of disease	American foulbrood odor = no AFB odor	62
Temnothorax albipennis		
Cavity height	1.6 mm > 0.8 mm	21
Cavity floor area	912 mm^2 > 456 mm^2	46, 54
Cavity entrance width	2 mm > 4 mm	21
Cavity illumination	Dark > light	21
Presence of dead ants	Grit particles > dead conspecifics	20

[a]A > B indicates that potential nest cavities with property A were occupied in preference to cavities with property B, and A = B indicates no preference. A question mark indicates that results of different studies varied.

Visscher PK. *Annu Rev Entomol* 2007

Octopamine increases collective foraging behaviors in bees



Peng T. *et al. Biol Lett.* 2020

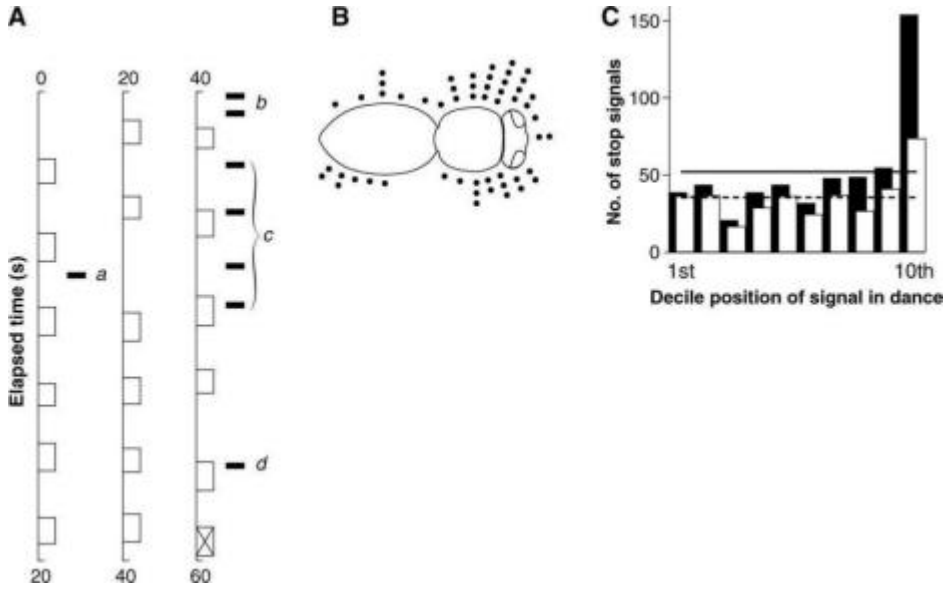
What exactly causes a colony to nurture its queen and thus begin the process of grouping?

When worker bees make the key decision to begin the swarm process, they are feeling and synthesizing what the specific motivation is?

IT'S NOT CLEAR.

Nest-site scouts send inhibitory stop signals to other scouts producing waggle dances

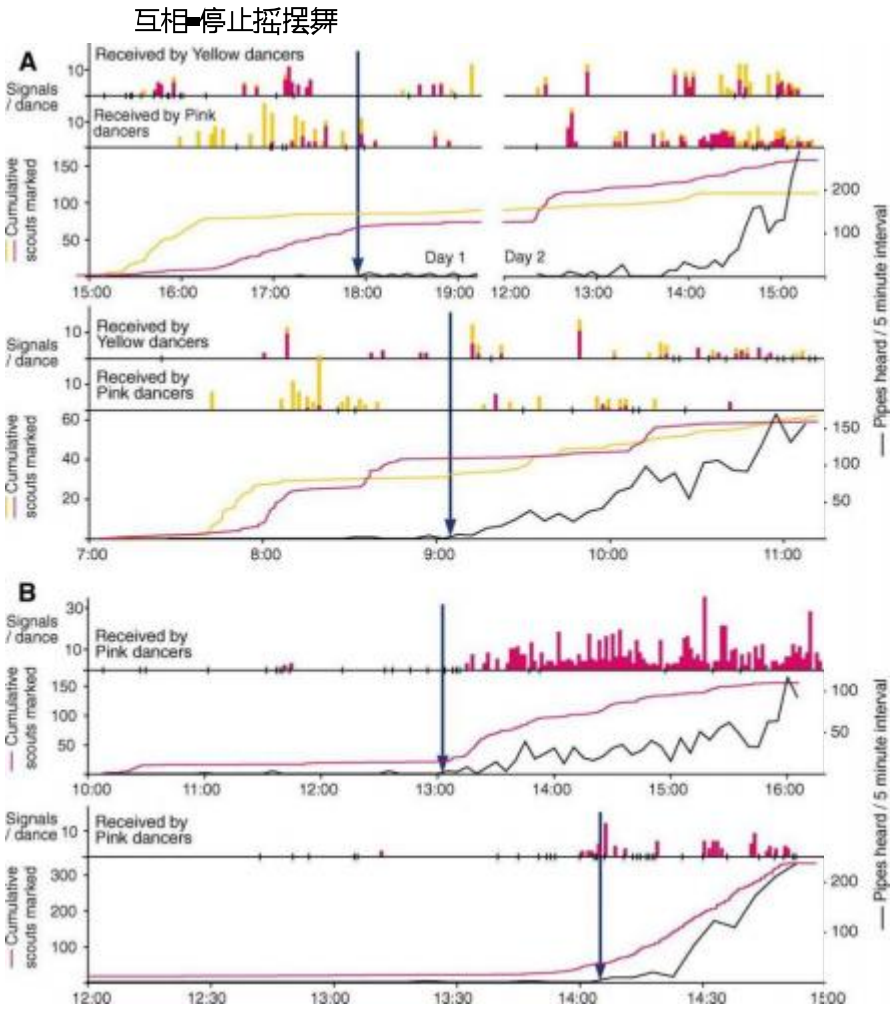
停止信号是一种振动信号，持续时间约为 150 ms，基频约为 350 Hz

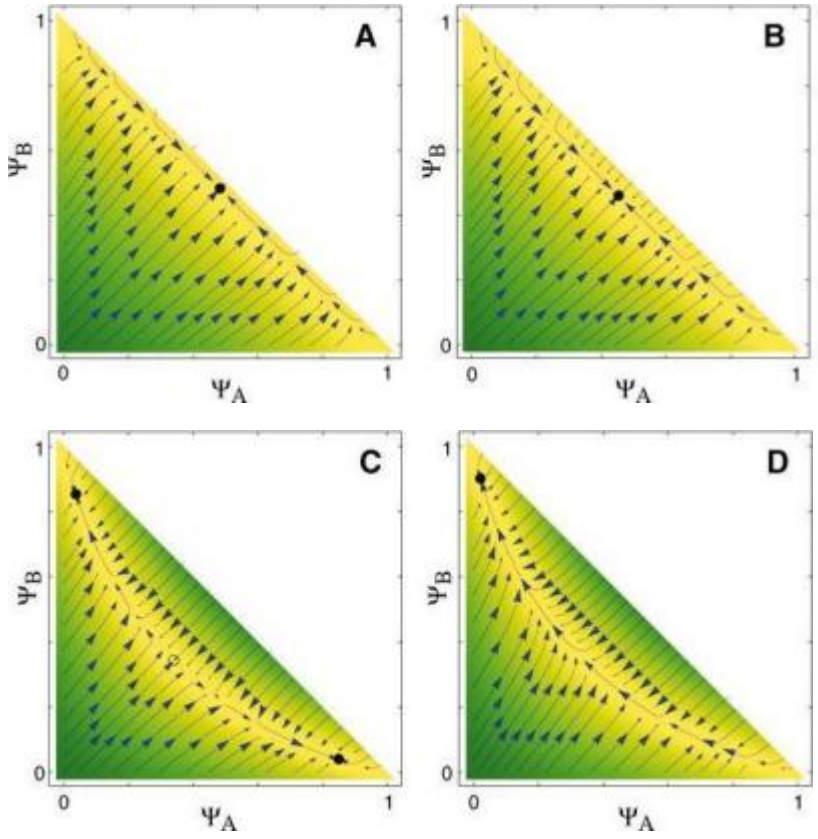


The cross-inhibition prevents the overall system from coming to an impasse

2 sites

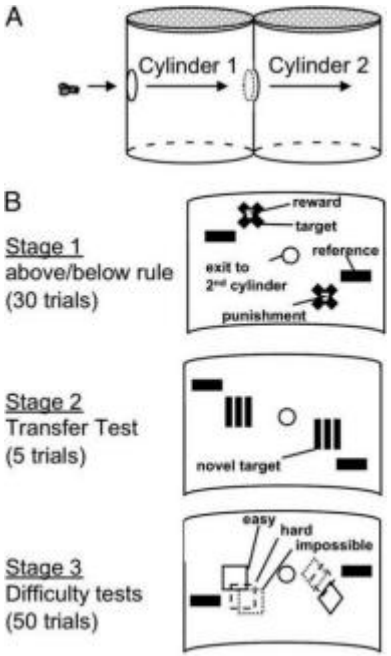
1 site

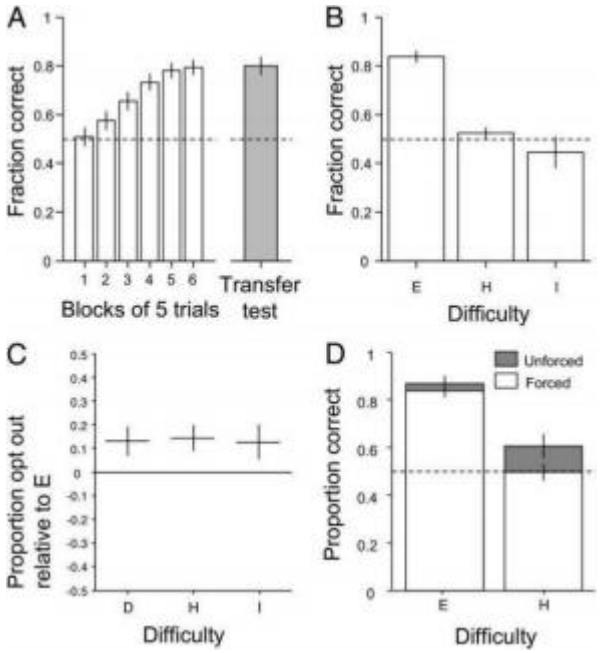




Honey bees selectively avoid difficult choices

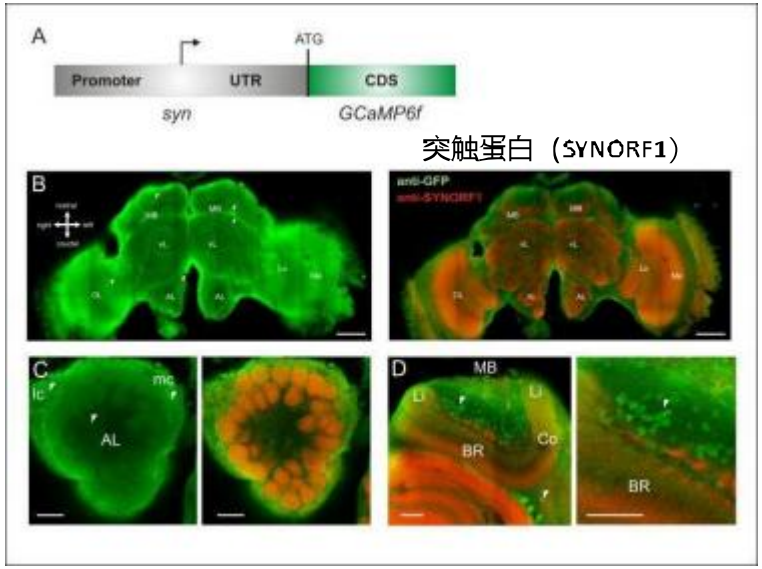
动物是否意识到不确定性?

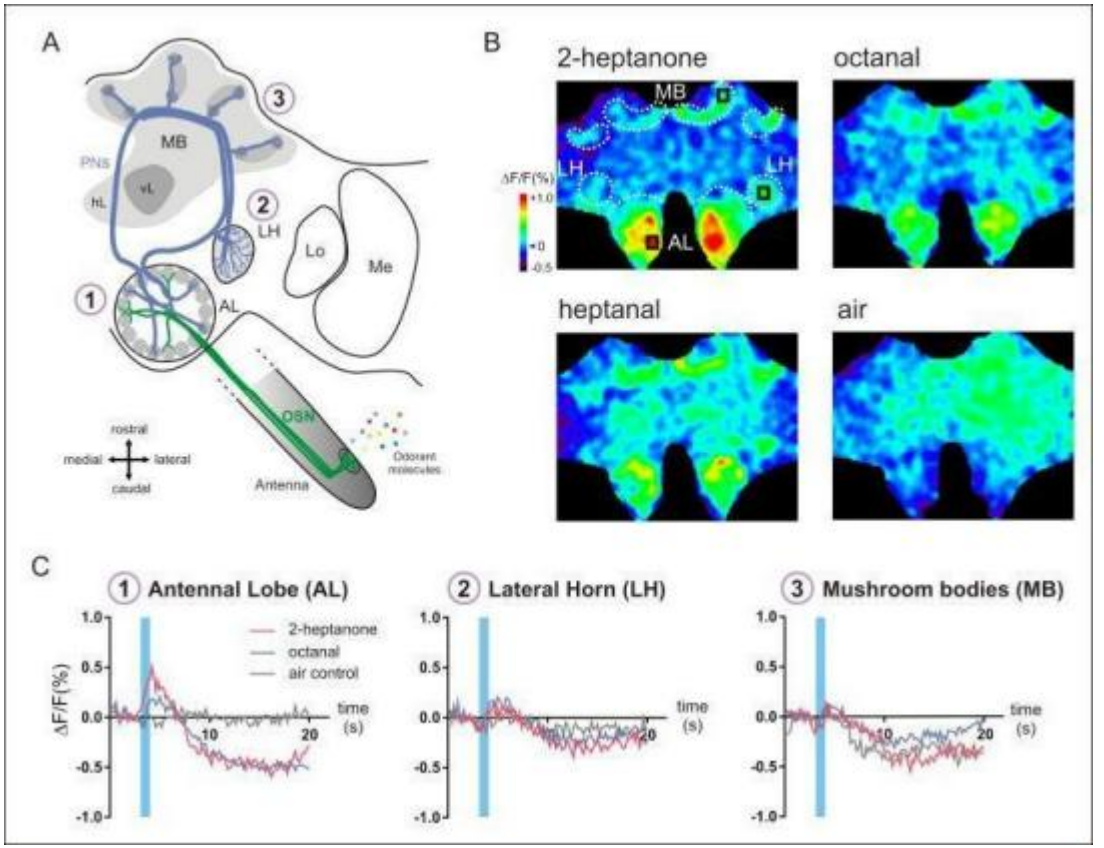




Perry CJ, Barron AB. *PNAS*. 2013

The first pan-neuronal genetic driver expressing *GCaMP6f* in honey bee

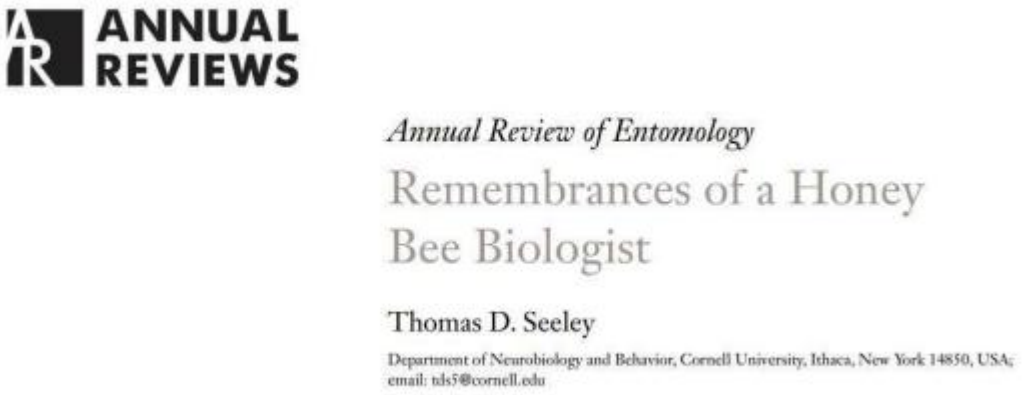




Carcaud J. *et al. PLoS Biol.* 2023

Take home message

- Different visual cues of flowers attract bees to land (e.g. completeness, size, color, etc.)
- Smell and taste are involved in the selection of nectar quality in bees.
- Bees' foraging decisions are also regulated by a variety of other external factors.
- However, the various factors affecting group decision-making behavior and the regulatory mechanism are still unclear.



THANKS

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