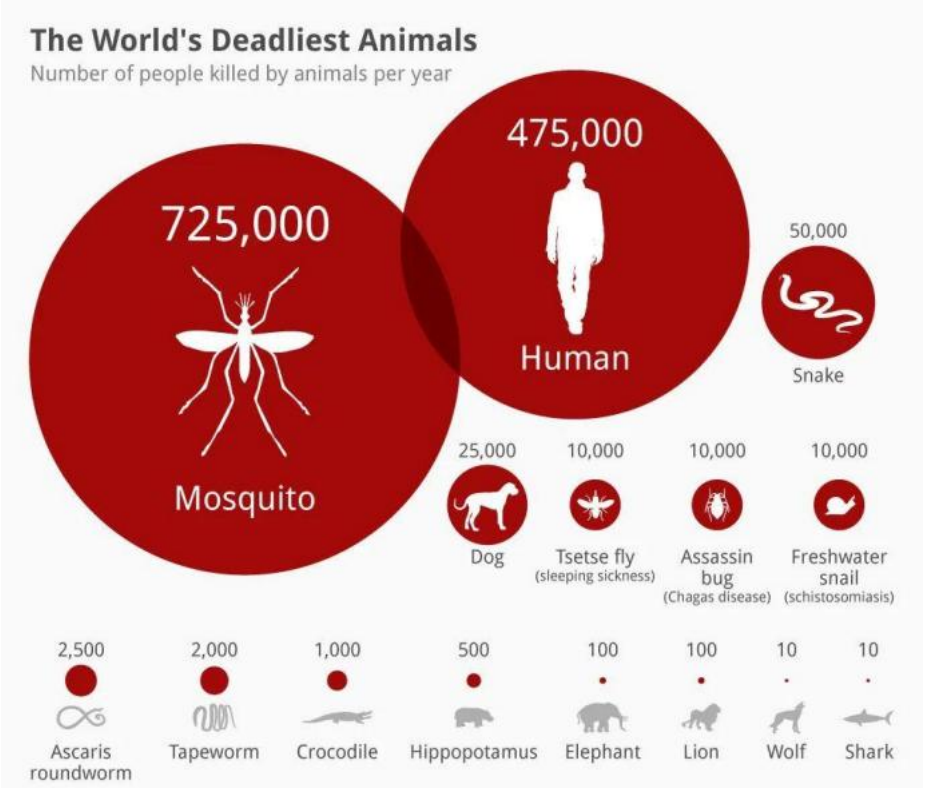
Don't bite me, mosquitoes!

李子奇、金思慧、姜思梅

2024.09.26



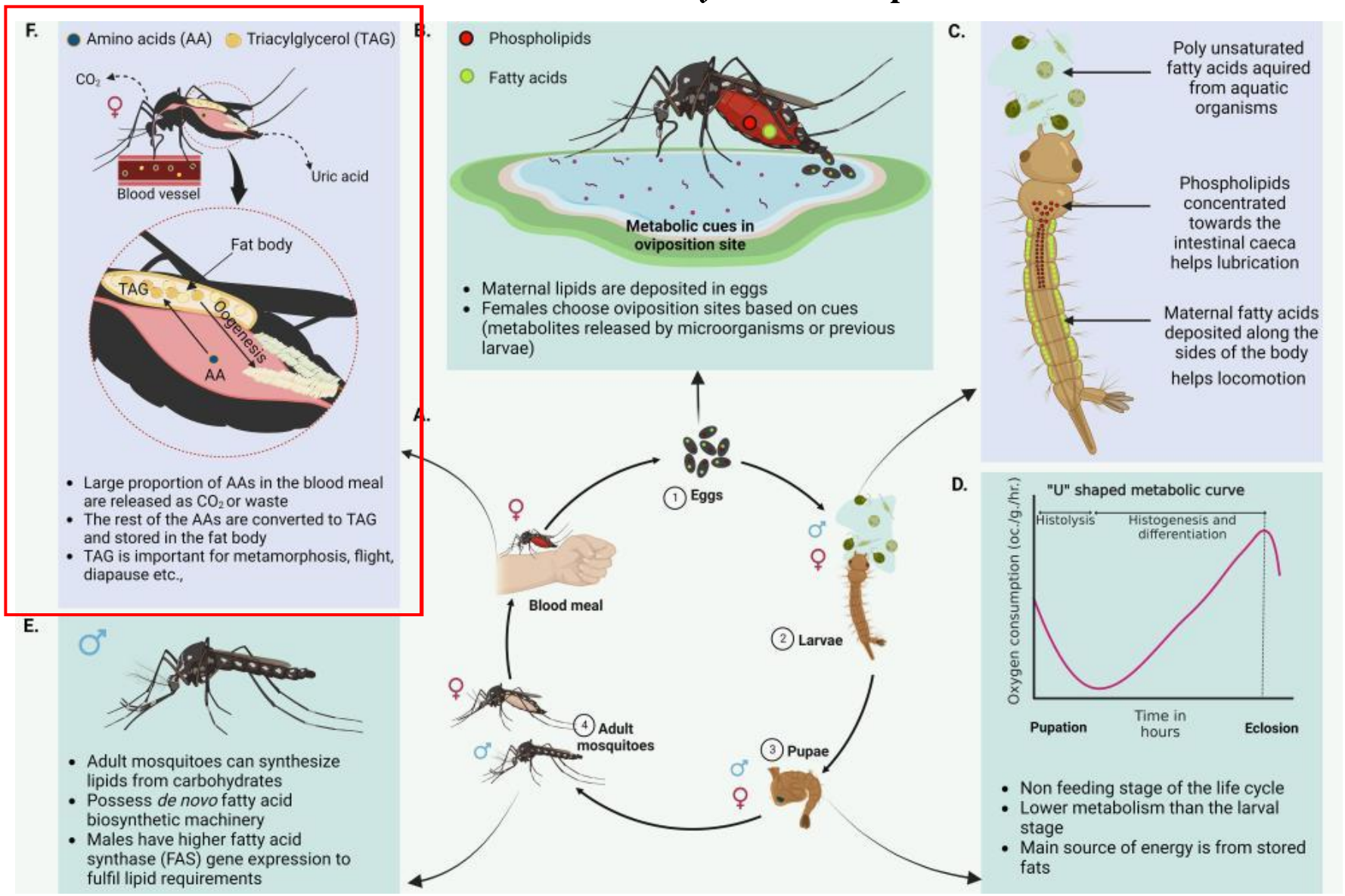
Content

- Overview of mosquito feeding——李子奇
- The internal mechanisms govern feeding——金思慧
- The external environment affects feeding——姜思梅

Overview of mosquito feeding

李子奇

The life history of the mosquitoes

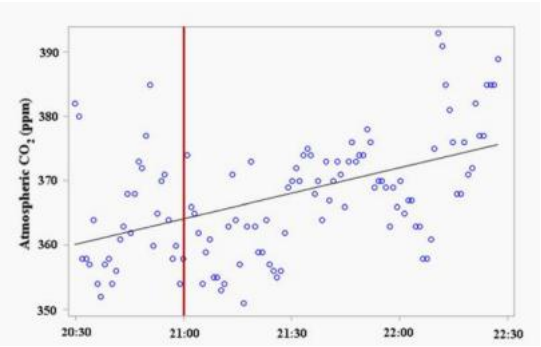


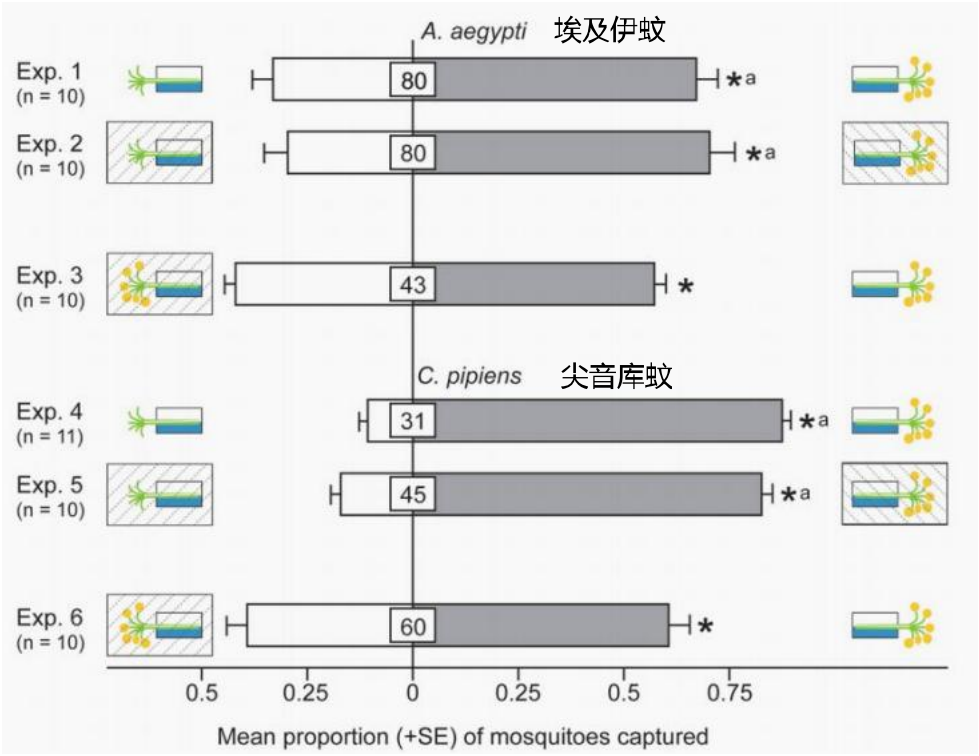
Ratnayake OC,Chotiwan N,et al., *Front Cell Infect Microbiol*,2023

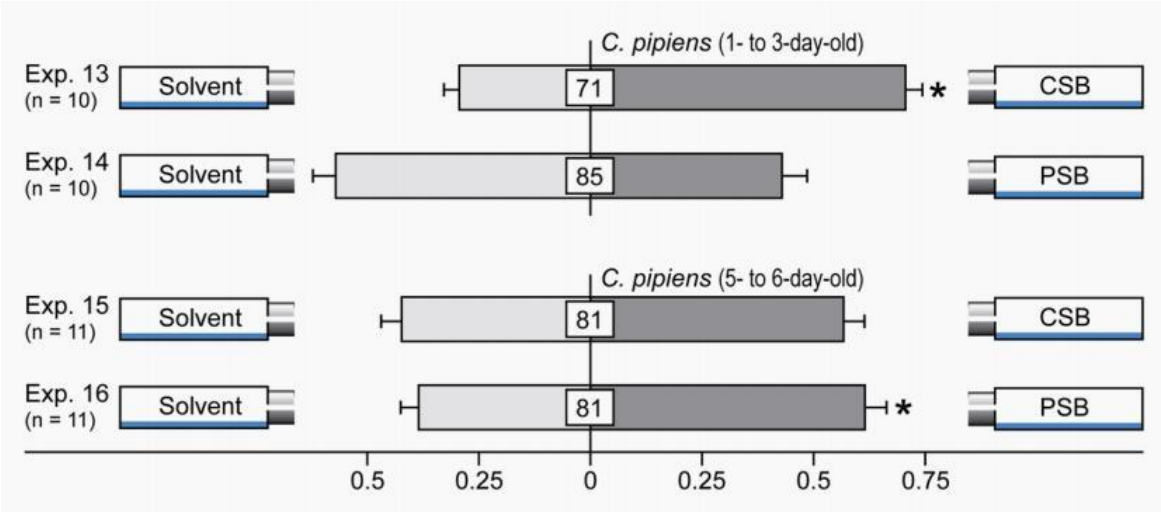
How do mosquitoes find nectar ?

- Visual cues
- Olfactory cues (CO_2)
- Gustatory cues

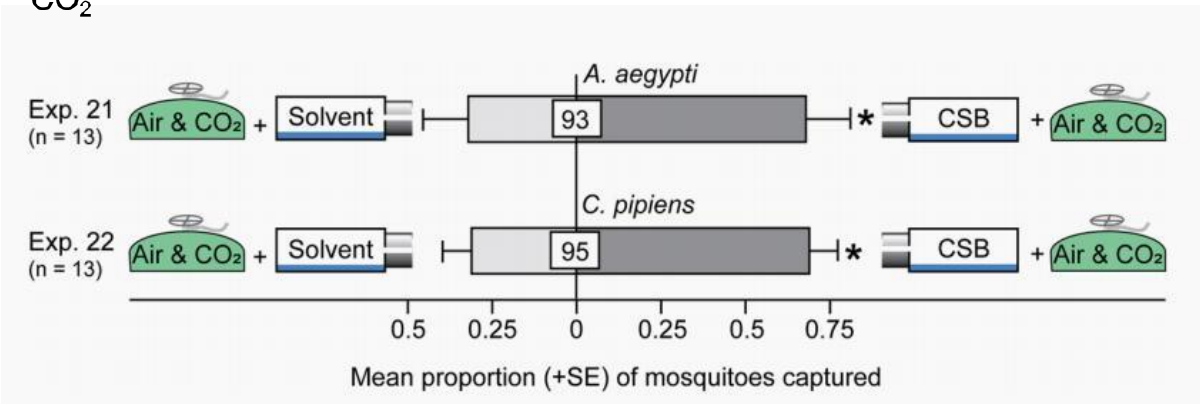
Multimodal foral cues guide mosquitoes to tansy inforescences







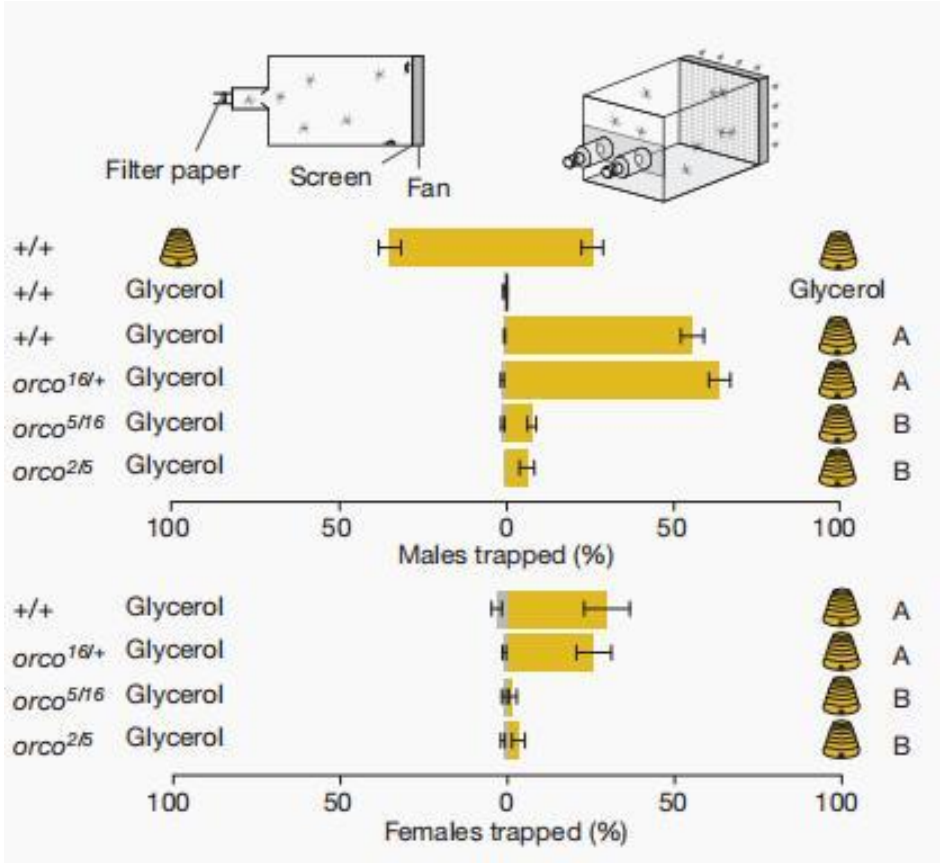
CO_2



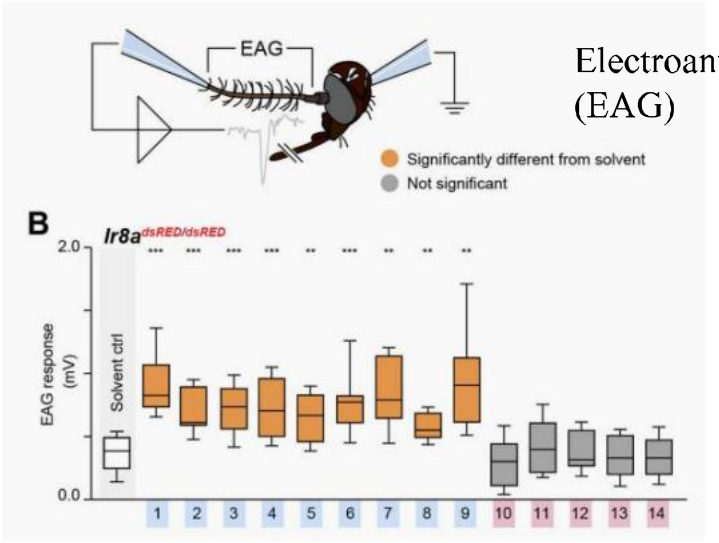
Peach DAH, Gries R, Zhai H, Young N, Gries G,*Sci Rep*,2019

Mosquitoes Use Olfaction to Locate Nectar Sources

Disruption of honey odour detection in orco mutants.



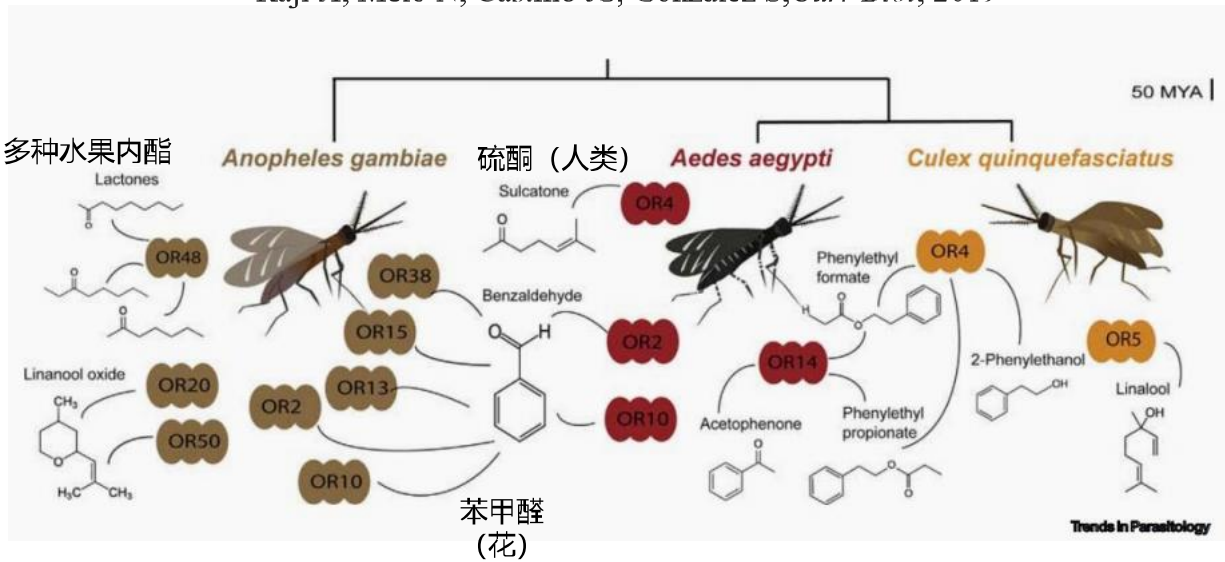
DeGennaro M, McBride CS,et al.,*Nature*, 2013



Electroantennogram (EAG)

IR8a

Raji JI, Melo N, Castillo JS, Gonzalez S,*Curr Biol*, 2019



Barredo E, DeGennaro M.,*Trends Parasitol,* 2020

Leucokinin mimetic elicits aversive behavior in Aedes aegypti and inhibits the sugar taste neuron

Movie S1

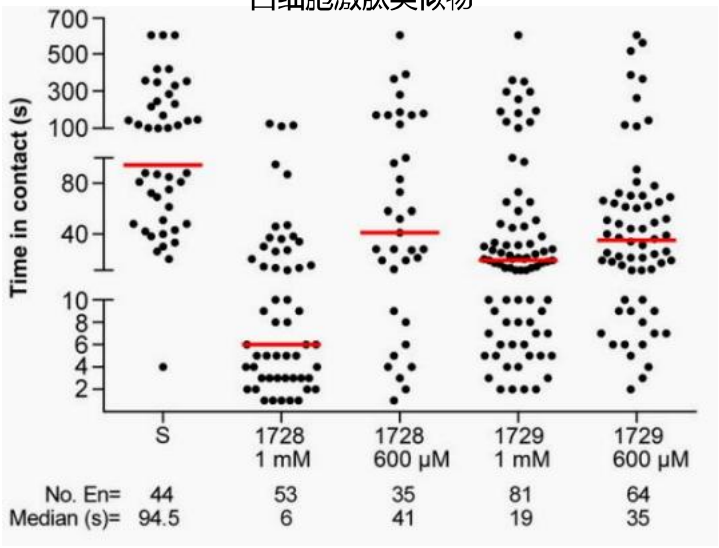
Females of *A. aegypti* feeding on

kinin analog 1728 at 1 mM

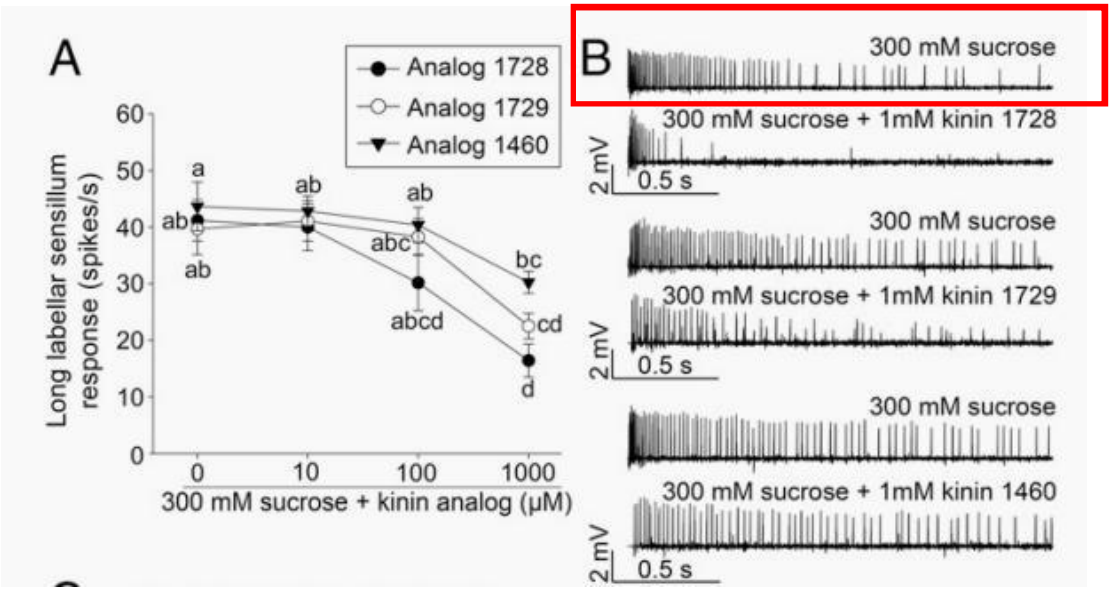
(10% sucrose solution, 0.1% Evans blue)

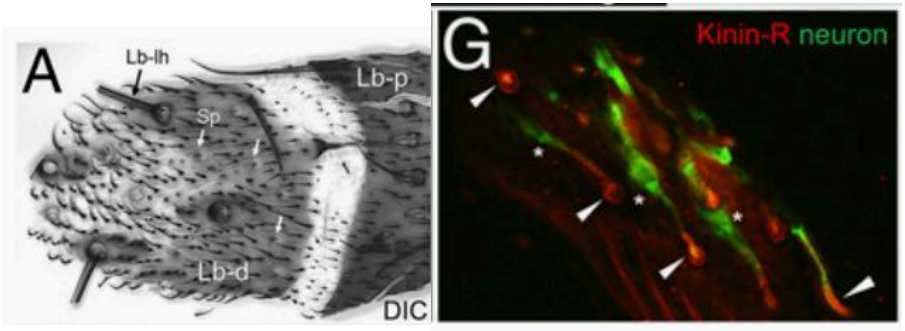
Leucokinin mimetic elicits aversive behavior in Aedes aegypti and inhibits the sugar taste neuron

白细胞激肽类似物



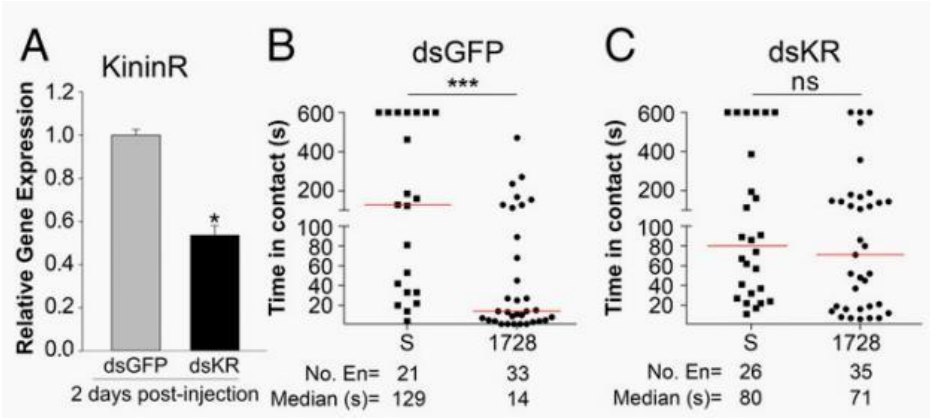
female labellum





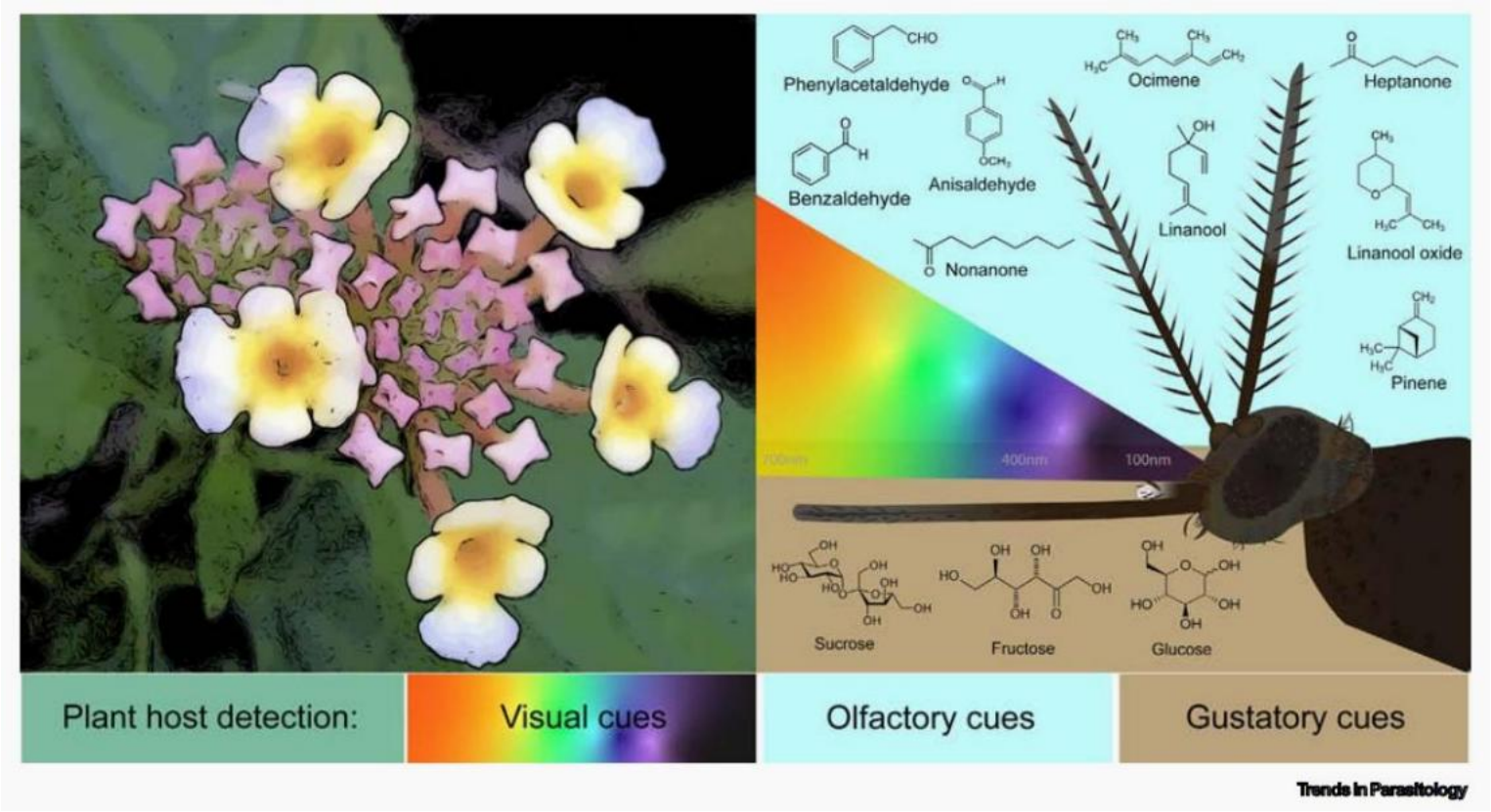
长唇形感受器

前胸跗骨



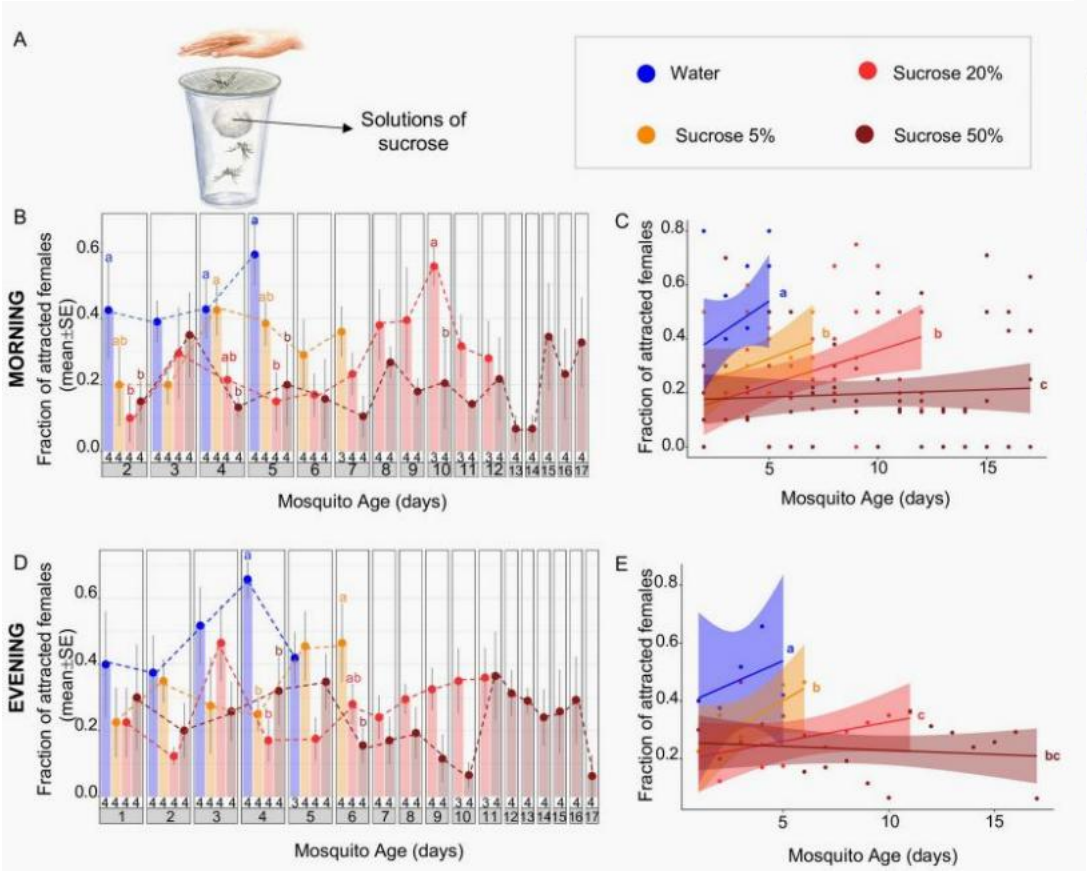
Kwon H, Ali Agha M, et al.,*PNAS.* 2016

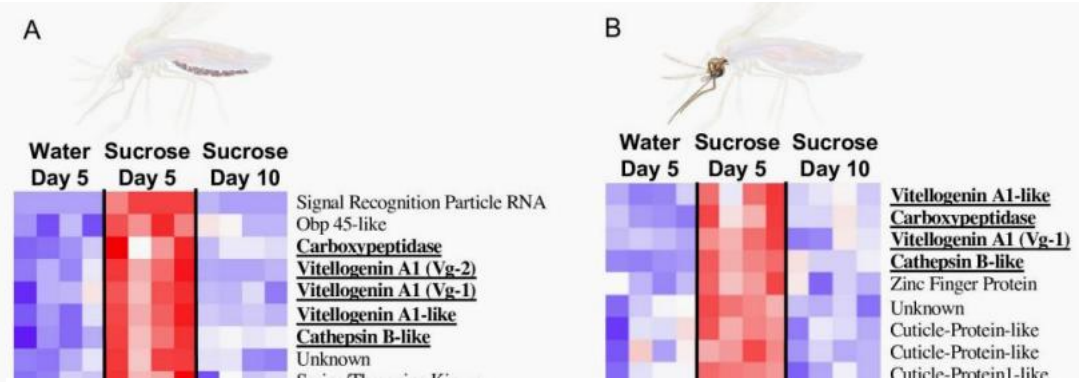
Not Just from Blood: Mosquito Nutrient Acquisition from Nectar Sources



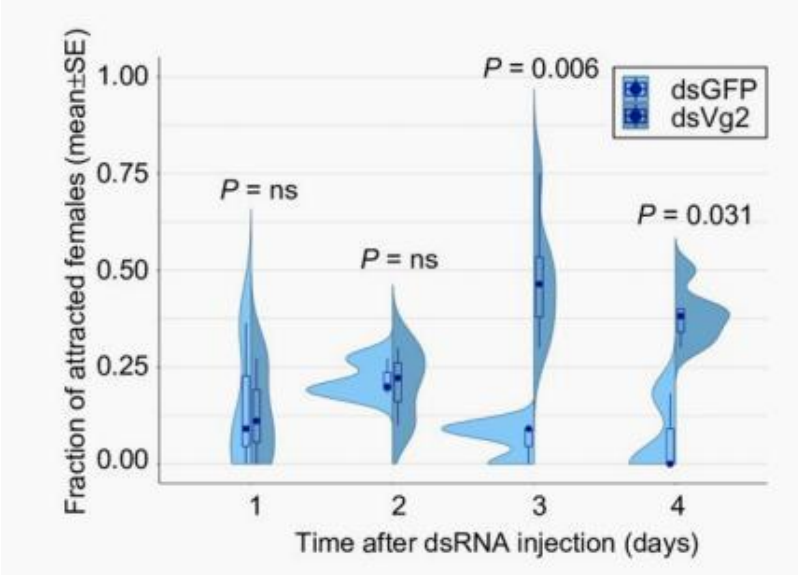
Barredo E, DeGennaro M.,*Trends Parasitol*, 2020

Sugar feeding reduces host-seeking behaviour





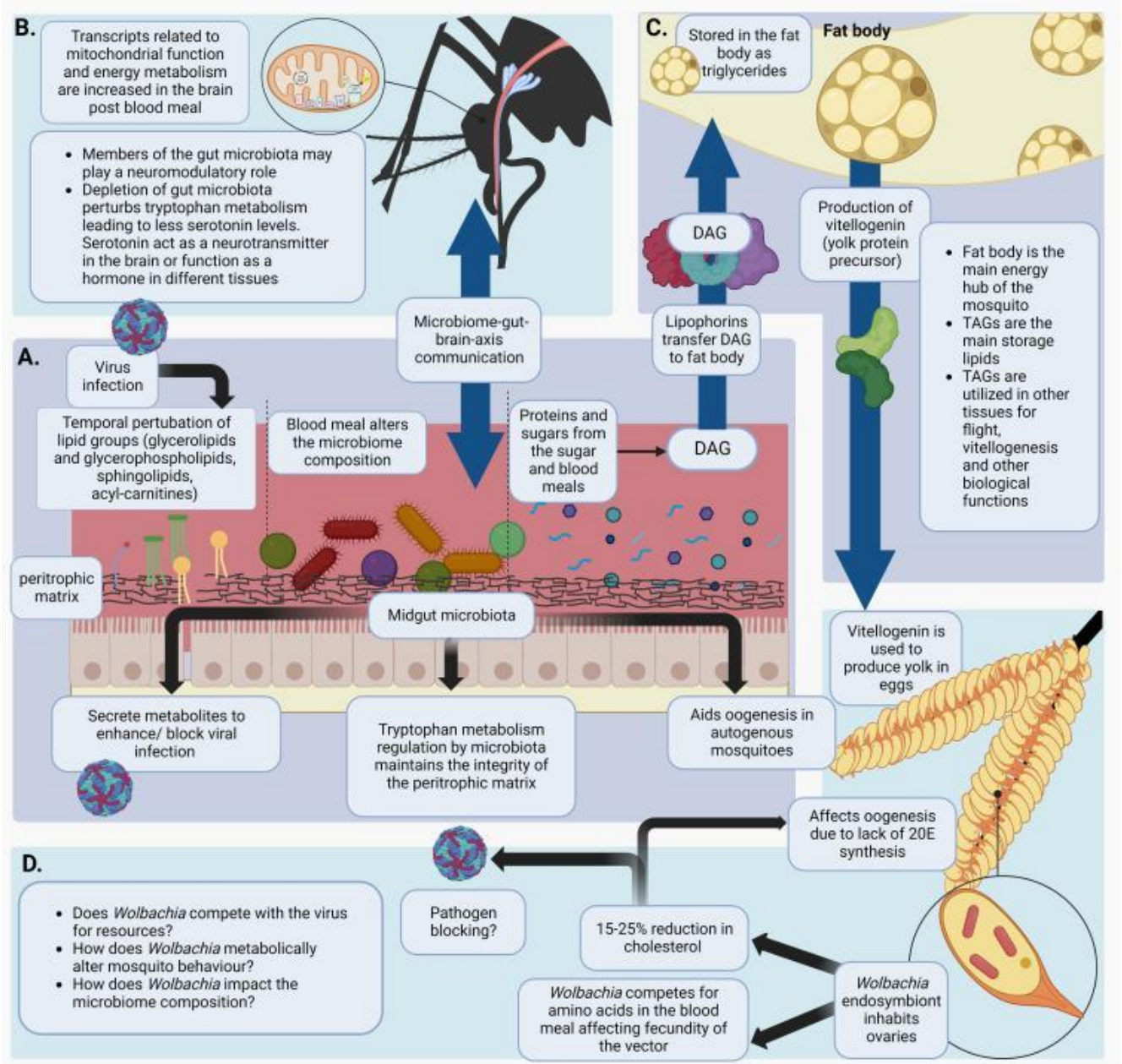
Vg-2 expression regulates host-seeking behaviour



Dittmer J, Alafndi A, Gabricli P., *PLoS Biol*, 2019

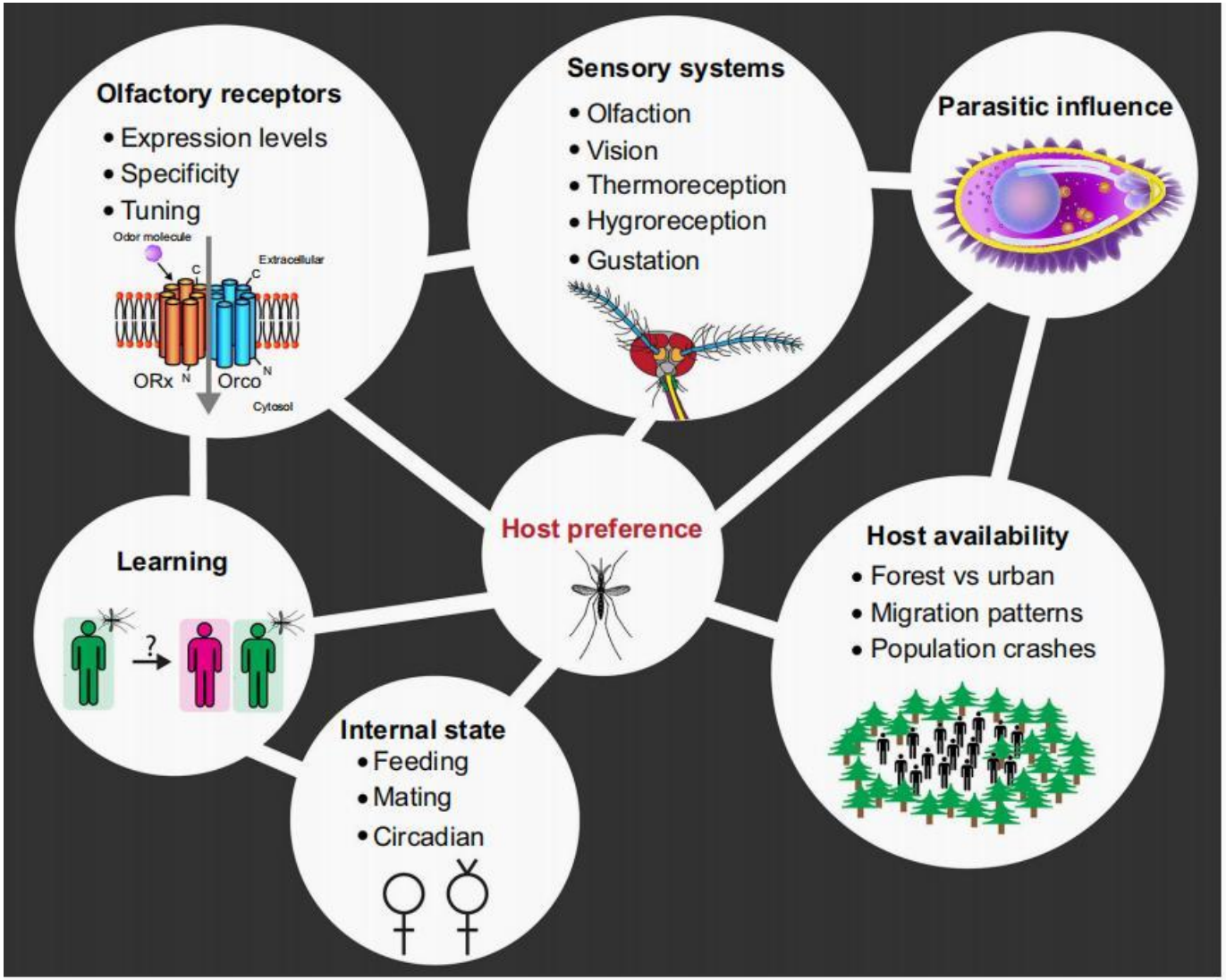
Why blood feed?

Blood meal induced metabolic changes in the mosquito.



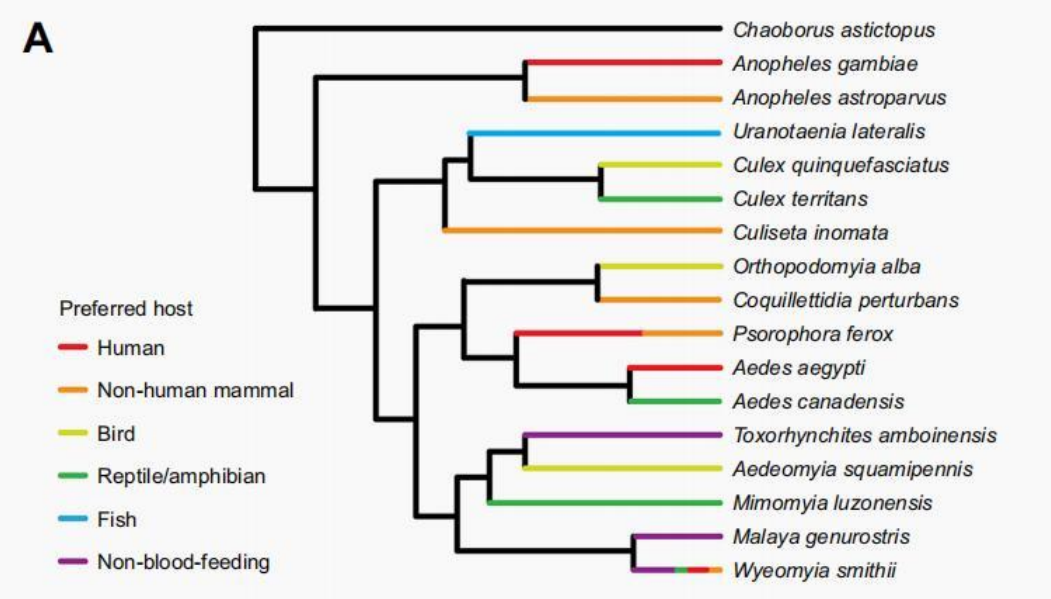
Ratnayake OC, Chotiwan N, et al.,
Front Cell Infect Microbiol, 2023

Factors influencing mosquito host-preference behaviors



Wolff GH, Riffell JA., *J Exp Biol,* 2018

Host preferences in specialists and generalists

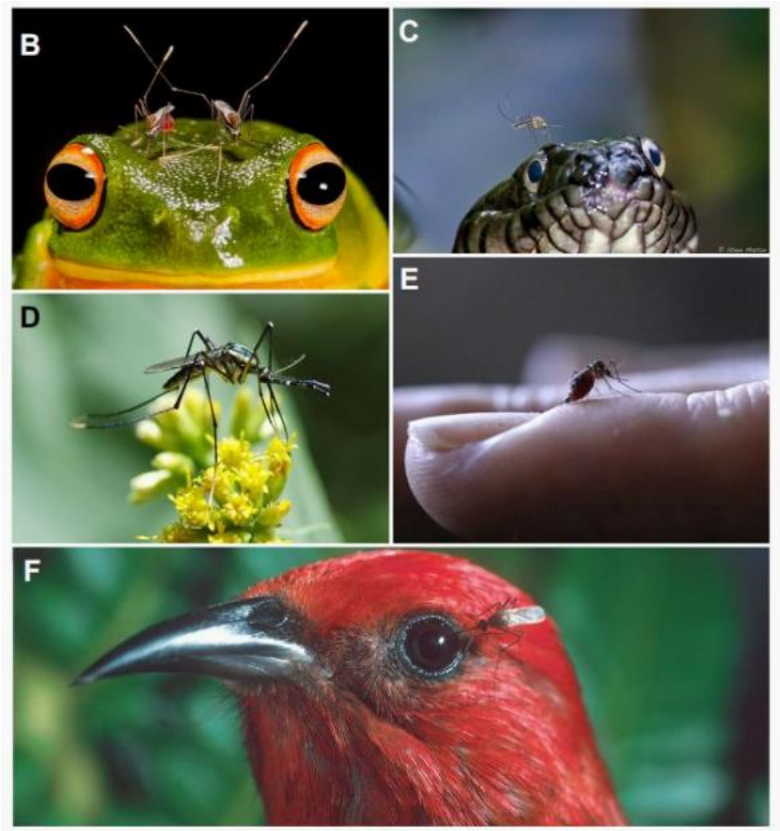


anthropophagic：feed often on humans

ornithophilic：prefer birds to mammals

mammalophilic：prefer mammals

zoophilic：often on non-human animals

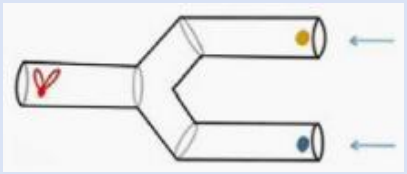


Specialists & Generalists & Opportunistic

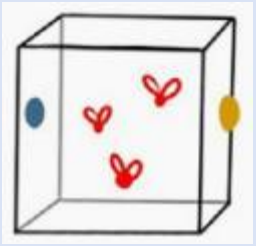
Wolff GH, Riffell JA., *J Exp Biol*, 2018

Methods to determine host preference:behavioral observation and blood meal analyses

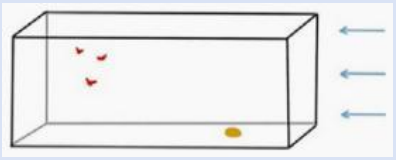
Behavioral observation



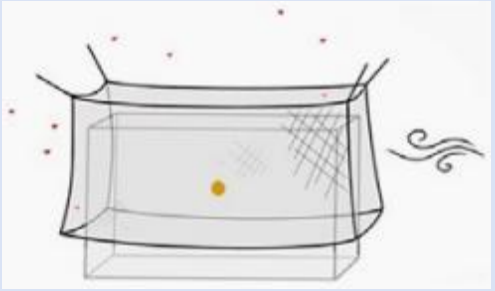
Y-tube



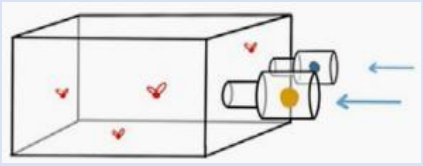
Choice chamber



Wind tunnel



Baited traps



Dual-port olfactometer

One limitation:

Certain genetic traits may get lost.

The preference may also be lost.

Blood meal analyses

The origin of blood meals can be assessed by:

multiplex PCR

microsphere assay

microsatellites

enzyme-linked immunosorbent assay (ELISA)

precipitin test.

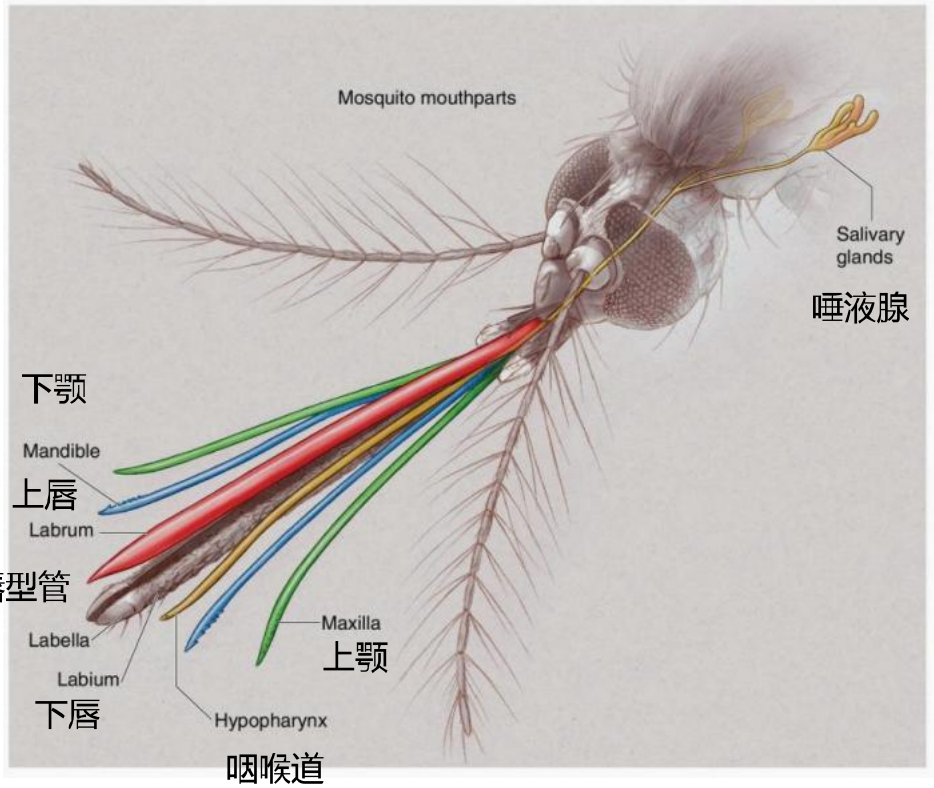
One limitation:

May be favor of the most abundant

host species locally available.

Fikrig K, Harrington LC.,*Trends Parasitol*, 2021

Blood feeding phases



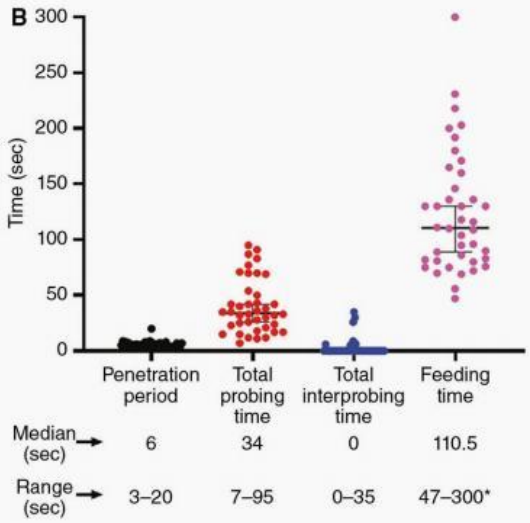
Penetration Time
insertion of the stylets into the host skin and usually lasts <10 sec

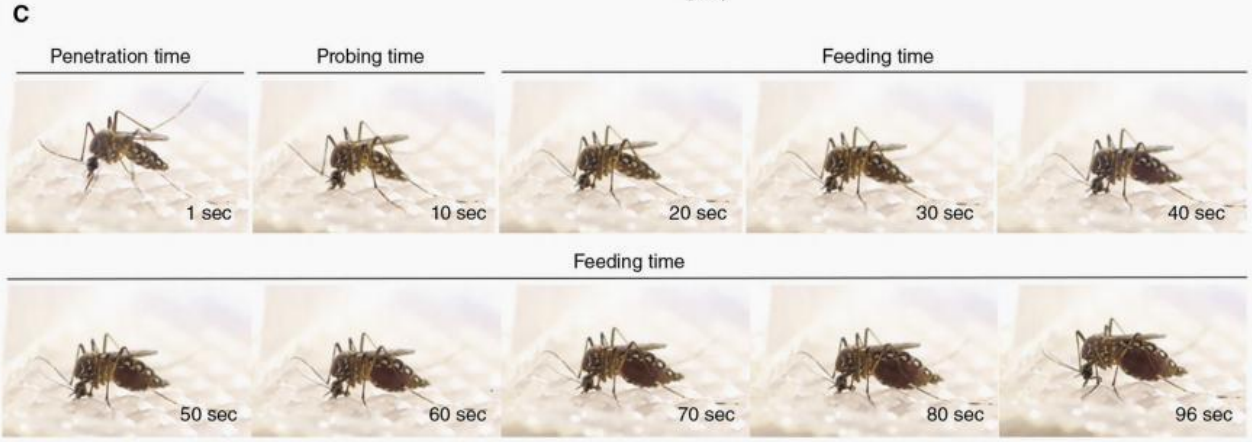
Probing Time
involves saliva secretion into the skin

Some researchers group penetration and probing time as the exploratory phase for blood.

Feeding Time
an active phase of blood ingestion and engorgement

Evaluation of Aedes aegypti Penetration, Probing, and Feeding Times on Mice.





Not interested in blood feeding

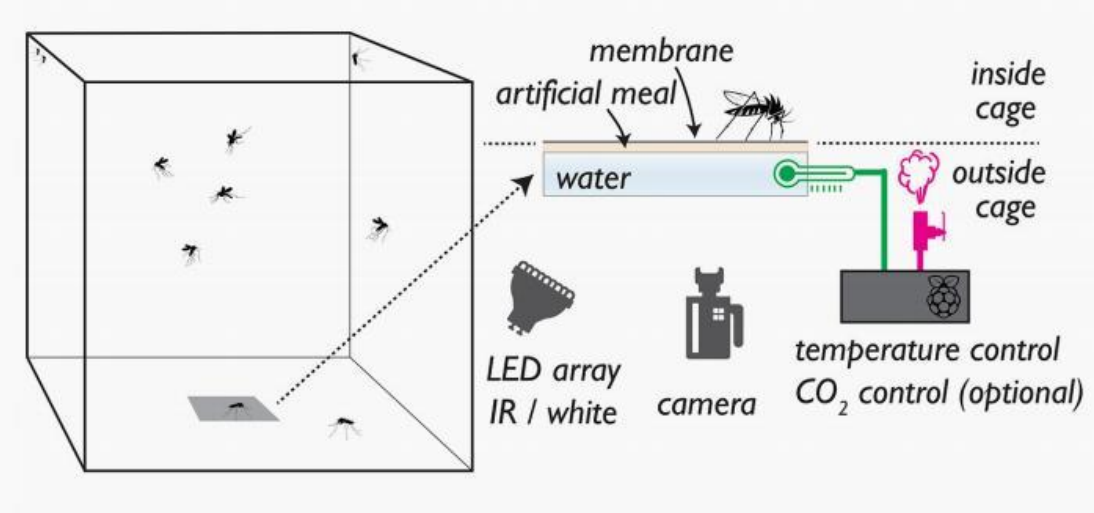
Solution:

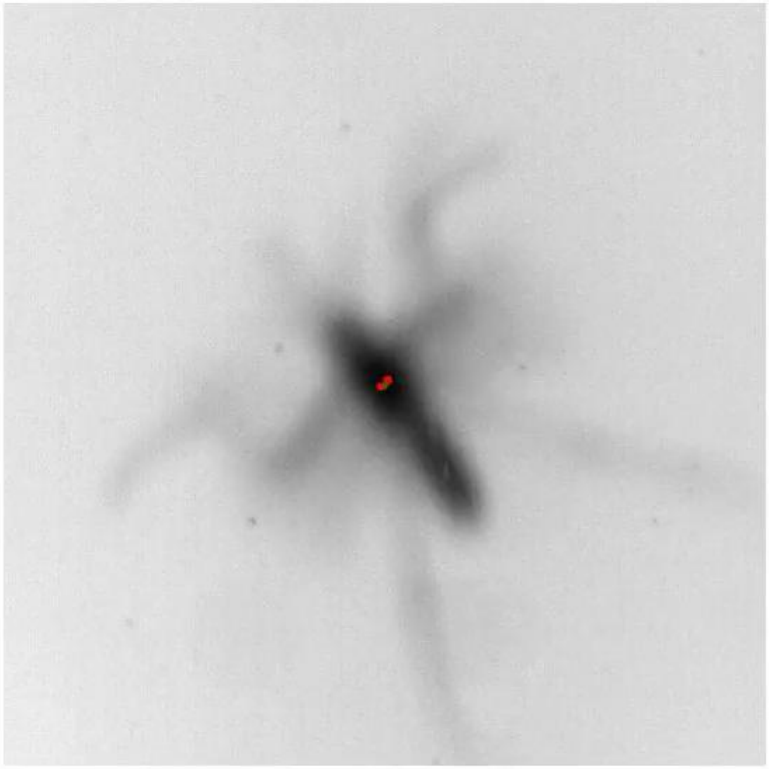
- Ensure that the temperature of the mouse did not drop .Perform in a room at 24°C– 26°C.
- Breathing near the mosquito vial
- Replace sugar cotton balls with water cotton balls in 2 d before the experiment. The night before the experiment, remove the water cotton balls.

The time between probing times is called interprobing time.

Martin-Martin I, Williams AE, Calvo E, *Cold Spring Harb Protoc,* 2023

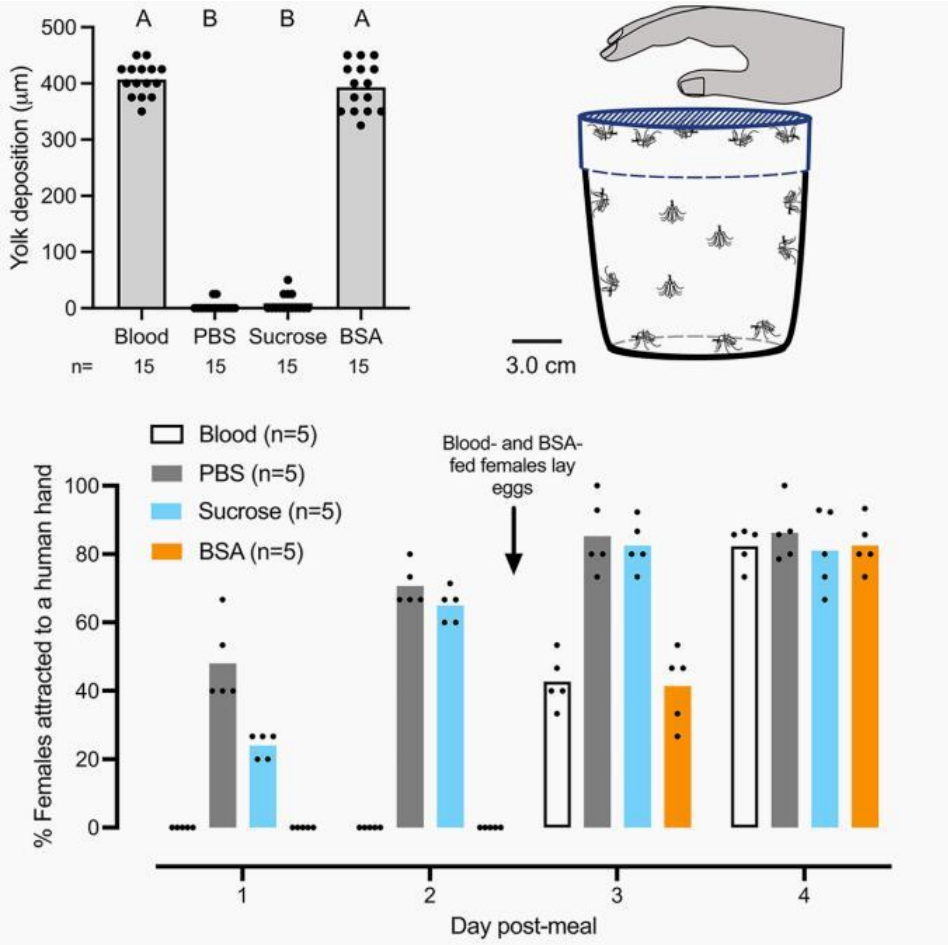
BiteOscope, an open platform to study mosquito biting behavior





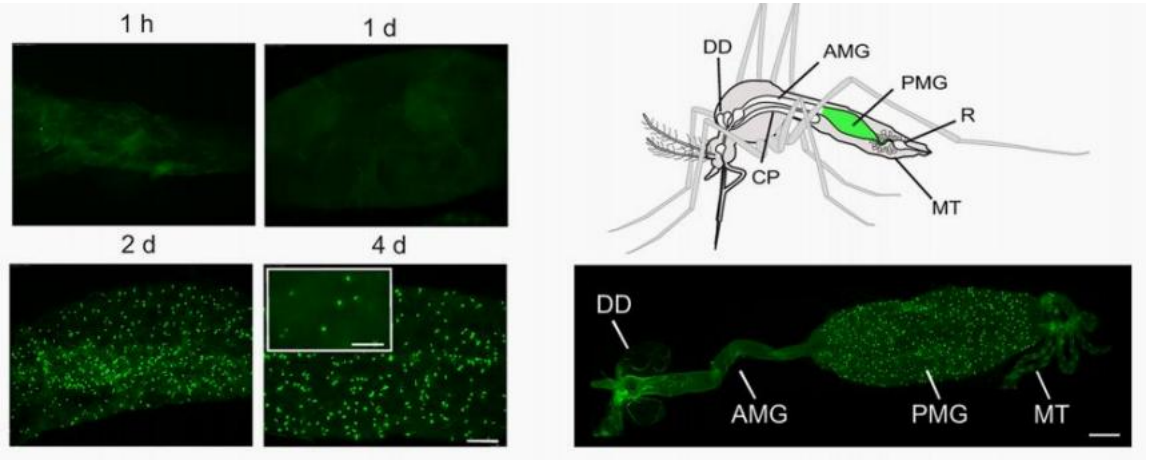
Hol FJ, Lambrechts L, Prakash M.,*Elife*, 2020

Neuropeptide F and RYamide regulate host attraction in the mosquito *Aedes aegypti*

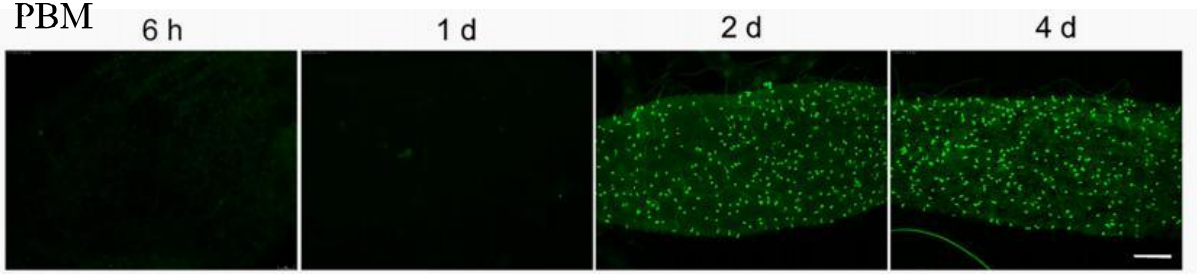


Only blood and protein meals activate the vitellogenic phase and suppress host attraction.

PE



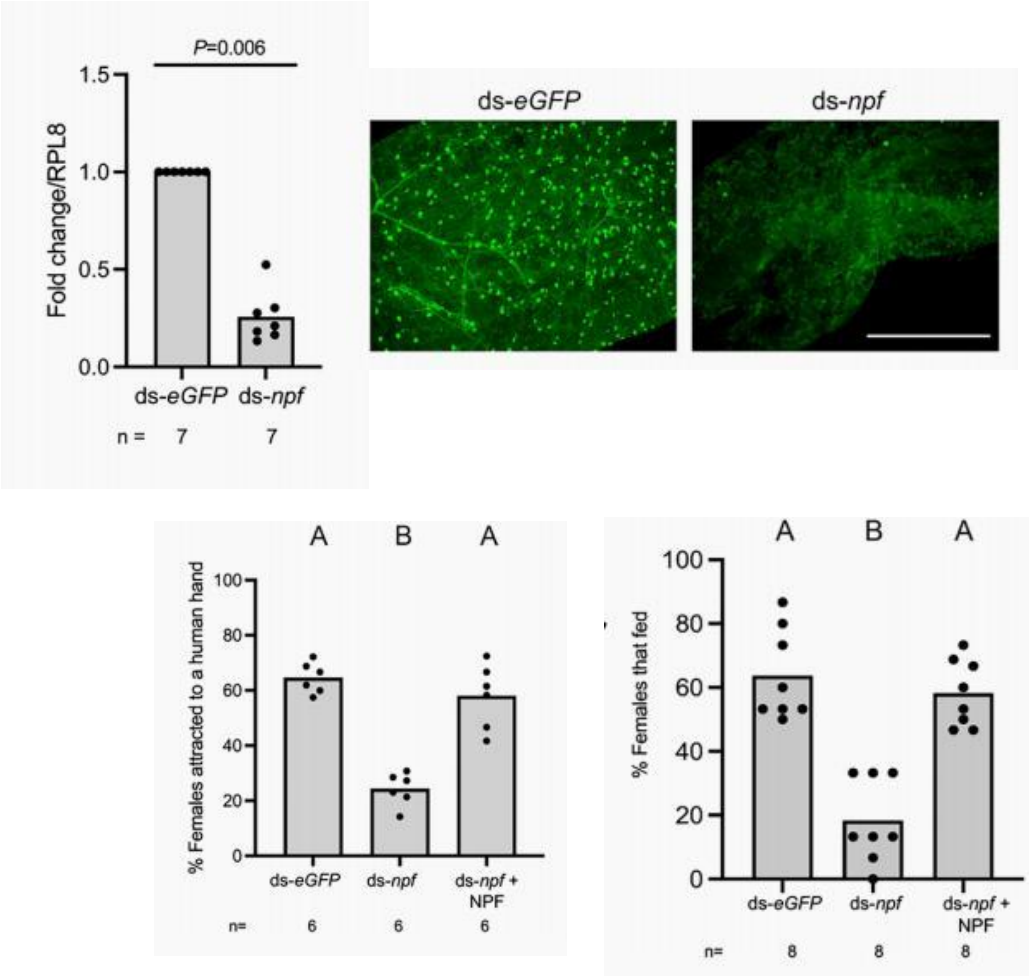
PBM



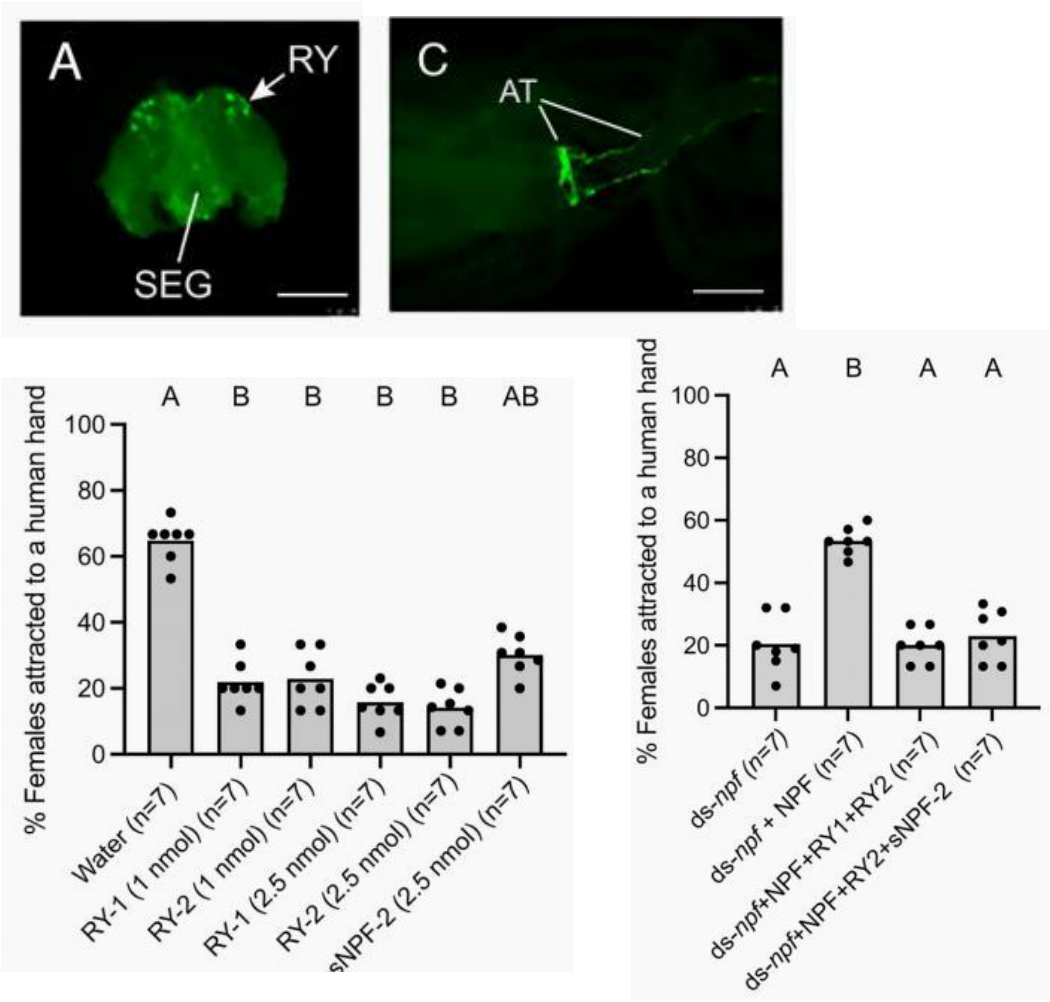
NPF accumulates in EECs of the posterior midgut after adult emergence but rapidly depletes after blood feeding.

Dou X, Chen K, Brown MR, Strand MR.*PNAS*, 2024

Neuropeptide F and RYamide regulate host attraction in the mosquito *Aedes aegypti*



RNAi knockdown of midgut NPF reduces host attraction and blood feeding.



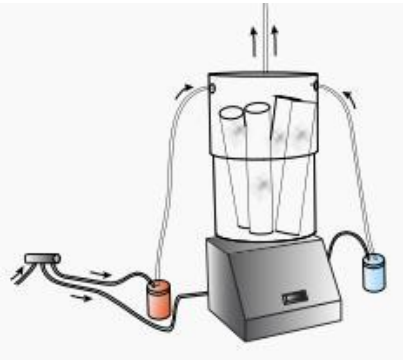
RY-amides suppress host seeking.

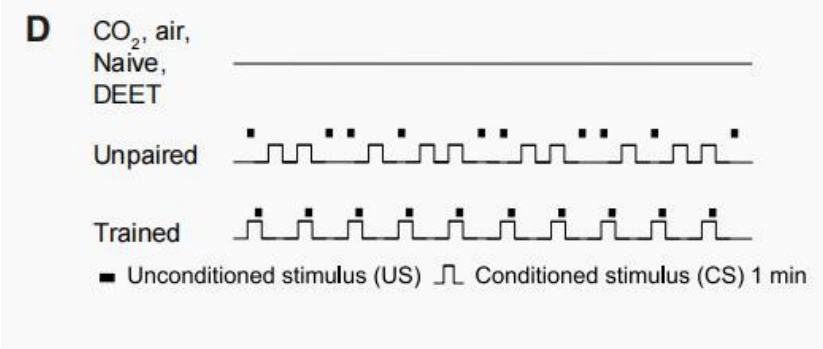
Dou X, Chen K, Brown MR, Strand MR., *PNAS*, 2024

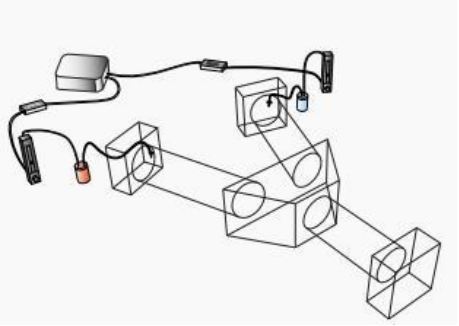
Can host preferences be changed?

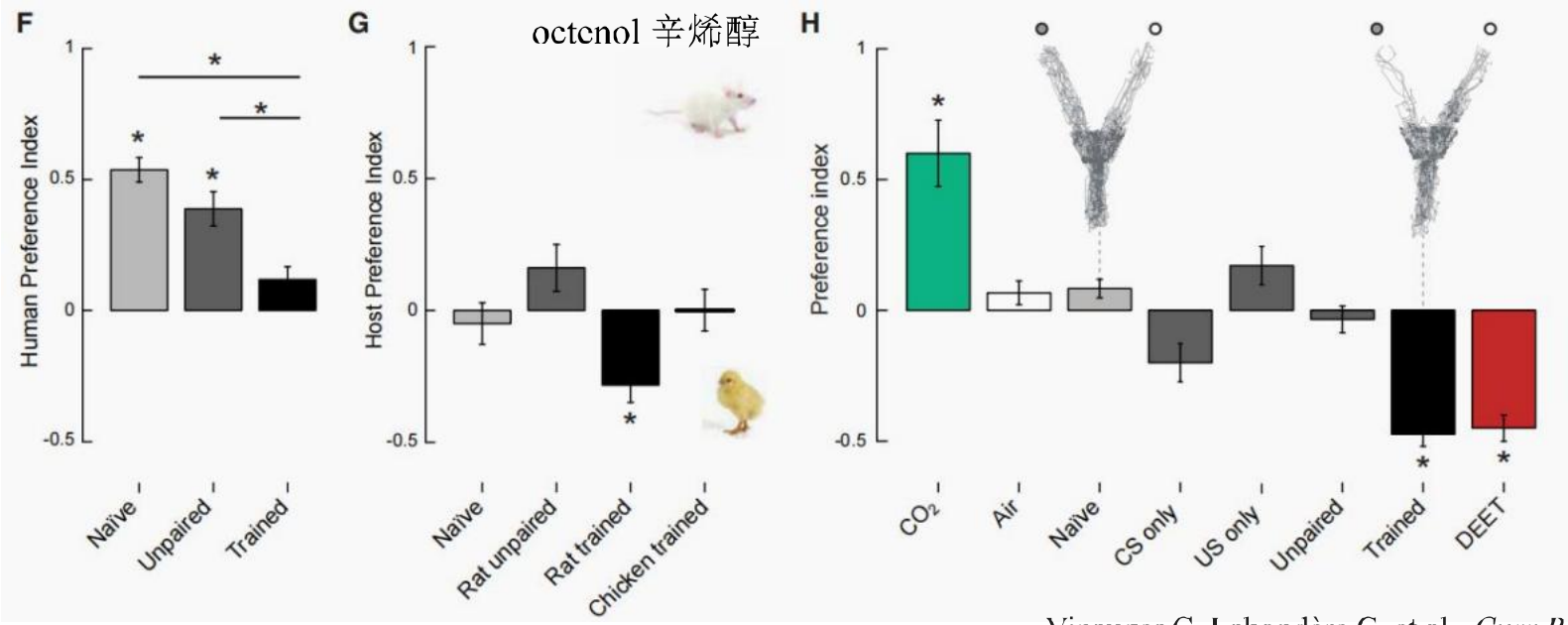
- Learning
- Viral infection

Learning: **Mosquitoes Aversively Learn Host Odors and Single Odorants**



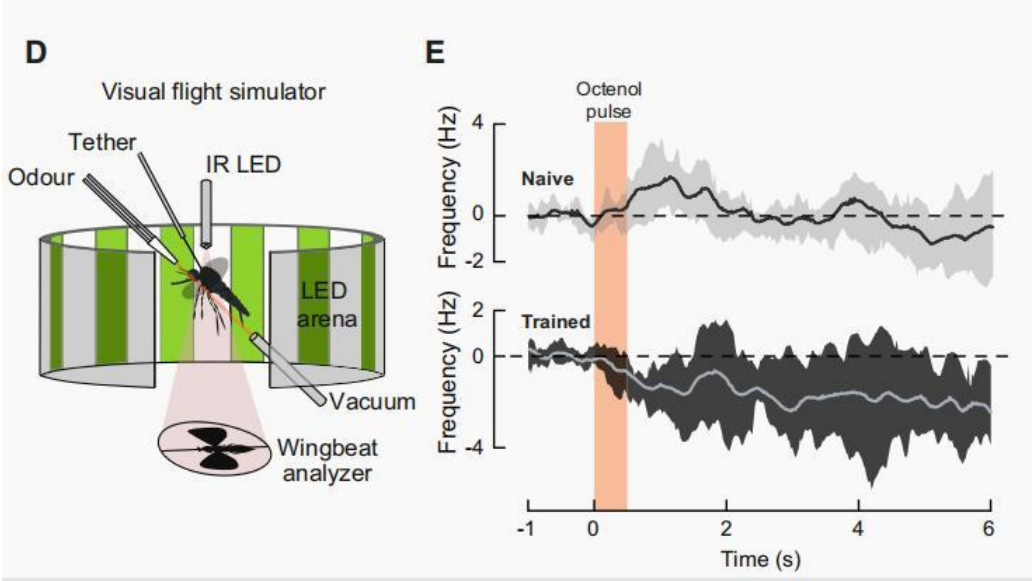


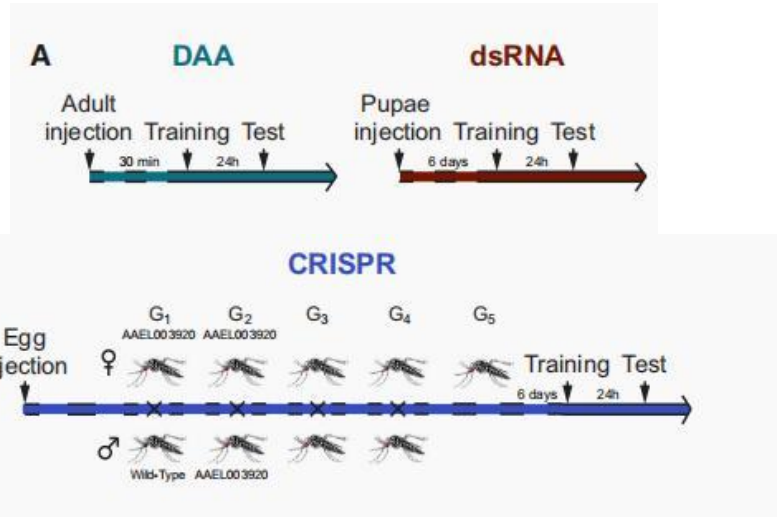


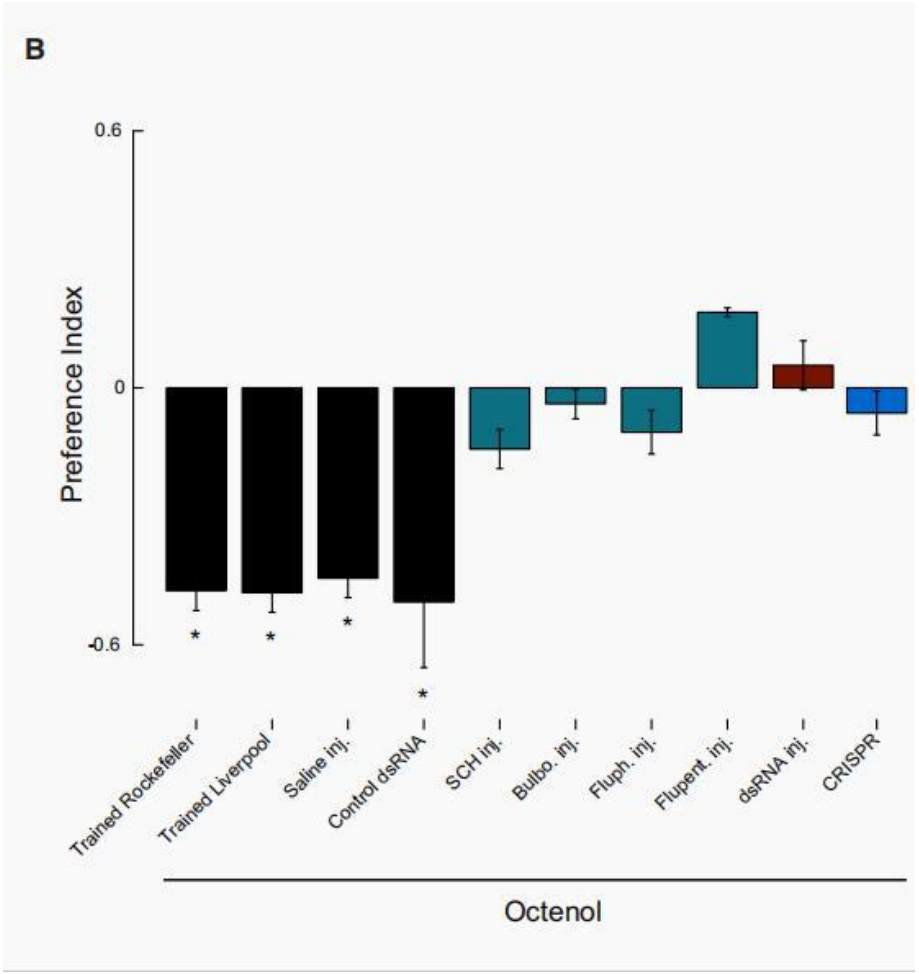


Vinauger C, Lahondère C, et al., *Curr Biol,* 2018

Dopamine Is Critical for Aversive Learning

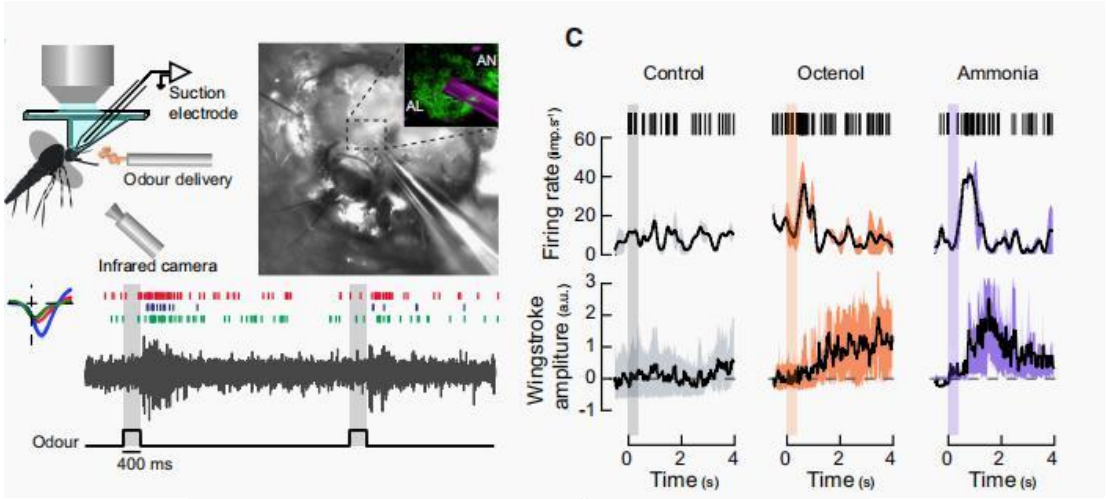


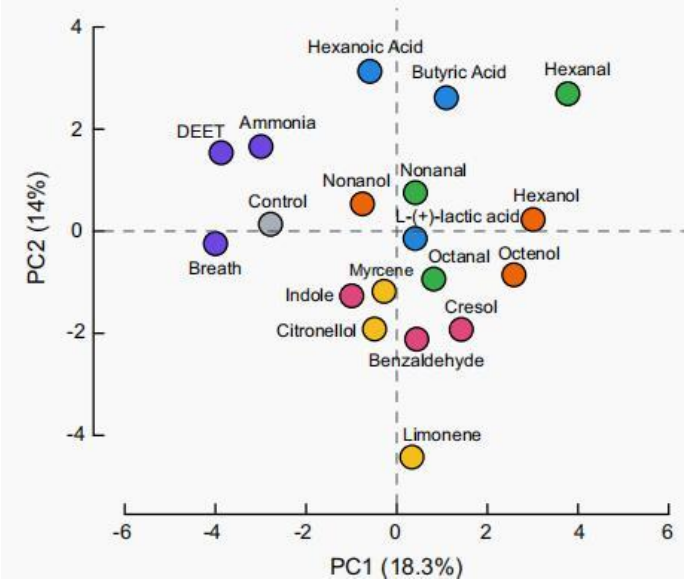




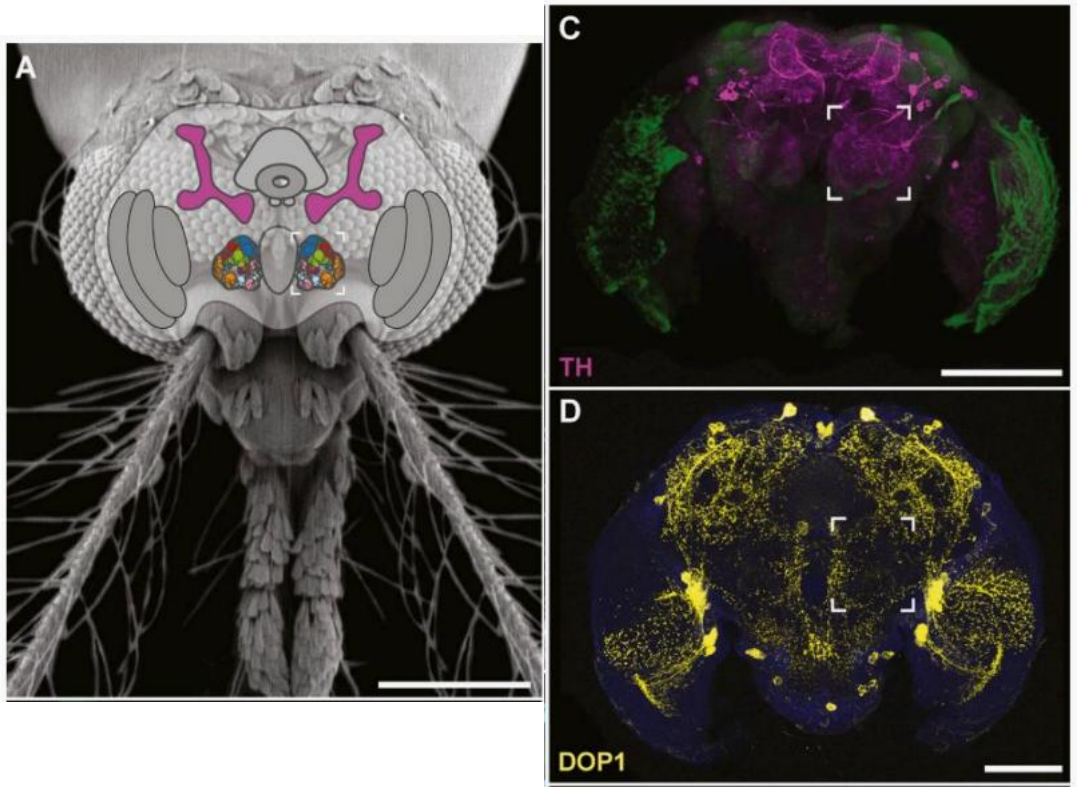
Vinauger C, Lahondère C, et al., *Curr Biol,* 2018

Odor Stimuli Are Learned and Represented Differentially in the Mosquito Brain



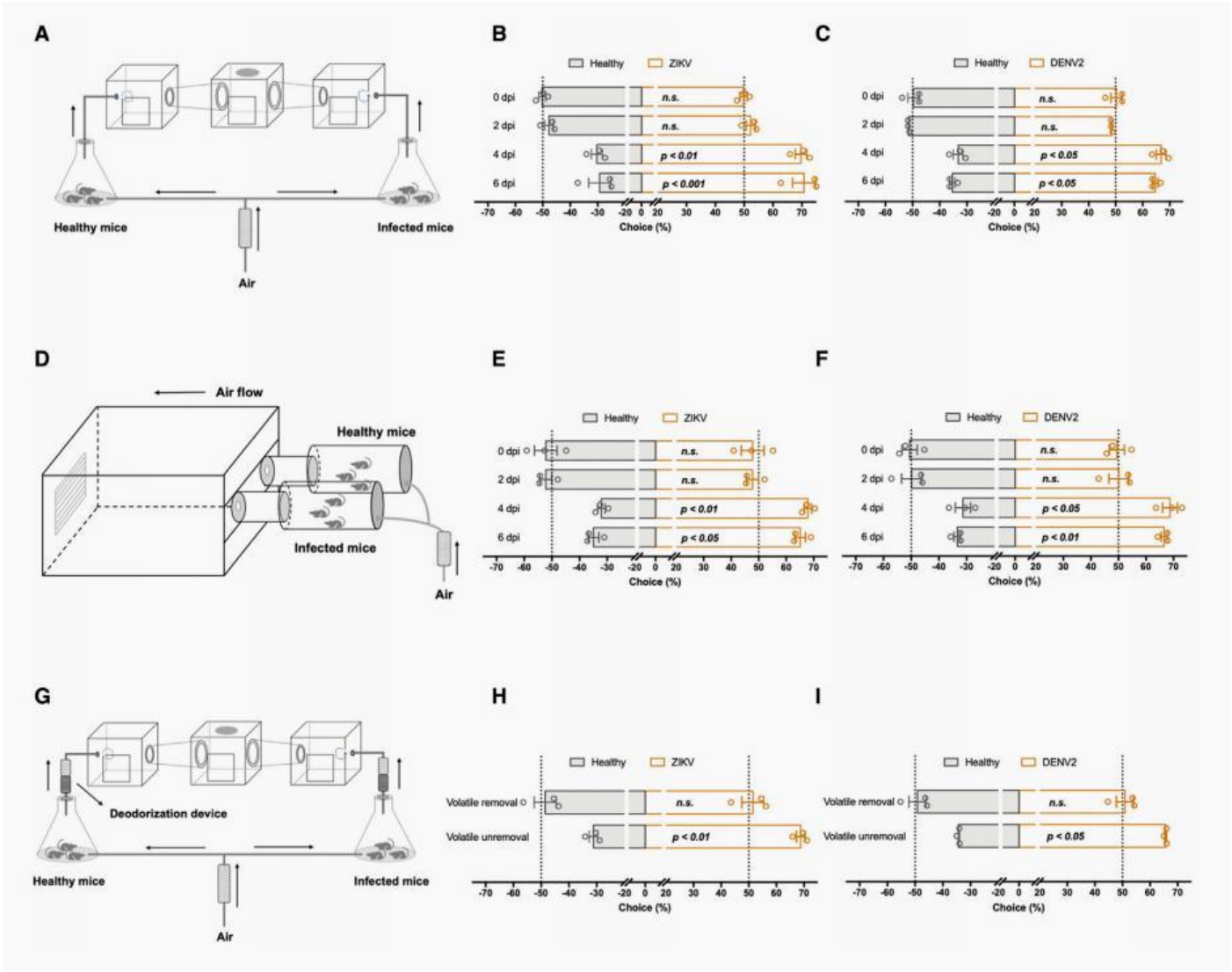


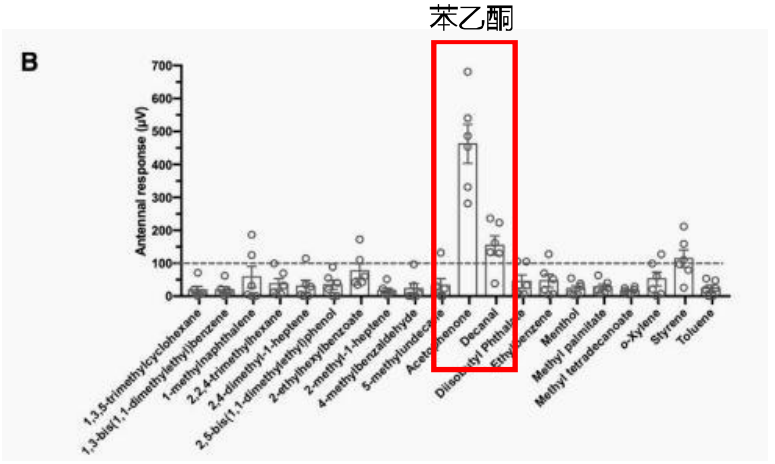
Tyrosine Hydroxylase and Dopamine Receptor Immunoreactivity

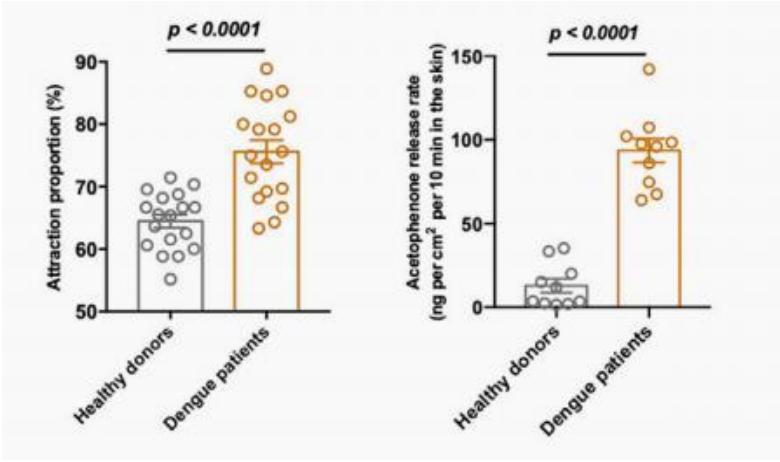


Vinauger C, Lahondère C, et al., *Curr Biol,* 2018

Viral infection: Mice infected by flaviviruses present a higher attraction to *A. aegypti*

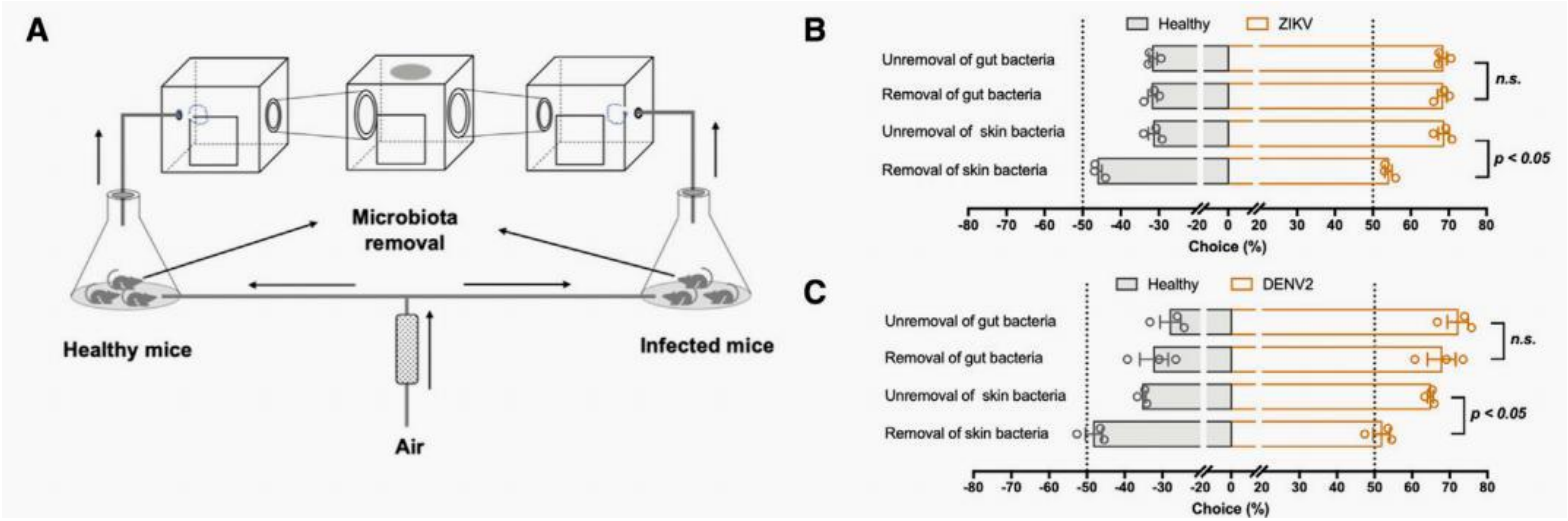


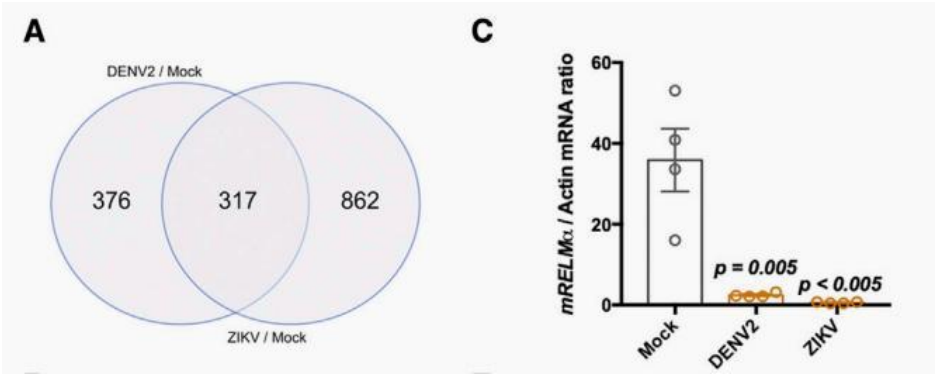


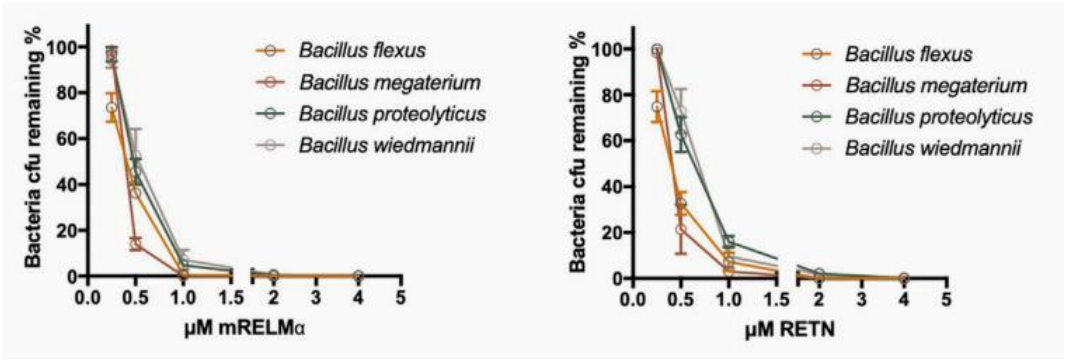


Zhang H, Zhu Y, et al., *Cell*, 2022

Skin microbiota regulated by flavivirus infection are responsible for releasing acetophenone for mosquito attraction





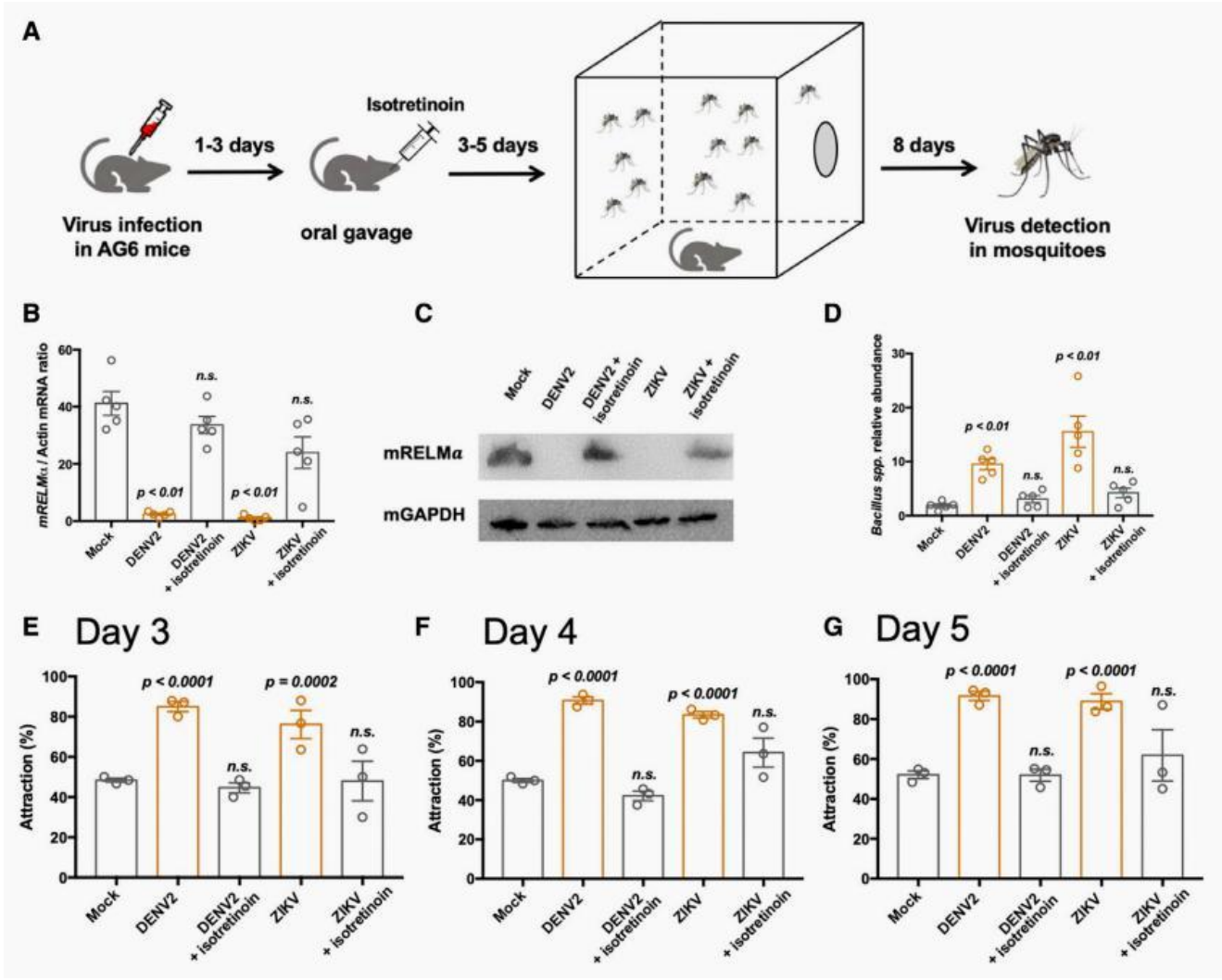


Retnla负责编码抵抗素样分子-α（RELMα），一种抗菌蛋白

Zhang H, Zhu Y, et al., *Cell*, 2022

Dietary administration of a vitamin derivative to flavivirus-infected mice reduces the acetophenone cue to mosquitoes and viral transmission

维生素A衍生物

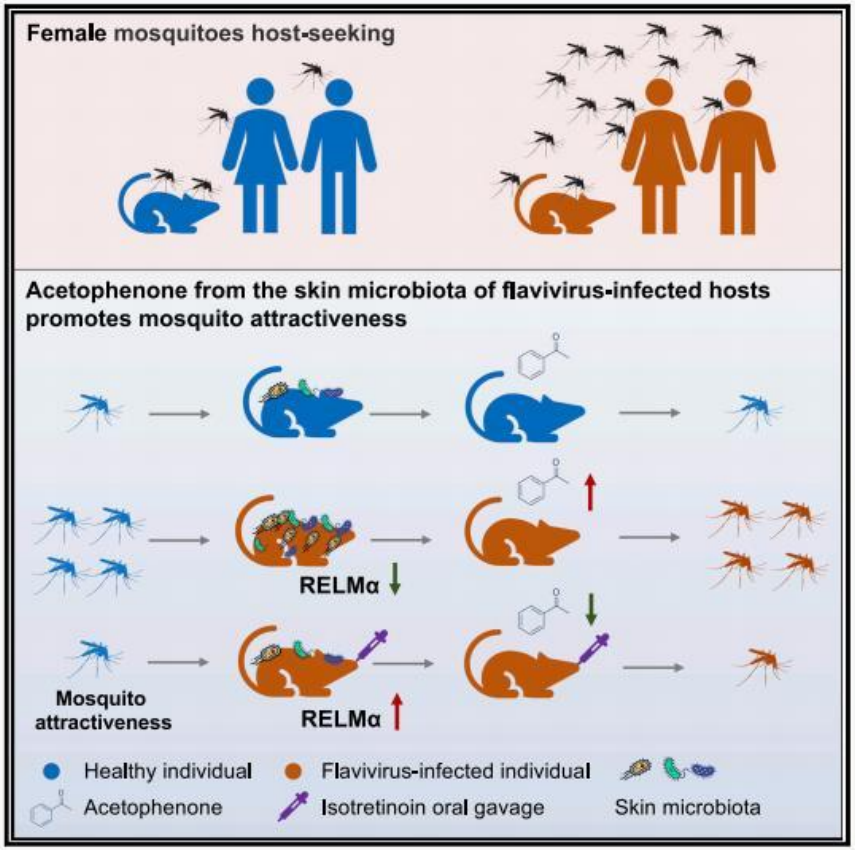


Zhang H, Zhu Y, et al., *Cell*, 2022

Cell

A volatile from the skin microbiota of flavivirus-infected hosts promotes mosquito attractiveness

Graphical abstract



Authors

Hong Zhang, Yibin Zhu, Ziwen Liu, ..., Qiyong Liu, Penghua Wang, Gong Cheng

Correspondence

gongcheng@mail.tsinghua.edu.cn

In brief

Flaviviruses such as dengue and Zika modulate murine host skin bacterial communities to increase acetophenone-producing bacteria. Acetophenone is a mosquito attractant, and its increased production by flavivirus-infected humans and mice make them more attractive to mosquitoes, facilitating viral transmission by mosquito vectors.

程功

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E-mail: Gongcheng@tsinghua.edu.cn

Tel: +86-10-62788494

技术专利

1.程功，肖小平。一种昆虫蛋白Hig及其编码基因和应用。授权号：ZL201410837328.9

2.程功，肖小平。获自埃及伊蚊的防御素及其编码基因和应用。授权号：ZL201310459570.2

3.程功，肖小平。获自埃及伊蚊的天蚕素及其编码基因和应用。授权号：ZL201310455321.6

4.程功，刘洋。一种用于登革热预防和/或治疗的疫苗。授权号：ZL201310181920.3。(申请PCT国际专利保护)

5.程功，刘建英，刘洋。一种登革热双效疫苗的制备方法及其应用。授权号：ZL201510830549.3。(申请PCT国际专利保护)

6.郑兆鑫，严维耀，程功，刘明秋。一种口蹄疫基因工程多肽疫苗佐剂及其制备方法和应用。 授权号：ZL200610147664.6。

7.郑兆鑫，赵欣，程功，严维耀，刘明秋。猪干扰素基因家族及其作为抗猪蓝耳病药物及疫苗佐剂的应用。授权号：ZL201010208935.0。

8.程功，杜森焱。 ZIKV-NS1蛋白及其在制备寨卡病毒传播阻断疫苗中的应用。申请号：201711327739.3。

9.程功，朱毅斌。 调控GABAA受体的物质在调控昆虫虫媒病毒载量中的应用。申请号：201710803946.5。

10.程功，太万博，冯胜勇，庞慕加。一种靶向激活体液免疫和细胞免疫的核酸疫苗载体构建及应用。申请号：202110655890.2。

从事蚊媒病毒感染传播机制与抗病毒免疫研究。研究主要涉及蚊媒病毒在哺乳动物宿主及节肢动物媒介中的感染机制，希望通过多种实验手段鉴定出与病毒感染高度相关的宿主蛋白，并利用鉴定出的宿主蛋白作为干预靶点，阻断虫媒病毒在自然界传播。

- **登革热病毒研究**

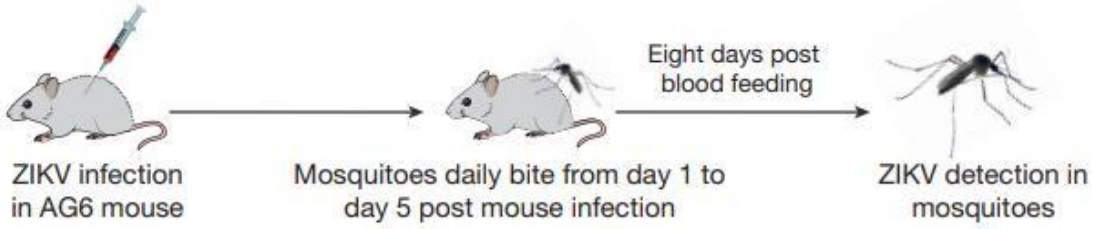
首次发现了登革病毒非结构蛋白NS1，回答了“登革病毒如何从宿主传播到蚊虫”这一重要科学问题。

- **首次阐明寨卡病毒暴发机制**

首先发现寨卡病毒的NS1蛋白同样也具有辅助病毒感染蚊虫的功能

- **疫苗研发**

新型mRNA疫苗和纳米颗粒疫苗



•代表性论著

1. Zhang H*, Zhu YB*, Liu ZW, Peng YM, Peng WY, Tong LQ, Wang JL, Liu QY, Wang PH, Cheng G#. (2022) A volatile from the skin microbiota of flavivirus-infected hosts promotes mosquito attractiveness. **Cell**. In Press.

2. Tong LQ*, Xiao XP*, Li M*, Fang SS*, Yu X, Zhu YB, Wu CL, Tian DY, Yang F, Sun J, Qu J, Zheng NZ, Liao SM, Tai WB, Feng SY, Zhang LM, Li YH, Wang L, Han XL, Sun SH, Yang L, Zhao JC, Liu WJ, Liu XH, Wang PH, Li L#, Zhao GY#, Zhang RL#, Cheng G#. (2022) A glucose-like metabolite deficient in diabetes inhibits cellular entry of SARS-CoV-2. **Nature Metabolism**. 4: 547–558.

3. Yu X, Shan C, ZHu YB, Ma EH, Wang JL, Wang PH, Shi PY, Cheng G#. (2021) A mutation-mediated evolutionary adaptation of Zika virus in mosquito and mammalian host. **Proceedings of the National Academy of the Sciences**. 118: e2113015118.

4. Zhu YB, Tong LQ, Nie KX, Wiwatanaratanabutr I, Sun P, Li QQ, Yu X, Wu P, Wu TS, Yu C, Liu QY, Bian ZQ, Wang PH, Cheng G#. (2019) Host serum iron modulates dengue virus acquisition by mosquitoes. **Nature Microbiology**. 4: 2405–2415

5. Wu P, Sun P, Nie KX, Zhu YB, Shi MY, Xiao CG, Liu H, Liu QY, Zhao TY, Chen XG, Zhou HN, Wang PH, Cheng G#. (2019) A gut commensal bacterium promotes mosquito permissiveness to arboviruses. **Cell Host & Microbe**, 25, 1-12.

6. Liu Y, Liu JY, Du SY, Shan C, Nie KX, Zhang RD, Li XF, Zhang RL, Wang T, Qin CF, Wang PH, Shi PY#, Cheng G#. (2017) Evolutionary enhancement of Zika virus infectivity in Aedes aegypti mosquitoes. **Nature**. 545: 482-486.

7. Cheng G, Cox J, Wang PH, Krishnan MN, Dai JF, Qian F, Anderson JF, Fikrig E. (2010) A C-Type Lectin collaborates with a CD45 phosphatase homolog to facilitate West Nile Virus infection of mosquitoes. **Cell.** 142, 714-725.

……

Evolutionary transition from blood feeding to obligate nonbiting in a mosquito

紫色猪笼草蚊

Florida population: a low propensity to bite

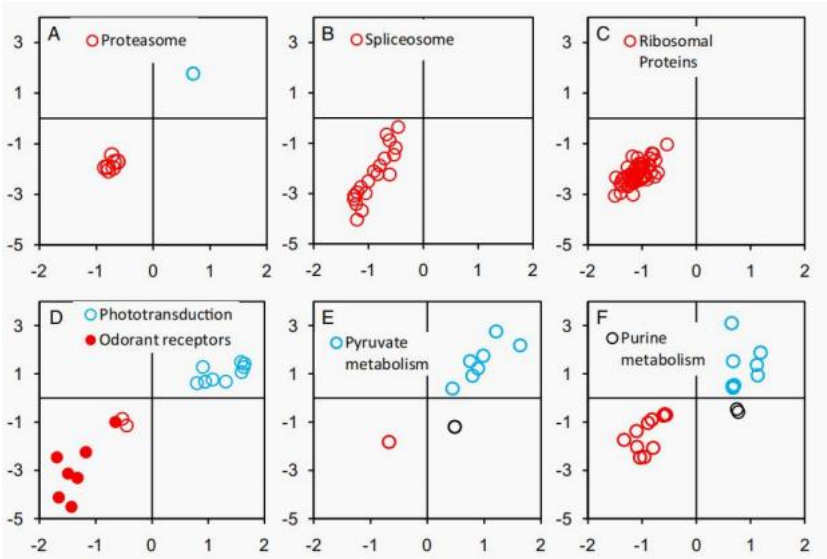
avid biters (FLavid) 强制

disinterested nonbiters (FLdis)

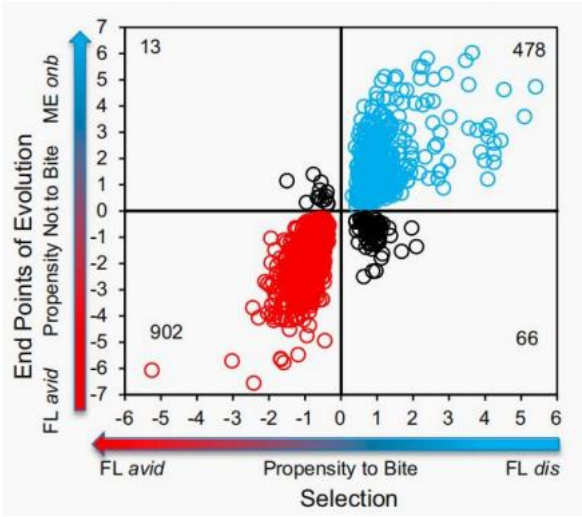
Maine population：

obligate nonbiters (MEonb)专性非咬人

differential gene expression (DGE)

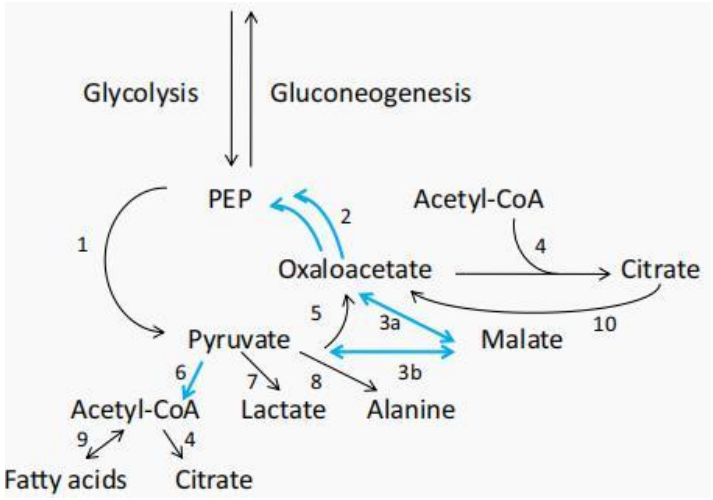


KEGG



anautogenous： require blood to develop eggs

autogenous： producing one or more clutches of eggs without blood



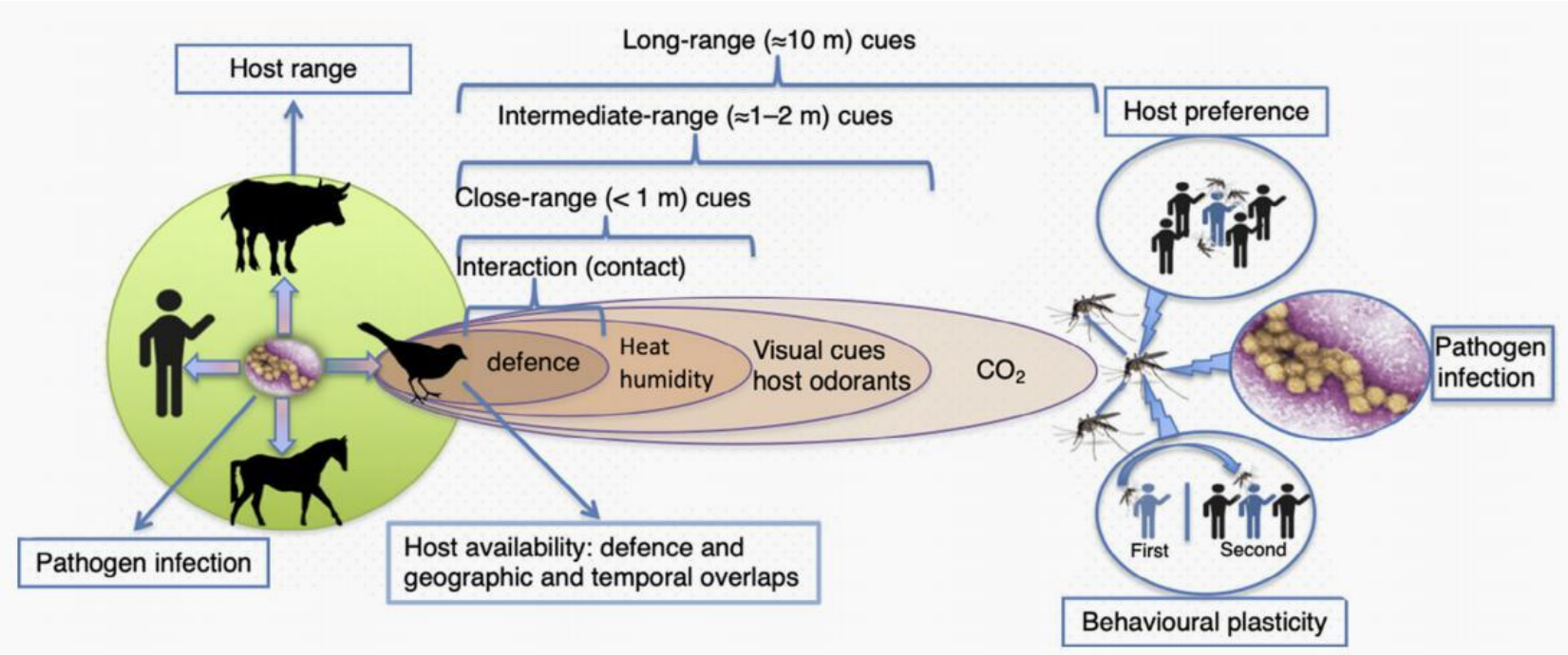
nonbiting：

a greatly reduced metabolic investment、greater reliance on visual rather than olfactory sensory input

Bradshaw WE, Burkhart J, et al., *PNAS*, 2018

Summary:

Mosquito host utilization is a highly complex phenomenon influenced by both intrinsic and extrinsic factors



Host preferences: limit what type of hosts mosquitoes feed on

Behavioural plasticity:enable shifting from a preferred host to an available one

Host-seeking cues and host availability:determine host–vector interactions

Pathogen infection:alter host and vector phenotypic traits

Yan J, Gangoso L,et al.,*Biol Rev Camb Philos Soc*, 2021

Take home message

- Sugar feeding is also important for mosquitoes, which search for nectar through visual, smell, taste and other clues, but the neuromolecular mechanism behind it has been less studied
- Some ways to study mosquito feeding behavior, such as Y-tube、three-cage olfactometers and two-port olfactometers
- Mosquitoes use multiple senses, including smell, sight, heat reception, humidity sensing, and taste, to track their hosts
- The mosquito's preference for the host can be changed by learning, being infected by viruses, etc.

Part II: The internal mechanisms govern feeding

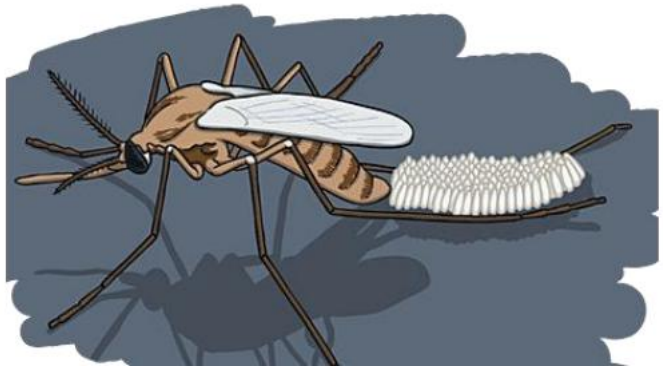
JSH

Q1: What drives mosquitoes to start blood feeding?

Q2: How can mosquitoes keep blood feeding for a while?

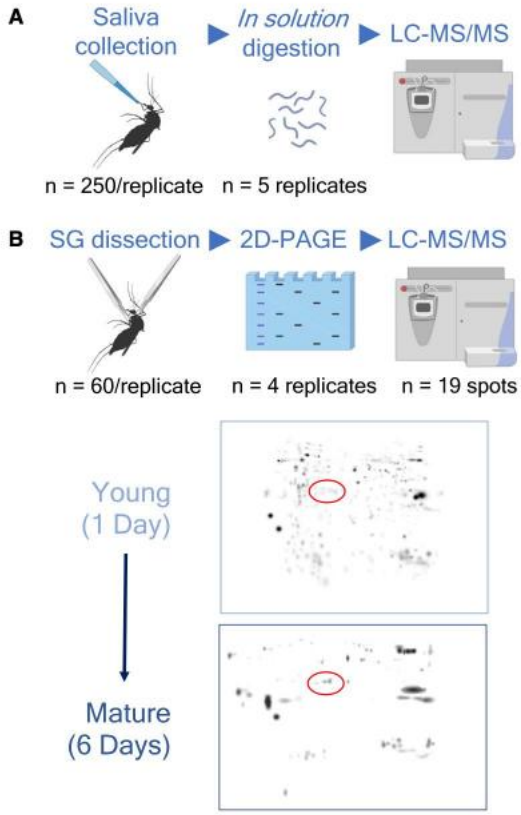
Q3: How do mosquitoes stop blood-feeding?

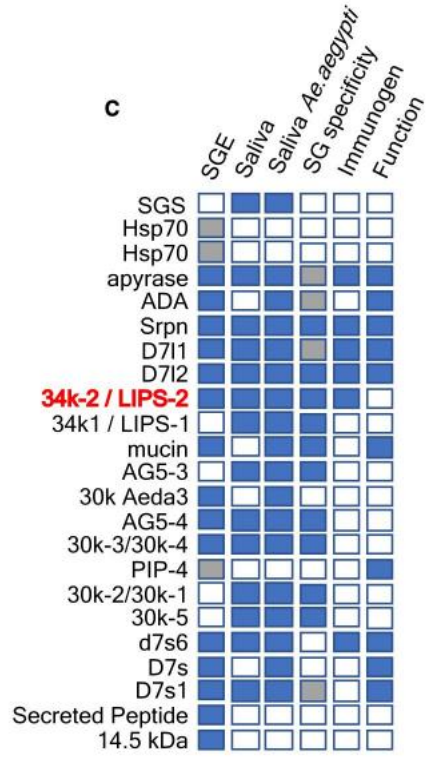
Risks always coexist with opportunities

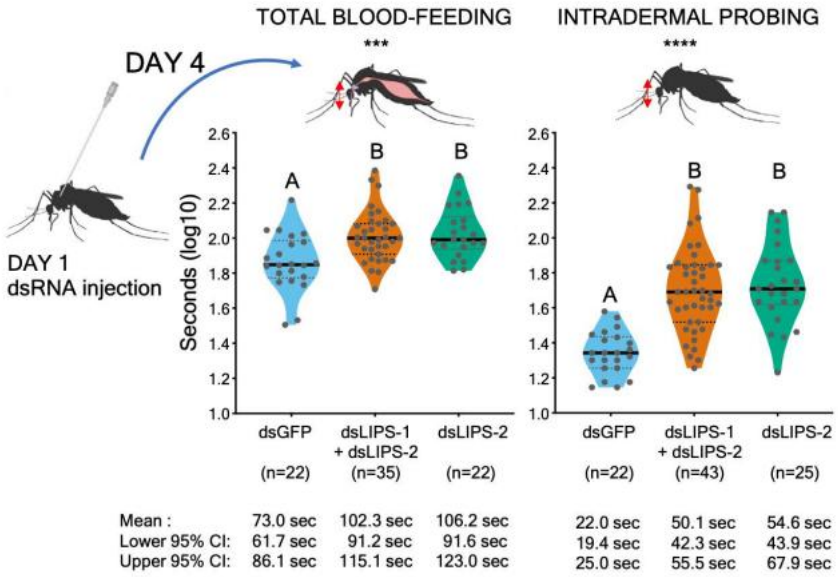


Blood-feeding initiation

The presence of LIPS proteins in Aedes saliva is critical for biting

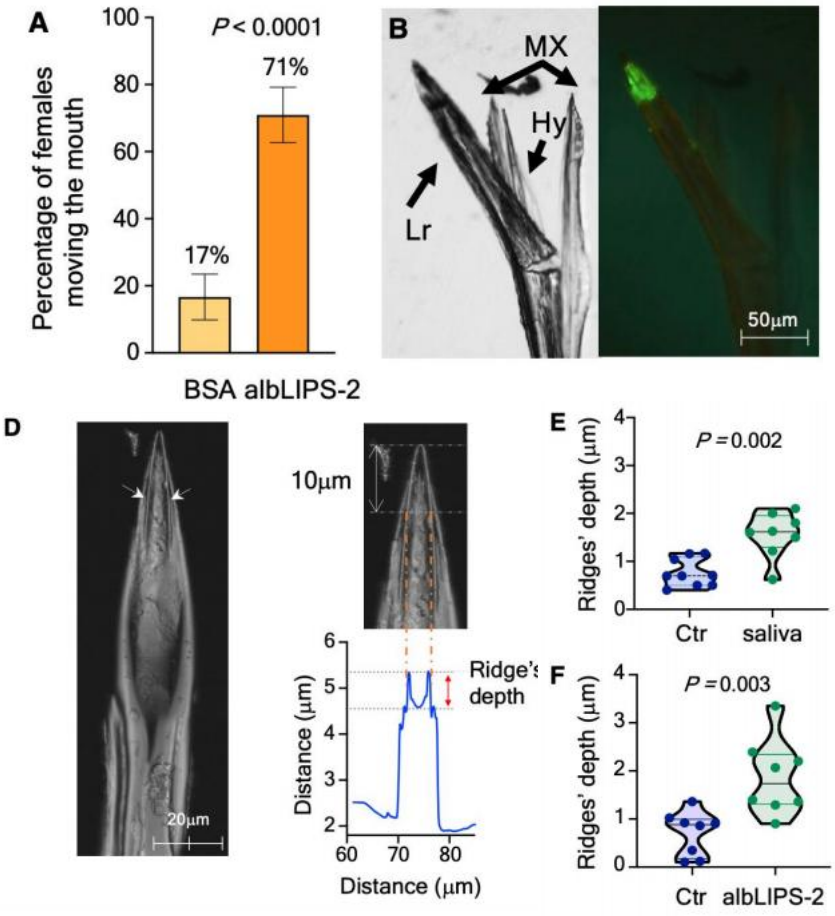


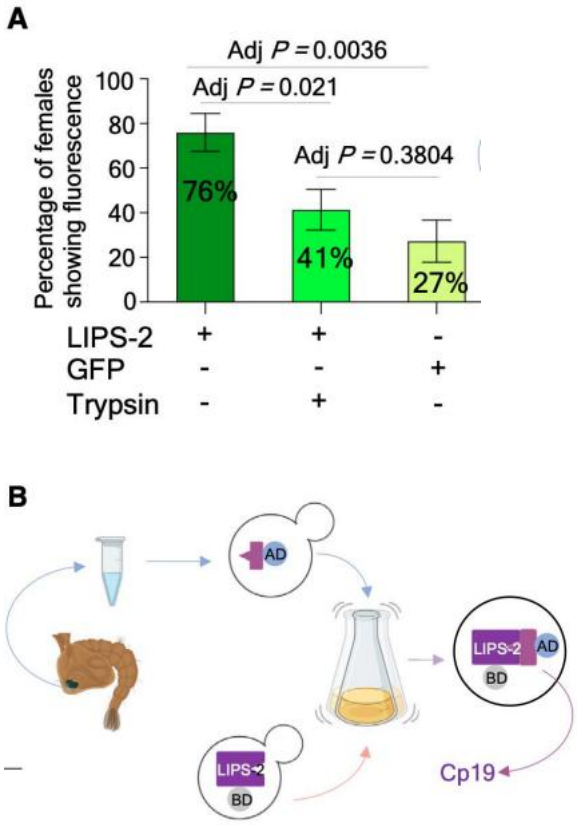


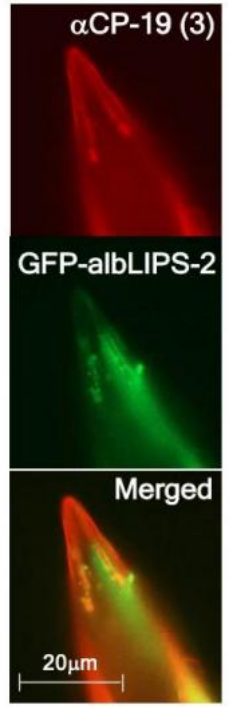


Arnoldi I, et al. Current Biology. 2022

LIPS-2 binding Cp19 causes a morphological change of the structures of the labrum



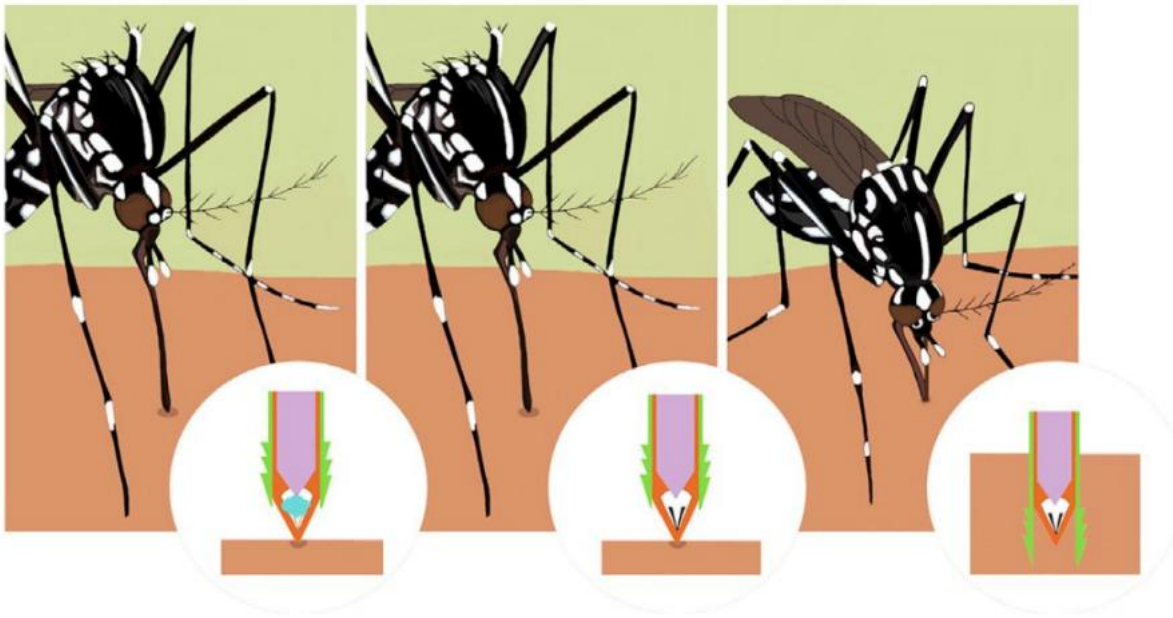




LIPS-2:CP19 interaction

Arnoldi I, et al. Current Biology. 2022

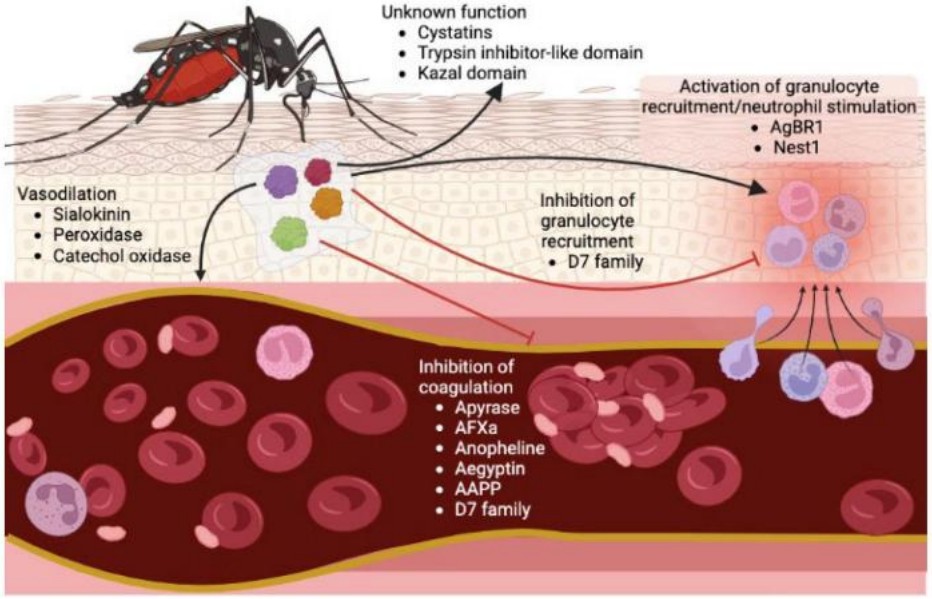
Initiation of Blood-feeding



Arnoldi I, et al. Current Biology. 2022

Salivary proteins facilitate mosquito blood feeding

Blood-feeding



Marín-López, A, et al. Pathogens. 2023

Host hemostasis:

- platelet aggregation
- vascular contraction
- blood clotting

Salivary proteins:

- D7 protein family
- sialokinin
- aegyptin
- adenosine deaminase

...

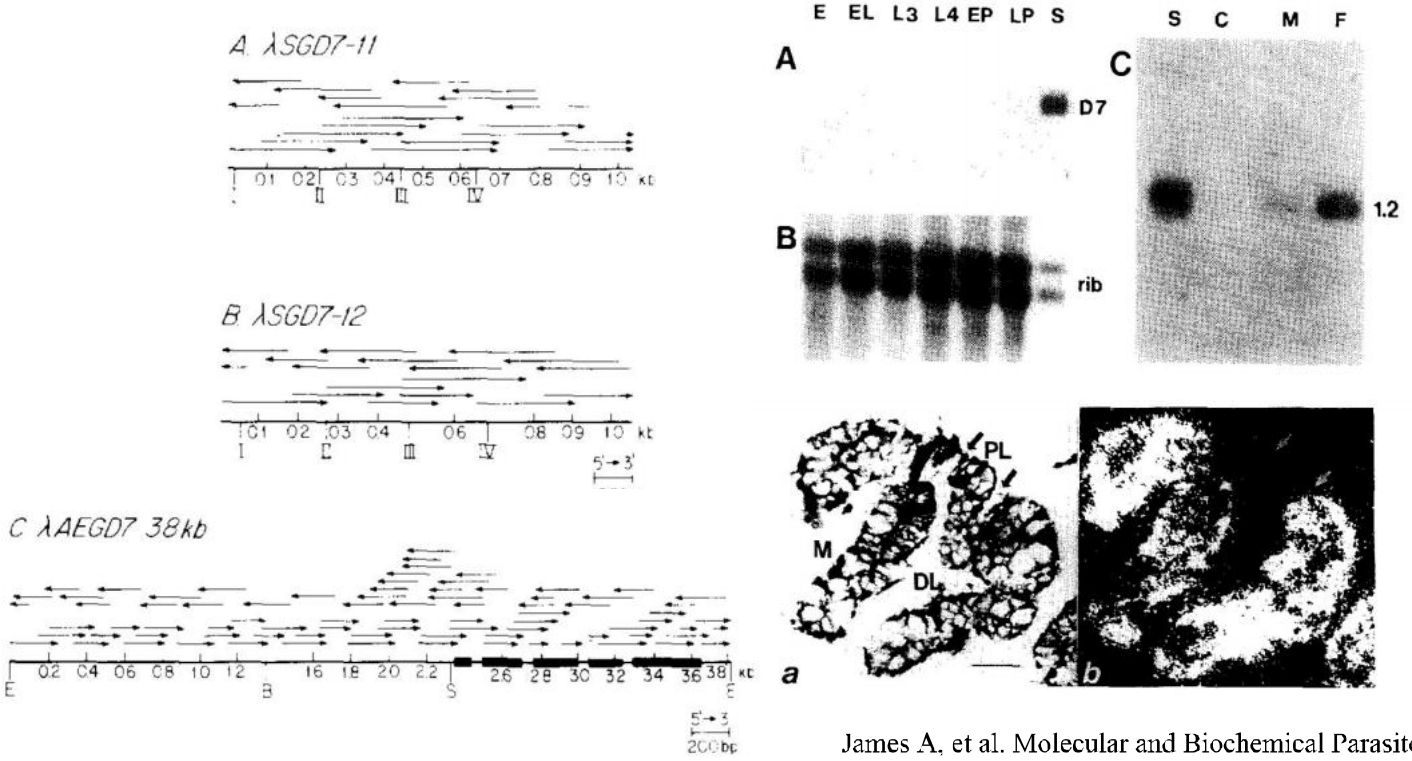
Isolation and characterization of the gene expressing the major salivary gland protein of the female mosquito, *Aedes aegypti*

Anthony A. James, Karen Blackmer*1, Osvaldo Marinotti*2, Corine R. Ghosn, and Jeffrey V. Racioppi*3

Department of Molecular Biology and Biochemistry, University of California, Irvine, CA, U.S.A.

(Received 13 July 1990; accepted 27 August 1990)

"sex- and stage-specificity"



James A, et al. Molecular and Biochemical Parasitolow. 1991

The feature of D7 Proteins:

1) widespread in hematophagous Diptera
(exclusively expressed in female salivary glands)

2) different length and amino acid sequence
(in different species and within the same species)

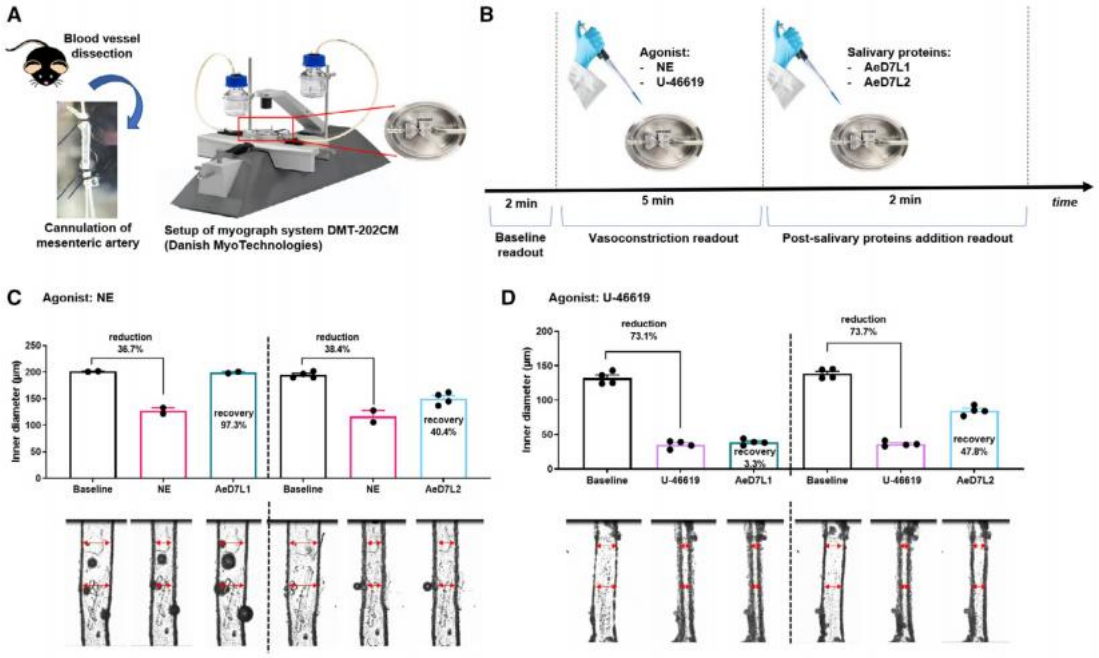
3) binding small hydrophobic molecules
(host responses : inflammation and hemostasis)

Ae. aegypti D7L 1 (AAEL006424)	**	3DXL
	Serotonin (0.39)	
	Norepinephrine (0.119)	3DYE
	Histamine (140)	
	Epinephrine (102)	
	LTC4 (57.4)	
	LTD4 (54.3)	
	LTE4 (60.2)	3DZT
	LTB4 (140)	
	No binding to U46619 TxA2	
Ae. aegypti D7L2 (AAEL006417)	Serotonin (1.68)	
	Norepinephrine (110)	
	Histamine (1130)	
	LTC4 (5270)	
	LTD4 (597)	
	LTE4 (1930)	
	LTB4 (769)	

Alvarenga, P.H. and Andersen, J.F. Biology. 2023

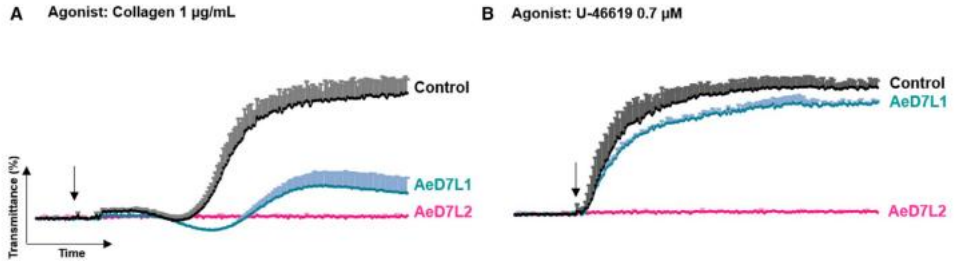
AeD7L1 and AeD7L2 interfere with vasoreactivity and platelet aggregation without compromising blood coagulation

vascular contraction

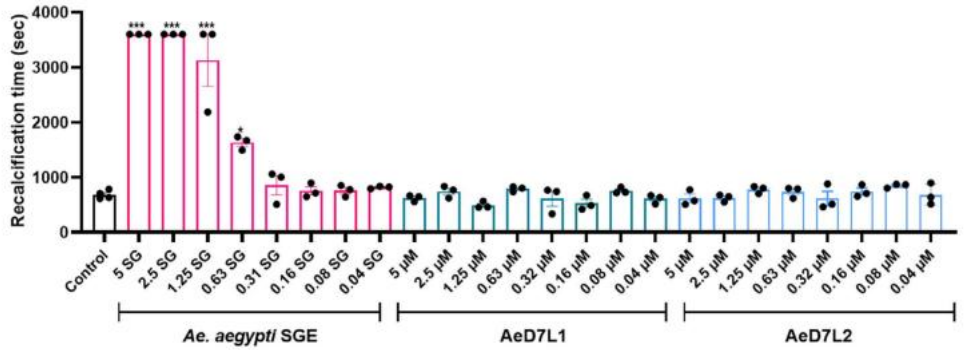


I. Martin-Martin et al. The FEBS Journal. 2021

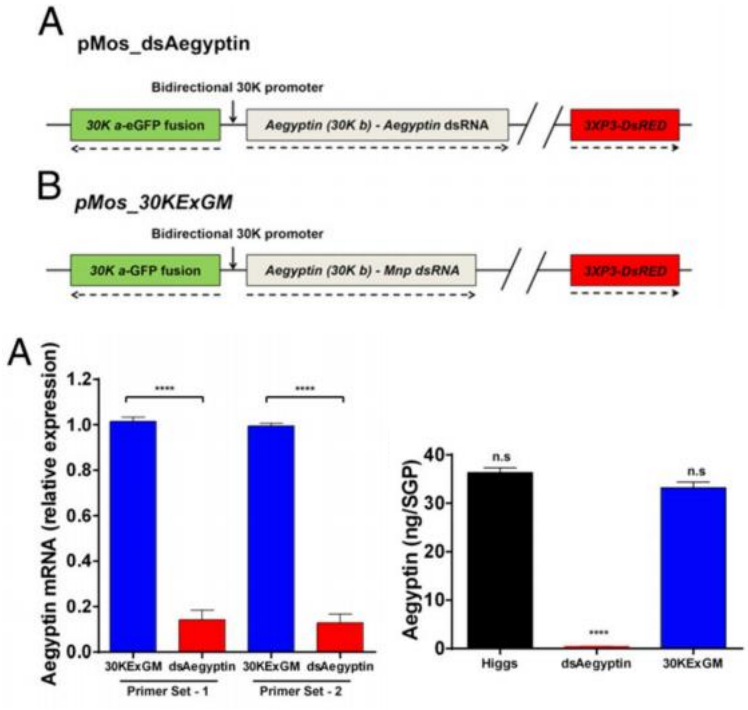
platelet aggregation



Not blood clotting

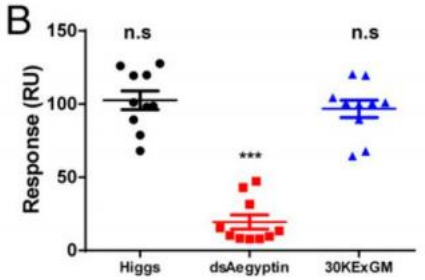


Aegyptin regulates probing time and blood feeding success via binding collagen

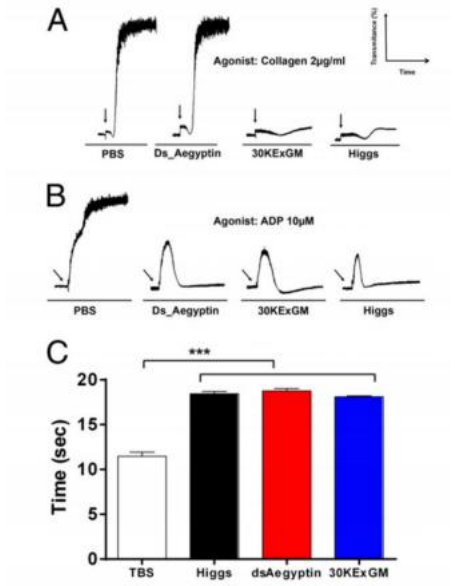


Chagas A.C, et al. PNAS. 2014

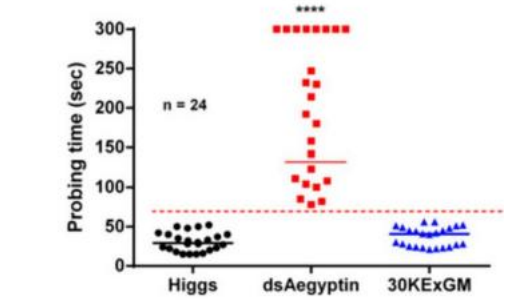
1) Collagen-Binding Activity



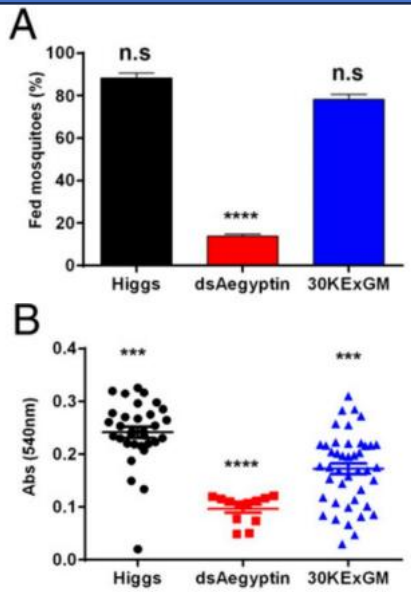
2) Platelet Aggregation & Blood Clot



3) Probing Time

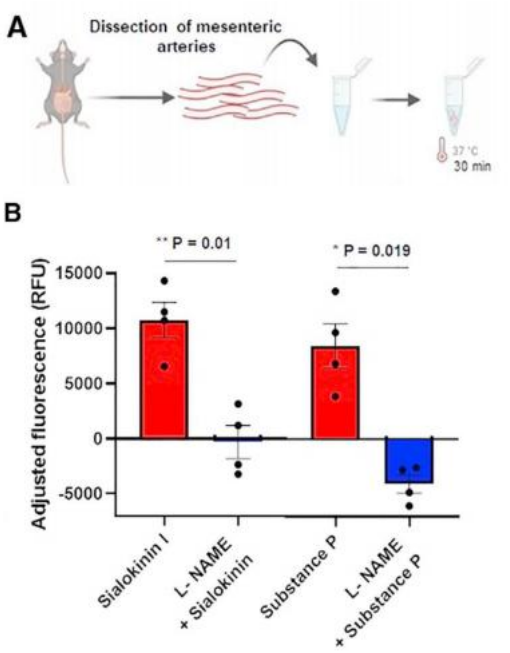


4) Feeding Success



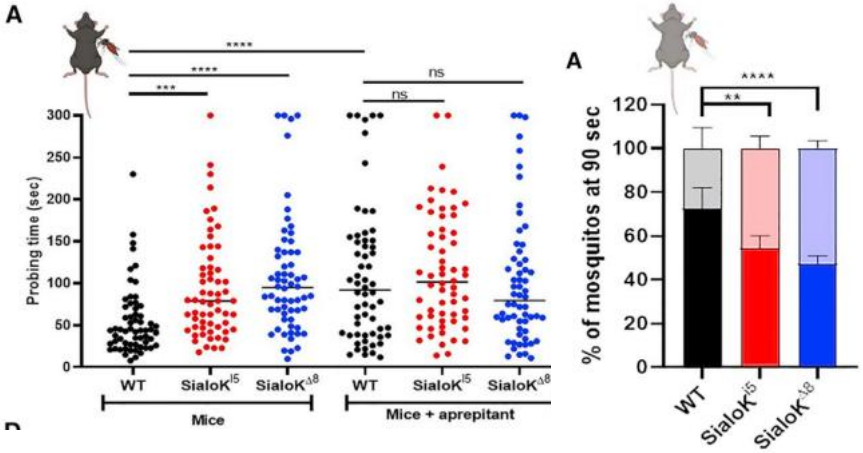
Sialokinin facilitates mosquito blood feeding

Induce nitric oxide release



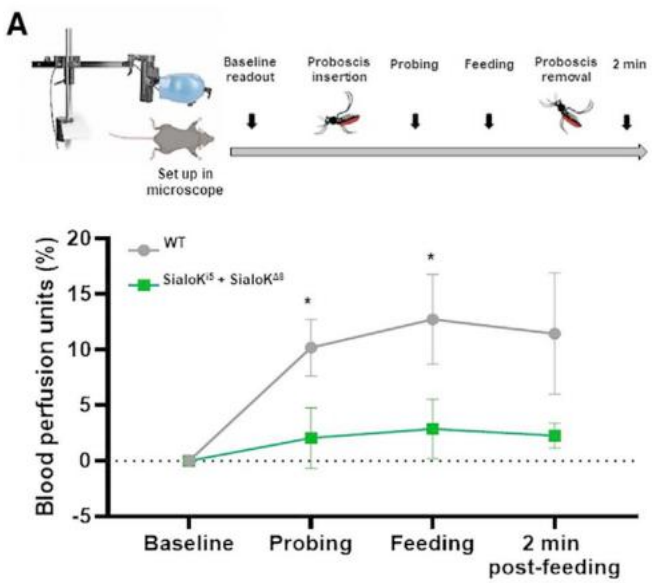
L-NAME: antagonist of NO synthase (NOS)

Interferes with host hemostasis via NK1R signaling



aprepitant: substance P receptor (NK1R) antagonist

Promotes blood perfusion at the bite site

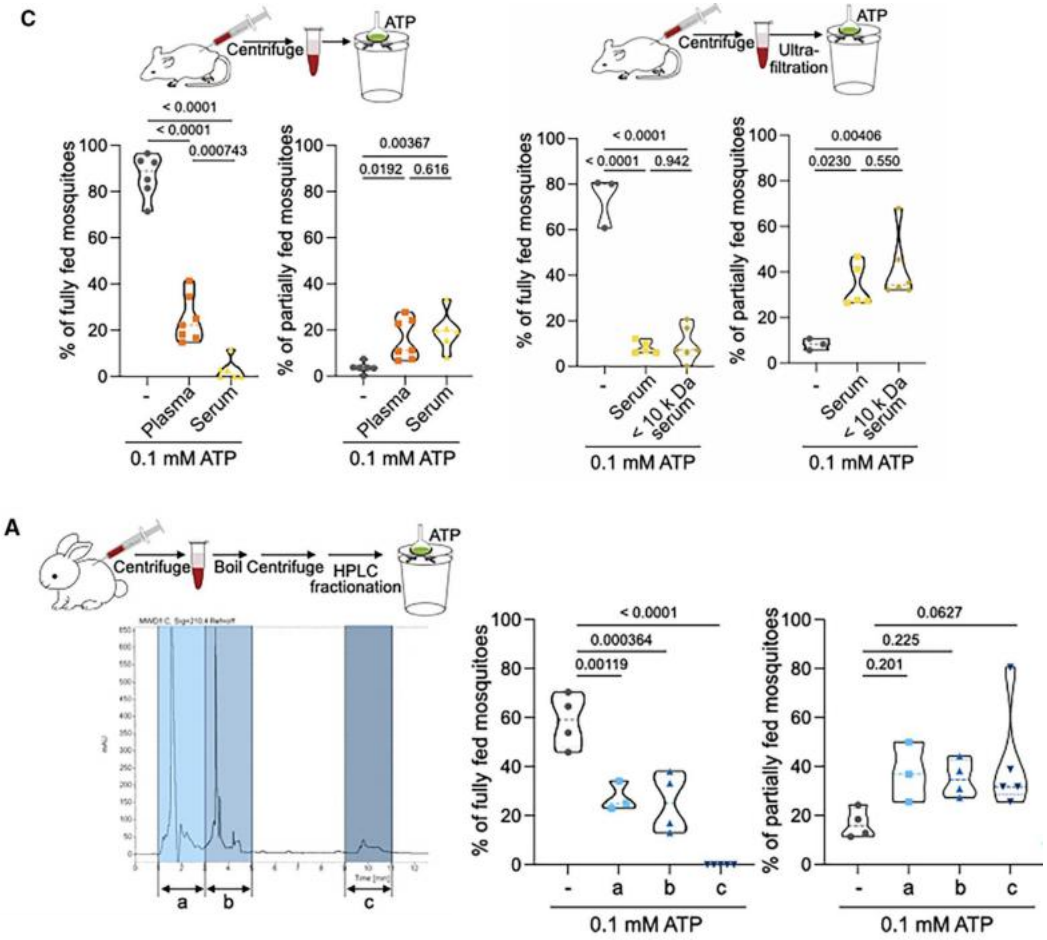


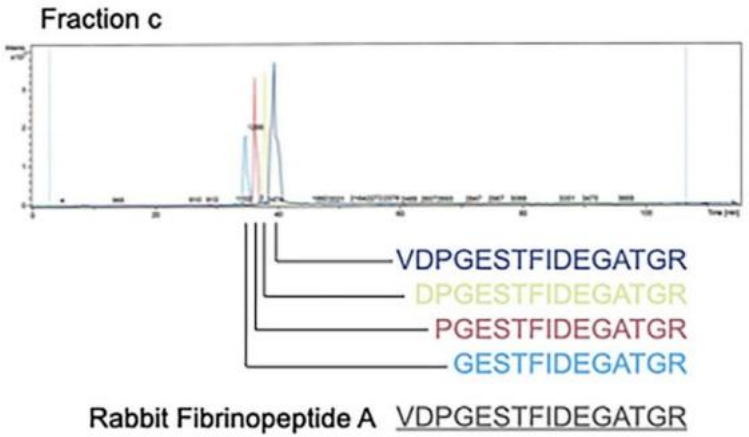
Ensures short probing time and successful blood feeding!

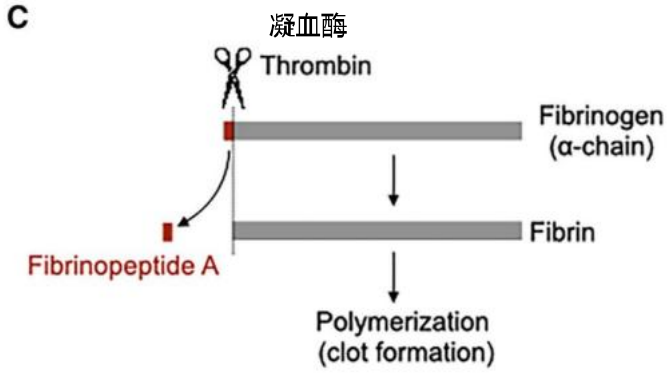
I. Martin-Martin et al. et al. Cell Reports. 2022

FPA from blood serum as a potential factor inhibiting blood feeding

Blood-feeding termination

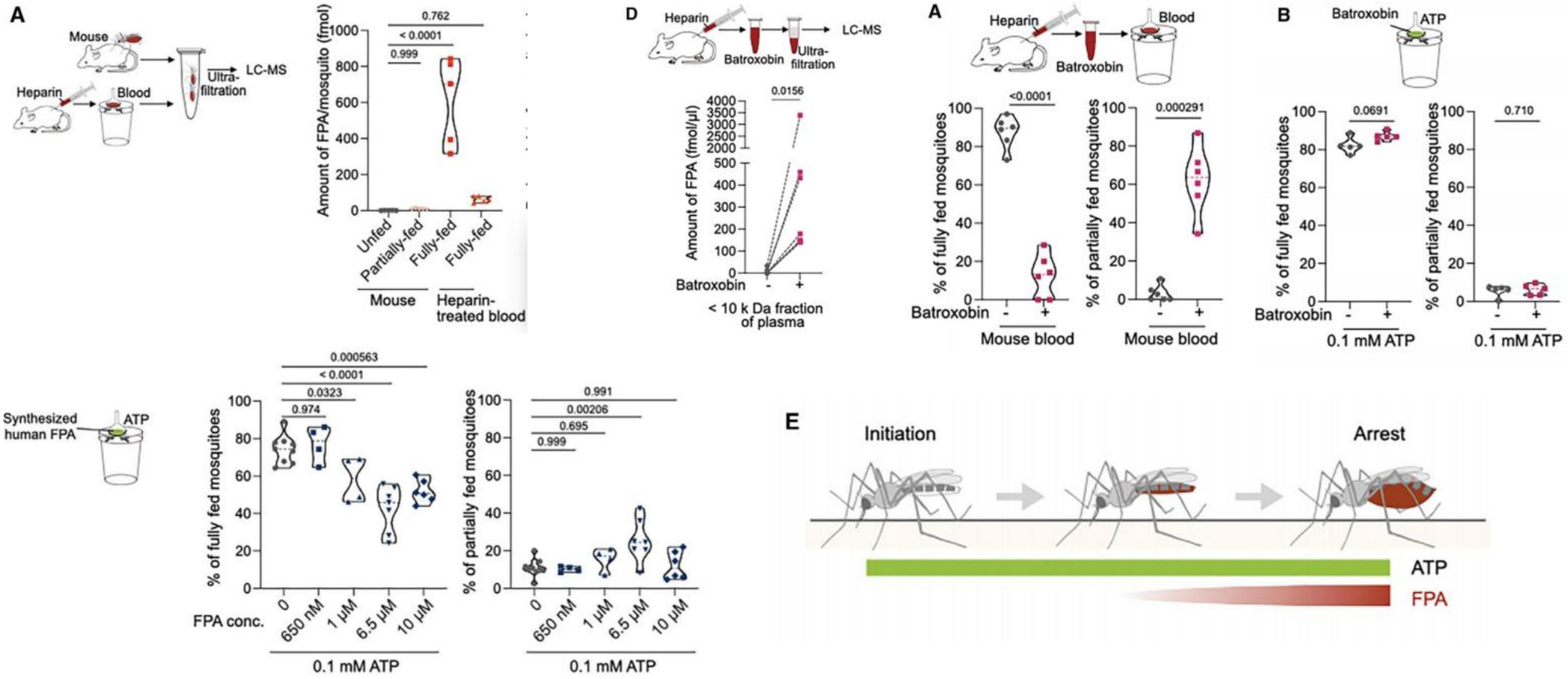






Sakuma C, et al. Cell Reports. 2024

FPA arrests the process of mosquito blood feeding



Sakuma C, et al. Cell Reports. 2024

Abdominal distension may participate in blood-feeding arrest

REGULATION OF BLOOD MEAL SIZE IN THE MOSQUITO*

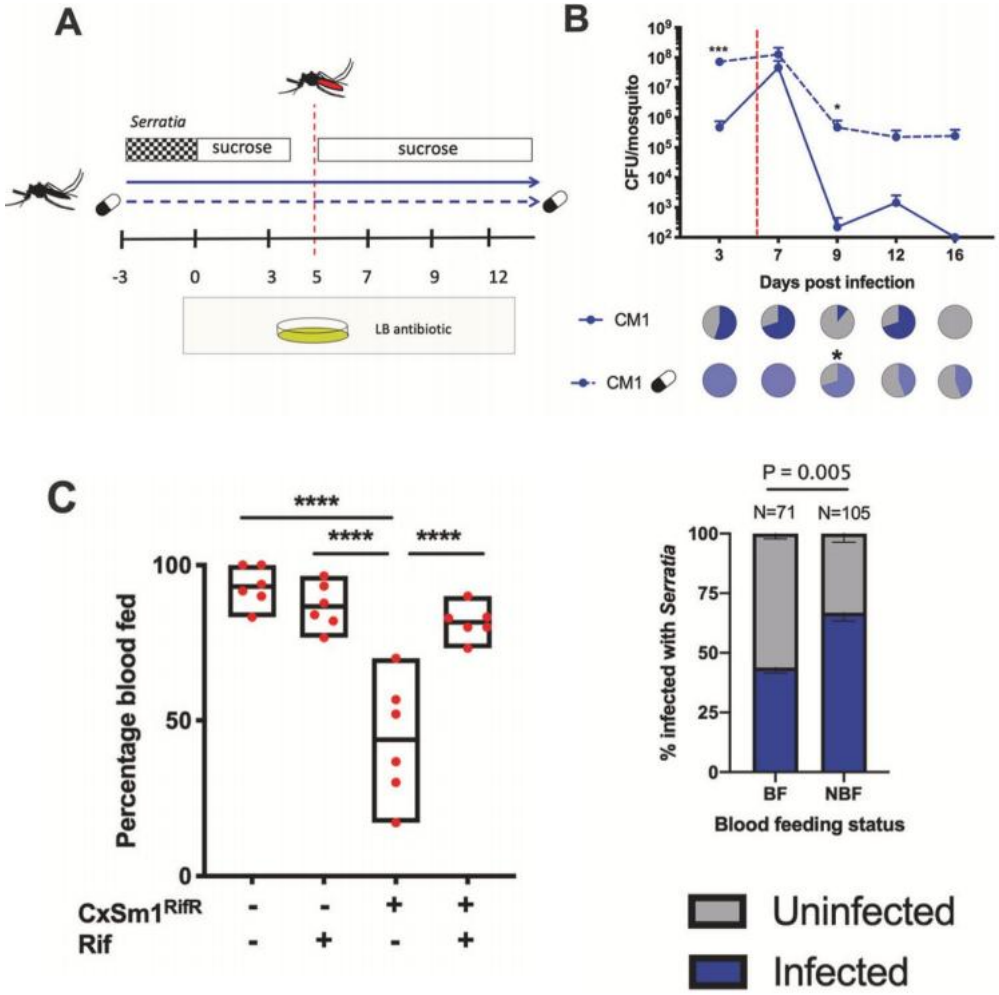
ROBERT W. GWADZ

Department of Biology, University of Notre Dame,
Notre Dame, Indiana 46556

(*Received* 14 *June* 1969)

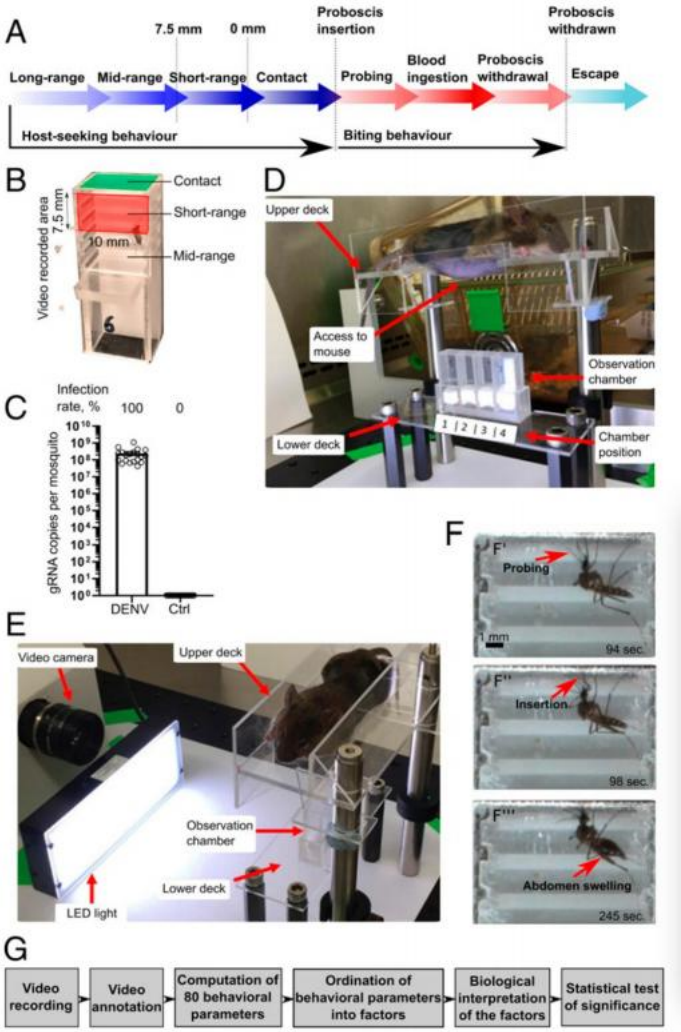
Treatment: Ventral nerve cord cut anterior to abdominal ganglion	No. females/ treatment	Mean for treated females (±95% confidence limits) Feeding time (min)	Blood meal weight (mg)	No. of eggs developed
No. 2	76	5·31 ± 0·24	11·99 ± 0·51	103·28 ± 4·31*
No. 3	42	3·21 ± 0·32	7·63 ± 0·70	97·17 ± 4·01
No. 4	36	2·69 ± 0·22	5·14 ± 0·40	92·32 ± 2·81
No. 5	40	2·19 ± 0·16	4·23 ± 0·46	88·88 ± 4·25
No. 6	36	1·98 ± 0·18	3·61 ± 0·21	87·14 ± 4·39
Sham-operated†	62	1·76 ± 0·11	2·93 ± 0·18	85·78 ± 3·03
No treatment‡	64	1·79 ± 0·10	2·85 ± 0·26	86·07 ± 3·30

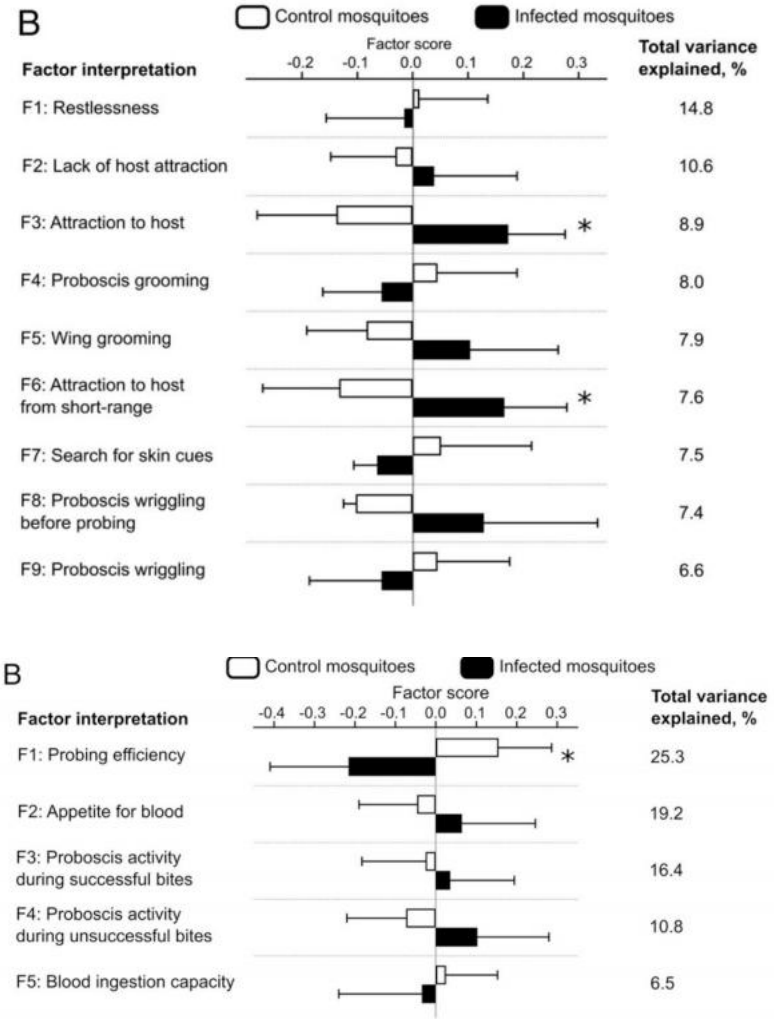
Microbial interactions in the mosquito gut determine blood-feeding behavior

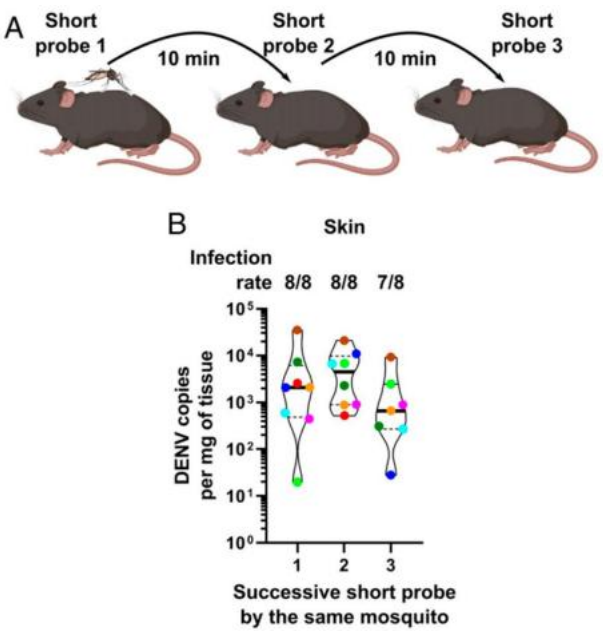


Kozlova E.V, et al. The ISME Journal. 2021

DENV Infection increases host attraction and frequency of infectious probes

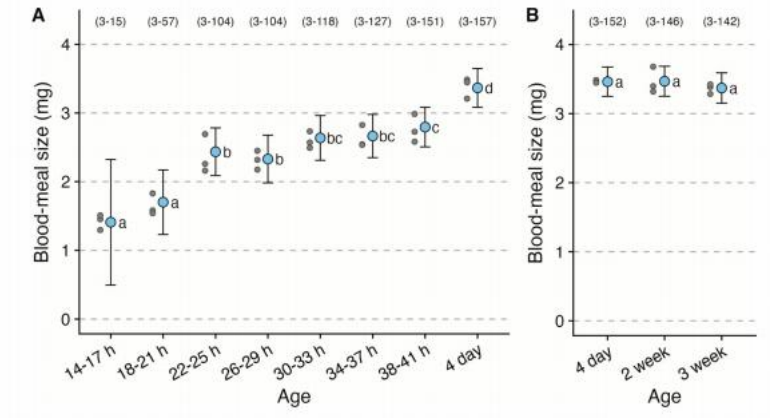




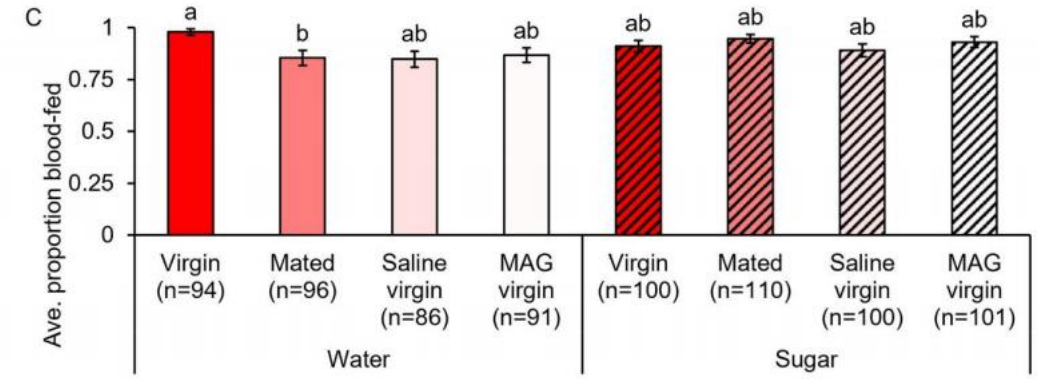


WeiXiang, etal. PNAS. 2022

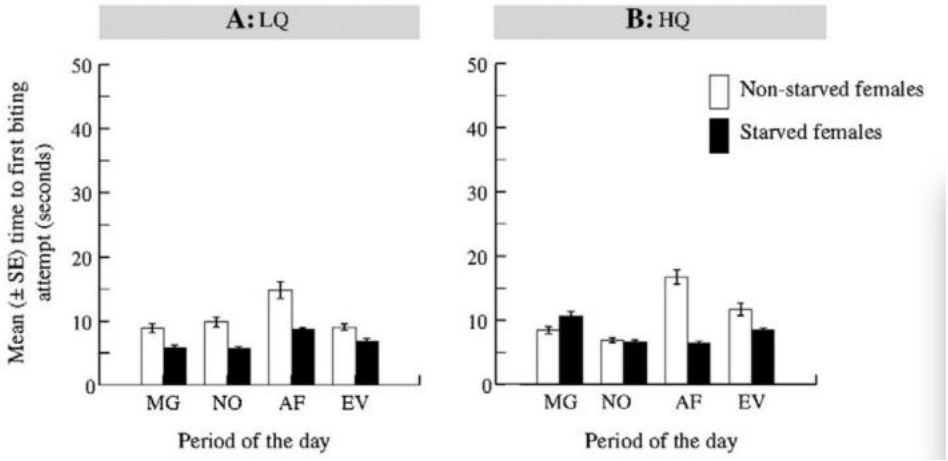
Physiological relevance in blood feeding



Ramírez-S´anchez L.F. et al. Journal of Insect Physiology. 2023



League G.P., et al. PLOS NEGLECTED TROPICAL DISEASES. 2021



Dieng H., et al. Journal of Asia-Pacific Entomology. 2015

Summary:

- The LIPS-2 in the saliva binding Cp19 causes a morphology change of the structures of the labrum.
- Saliva contains many bioactive molecules that promote blood feeding by inhibiting hemostasis.
- There are negative controls arresting blood-feeding. eg. FPA, stretch receptors.
- Bacterial flora and disease pathogens change probing efficiency.
- Physiological state affects blood feeding.

Mechanisms of external factors affecting mosquito feeding

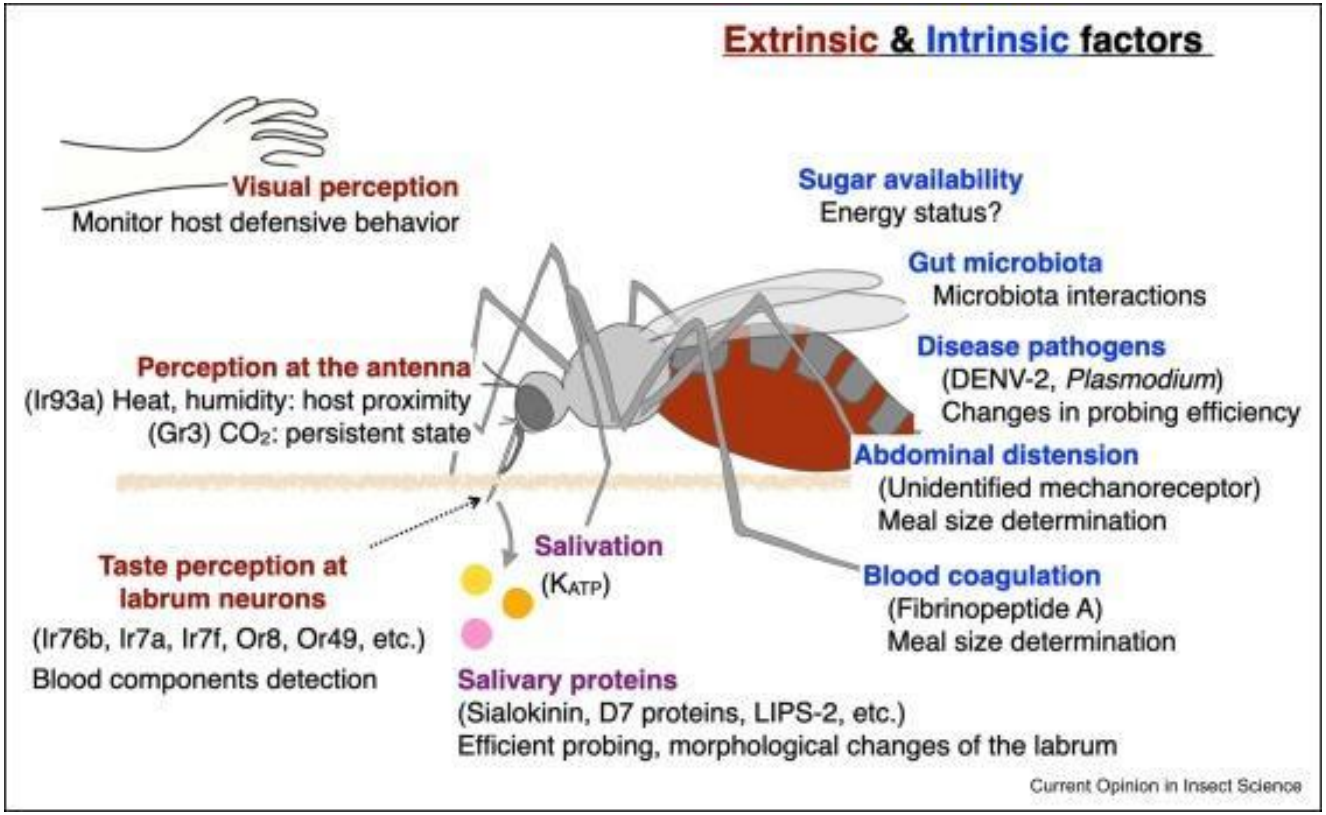
姜思梅

2024.9.26

Contents

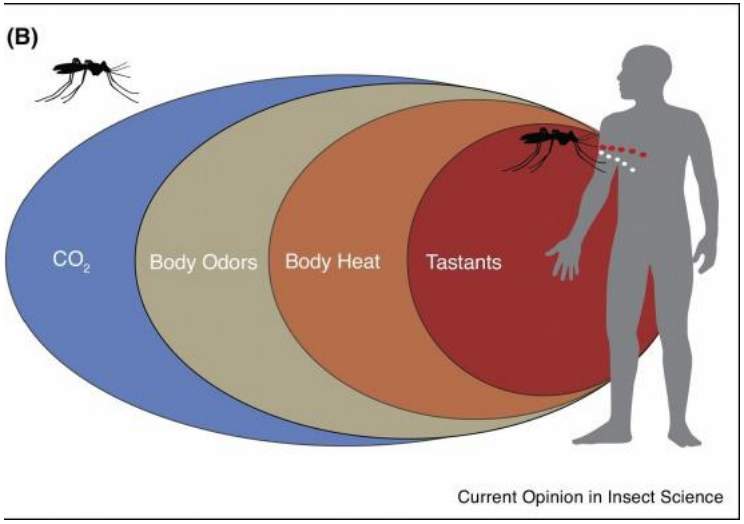
Which external factors affect mosquito feeding?

- Vision：host defensive behavior
- Olfaction：host's skin odour, CO_2
- Gustation：the taste and the quality of host blood
- Environmental factors：temperature, humidity, light

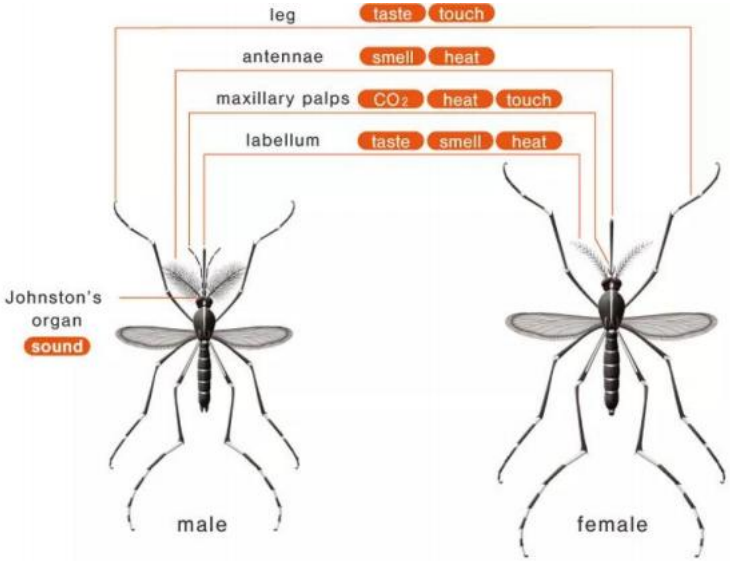


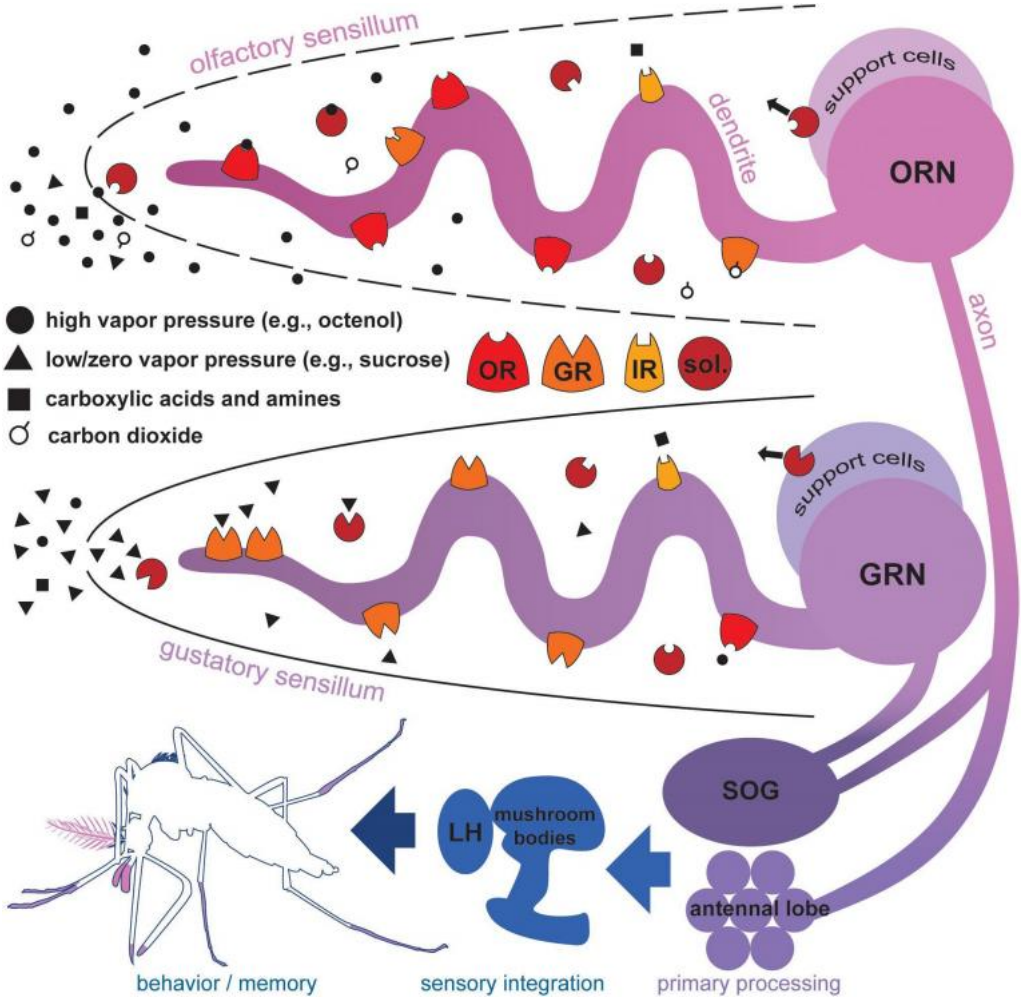
Kato Yusuke, et al. *Curr Opin Insect Sci*. 2024

How do these factors affect mosquito feeding?



Raji JI, et al. *Curr Opin Insect Sci.* 2017



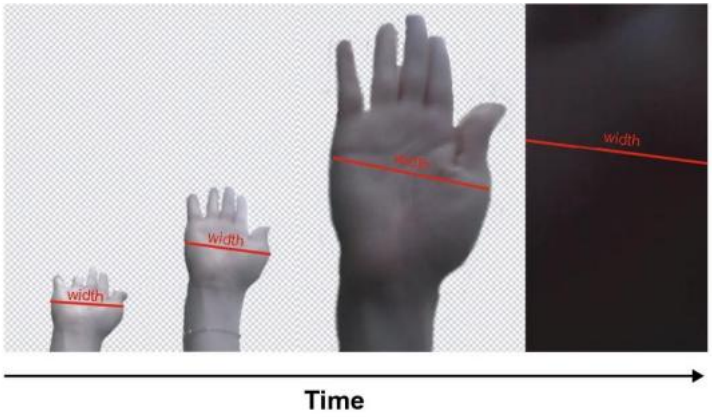


Sparks JT, et al. *Front Physiol.* 2018

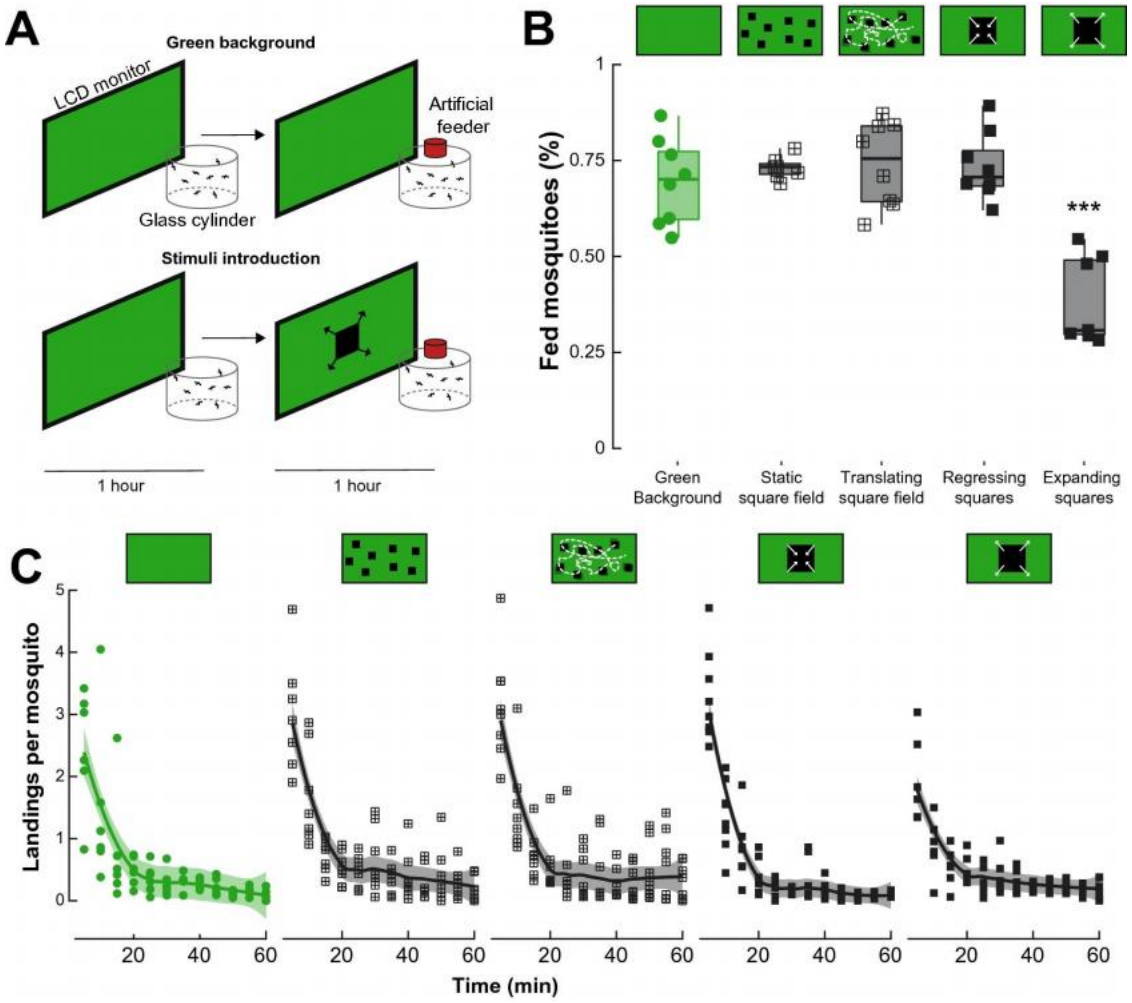
- **Vision**

Visual motion reduces feeding, but not landing in *Aedes aegypti*

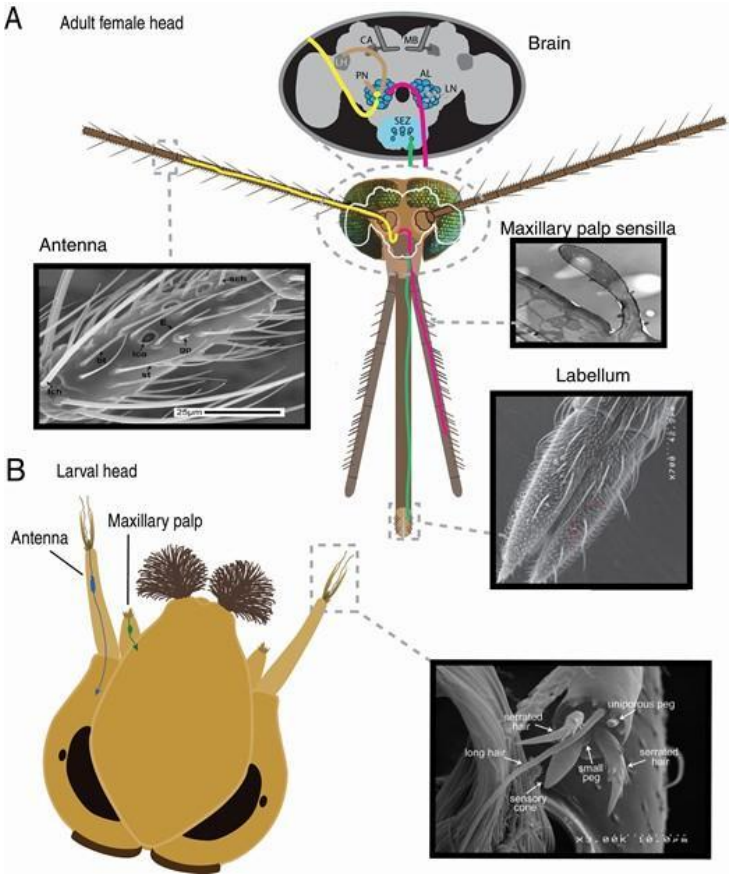
拍手
- 空气流动（机械成分）
- 视野中物体的快速扩张（视觉成分）



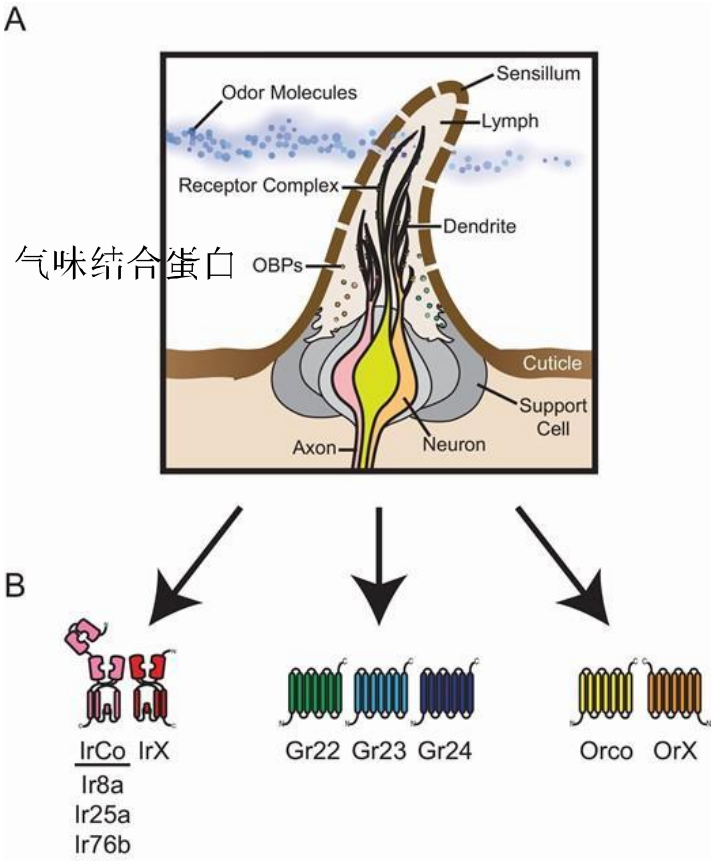
Wynne NE, et al. *Sci Rep*. 2022



- **Olfaction**



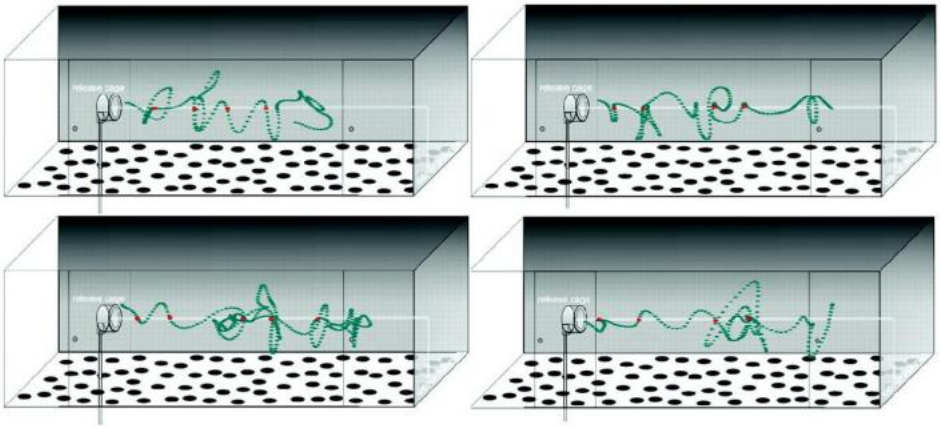
按蚊嗅觉系统示意图



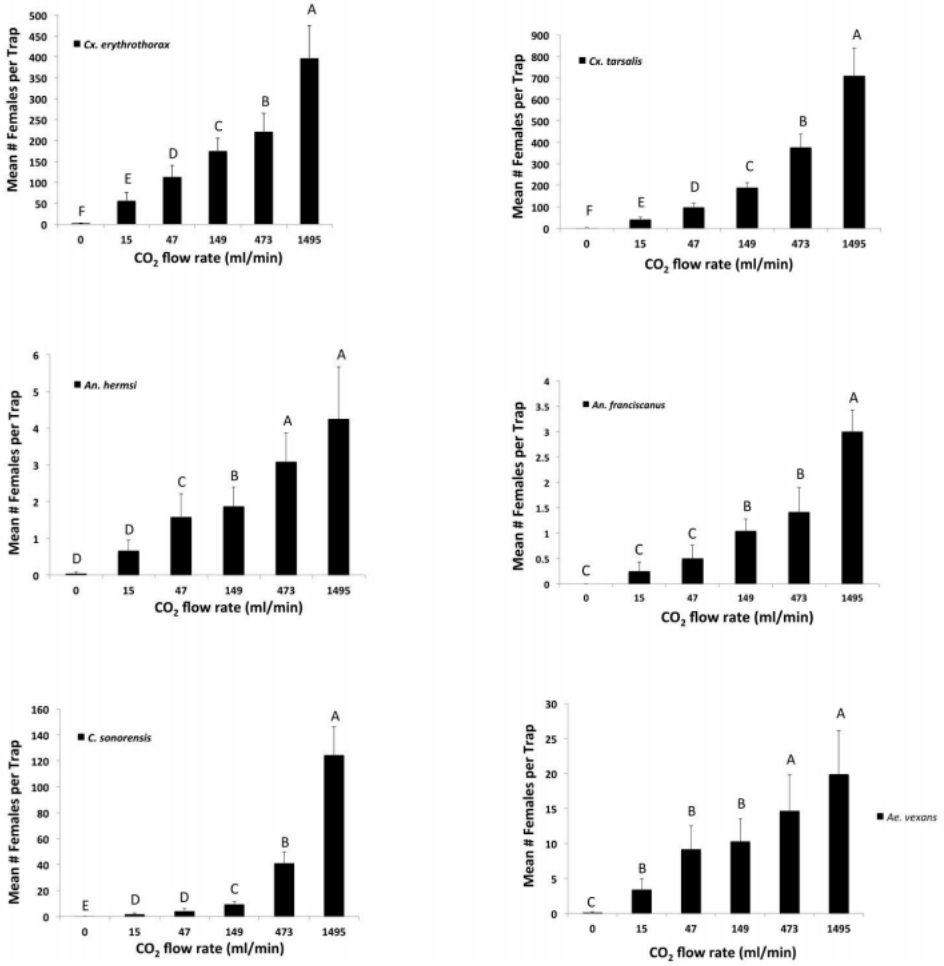
按蚊的感觉器和嗅觉受体的解剖结构

Konopka Joanna K, et al. *Chem Senses*. 2021

CO_2 is highly attractive to mosquitoes and causes behavioral changes

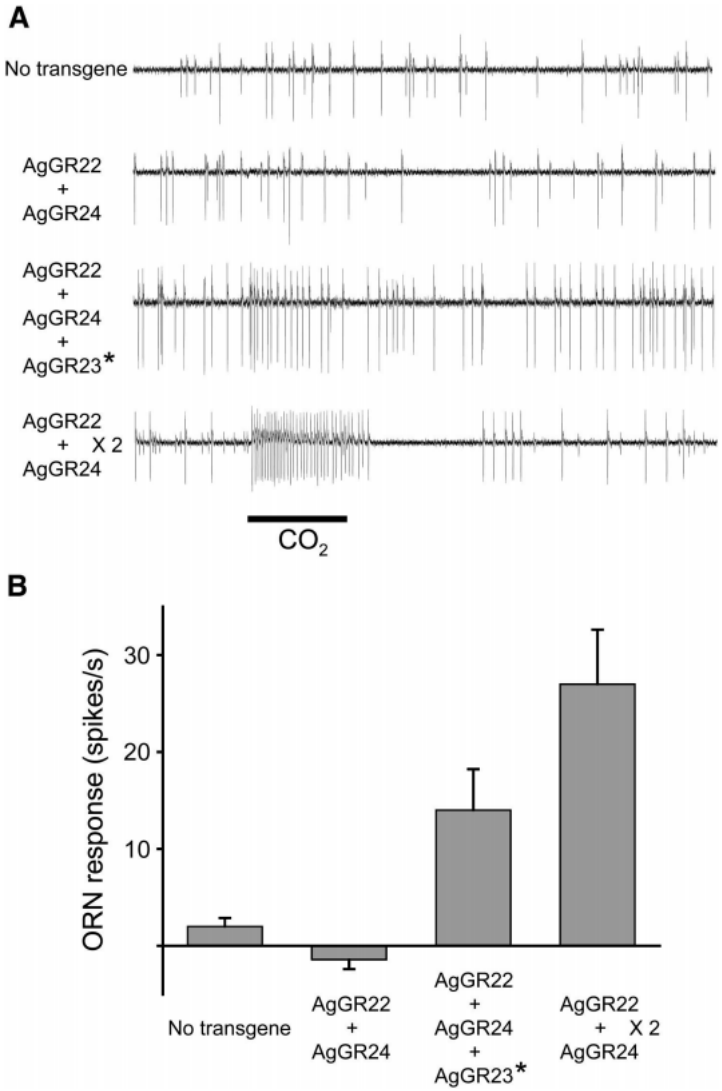


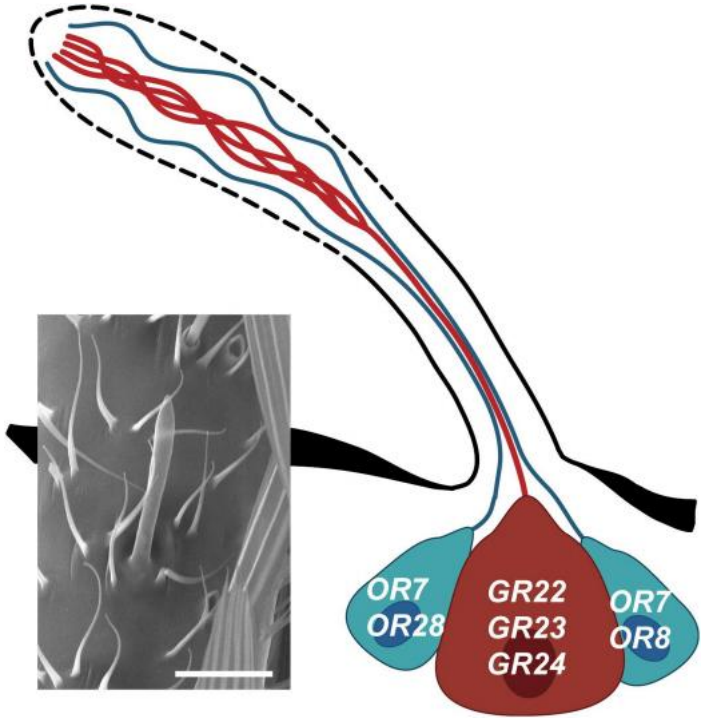
Dekker T, et al. *J Exp Biol*. 2011



McPhatter L, et al. *J Vector Ecol*. 2017

An ORN that expresses three receptors in the maxillary palp mediates the response to CO_2

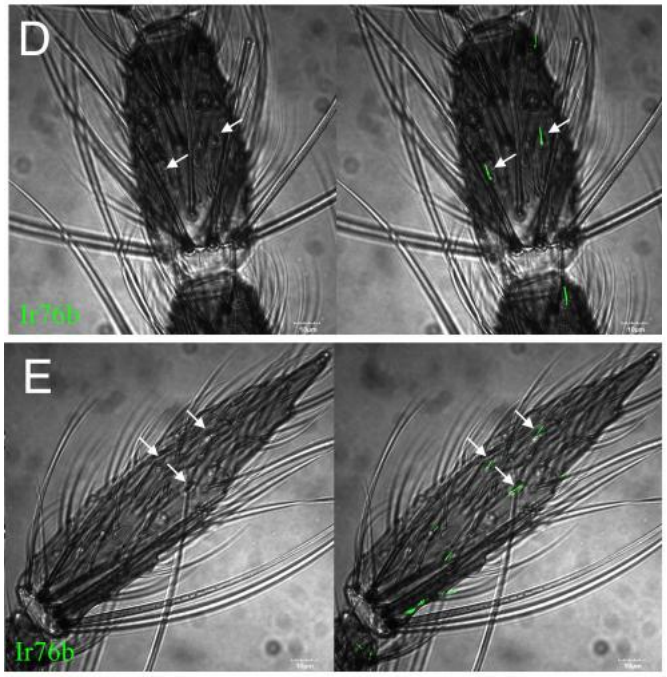


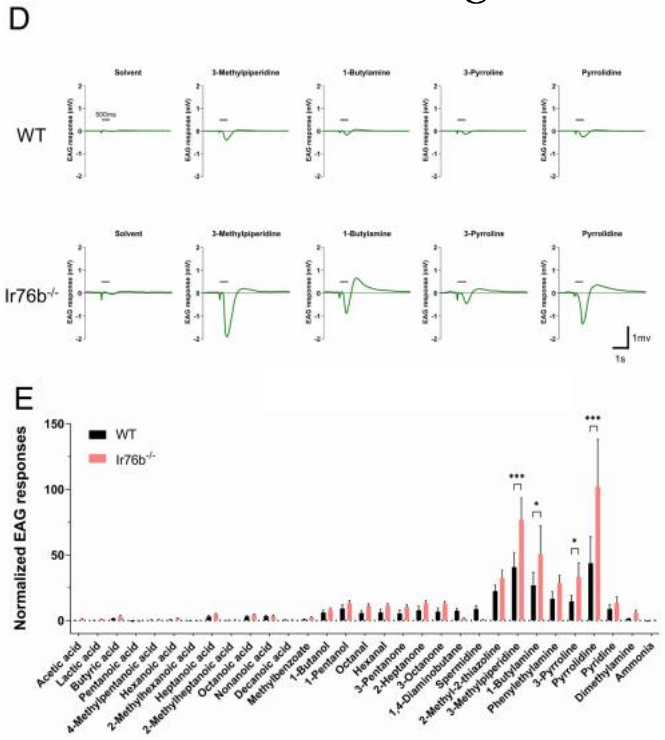


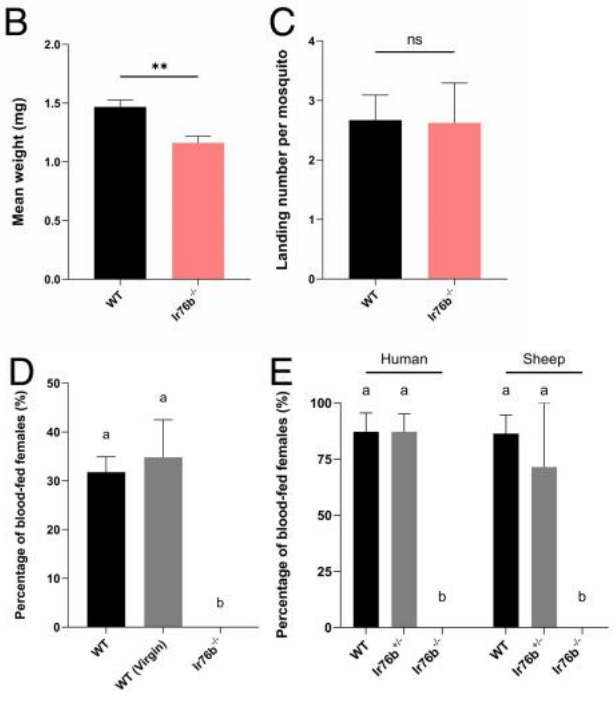
三种ORNs在下颚须的感觉器中形成固定的三联体形式

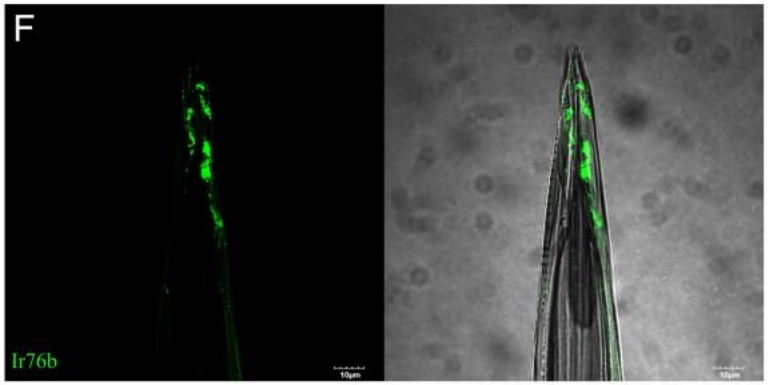
Lu T, et al. *Curr Biol*. 2007

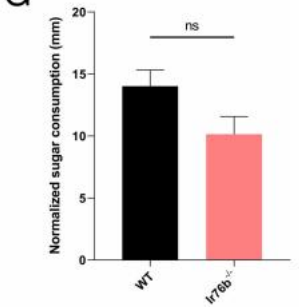
Ir76b ionotropic coreceptor impact olfaction and blood feeding in the mosquito *Anopheles coluzzii*





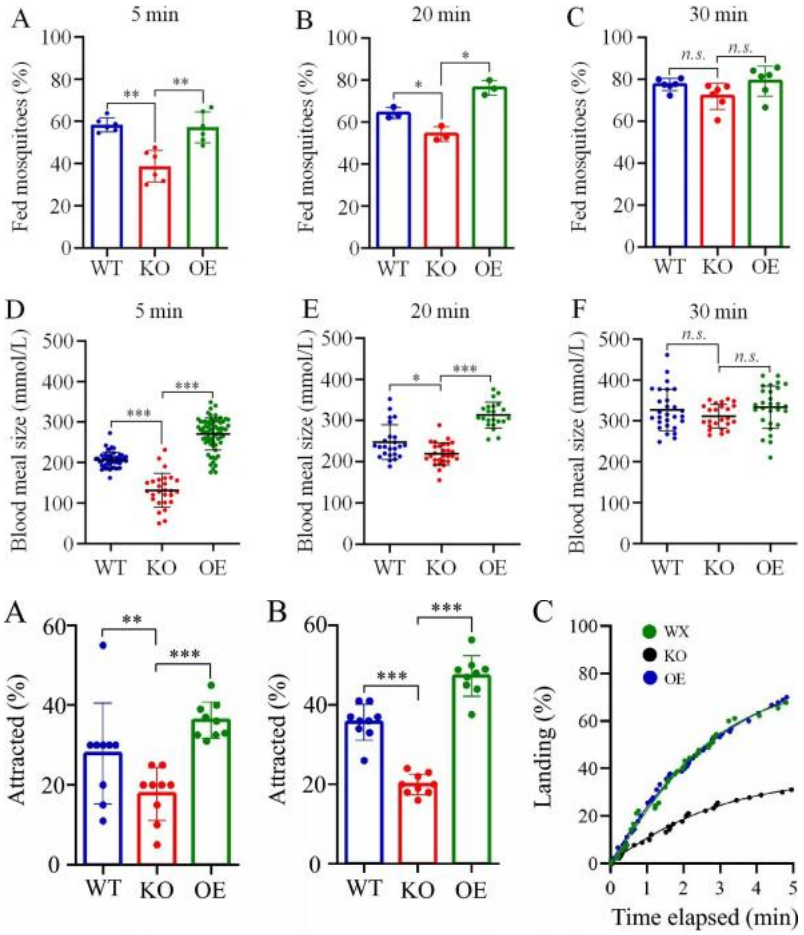


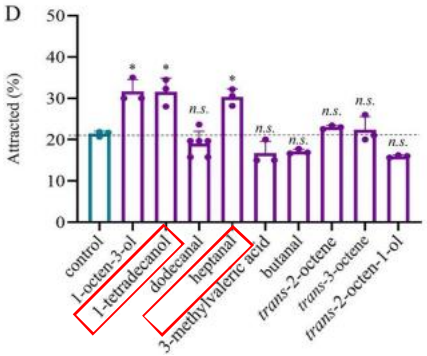


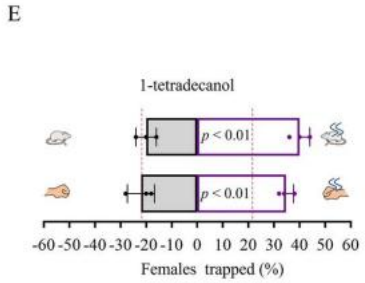


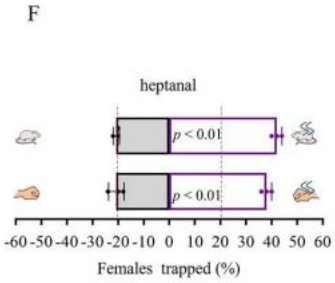
Ye Z, et al. *PNAS*. 2022

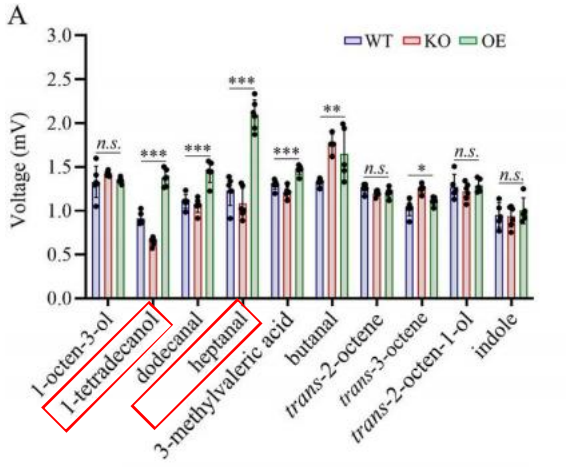
AsOBP1 is required for host seeking in the *Anopheles sinensis*







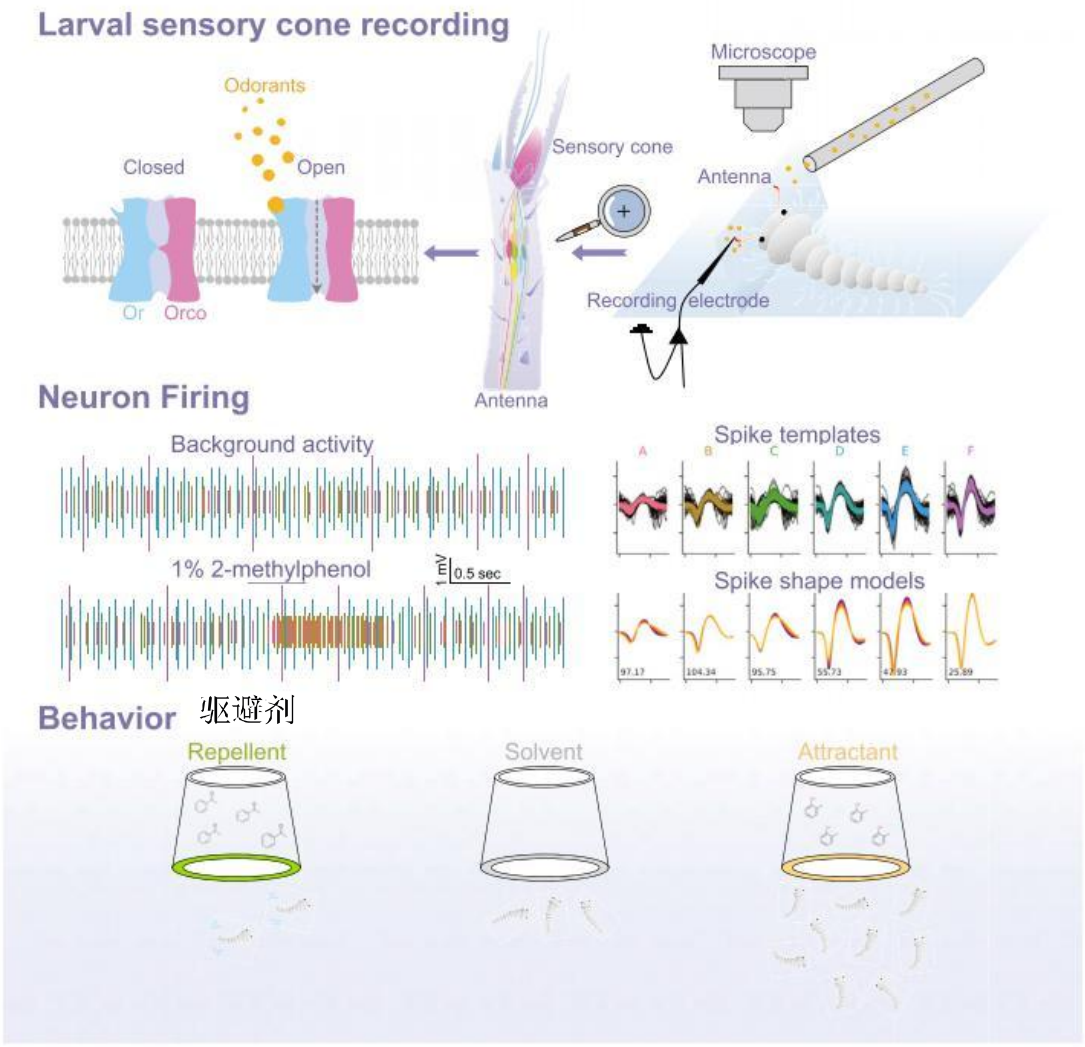


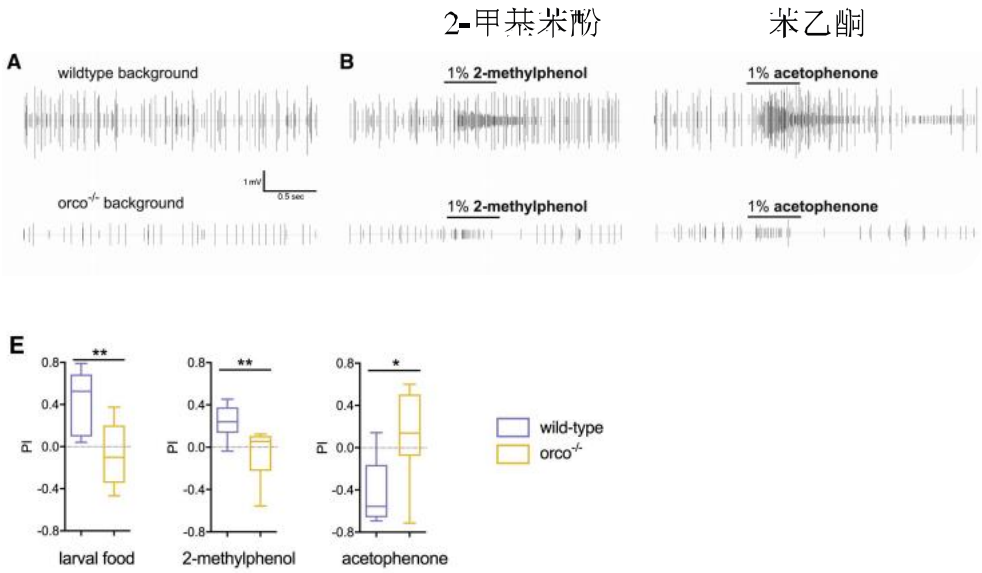


1-tetradecanol：正十四醇
heptanal：庚醛

Zhang JJ, et al. *J Pest Sci*. 2024

Neuronal and behavioral responses to volatiles from aquatic habitats are Orco-mediated in mosquito larvae

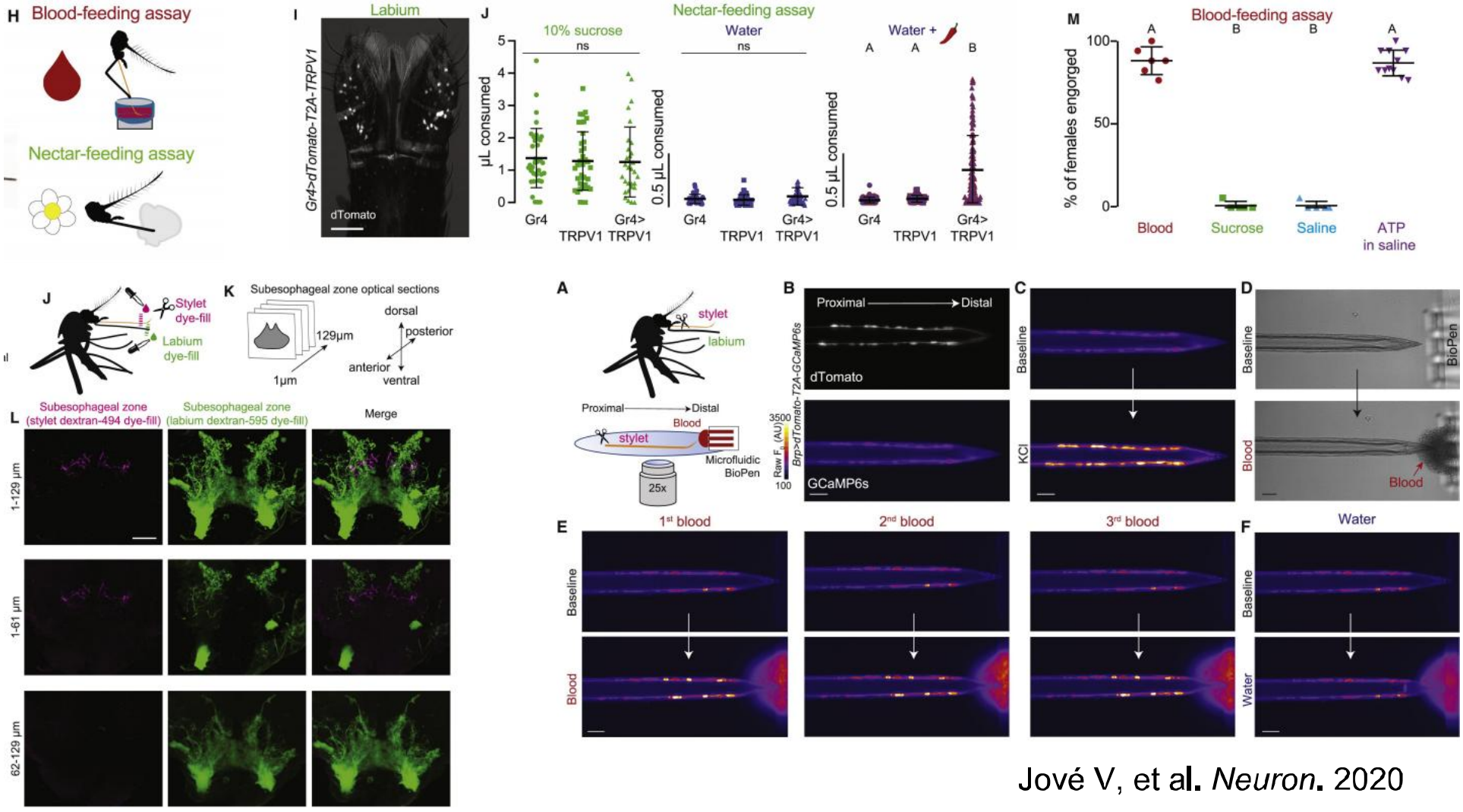




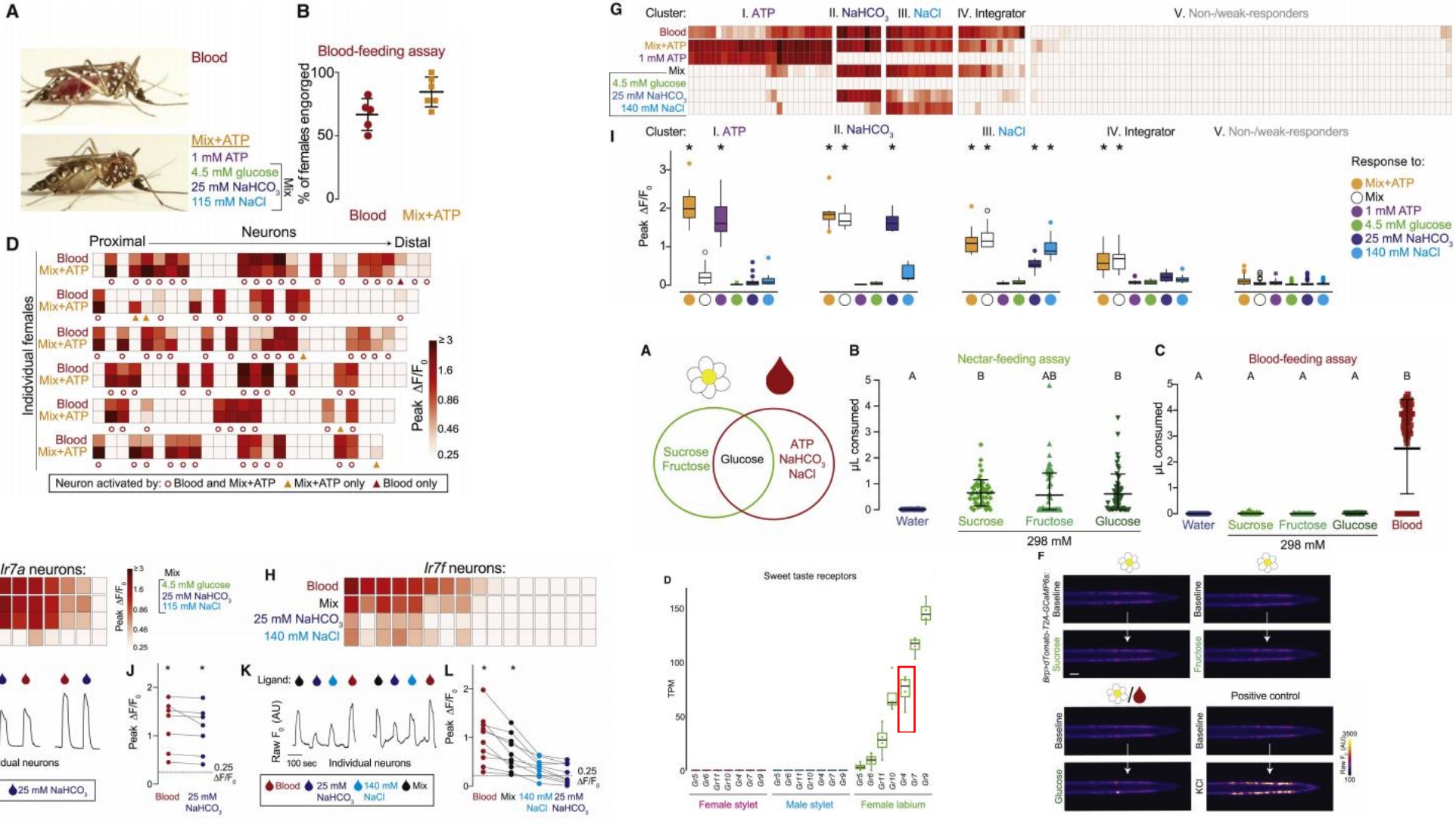
Sun HH, et al. *Cell Rep*. 2021

- **Gustation**

Gustatory sensory discrimination of blood and floral nectar by *Aedes aegypti*

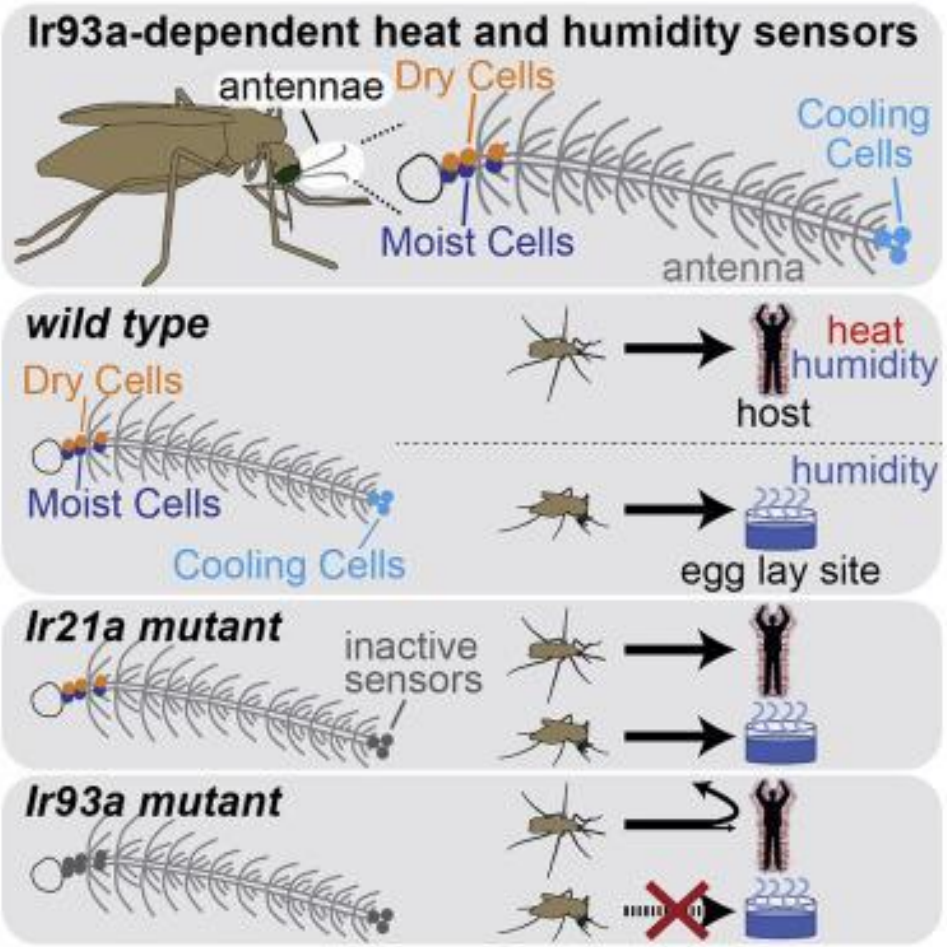


Jové V, et al. *Neuron*. 2020

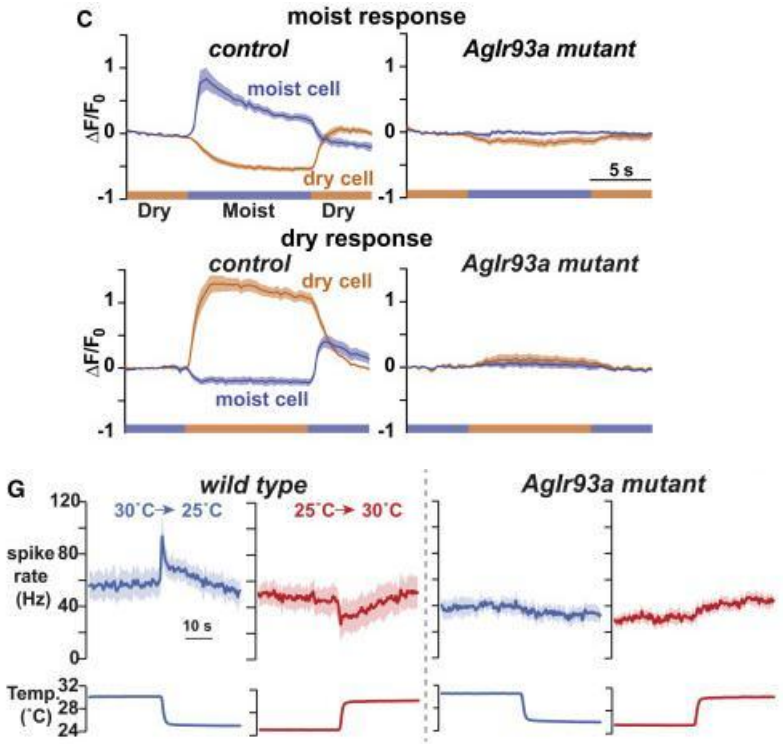


Jové V, et al. *Neuron*. 2020

- **Environmental Conditions**

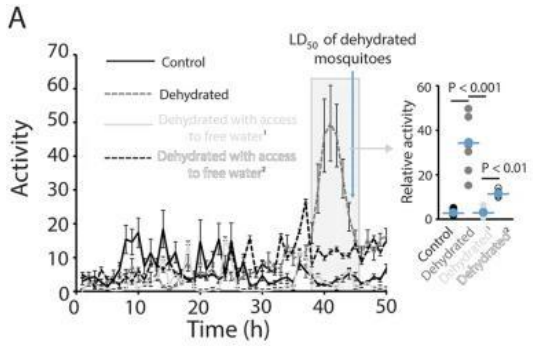


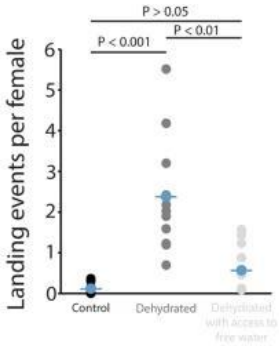
***AgIr93a* mediates hygrosensation and thermosensation**

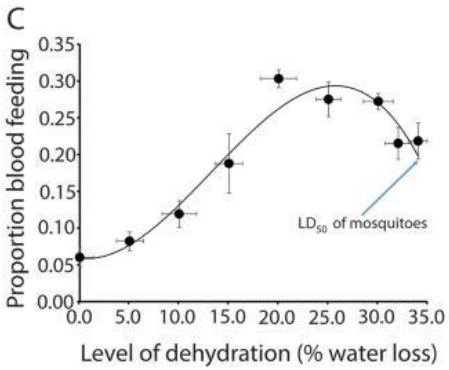


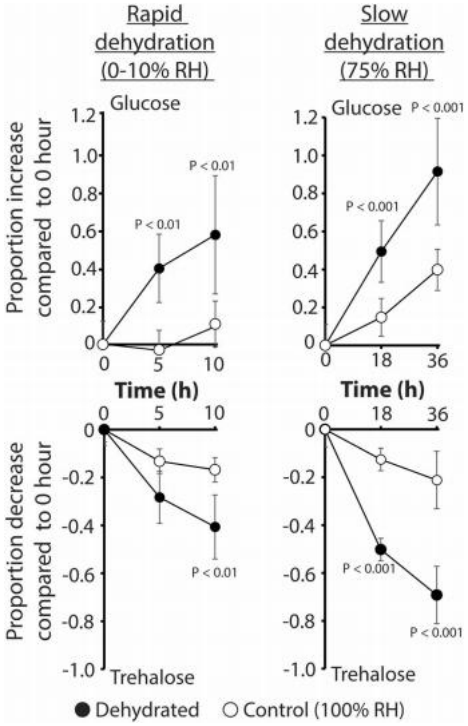
Laursen WJ, et al. *Neuron*. 2023

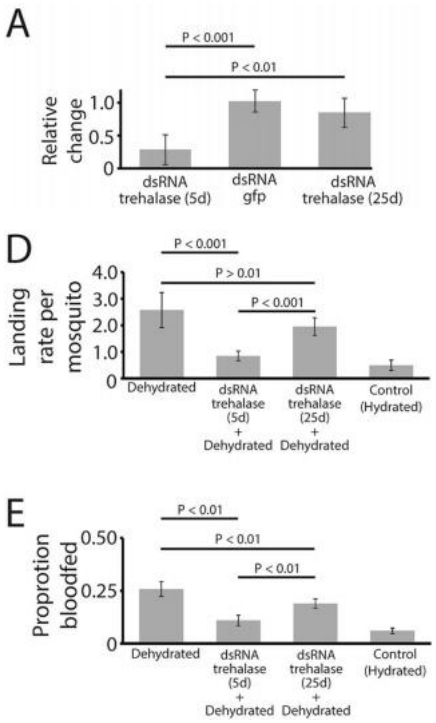
Dehydration prompts increased activity and blood feeding by mosquitoes

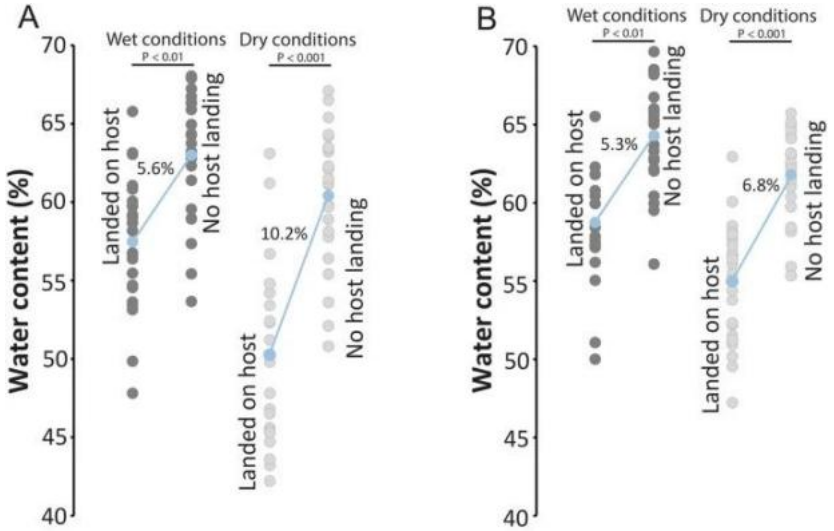






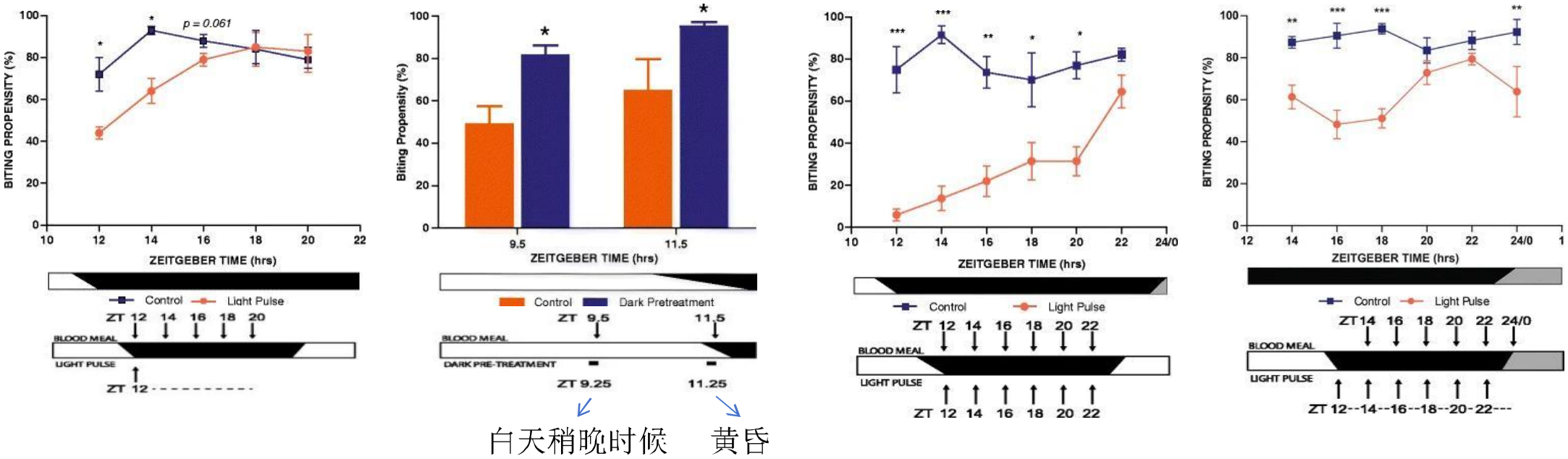






Hagan RW, et al. *Sci Rep*. 2018

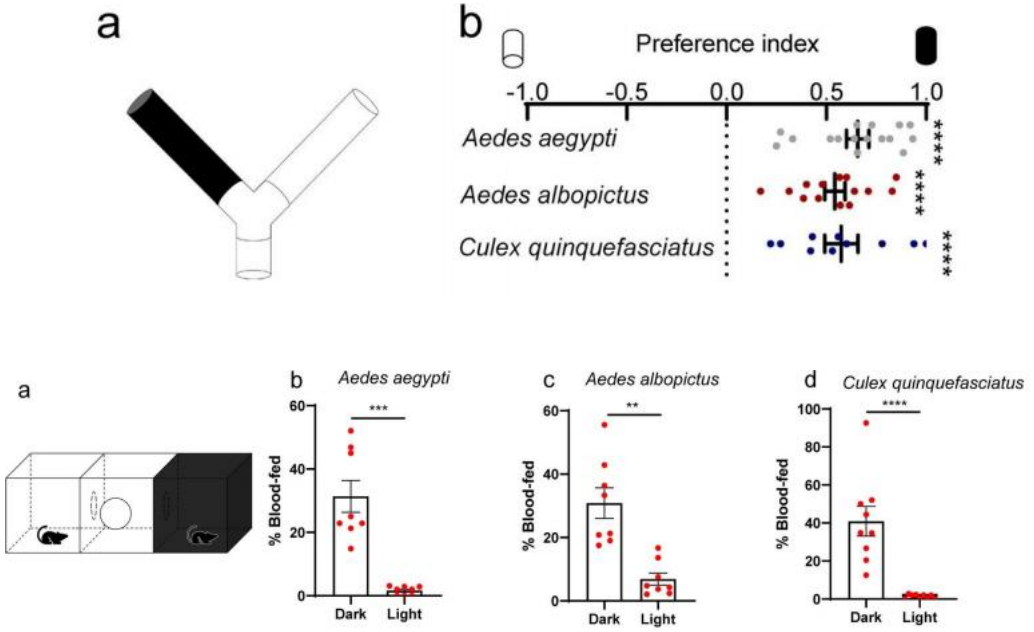
Biting behavior is closely tied to photoperiod

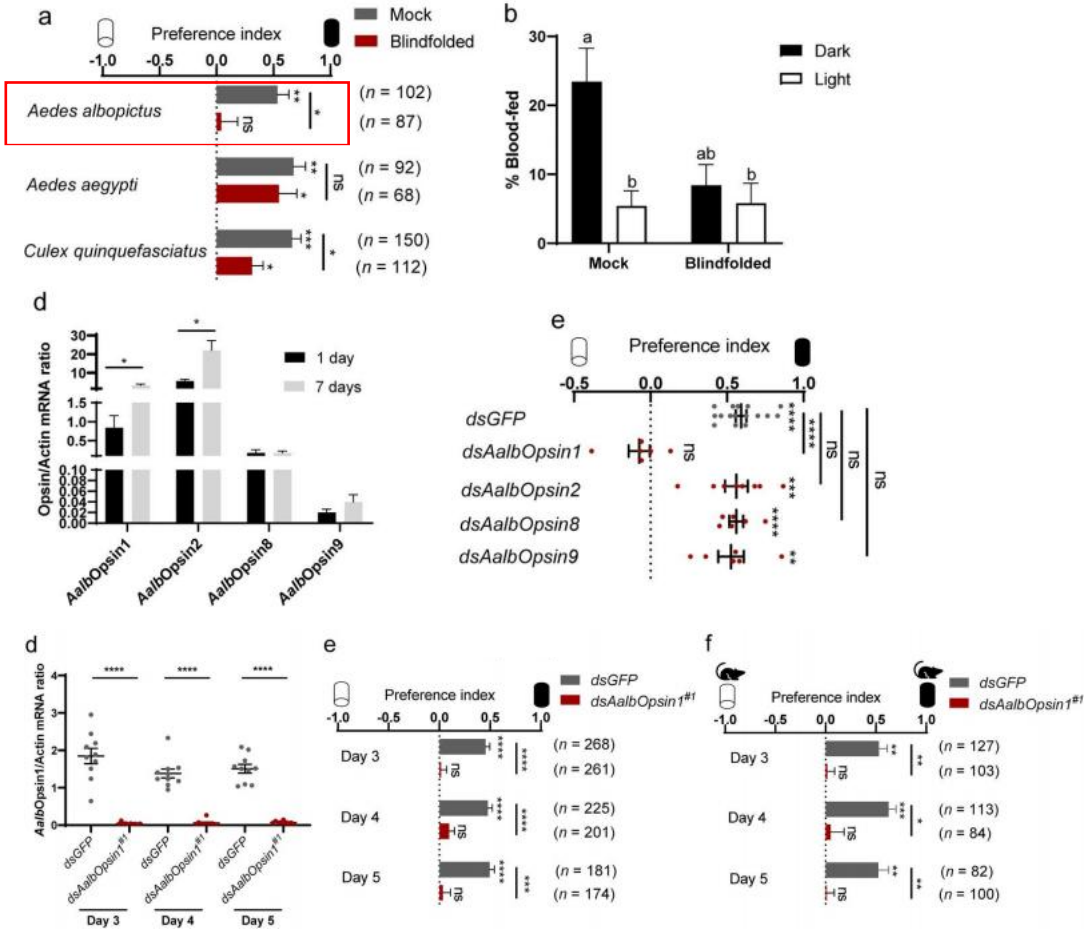


白天稍晚时候　黄昏

Sheppard AD, et al. *Parasit Vectors*. 2017

Opsin1 regulates light-evoked avoidance behavior in *Aedes albopictus*

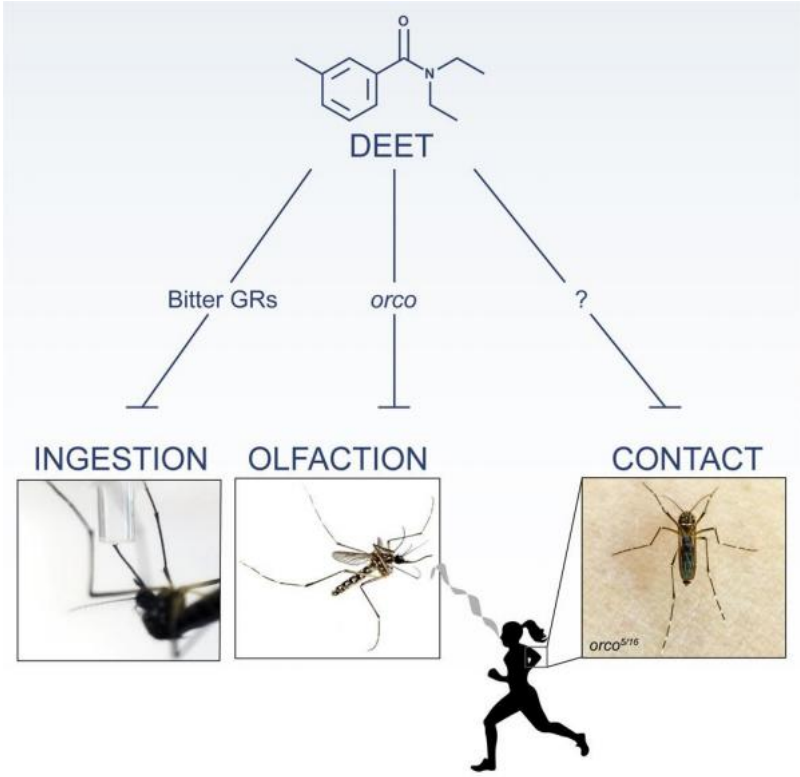




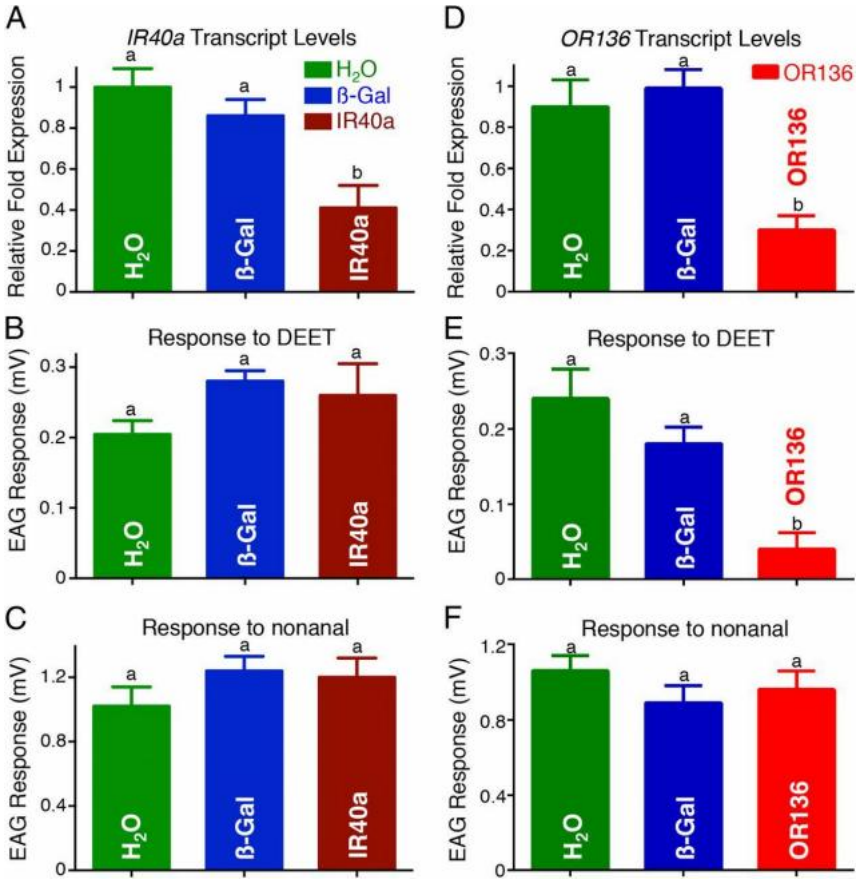
Liu XY, et al. *BMC Biology*. 2022

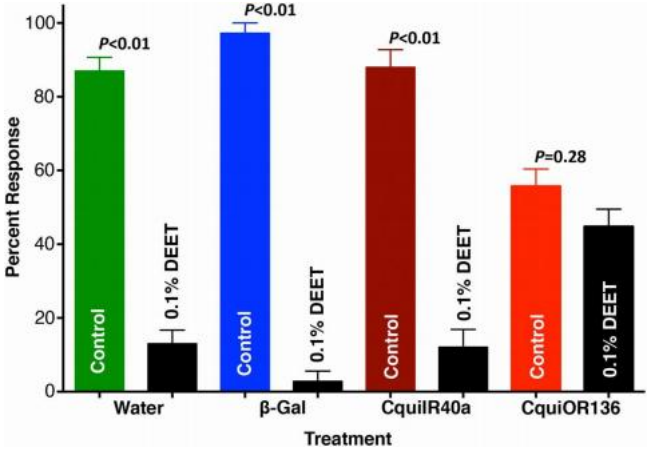
The most famous mosquito repellent - DEET

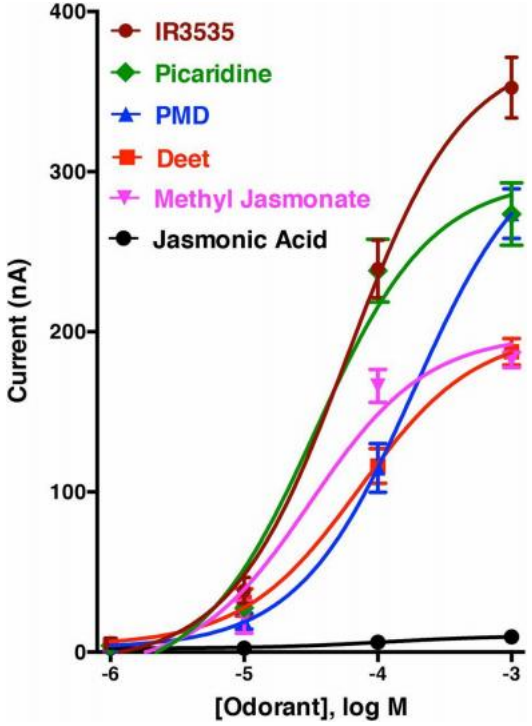
通用名称 Generic name	化学名称 Chemical name	结构式 Structure
避蚊酯、驱蚊油 DMP	邻苯二甲酸二甲酯	
避蚊酮 Indalone	2-二甲基吡喃-4-酮-6-羧酸丁酯	
驱蚊醇 Rutger's 612	2-乙基-1，3己二醇	
避蚊胺 DEET	N，N-二乙基间甲基苯甲酰胺	
DEPA	N，N-二乙基苯乙酰胺	
R202	环烯酰胺	
依默宁 IR3535	3-(N-丁基-N-乙酰基)氨基丙酸乙酯	
KBR3023 Picaridin	2-羟乙基-1-哌啶酸-2-仲丁酯	



Mosquito odorant receptor for DEET and methyl jasmonate——CquiOR136



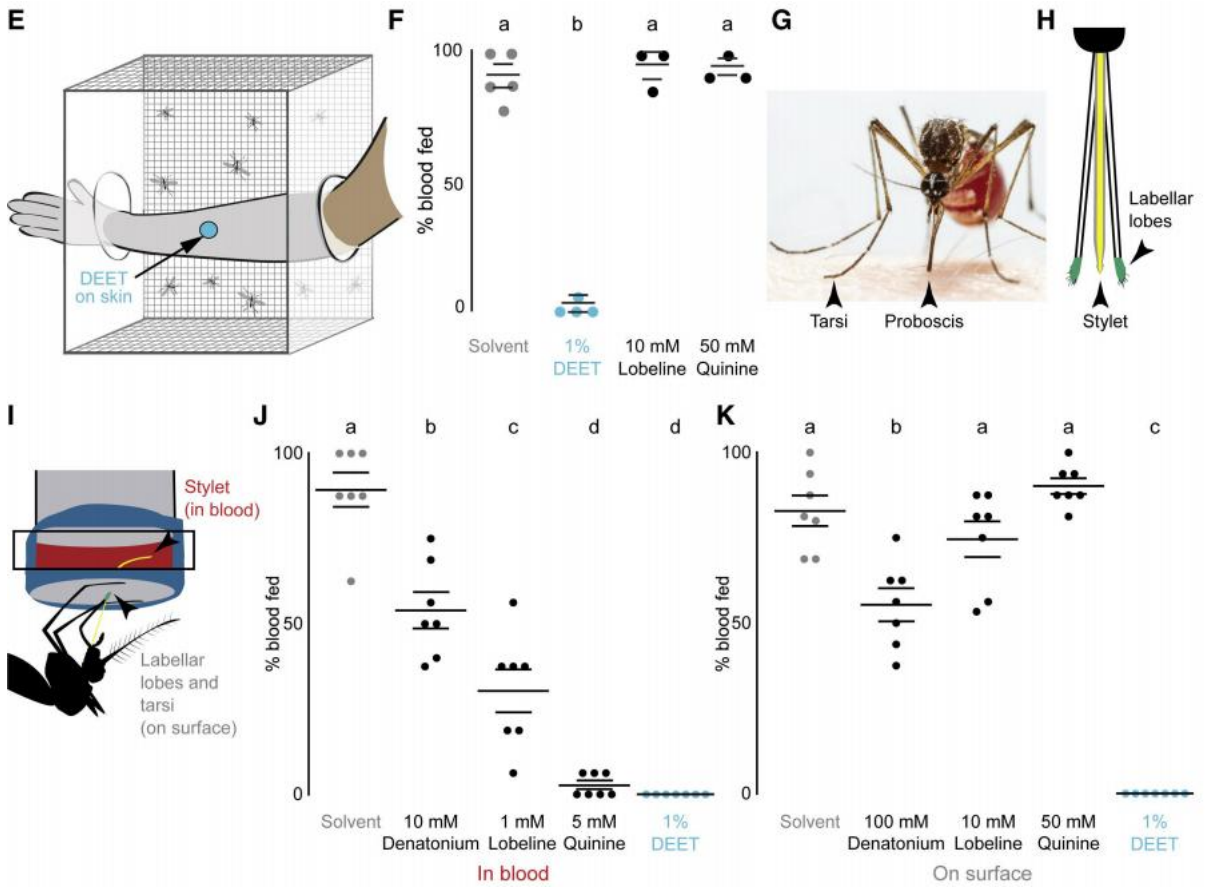




nonanal：壬醛，对照气味

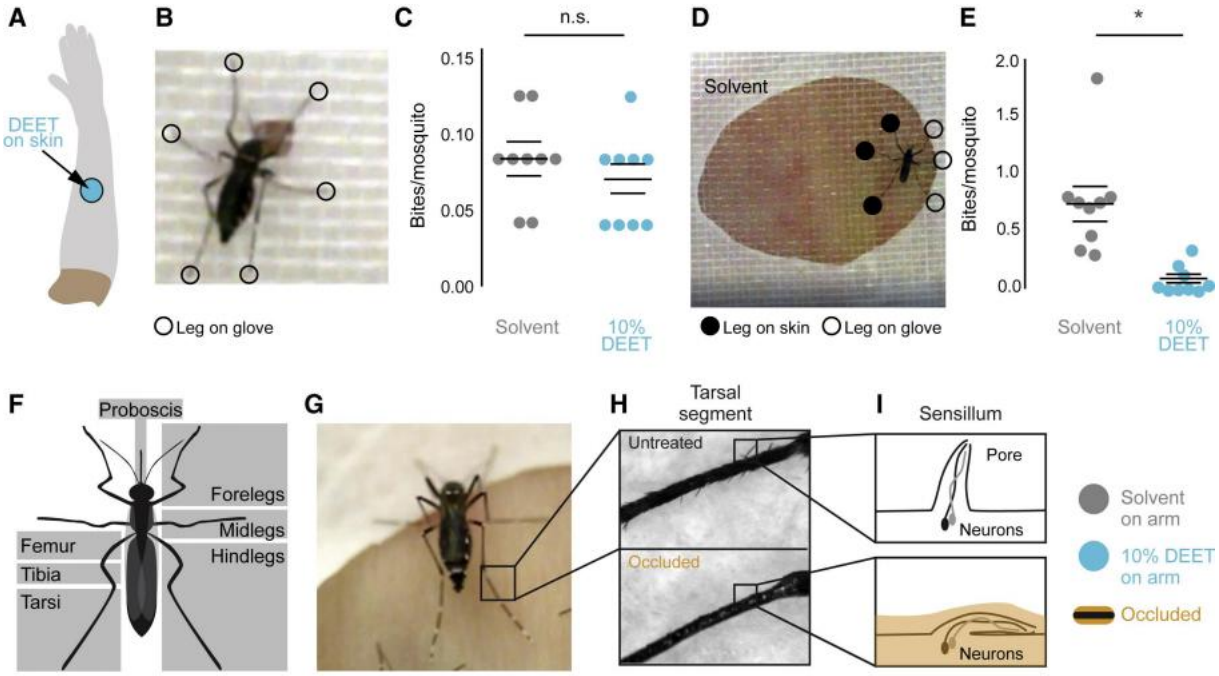
Xu PX, et al. *PNAS*. 2014

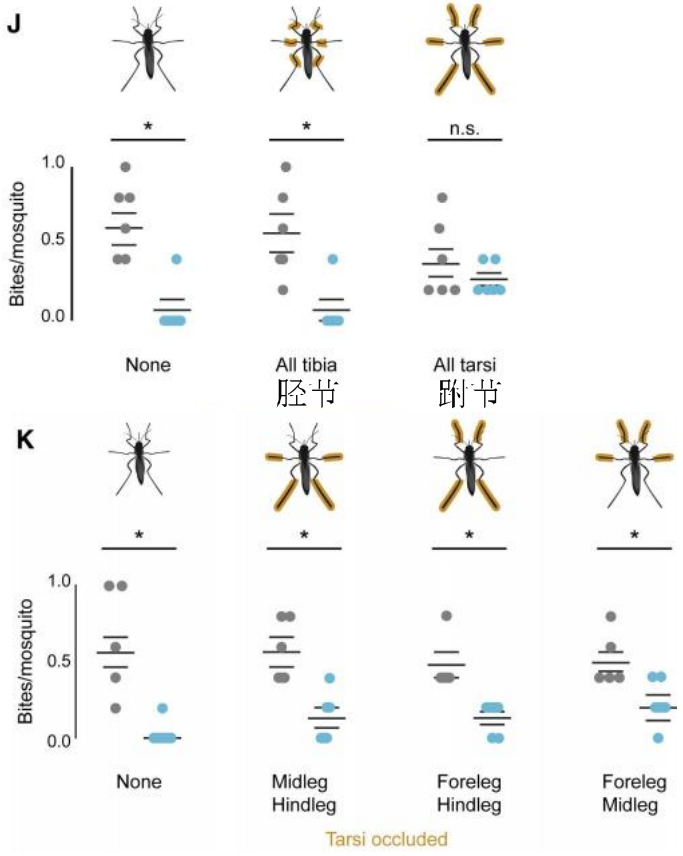
Aedes aegypti mosquitoes use their legs to sense DEET on contact



使用*orco*$^{5/16}$突变蚊子来消除避蚊胺的嗅觉影响

Dennis EJ, et al. *Curr Biol*. 2019





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Summary

- Mosquitoes perceive their host and changes in the external environment through multiple sensory cues.

  vision、olfaction、gustation

- Disruption of any of these sensory cues could impair the mosquito's host-seeking and blood-feeding behavior.

- Gustatory neurons on the mosquito's stylet distinguish between two food components: blood and nectar.

- DEET is rejected by mosquitoes via the non-contact olfactory pathway and the contact pathway.

Thank you!