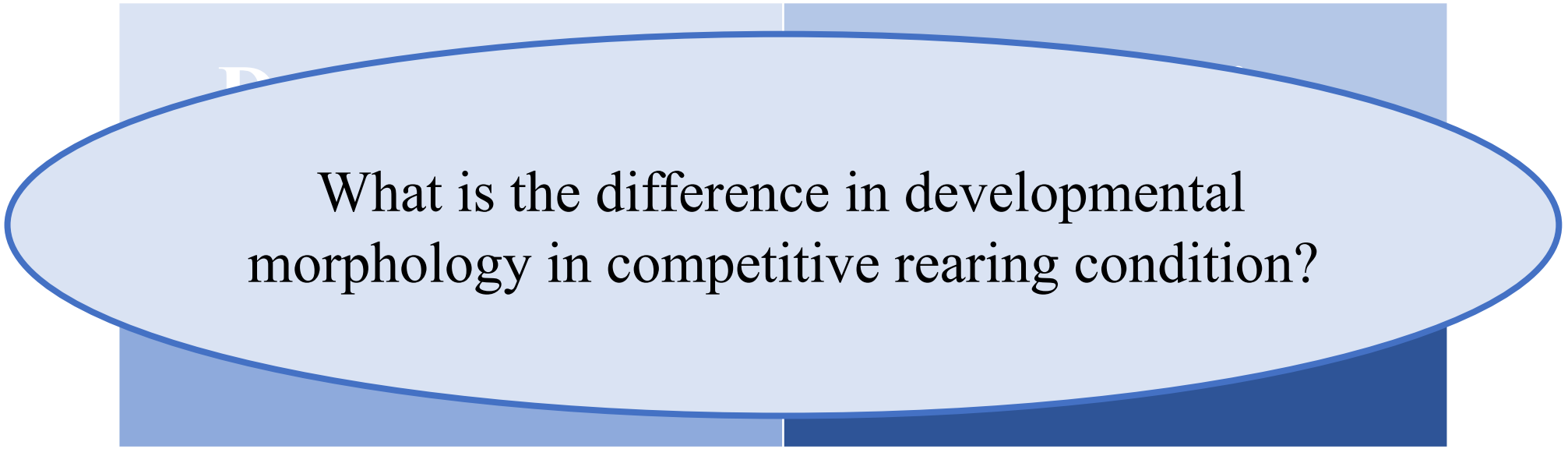
Competitive behaviors in animals and the underlying regulatory mechanisms

2023-12-07

- Competitive behaviors in reproduction and the neuronal regulating pathways
  —— 赵 环
- Competitive behaviors for food and the neuronal regulating pathways
  —— 王 蓉
- Competitive behaviors for territory and the neuronal regulating pathways
  —— 涂 雯

Competitive behaviors in reproduction and the neuronal regulating pathways

What kinds of competitive strategies are there in the reproductive process?



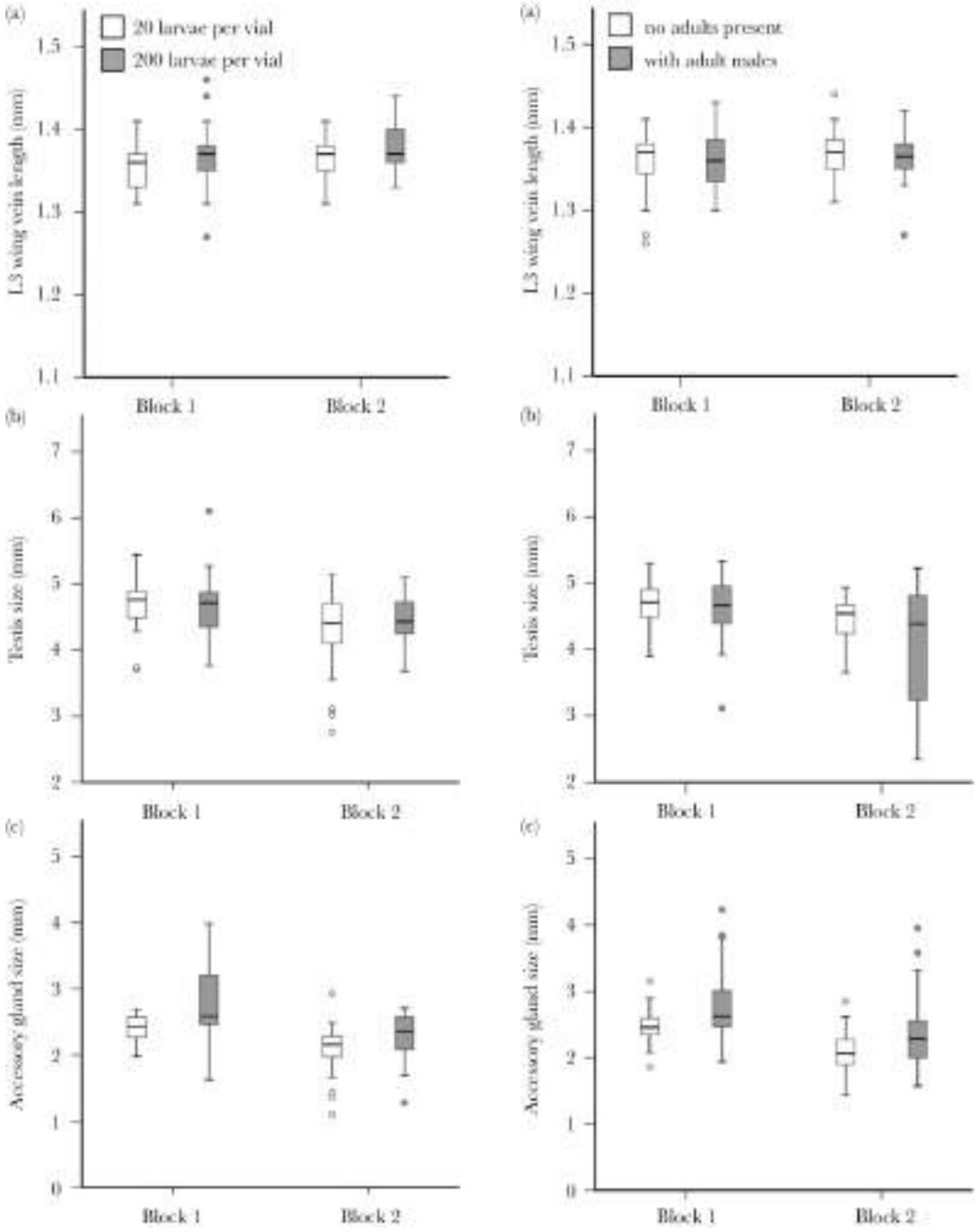
Reproductive organ size change in *Drosophila* in detection of rivals

Behav Ecol. 2016 Mar-Apr;27(2):452-461. doi: 10.1093/beheco/arv170. Epub 2015 Oct 25.

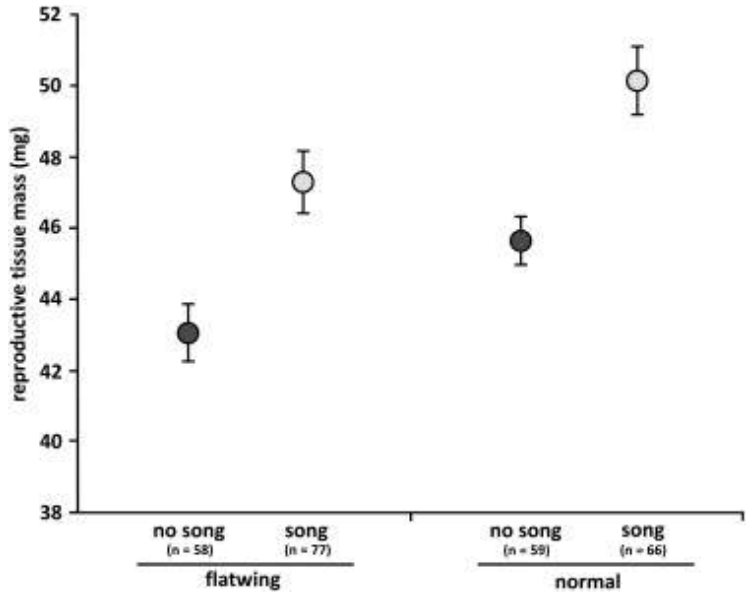
Effect of competitive cues on reproductive morphology and behavioral plasticity in male fruitflies

Amanda Bretman [1], Claudia Fricke [2], James D Westmancoat [3], Tracey Chapman [3]

Larvae can use cues from their contemporaries as well as from previous cohorts to form the basis of their responses to anticipated future reproductive competition.



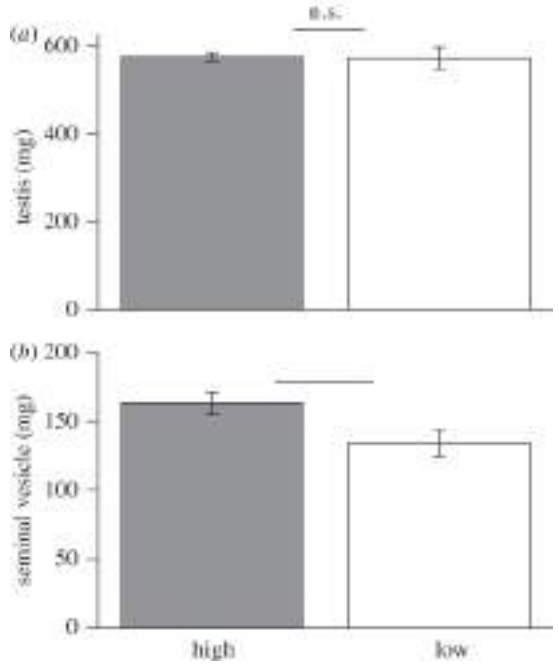
Reproductive organ size change in other species in detection of rivals



› Proc Biol Sci. 2011 Apr 22;278(1709):1171-6. doi: 10.1098/rspb.2010.1828. Epub 2010 Sep 29.

Social cues of sperm competition influence accessory reproductive gland size in a promiscuous mammal

Jean-François Lemaître [1], Steven A Ramm, Jane L Hurst, Paula Stockley

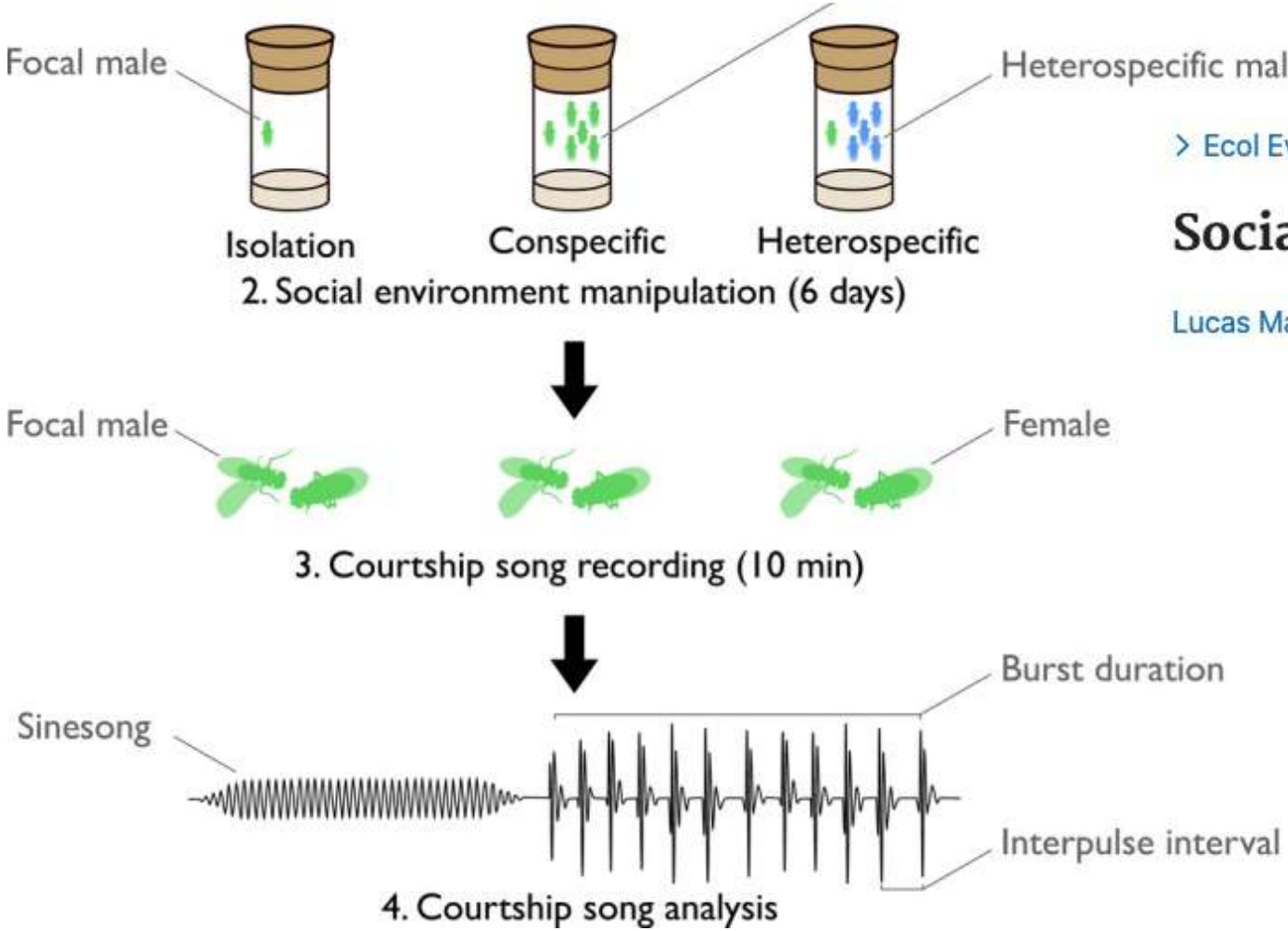


› Curr Biol. 2010 May 11;20(9):845-9. doi: 10.1016/j.cub.2010.02.063. Epub 2010 Apr 22.

Acoustic experience shapes alternative mating tactics and reproductive investment in male field crickets

Nathan W Bailey [1], Brian Gray, Marlene Zuk

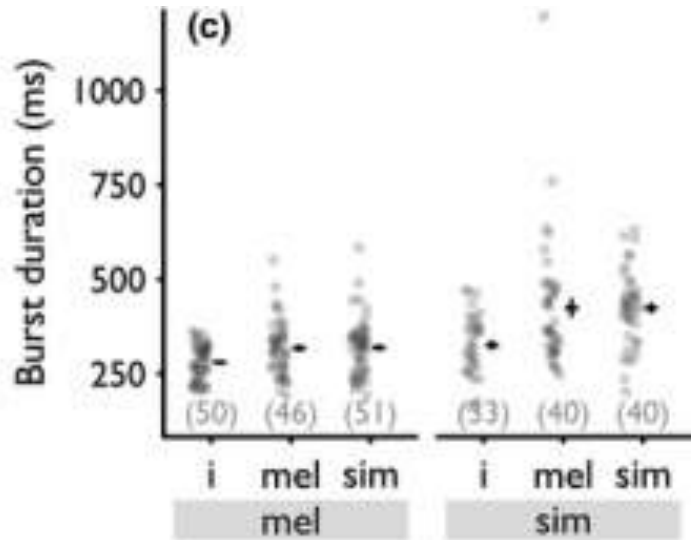
What is the difference in courtship behavior in competitive environment?



> Ecol Evol. 2018 Dec 10;9(1):410-416. doi: 10.1002/ece3.4759. eCollection 2019 Jan.

Social effects on fruit fly courtship song

Lucas Marie-Orleach [1], Nathan W Bailey [1], Michael G Ritchie [1]

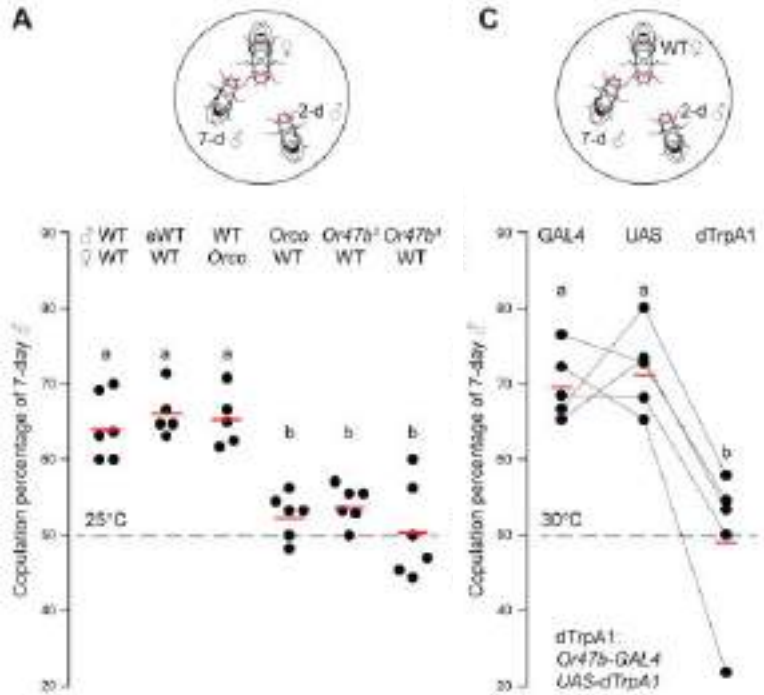


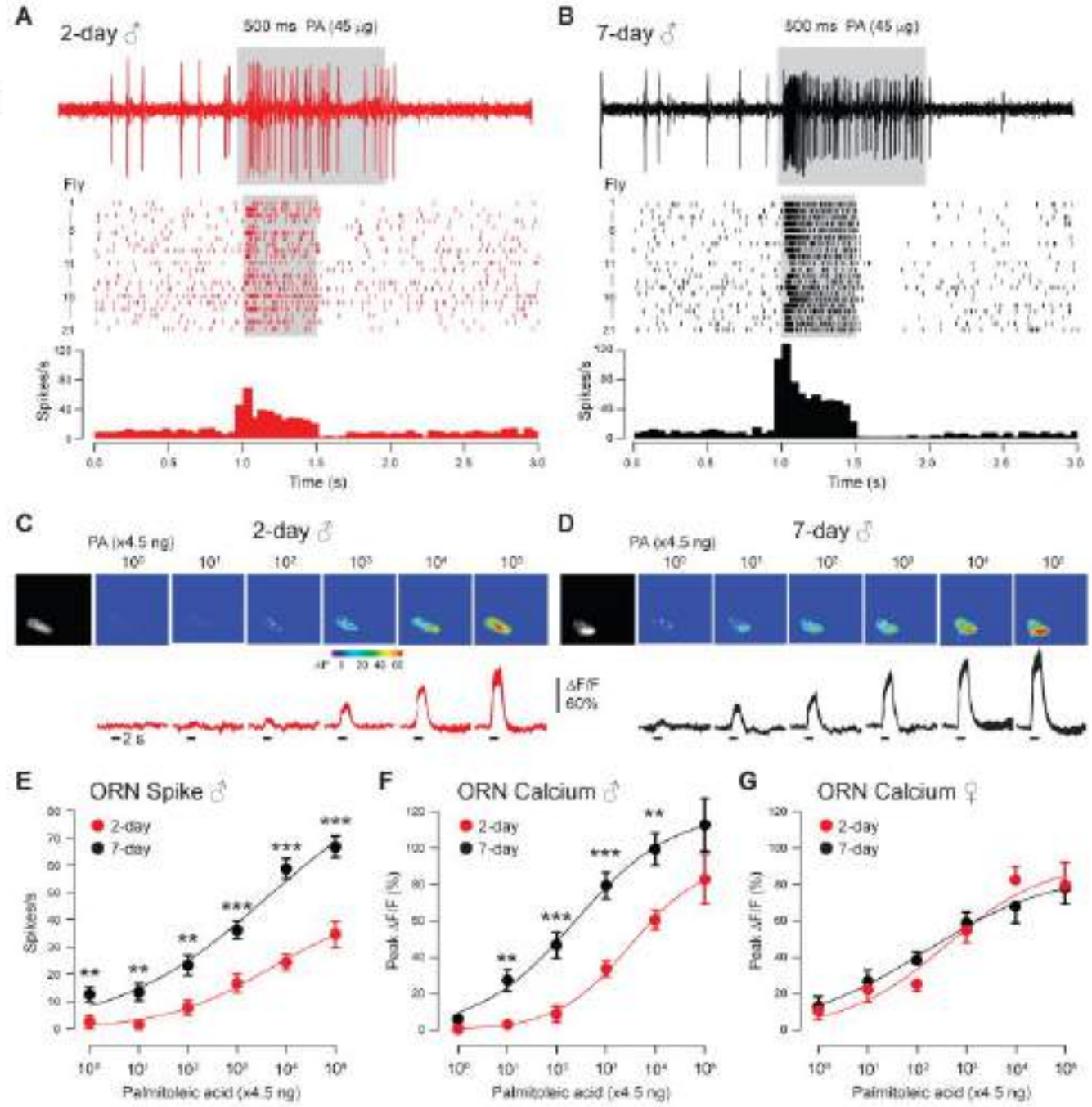
Longer pulse song duration produced by males previously reared with a social partner is not due to longer IPI, but reflects a greater number of pulses per burst.
males raised in isolation: 8.2 ± 1.3 pulses/burst
males raised with conspecific males: 9.3 ± 1.9 pulses/burst
males raised with heterospecific males: 9.5 ± 2.4 pulses/burst

> Neuron. 2016 Jun 15;90(6):1272-1285. doi: 10.1016/j.neuron.2016.05.004. Epub 2016 Jun 2.

Hormonal Modulation of Pheromone Detection Enhances Male Courtship Success

Hui-Hao Lin [1], De-Shou Cao [1], Sachin Sethi [1], Zheng Zeng [1], Jacqueline S R Chin [2], Tuhin Subhra Chakraborty [1], Andrew K Shepherd [1], Christine A Nguyen [1], Joanne Y Yew [3], Chih-Ying Su [4], Jing W Wang [5]

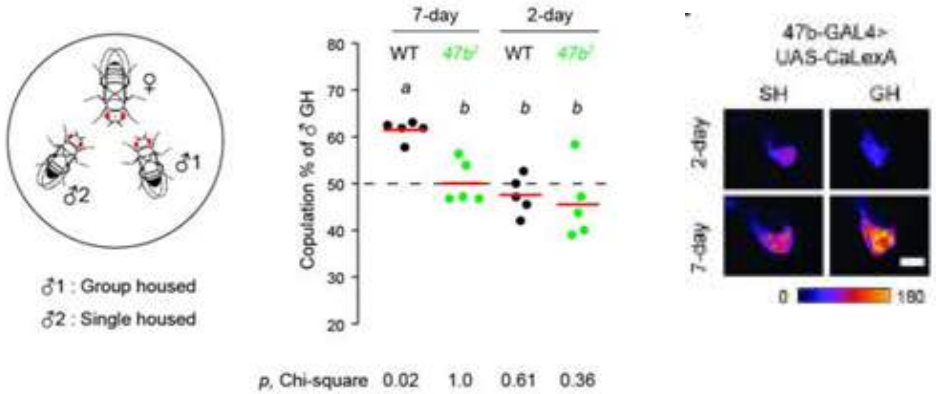


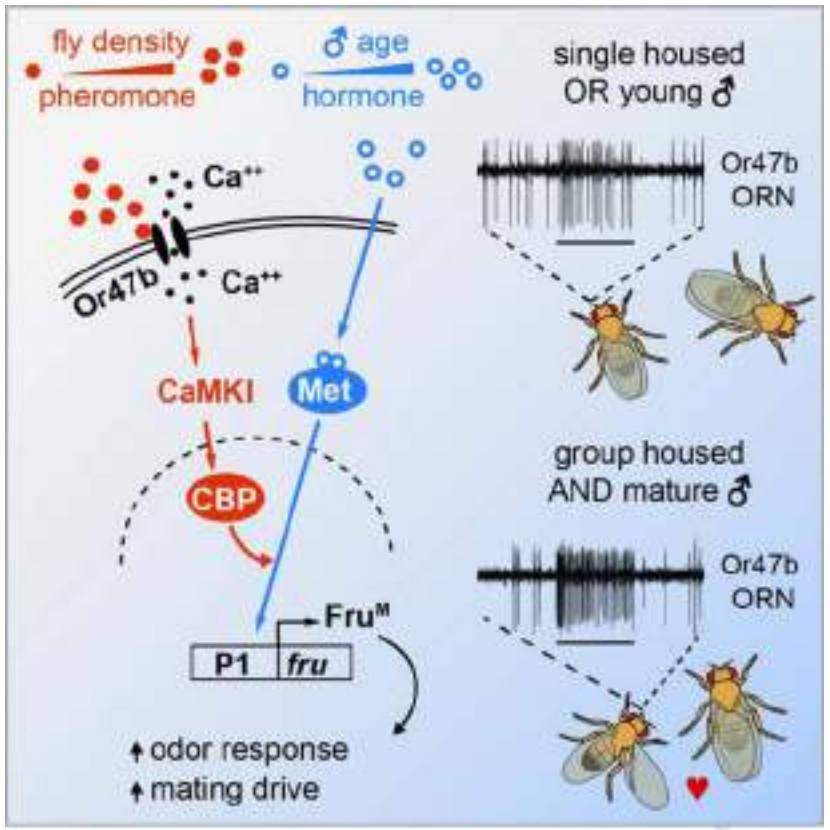


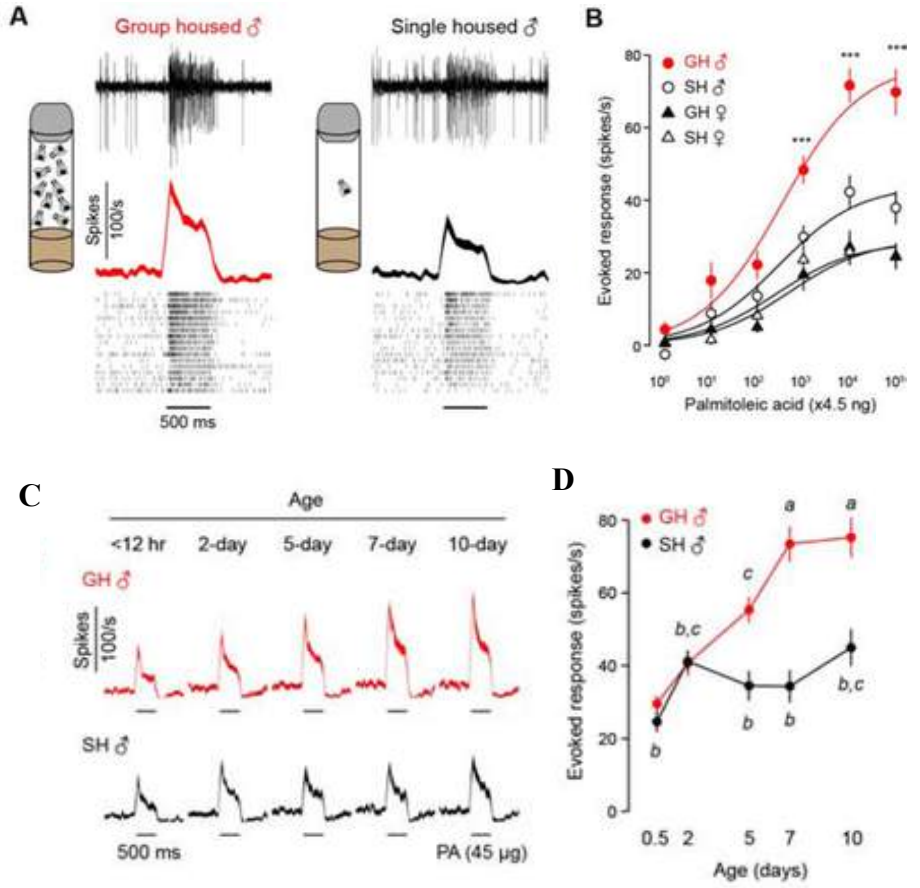
› Curr Biol. 2019 Nov 18;29(22):3887-3898.e4. doi: 10.1016/j.cub.2019.09.045. Epub 2019 Oct 31.

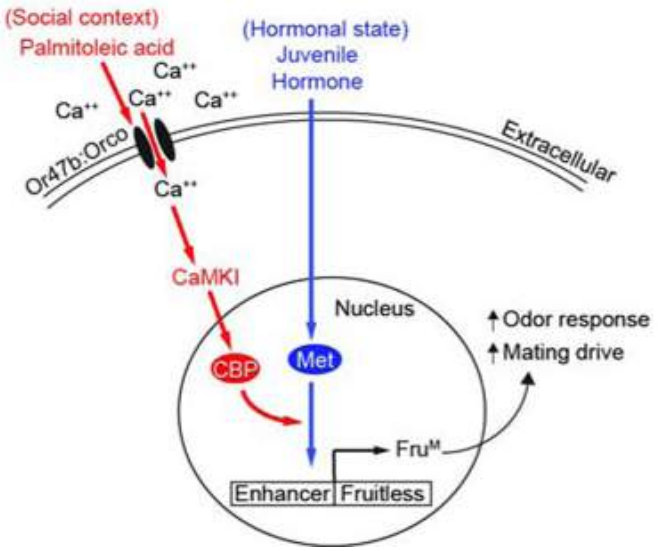
Social Context Enhances Hormonal Modulation of Pheromone Detection in Drosophila

Sachin Sethi [1], Hui-Hao Lin [1], Andrew K Shepherd [1], Pelin C Volkan [2], Chih-Ying Su [1], Jing W Wang [3]



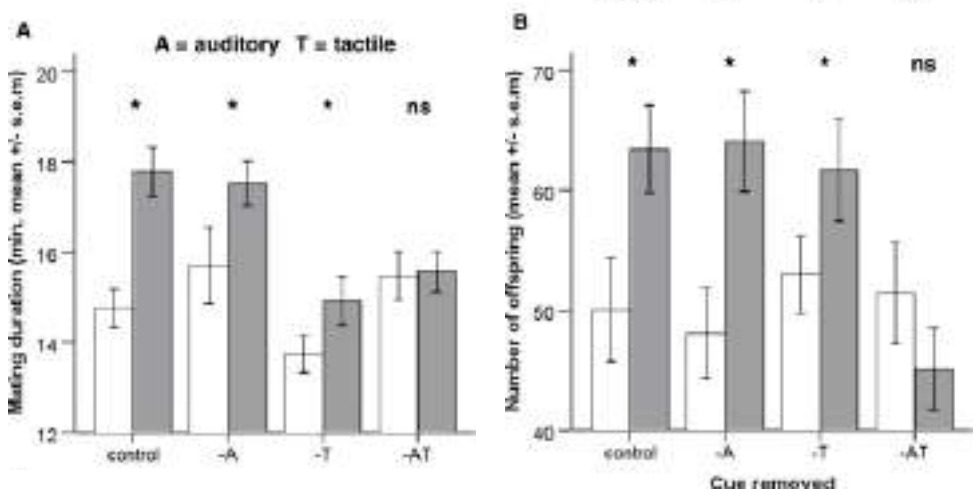


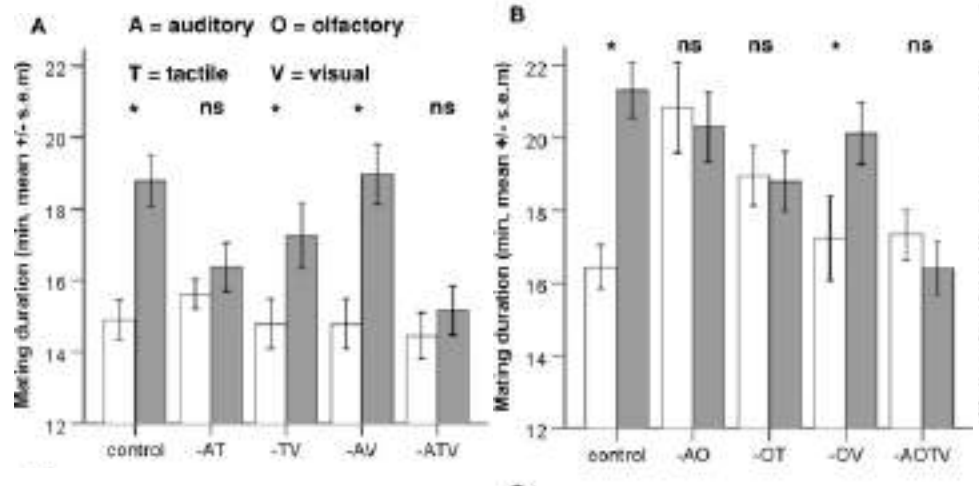





duration and
What is the strategy in copulation behavior
in competitive environment?

Prolonged mating duration in detection of rivals





(white)： males not exposed to a rival prior to mating
(gray) ：males exposed to a rival prior to mating

> Curr Biol. 2011 Apr 12;21(7):617-22. doi: 10.1016/j.cub.2011.03.008.

Males use multiple, redundant cues to detect mating rivals

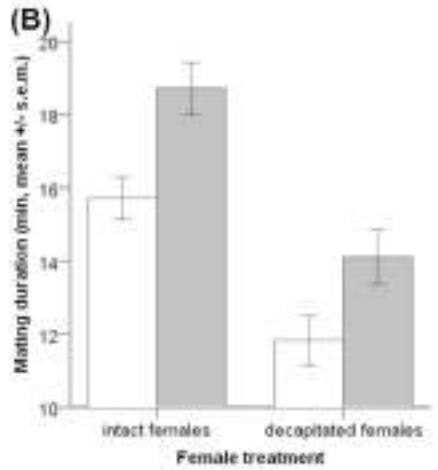
Amanda Bretman [1], James D Westmancoat, Matthew J G Gage, Tracey Chapman

Amanda Bretman et al. 2011

> J Insect Physiol. 2013 Aug;59(8):824-7. doi: 10.1016/j.jinsphys.2013.05.011. Epub 2013 May 30.

Male control of mating duration following exposure to rivals in fruitflies

Amanda Bretman [1], James D Westmancoat, Tracey Chapman



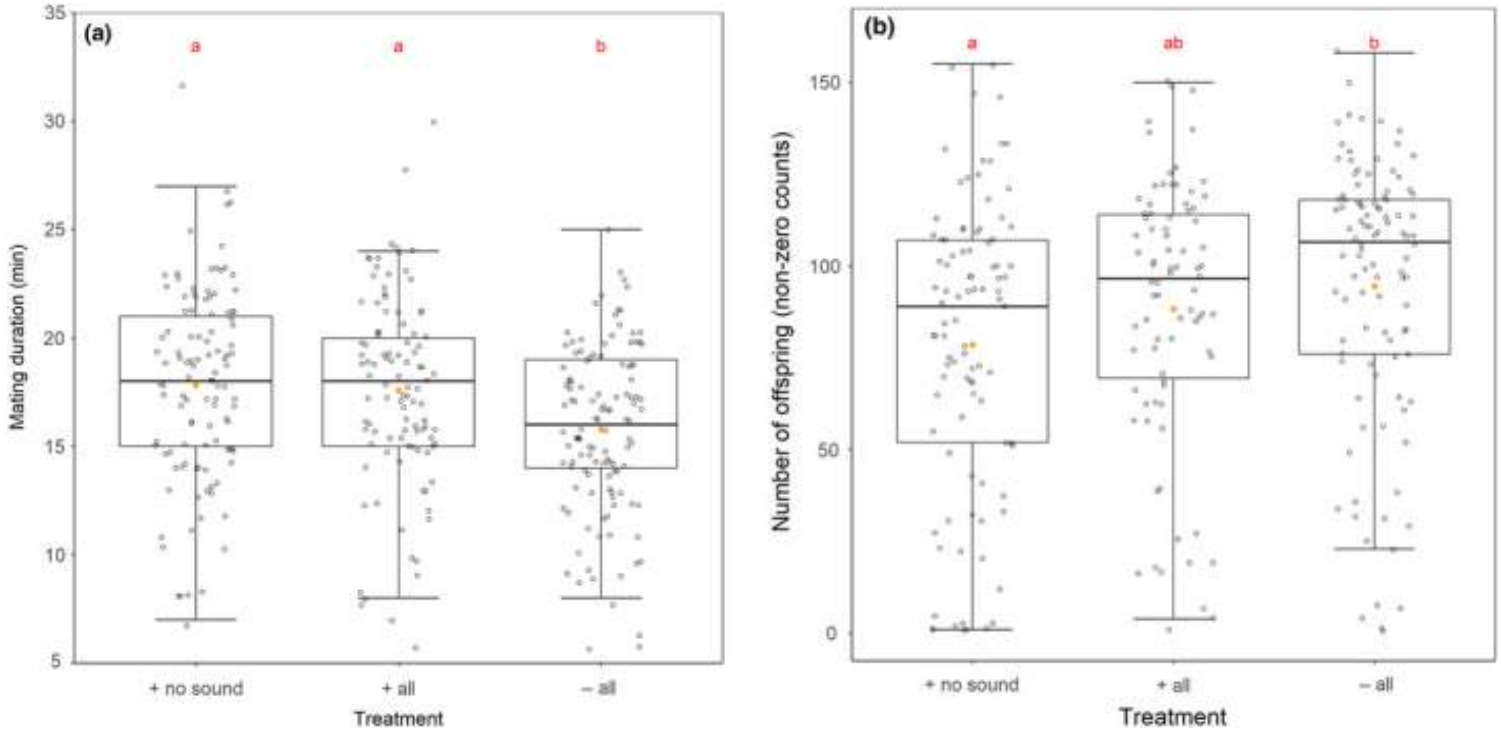
Amanda Bretman et al. 2013

Prolonged mating duration without larger number of offspring in detection of rivals

> Ecol Evol. 2020 May 4;10(12):5517-5526. doi: 10.1002/ece3.6293. eCollection 2020 Jun.

Fitness consequences of redundant cues of competition in male *Drosophila melanogaster*

Alice A Dore [1], Amanda Bretman [2], Tracey Chapman [1]



Regulating pathway for prolonged mating duration in detection of rivals

> Nat Neurosci. 2012 Jun;15(6):876-83. doi: 10.1038/nn.3104.

Contribution of visual and circadian neural circuits to memory for prolonged mating induced by rivals

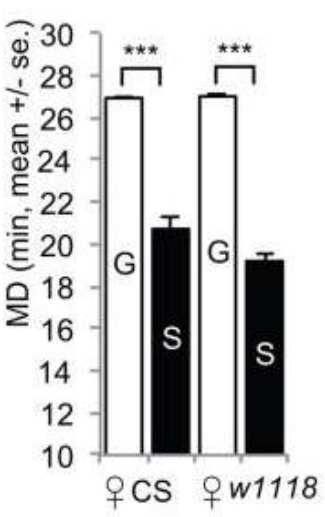
Woo Jae Kim [1], Lily Yeh Jan, Yuh Nung Jan

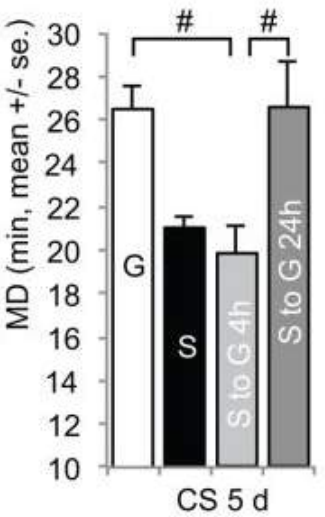
> Neuron. 2013 Dec 4;80(5):1190-205. doi: 10.1016/j.neuron.2013.09.034.

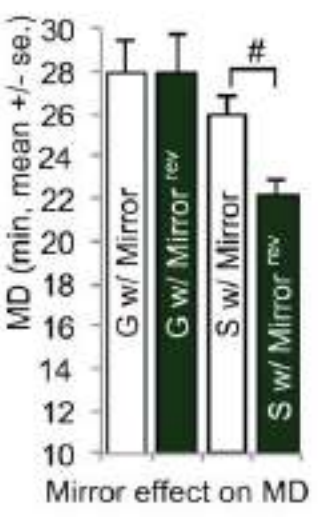
A PDF/NPF neuropeptide signaling circuitry of male Drosophila melanogaster controls rival-induced prolonged mating

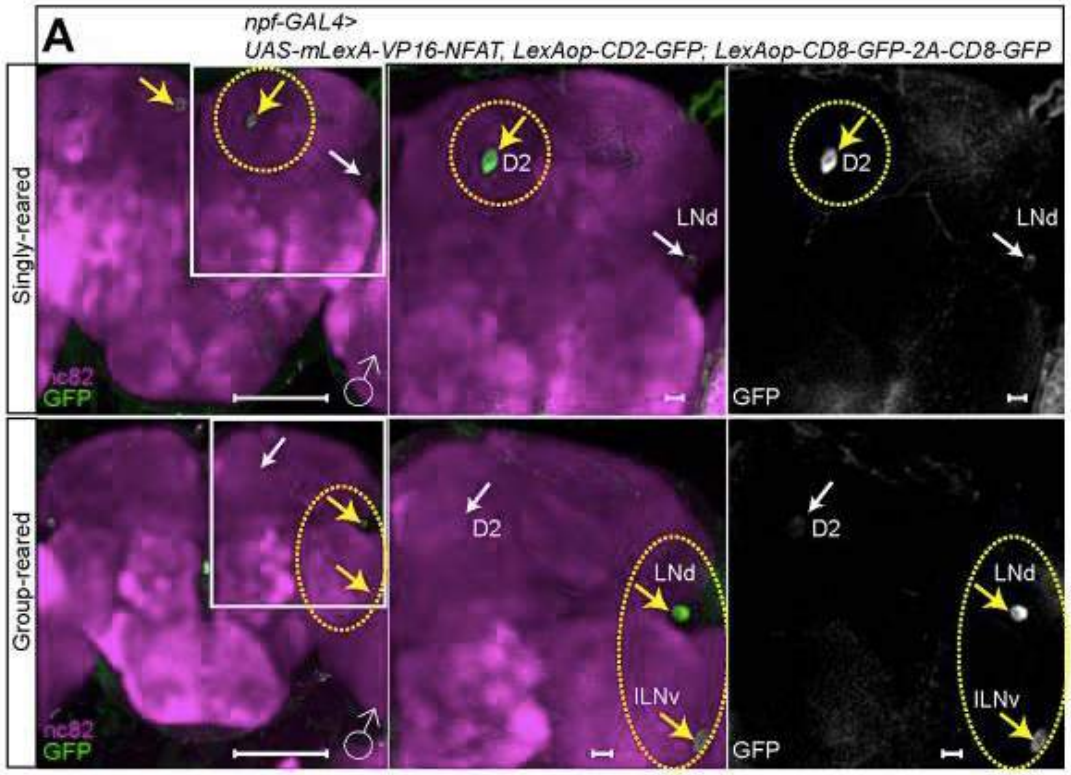
Woo Jae Kim [1], Lily Yeh Jan, Yuh Nung Jan

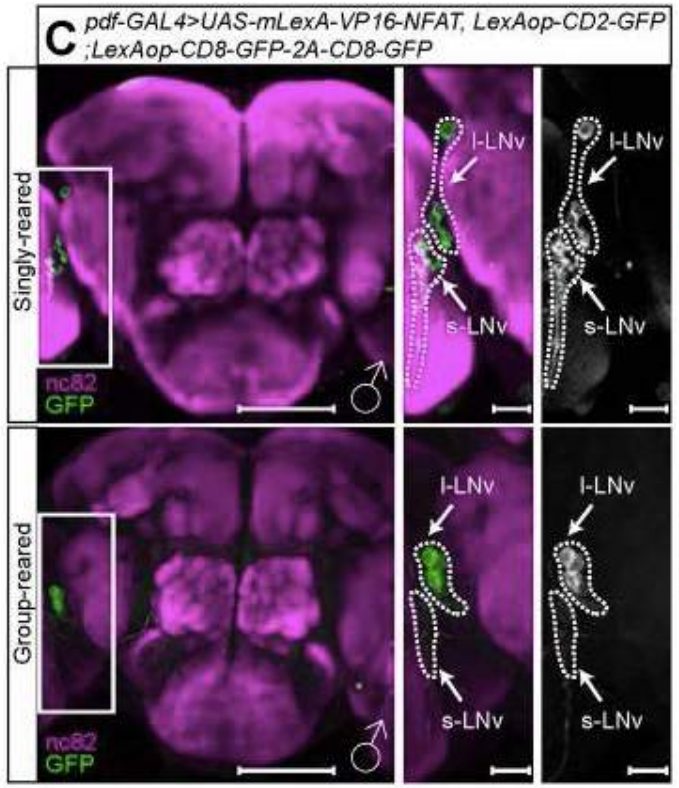
Visual and circadian pathways regulate the mating duration.

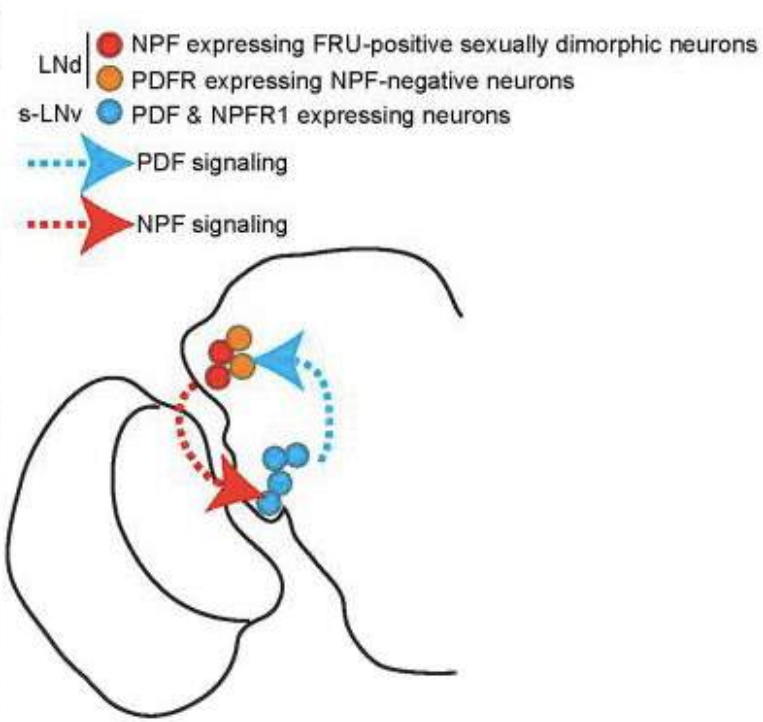


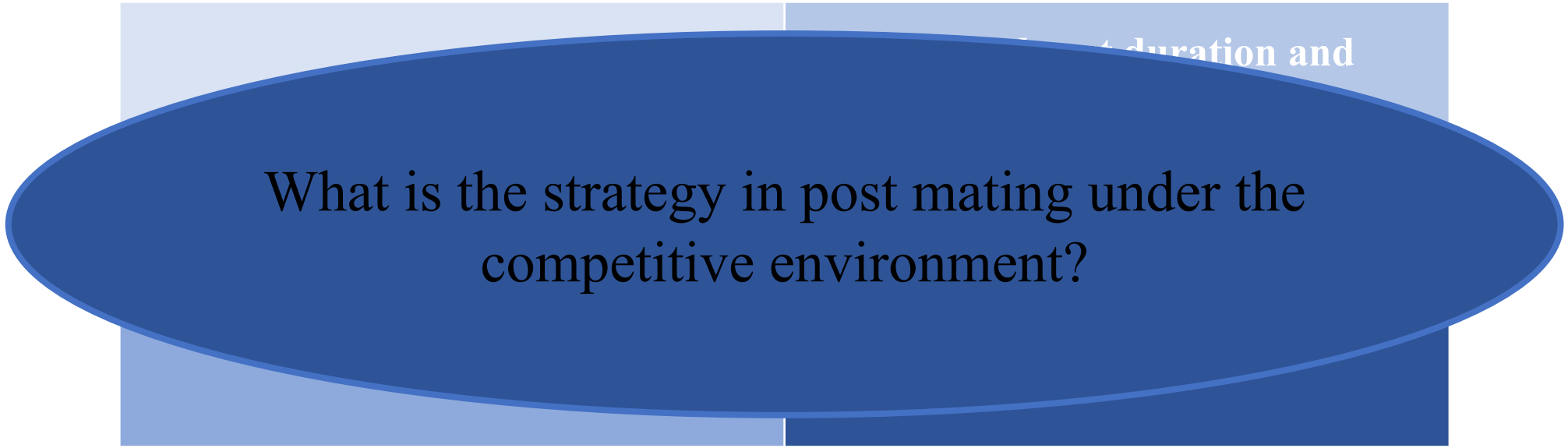




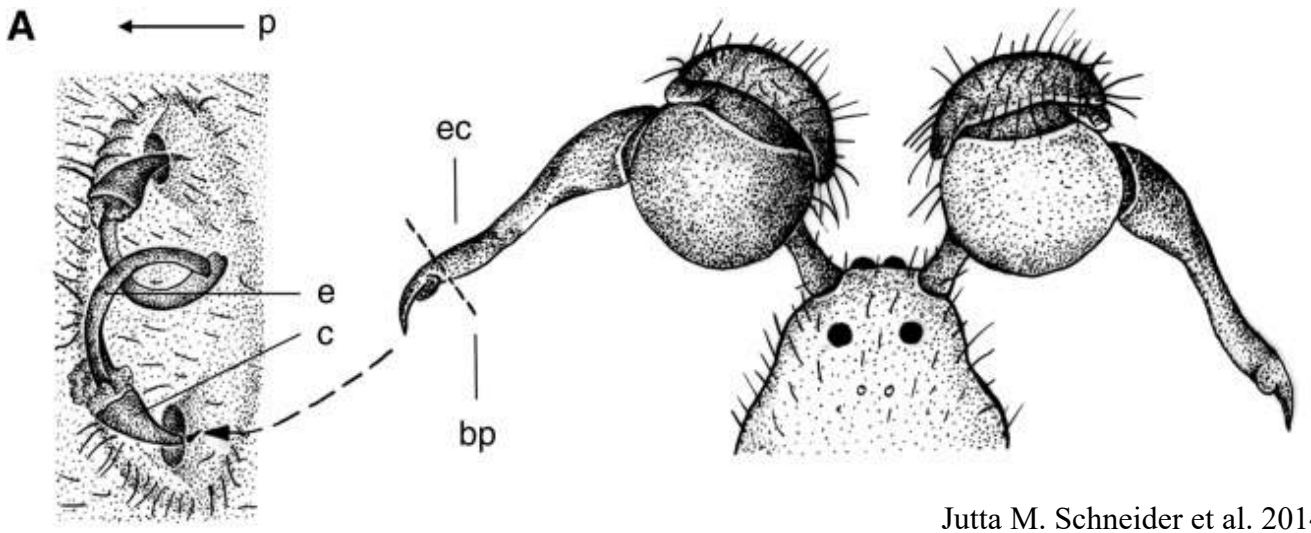






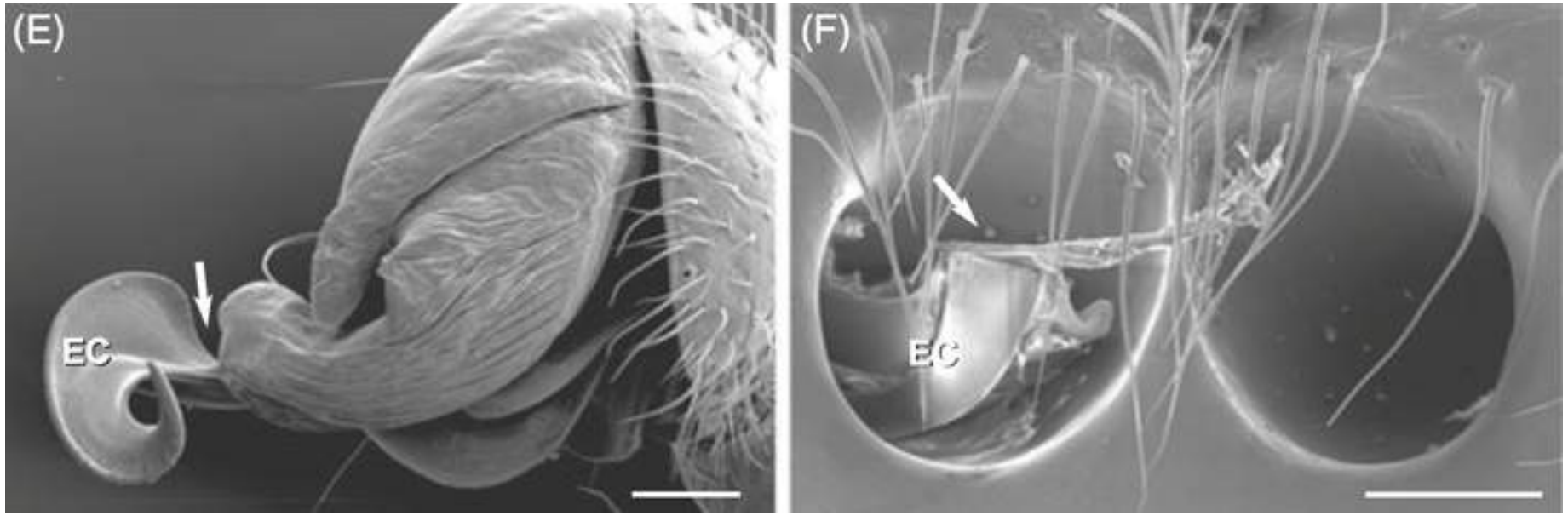

duration and
What is the strategy in post mating under the competitive environment?

Mating plugs through genital damage in spiders



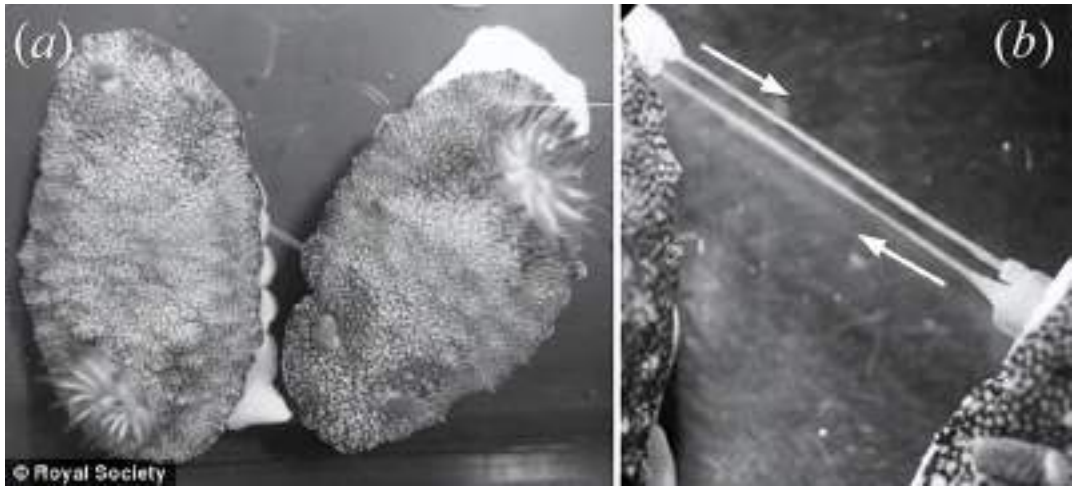
Jutta M. Schneider et al. 2014

The tip of the male sperm transfer organ (embolic conductor, ec) breaks and remains stuck in the genital opening.

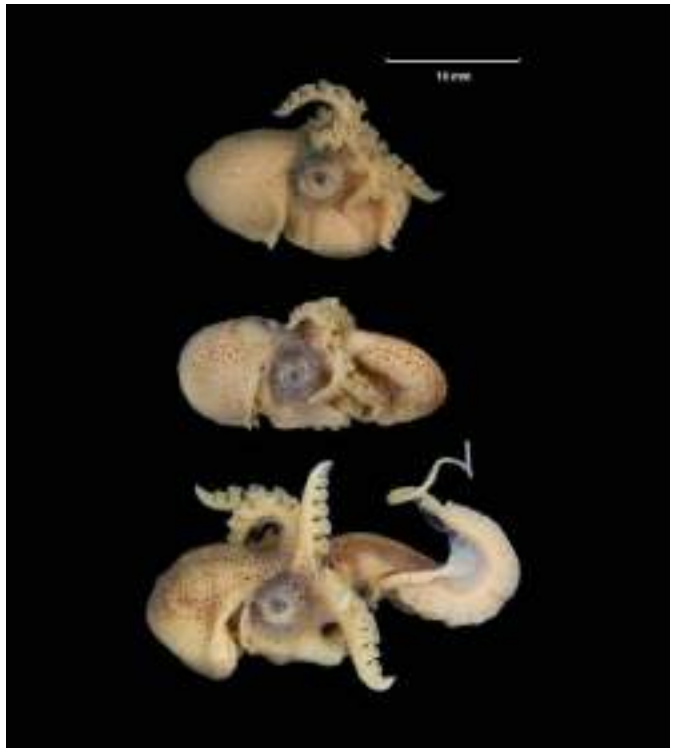


Fromhage, L., & Schneider, J. M. 2006

Mating plugs through genital damage in other species.



Regeneration of the genital in nudibranchs



Hectocotylus: mating arm in octopuses

Larger AG size	Longer burst duration and enhanced pheromone detection
Prolonged mating duration	Block the copulatory opening

Sexual cannibalism as a manifestation of sexual conflict

Jutta M. Schneider et al. 2014

Thank you!

Competitive behaviors for food in animal

- What are the **effects** of food competition on animals?
- How does **food** resource **relate to aggression ?**
- What about food competition and neural modulation in **male and females**?

2023.12.07

WR

What and Why ?——Competition for food in nature

In the process of finding food, especially when food is in short supply, animals compete with other animals in their own species and other species for food resources.

Types of food competition

Animals Compete for Food

- Performance competition

- Head-to-head competition

- Predatory competition
  - Within species

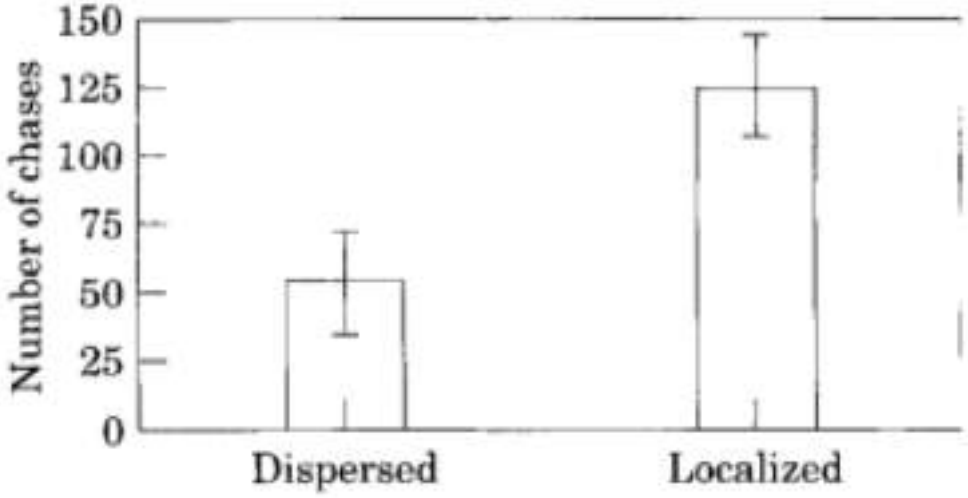
  - Steal across species

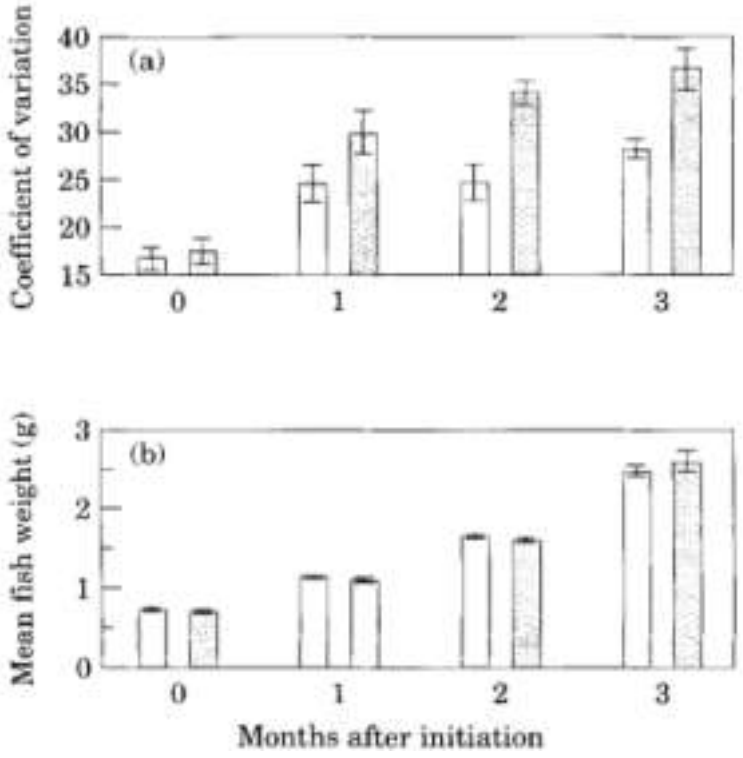
  - Eat other animal

by Ron Kurtus

What are the effects of food competition on animals ?

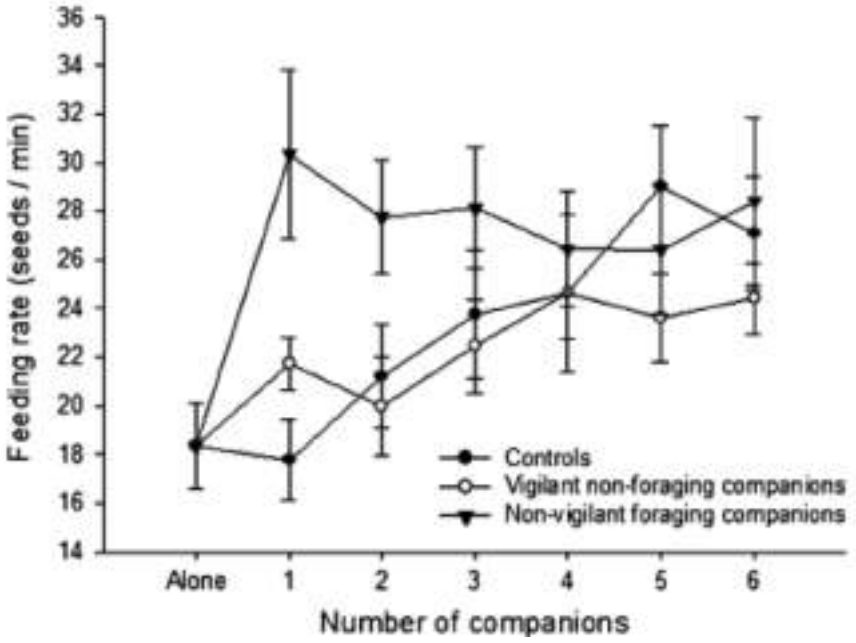
Groups receiving localized food displayed more aggression than those receiving dispersed food

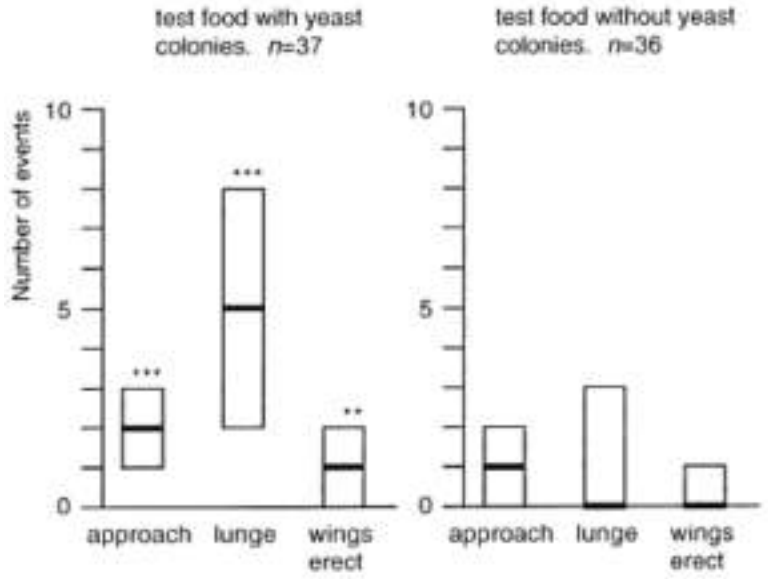




(C. H. Ryer and B. L. Olla.*Journal of Fish Biology* .1995)

Competition for food increases the rate of feeding and aggression

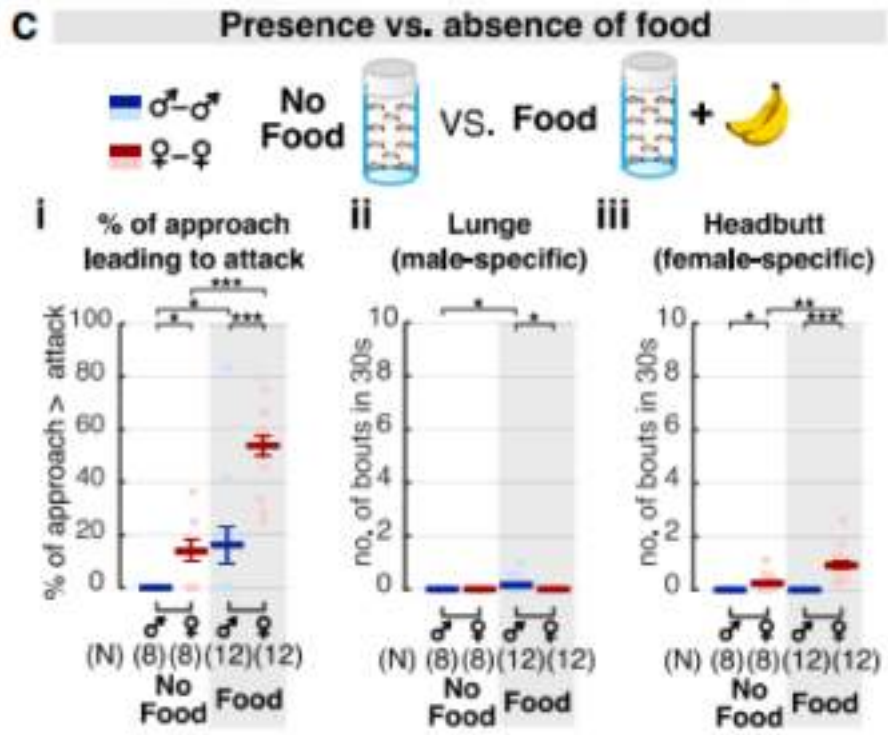




（Guillaume Rieucau and Luc-Alain Giraldeau.*Behavioral Ecology*.2009）

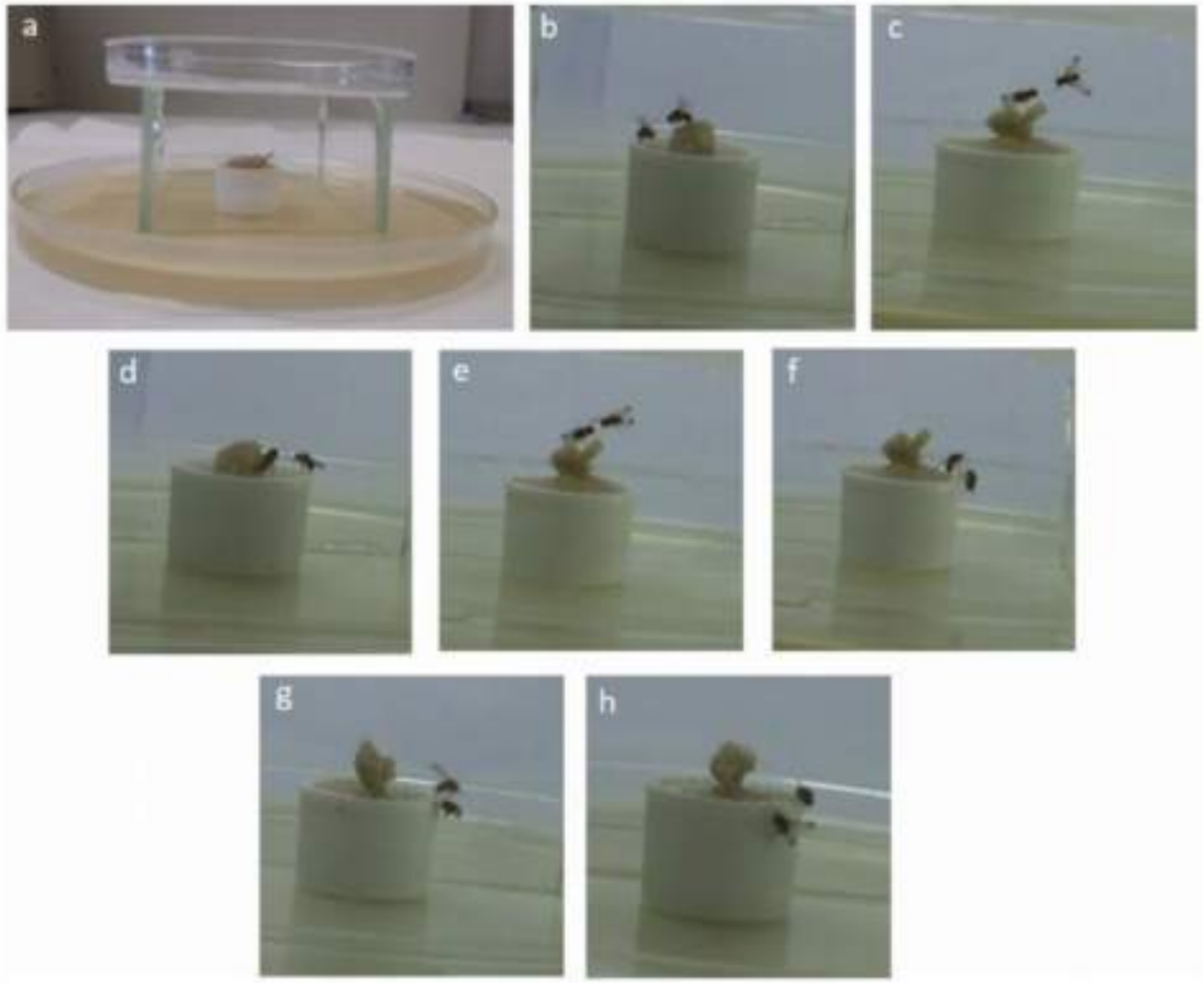
（Atsushi Ueda and Yoshiakikidokoro.*Physiological Entomology*.2002）

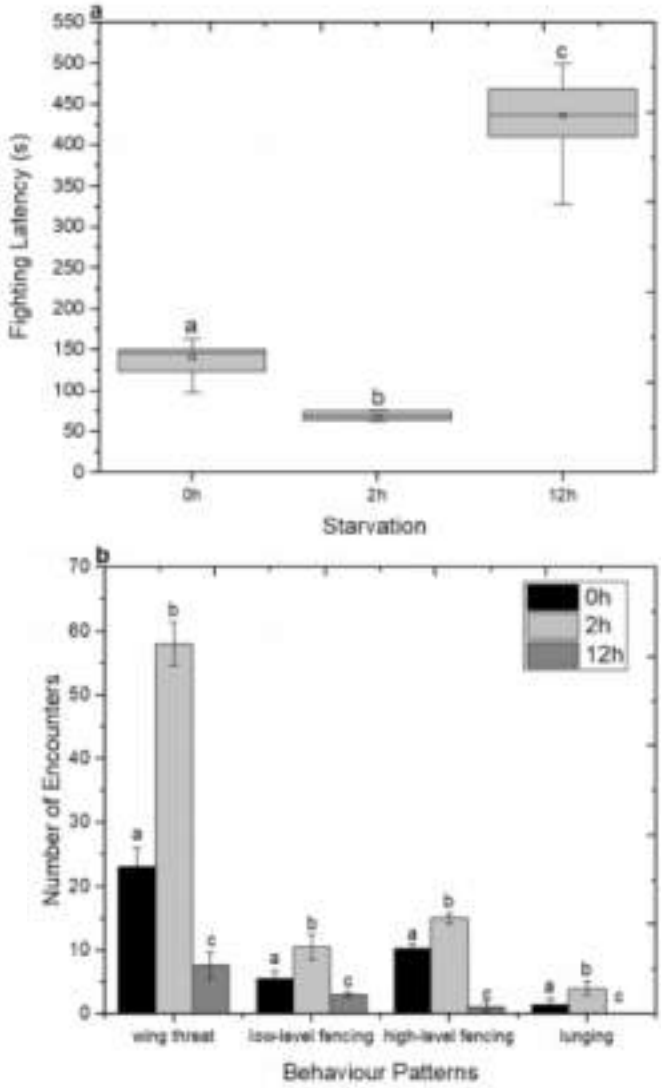
Aggression can be promoted by food in both males and females



(Hui Chiu et al.*Cell*.2021)

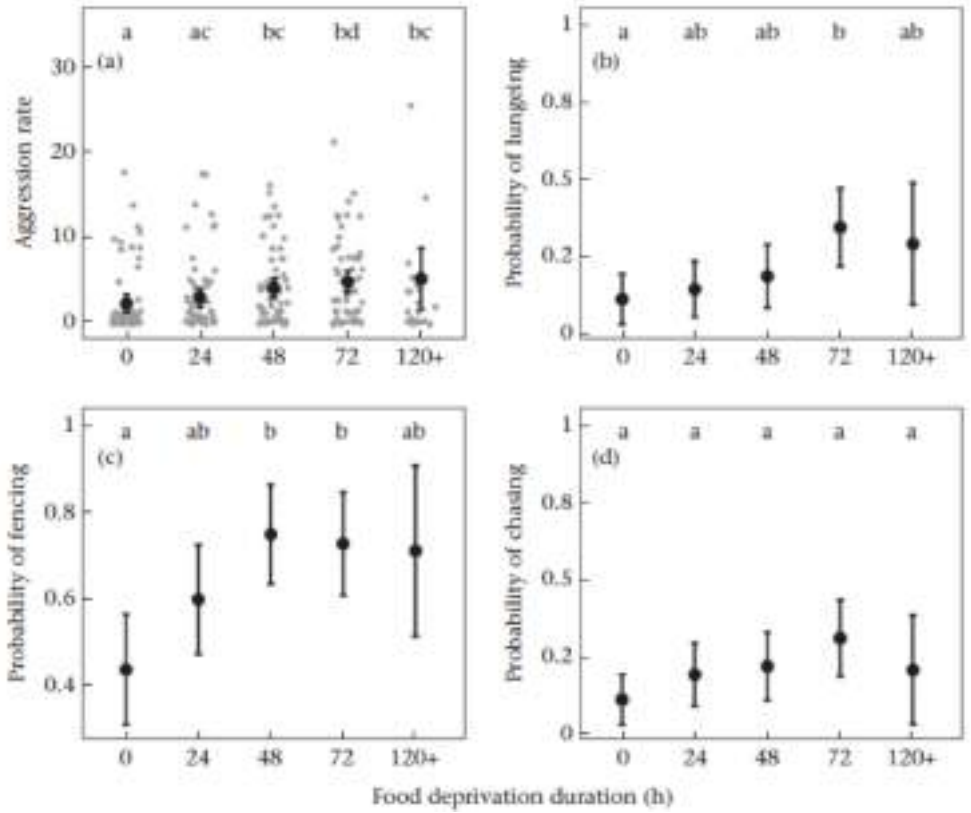
Effect of starvation on aggression of D. suzukii males

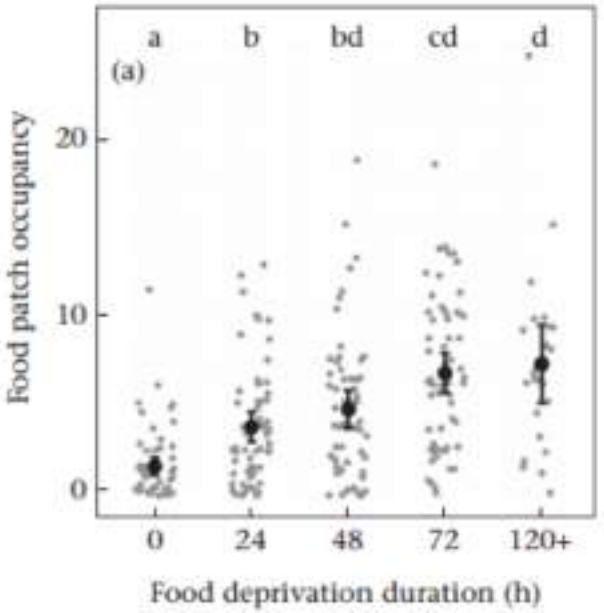


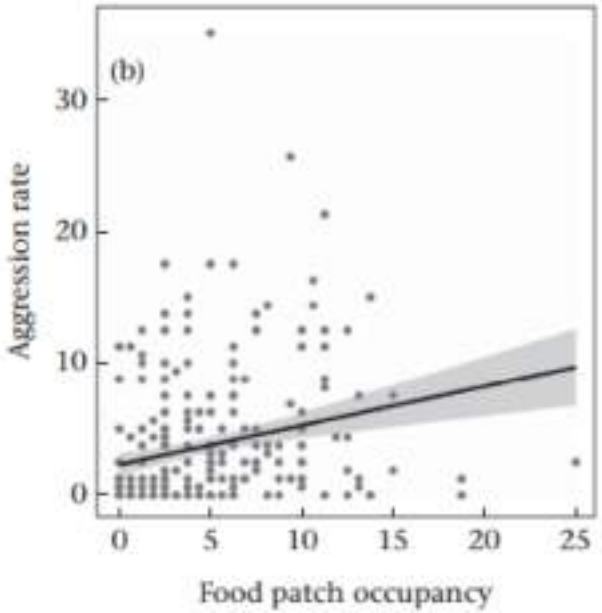


(Maria Belenioti and Nikolaos Chaniotakis.*Scientific Reports*.2020)

Food deprivation increased aggression and food patch occupancy

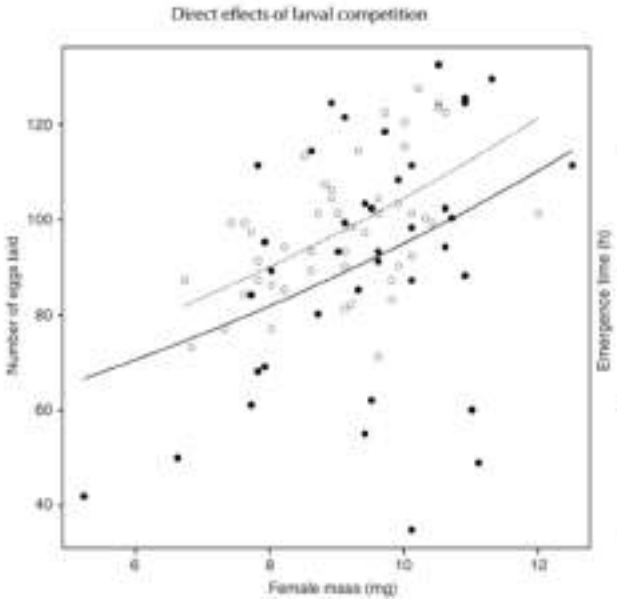


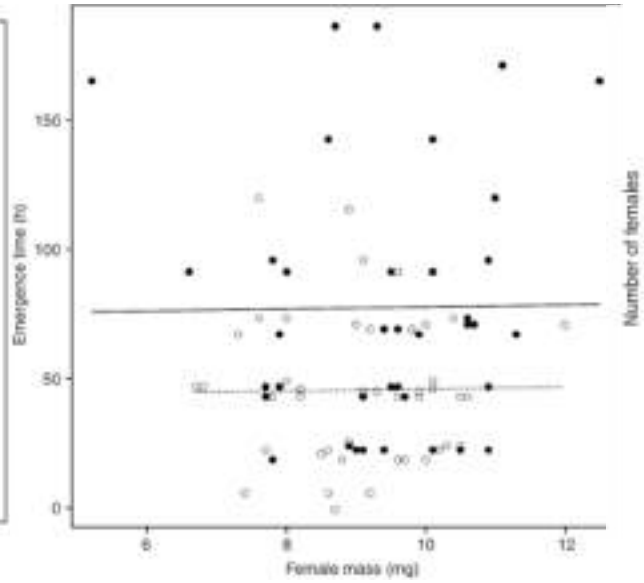


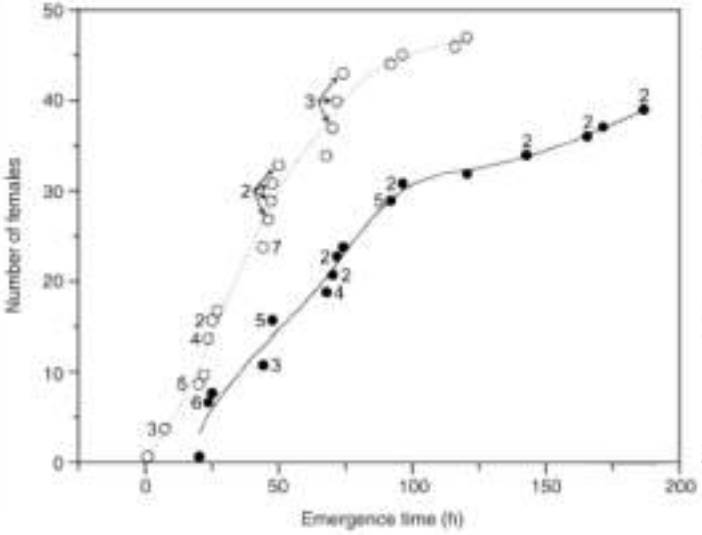


(Danielle Edmunds et al.*Animal Behaviour*.2021)

Direct effects of larval competition on development time and fecundity in seed beetles





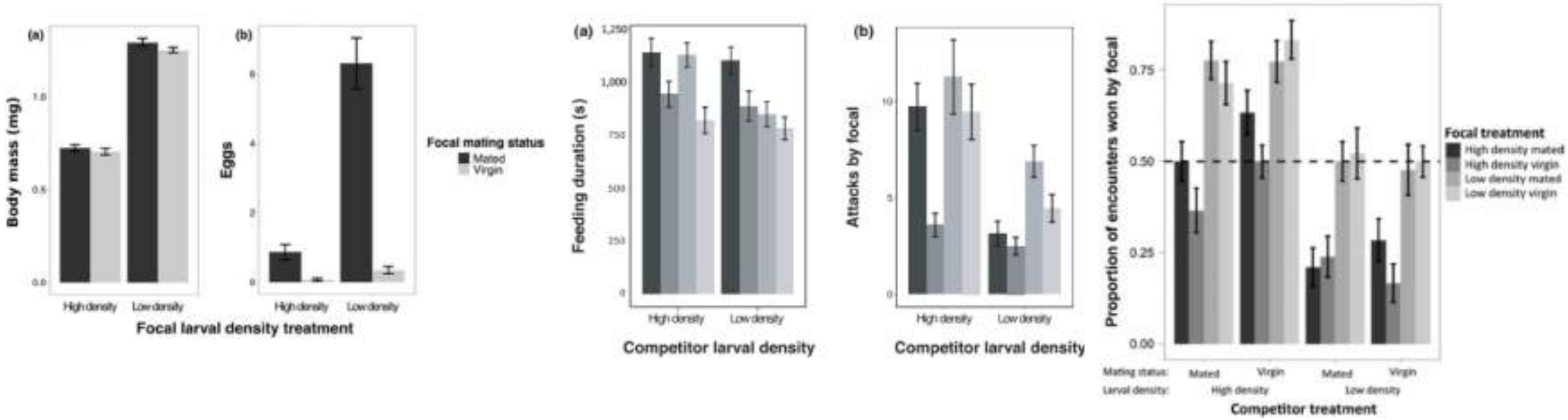


Species	Bean	Larval density	Fecundity	*P*
C. maculatus	Adzuki	1	67·0 ± 1·8[a]	0·0001
		2	66·7 ± 1·8[a]	
		3	56·3 ± 1·9[b]	
	Mung	1	59·2 ± 3·6	0·085
		2	49·6 ± 3·6	
C. chinensis	Adzuki	1	56·7 ± 1·4	0·45
		2	54·6 ± 1·5	
		3	54·3 ± 1·4	
	Mung	1	57·2 ± 1·6[a]	0·01
		2	51·0 ± 1·6[b]	

（Steven M. Vamosi and Terra L. Lesack.*Evolutionary Ecology Research*.2007）

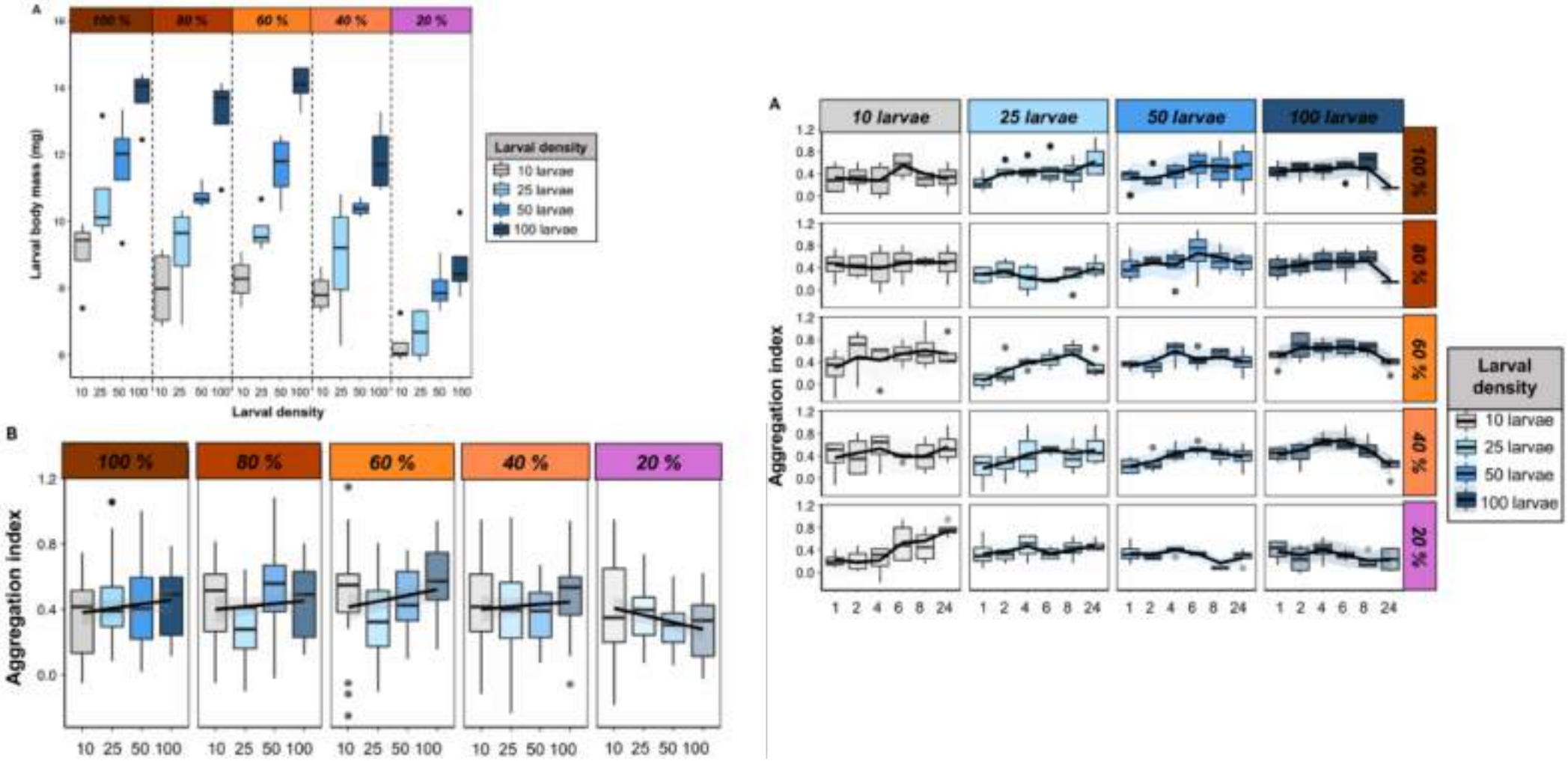
（S. M. Vamosi.*Functional Ecology*.2005）

The developmental environment modulates mating-induced aggression and fighting success in adult female Drosophila



（Eleanor Bath et al.*Functional Ecology*.2018）

The relationship between larval aggregation and larval body mass is dietdependent



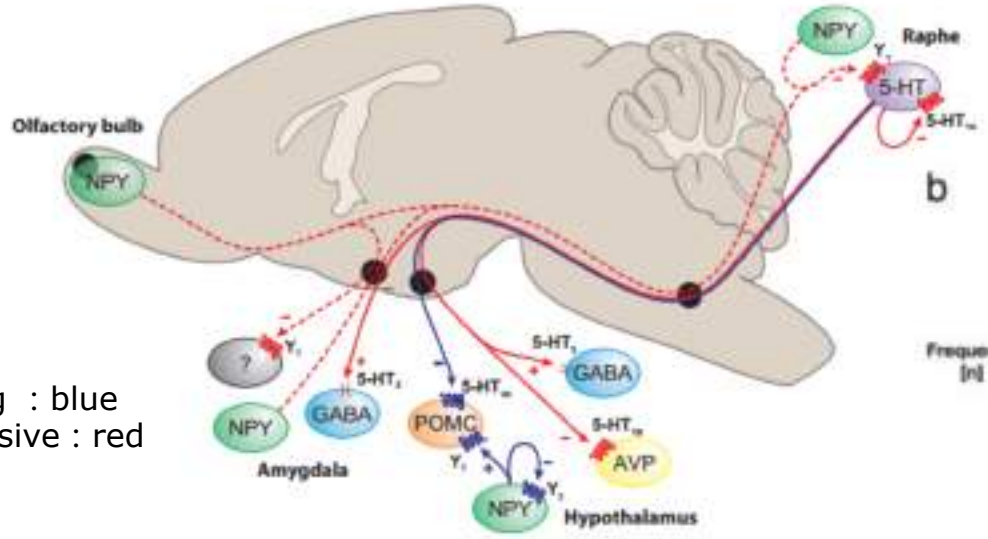
(Juliano Morimoto.et al.*Scientific Reports*.2018)

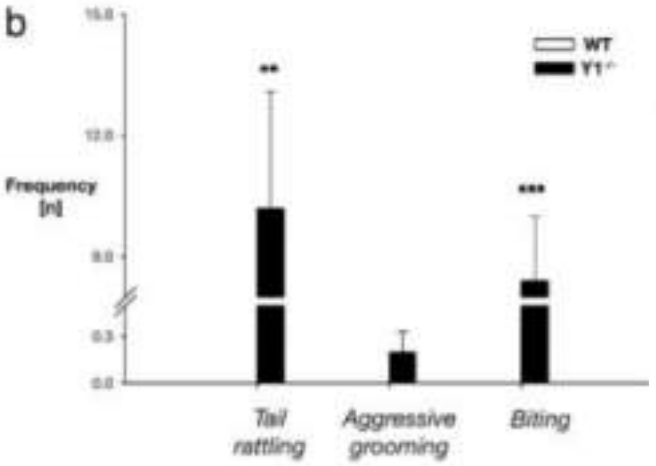
How does food resource relate to aggression ?

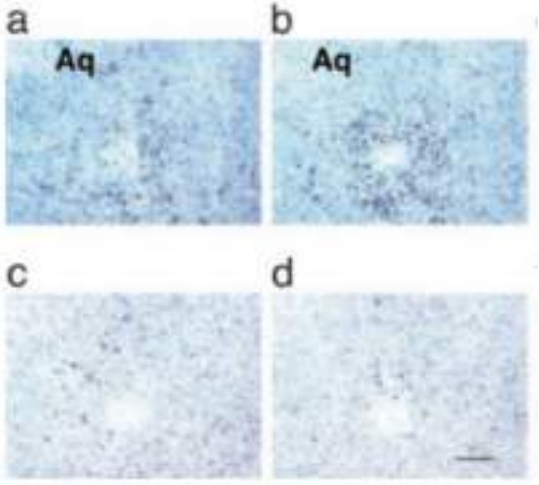
NPY acting through Y1 receptors regulates the 5-HT system, thereby coordinately linking food intake with enabling territorial aggressive behavior

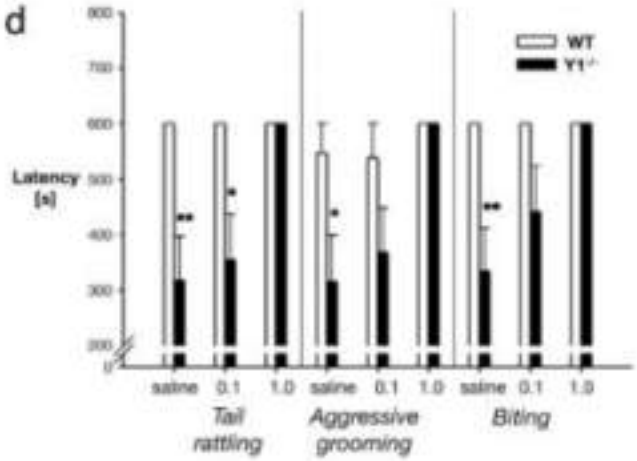
Interactions between synaptic circuits regulating aggression and feeding behavior

feeding : blue
aggressive : red





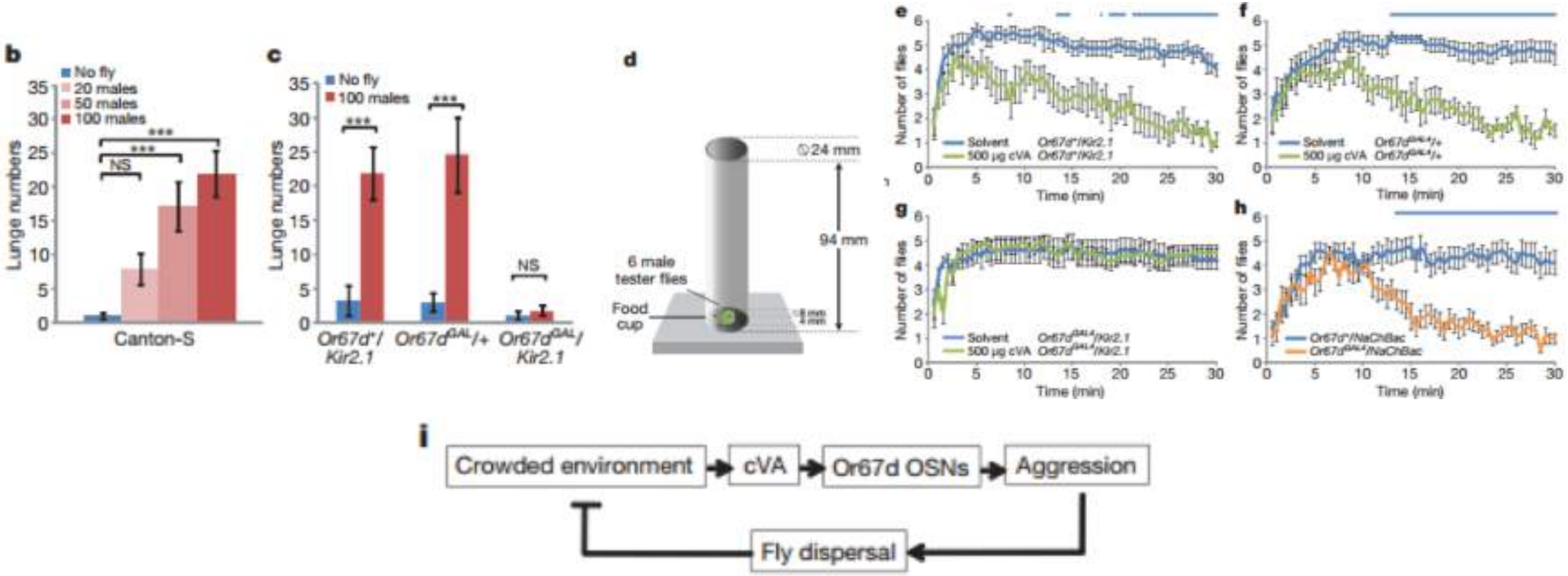




(Ronald B. Emeson and Michael V. Morabito.*Sci. STKE*.2005)

(Tim Karl et al. Morabito.*PNAS* .2004)

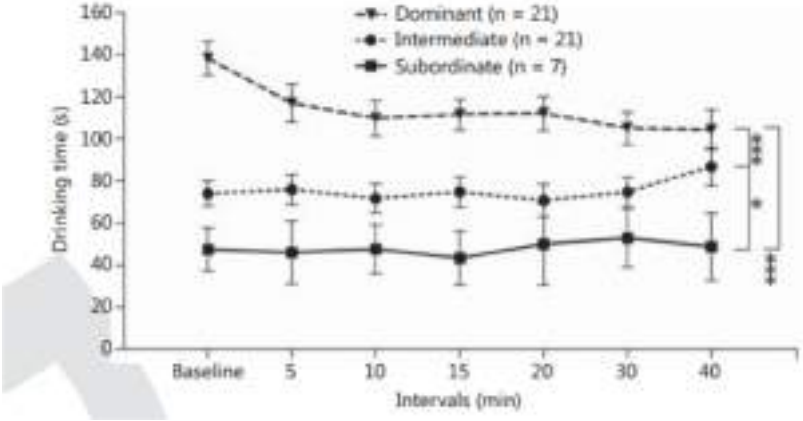
cVA promotes aggression at high fly densities and dispersal of male flies from a food resource

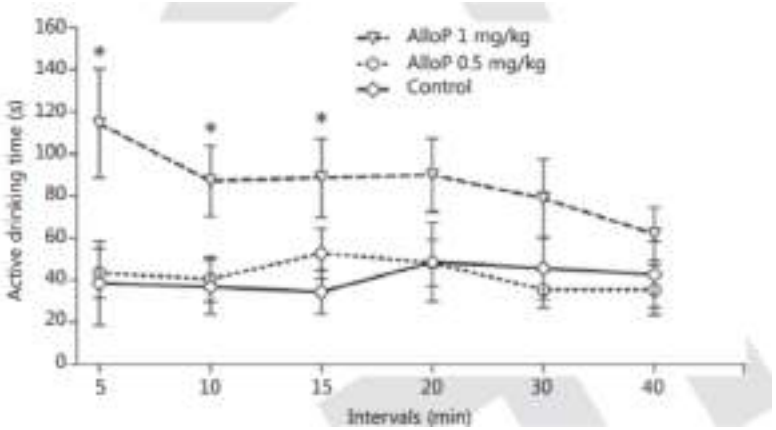


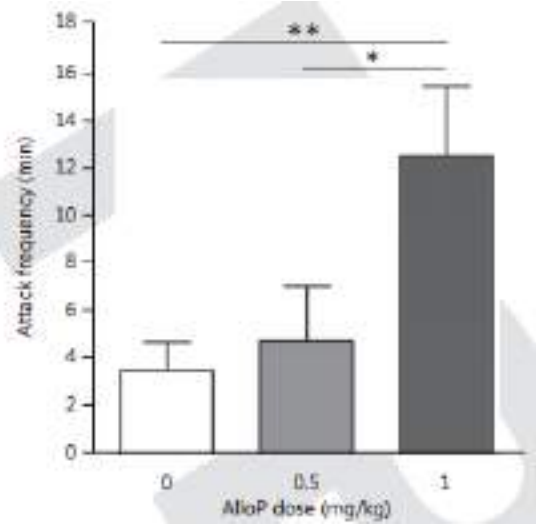
(Liming Wang & David J. Anderson.*Nature*.2010)

What about food competition and neural modulation in males and females?

Allopregnanolone promotes success in food competition in subordinate male rats

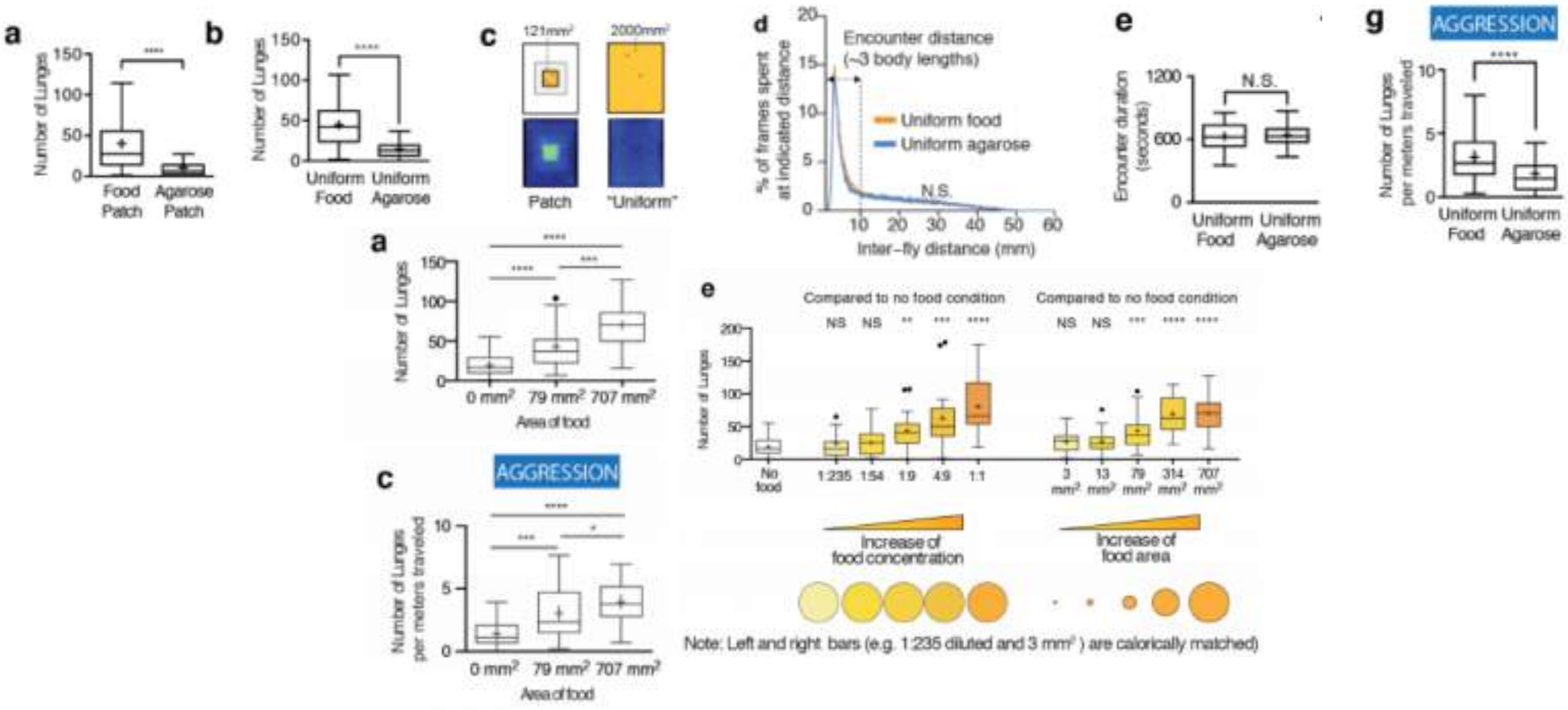






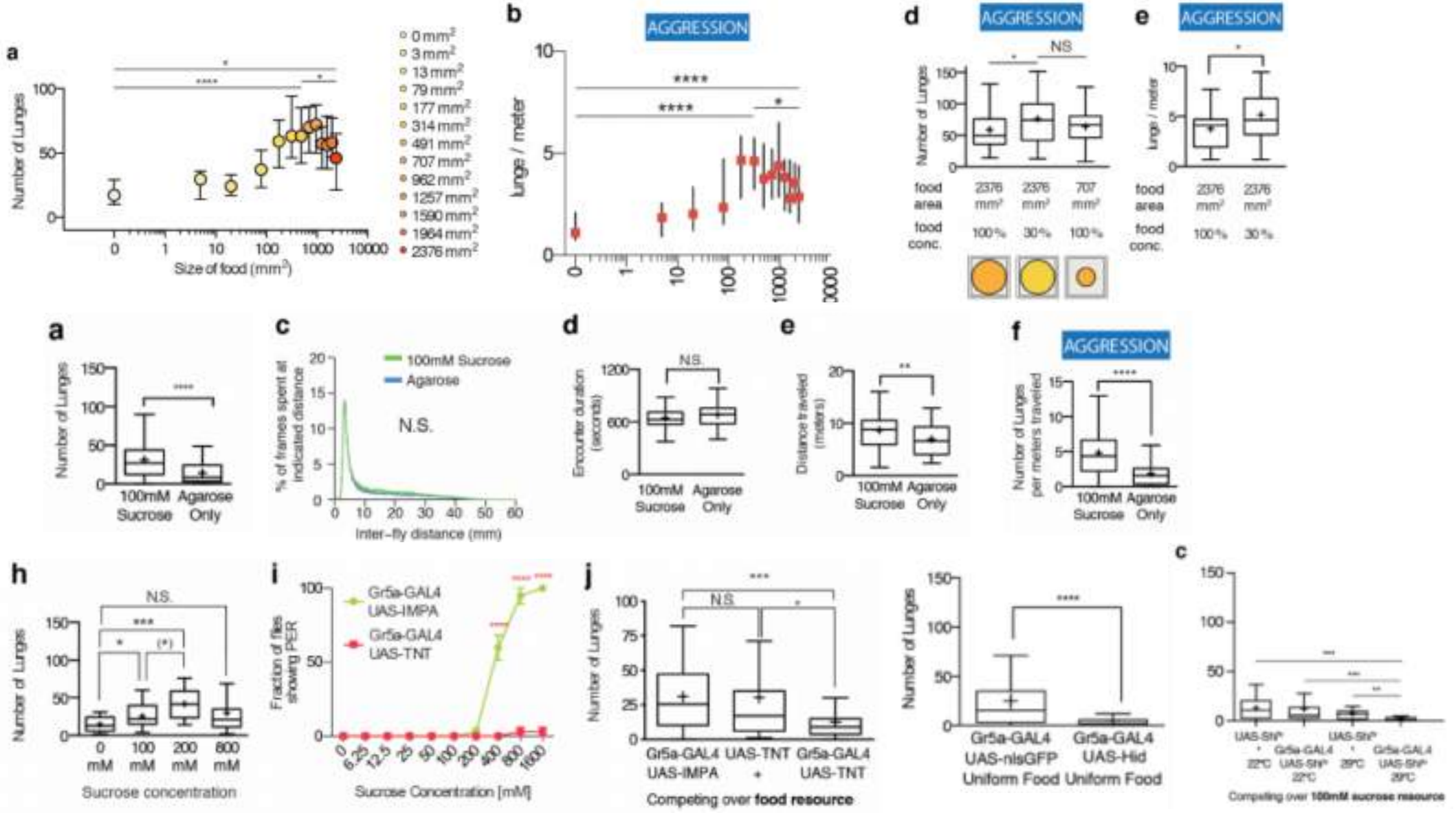
（ Magnus Löfgren.et al. *Neuropsychobiology*.2012 ）

Food promote aggression and the level of aggression depends on the absolute amount of food

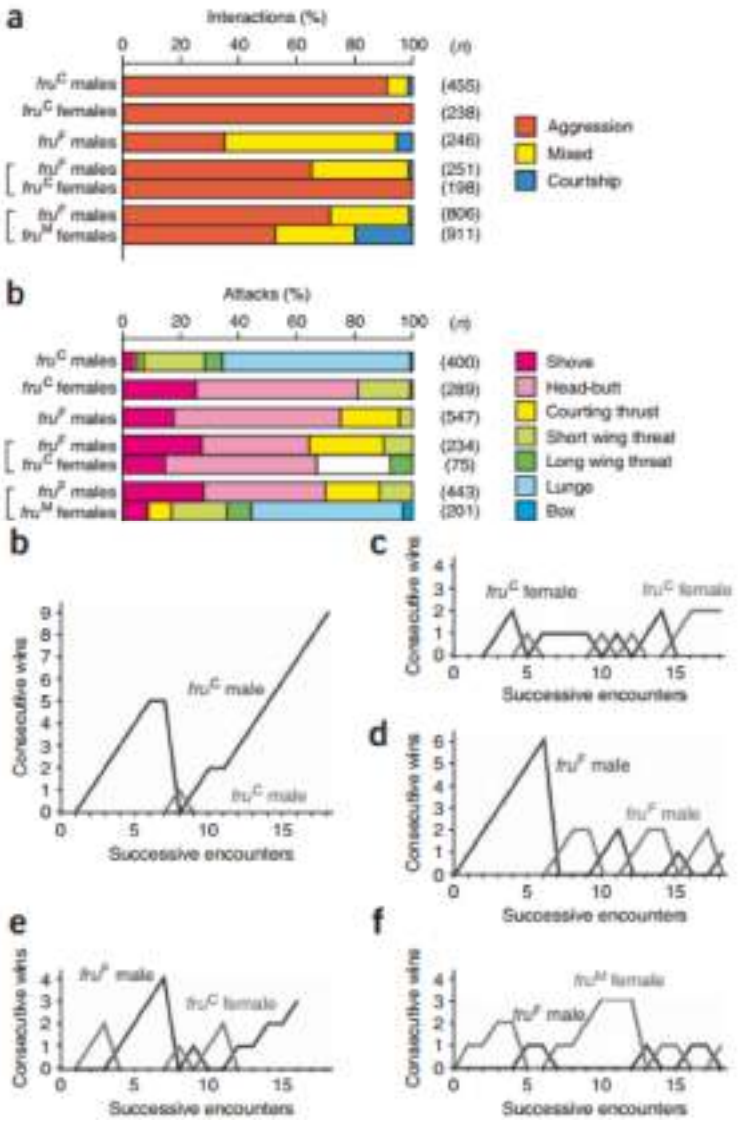


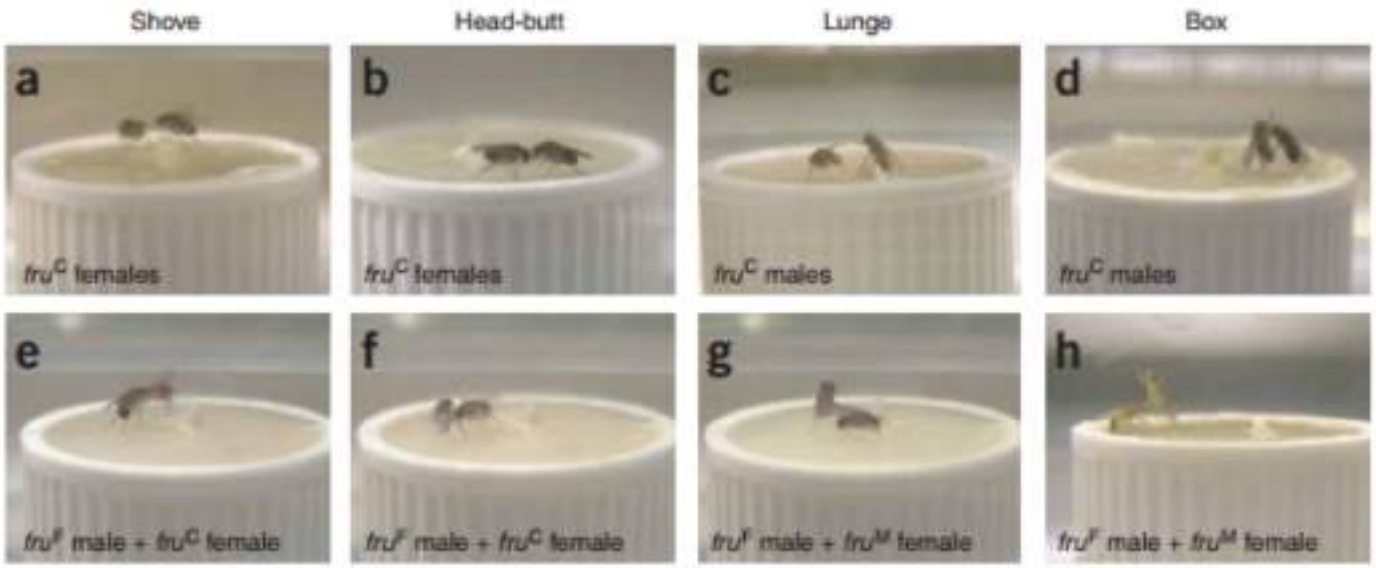
(Rod S. Lim et al.*PLOS ONE*.2014)

Flies decrease fighting when food exceeds a certain threshold and the activity of sugar sensing Gr5a+ gustatory receptor neurons is required for aggression



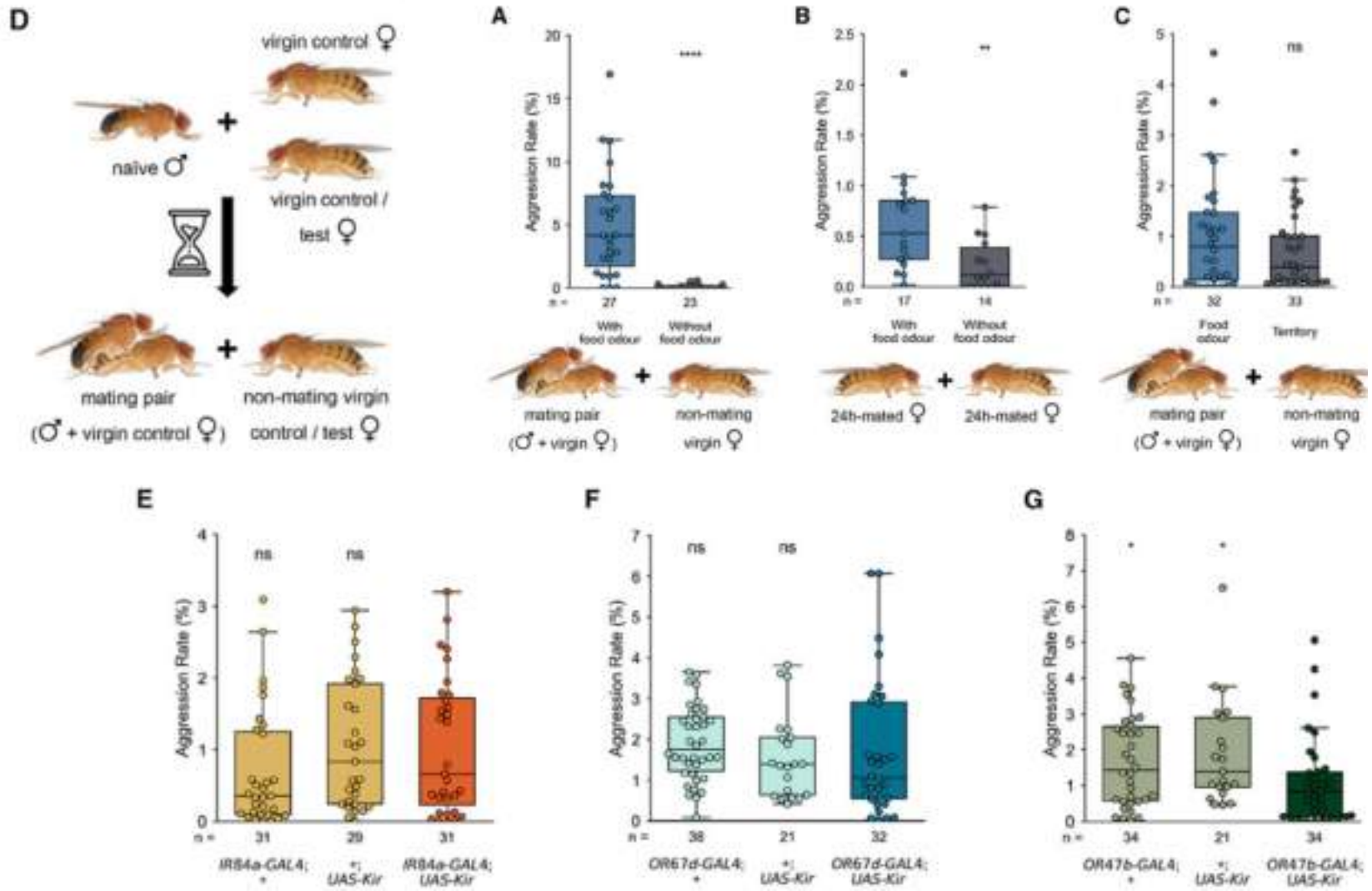
fruitless regulates aggression and dominance in Drosophila





(Eleftheria Vrontou et al.*Nature Neuroscience*.2006)

Presence of food odor, copulating male and activity of OR47b olfactory sensory neurons contribute to **female** aggressive behavior



(Miguel Gaspar .et al.*Current Biology*.2022)

Summary

1、In general, food competition affects body mass and aggressive behavior；

2、Food-related aggressive behavior in mammals has been linked to other behavioral pathways,including feeding and anxiety-related behaviors, and these links are maintained by multiple hormone and neurotransmitter systems that signal through complex neuronal circuits to control impulsiveness and aggressiveness；

3、In males, Gr5a+ GRN is required for normal levels of food-induced aggression and fru regulates aggression in fruit flies; In females, food odors through OR47b causing aggressive behavior.

THANK YOU !

Competitive behaviors for territory and the neuronal regulating pathways

- How do organisms compete for territory in time and space?
- How do neurons drive competition related to social hierarchy?

TW

2023.12.7

Territorial competition

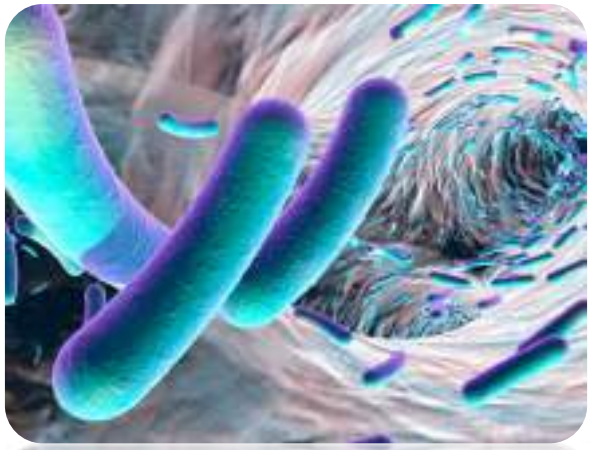
Two tigers can not share one mountain.

Chimpanzee

Land

Birds

Air



Bacteria

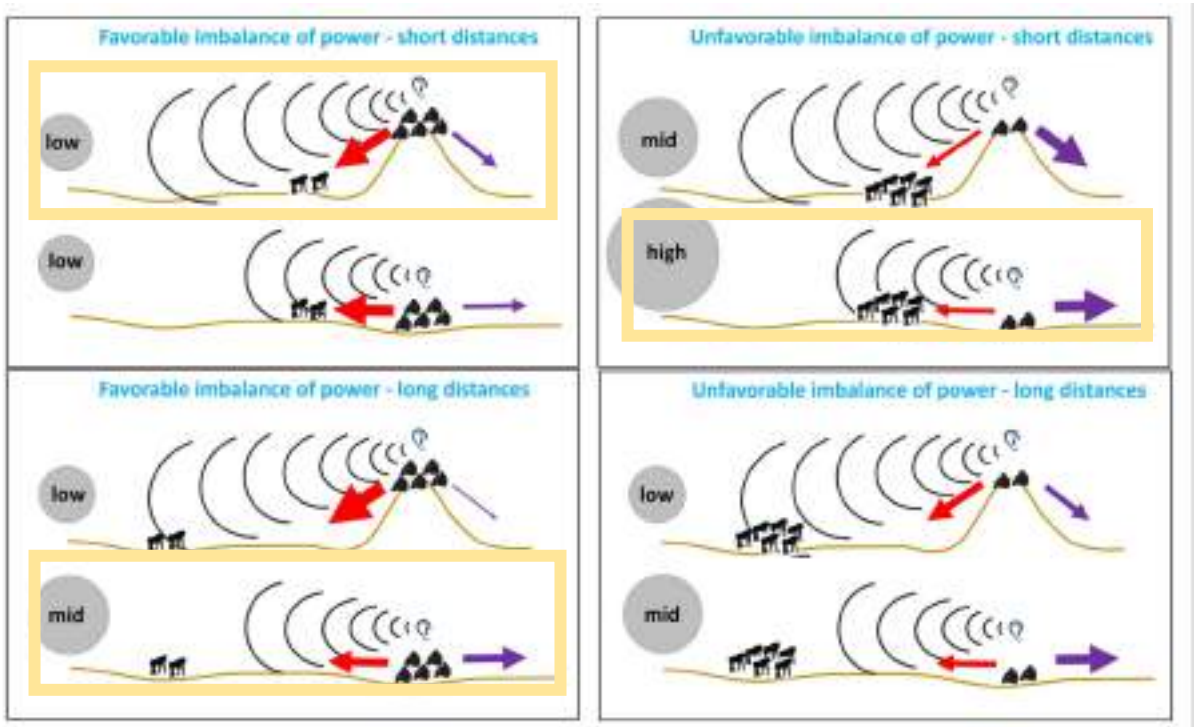
Microorganism

How do organisms compete for territory in time and space?

Tactical use of elevation by wild chimpanzees

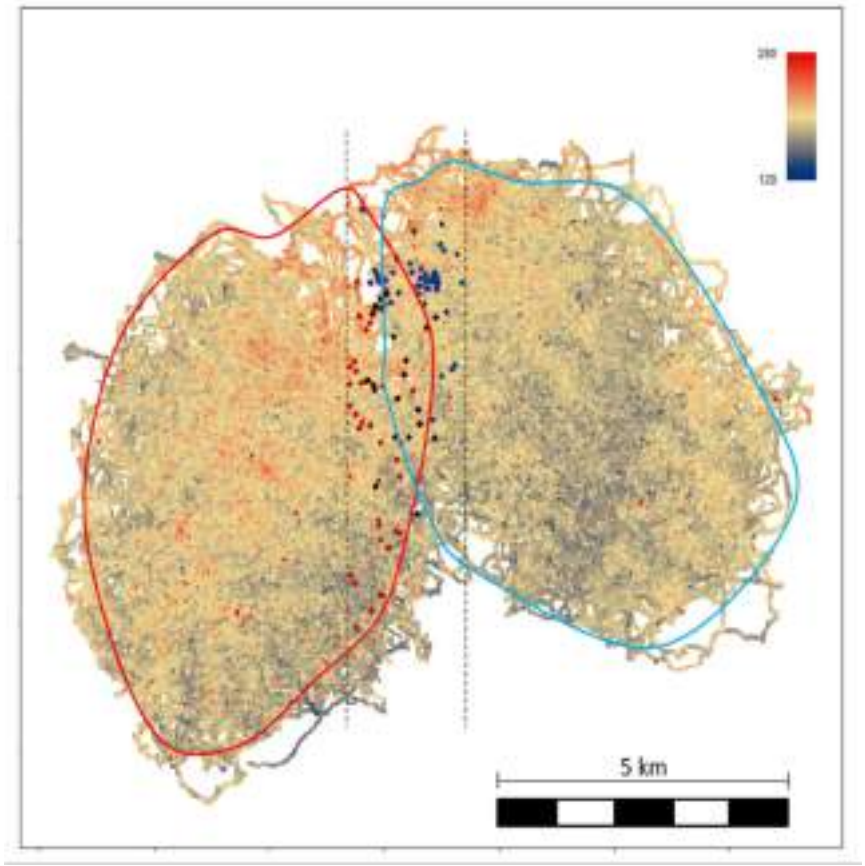
"Be before the enemy in occupying the raised and sunny spots (. . .) Then you will be able to fight with advantage"

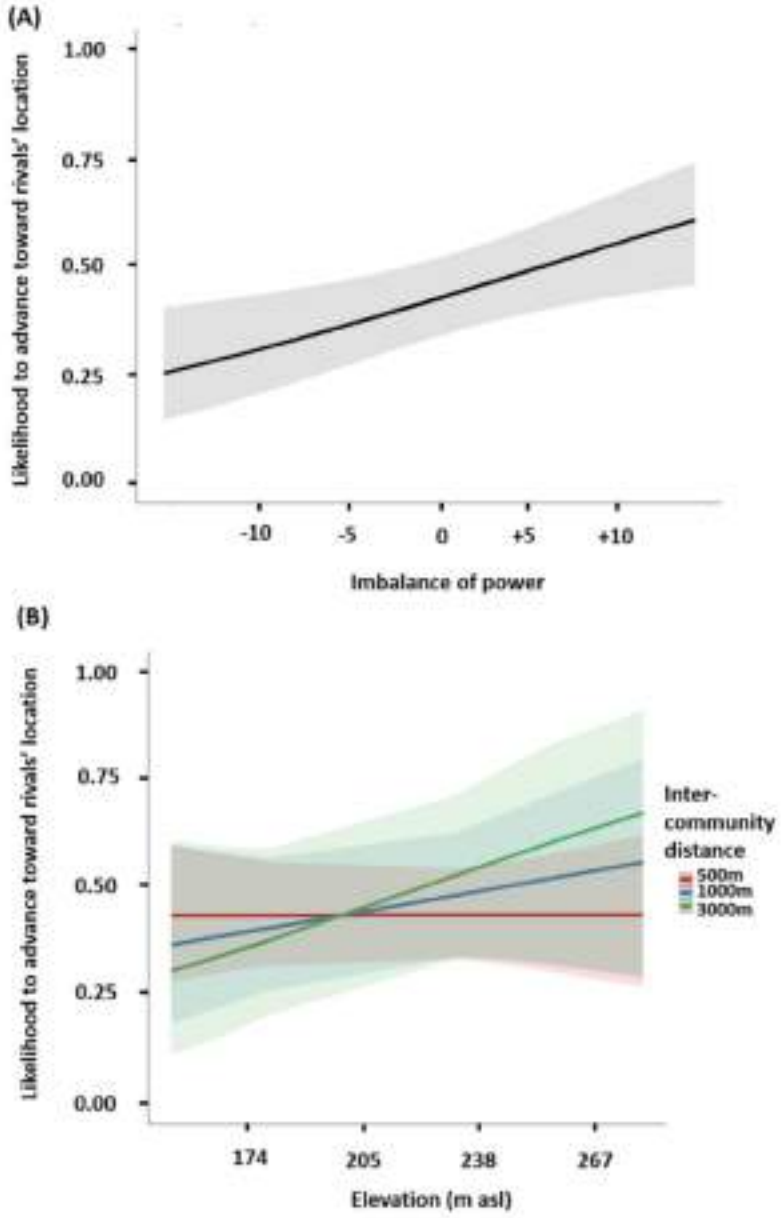
–Sun Tzu



(Lemoine SRT, et al. PLoS Biol. 2023)

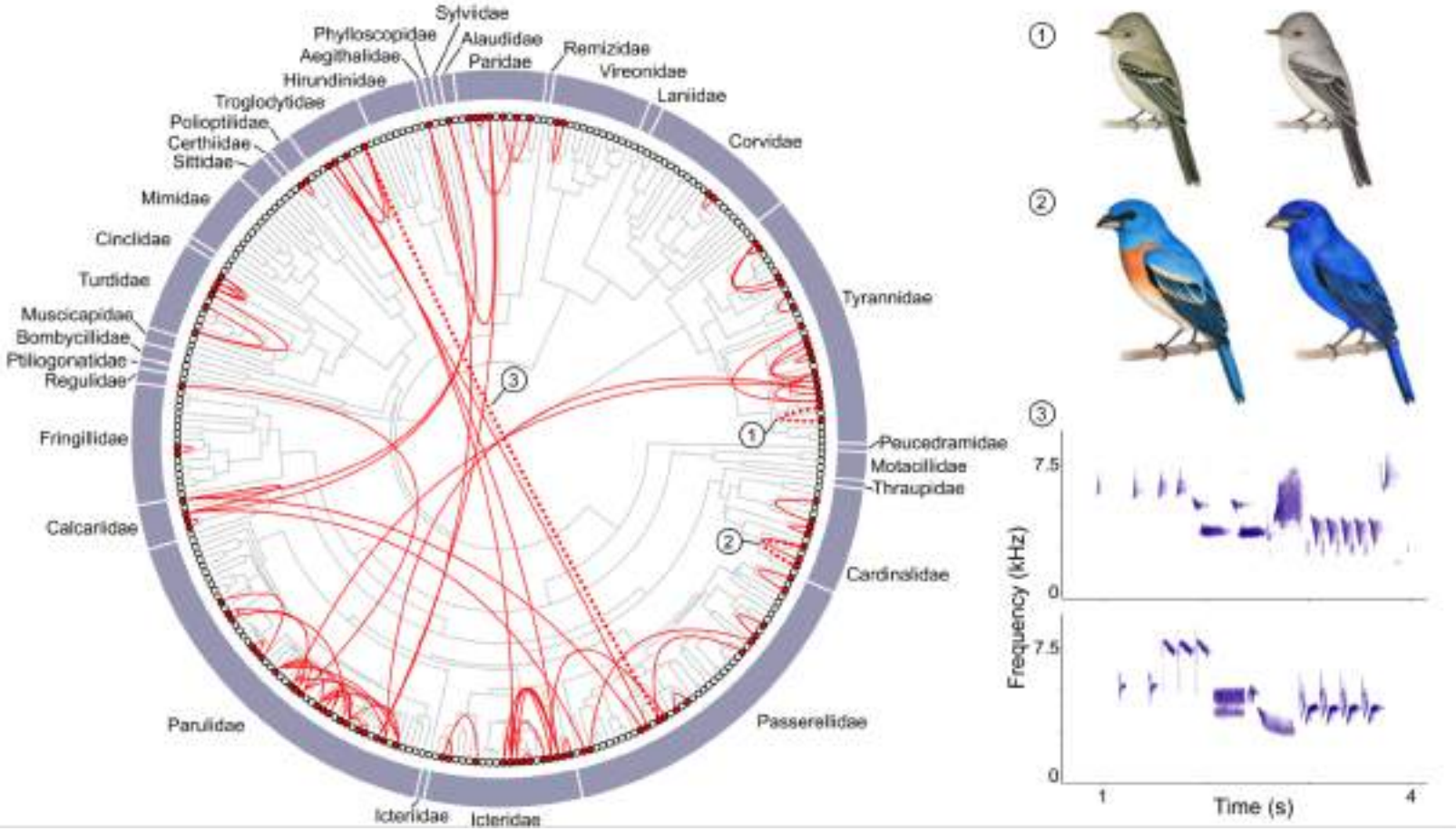
Tactical use of elevation by wild chimpanzees





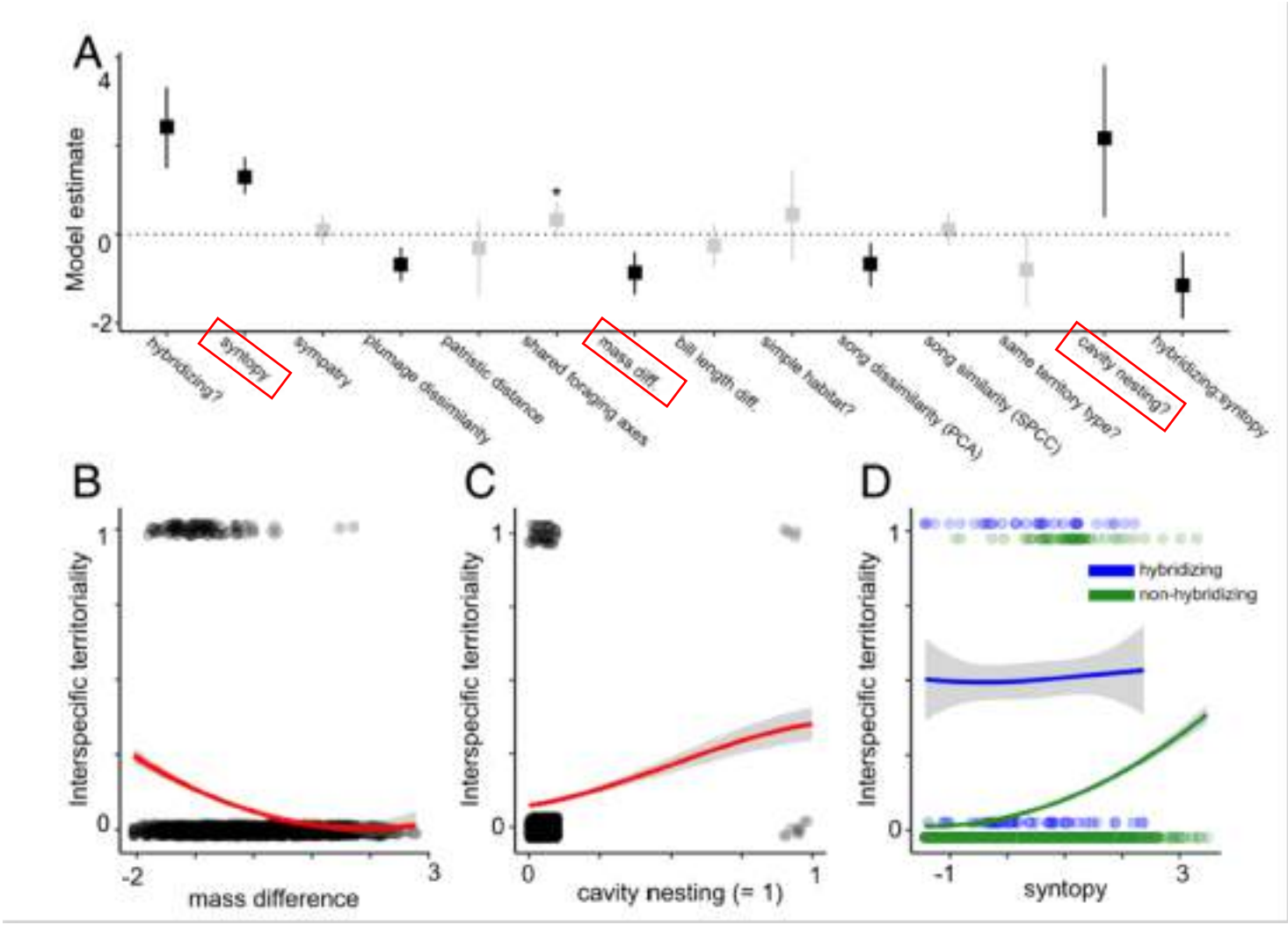
(Lemoine SRT, et al. PLoS Biol. 2023)

Interspecific territoriality is widespread



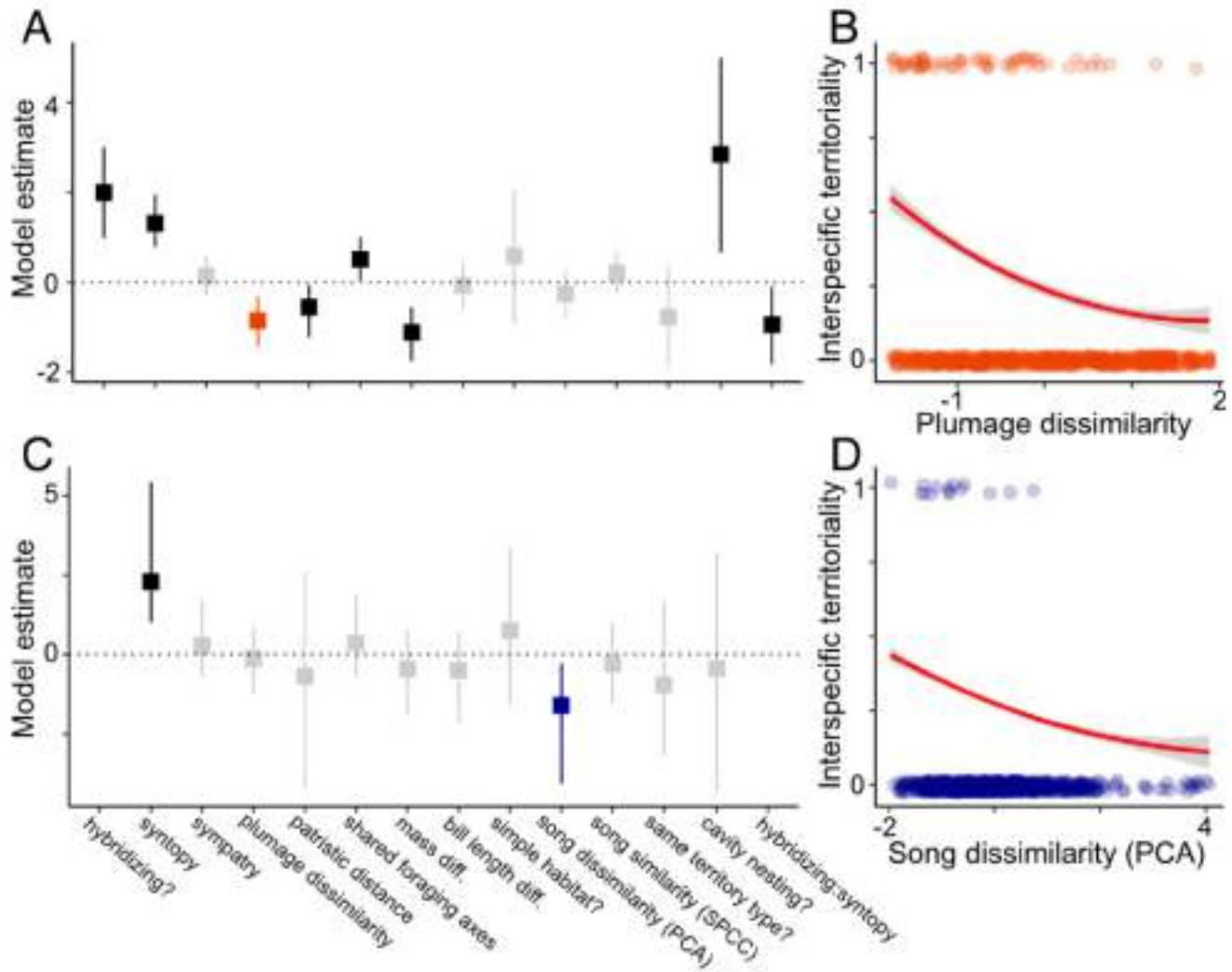
(Drury JP, et al. PNAS. 2020)

Resource competition as a primary driver of interspecific territoriality



(Drury JP, et al. PNAS. 2020)

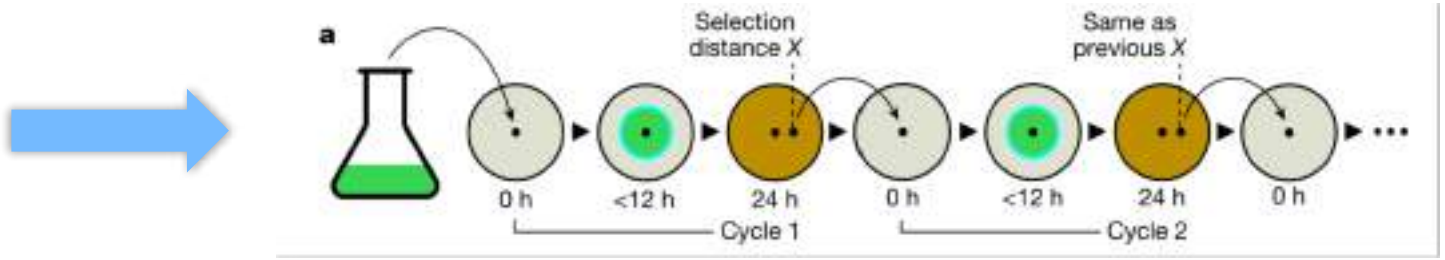
Different factors mediate interspecific territoriality between species of the same family



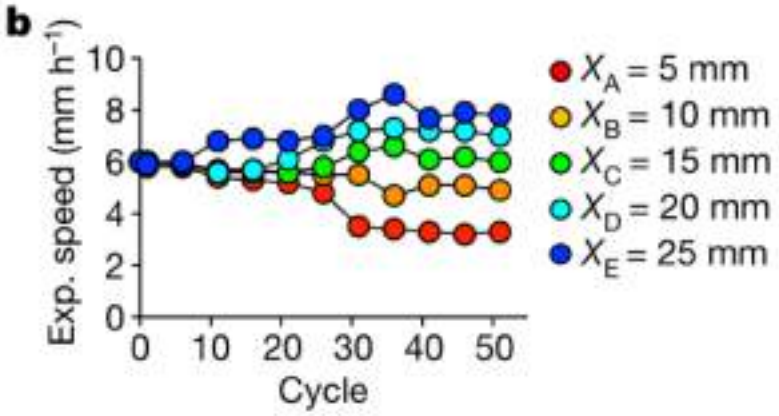
(Drury JP, et al. PNAS. 2020)

Experimental evolution with position-dependent selection

The Great Migration of East African Animals



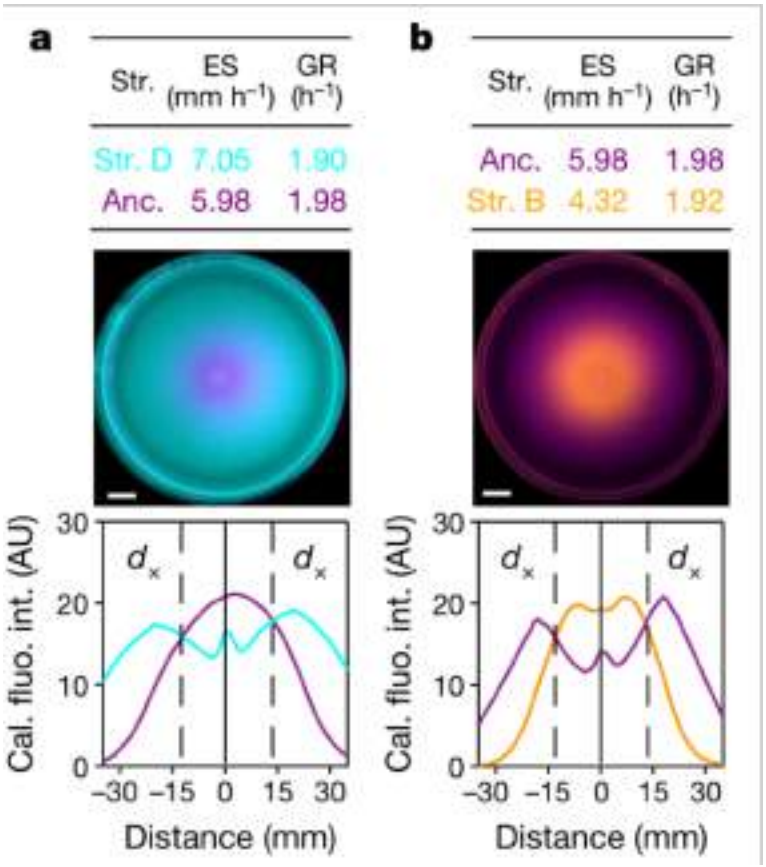
Bacterial migration

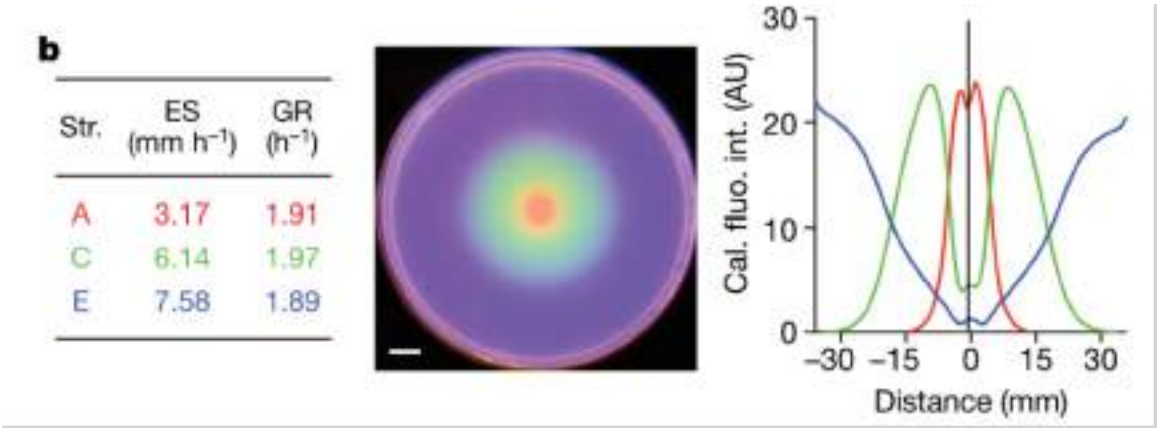


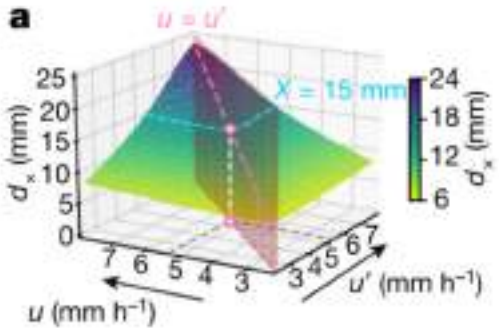
(Liu W, et al. Nature. 2019)

Competitive expansion in space

expansion speeds
growth rates







(Liu W, et al. Nature. 2019)

Summary

1. Smart decision-making in the competition of biological territories

Chimpanzee, high elevation in territorial contexts (Depending on elevation, imbalance of power, and intercommunity distance)

North American passerine, interspecific territoriality (Plumage dissimilarity and song dissimilarity)

Chemotaxing bacteria, colonizing a habitat (Quantitative analysis of time and space in microecological evolution)

How do neurons drive competition related to social hierarchy?

HAILAN HU LAB

School of Brain Science and Brain Medicine，ZJU

MOE Frontier Science Center for Brain Research and Brain-Machine Integration, ZJU

Zhejiang University School of Medicine

Research

- Neural Representation of Emotional Value
- Molecular and Circuit Mechanism of Depression
- Neural Circuit Mechanism of Social Hierarchy

Publications

Dong Y, Li Y, Xiang X, Xiao Z, Hu J, Li Y, Li H, Hu H*.(2023). Stress relief as a natural resilience mechanism against depression-like behaviors. ***Neuron***. 111: 1-13.

Fan Z, Chang J, Liang Y, Zhu H, Zhang C, Zheng D, Wang J, Xu Y, Li Q, Hu H*.(2023). Neural mechanism underlying depressive-like state associated with social status loss. ***Cell***. 186: 1–17.

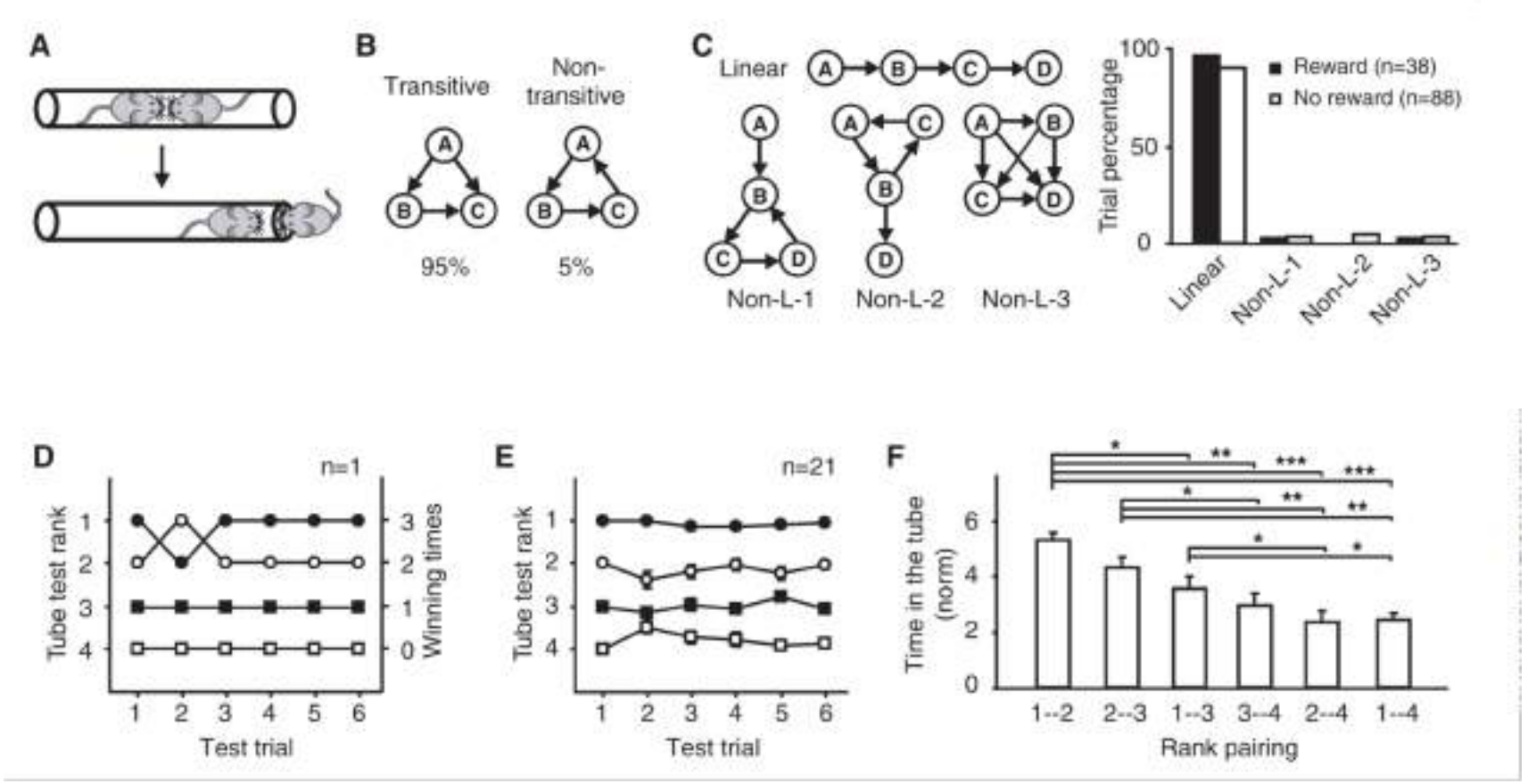
Zhang C#, Zhu H#*, Ni Z#, Xin Q, Zhou T, Wu R, Gao G, Gao Z, Ma H, Li H, He M, Zhang J, Chen H, Hu H*.(2022). Dynamics of a disinhibitory prefrontal microcircuit in controlling social competition. ***Neuron***. 110: 516-531.

Yang Y, Cui Y, Sang K, Dong Y, Ni Z, Ma S, Hu H.(2018). Ketamine blocks bursting in the lateral habenula to rapidly relieve depression. ***Nature***. 554: 317-22.

Cui Y, Yang Y, Ni Z, Dong Y, Sang K, Cai G, Foncelle A, Ma S, Sang K, Tang S, Li Y, Shen Y, Berry H, Wu S, Hu H.(2018). Astroglial Kir4.1 in the lateral habenula drives neuronal bursts in depression. ***Nature***. 554: 323-27.

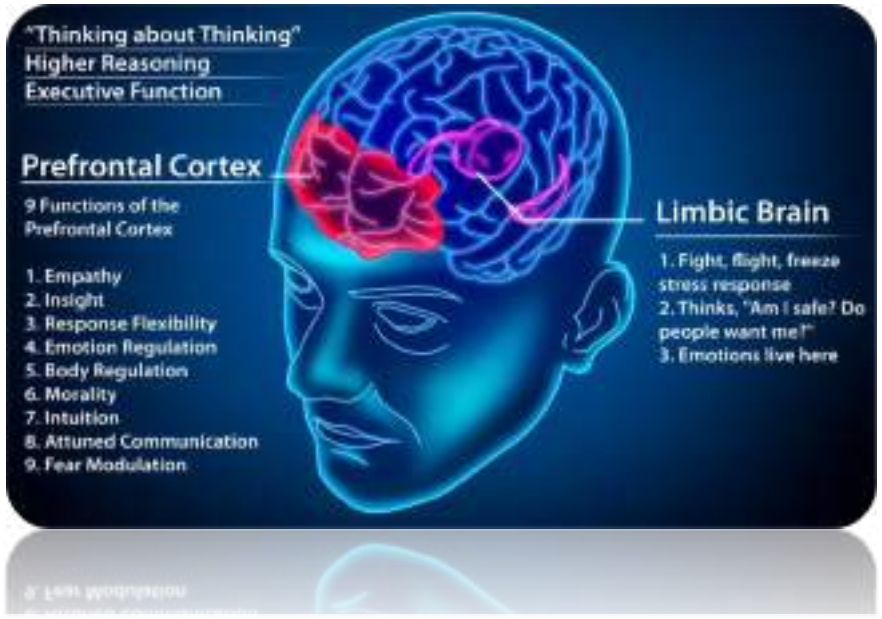
Zhou TT, Zhu H, Fan ZX, Wang F, Chen Y, Liang HX, Yang ZF, Zhang L, Lin LN, Zhan Y, Wang Z, Hu H.(2017). History of winning remodels thalamo-PFC circuit to reinforce social dominance. ***Science***. 357: 162-168.

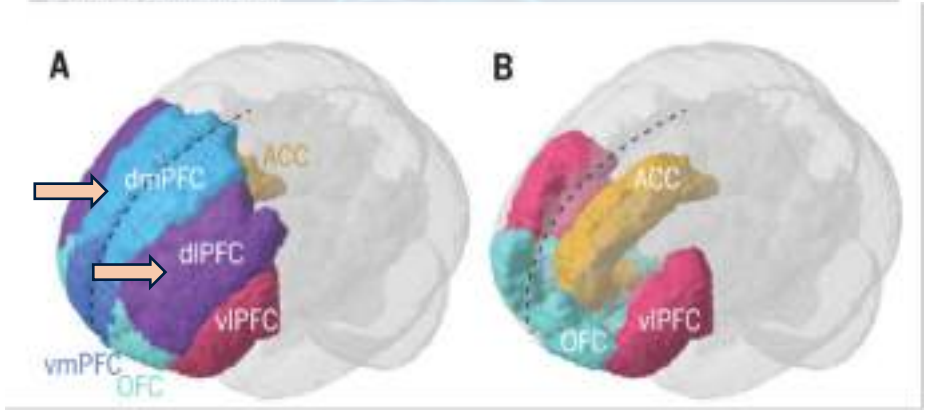
Tube-test ranking for social hierarchy



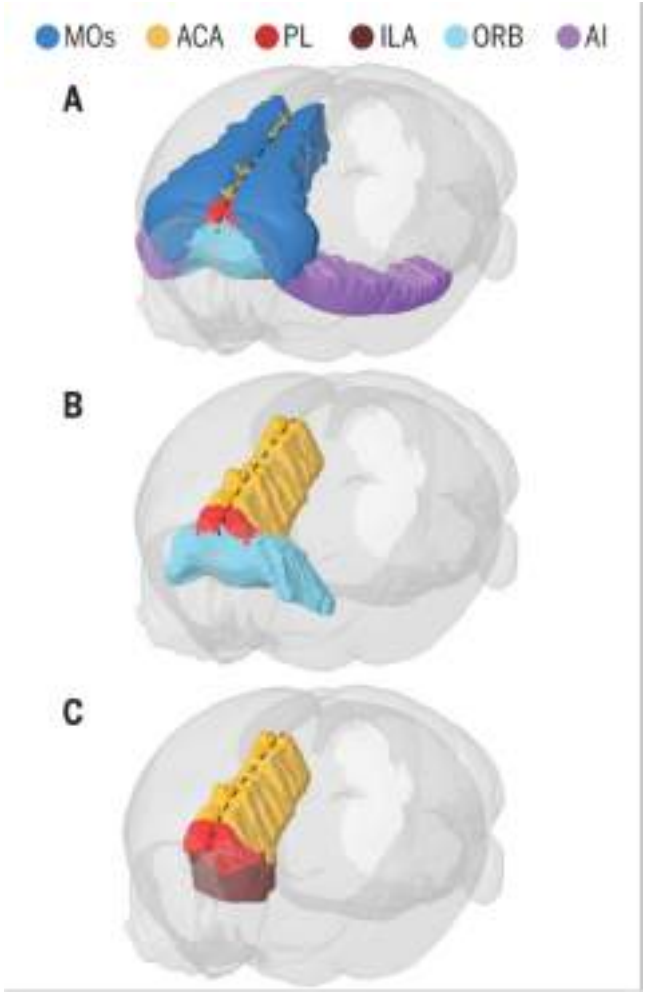
(Wang F, et al. Science. 2011)

Prefrontal cortex

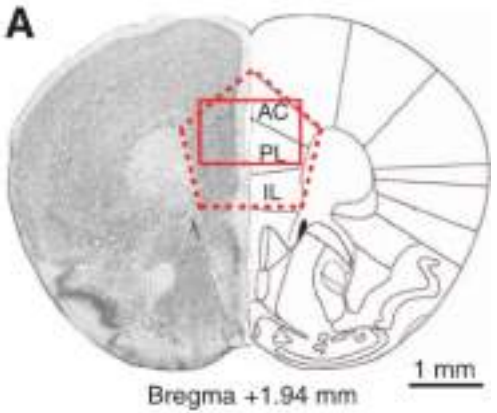




Functional division of the human prefrontal cortex



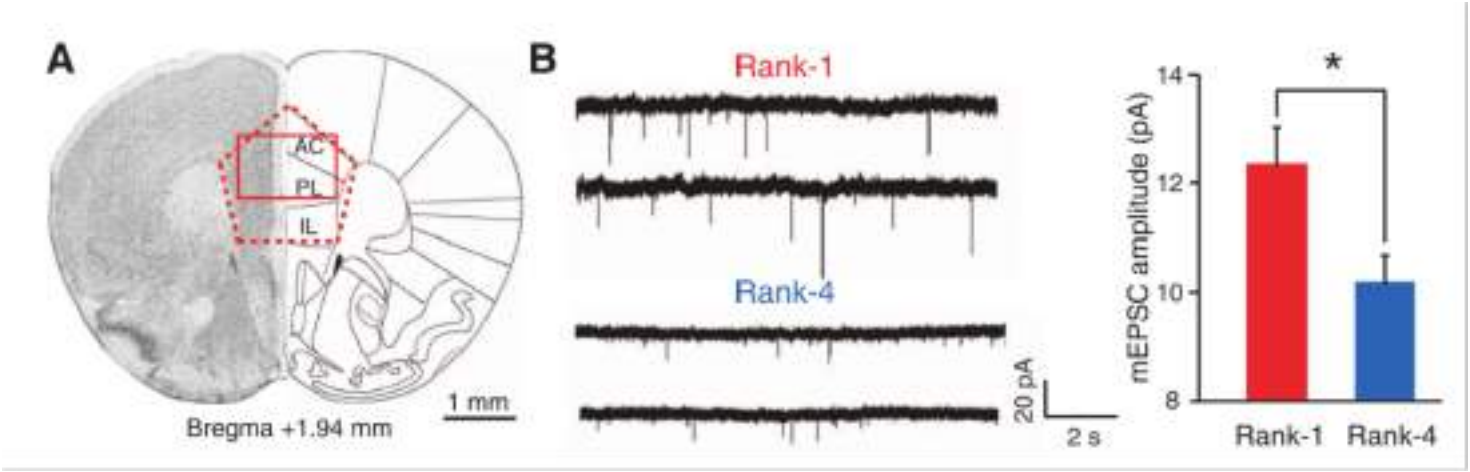
The mouse prefrontal cortex



(Wang F, et al. Science. 2011)

(Carlén M. Science. 2017)

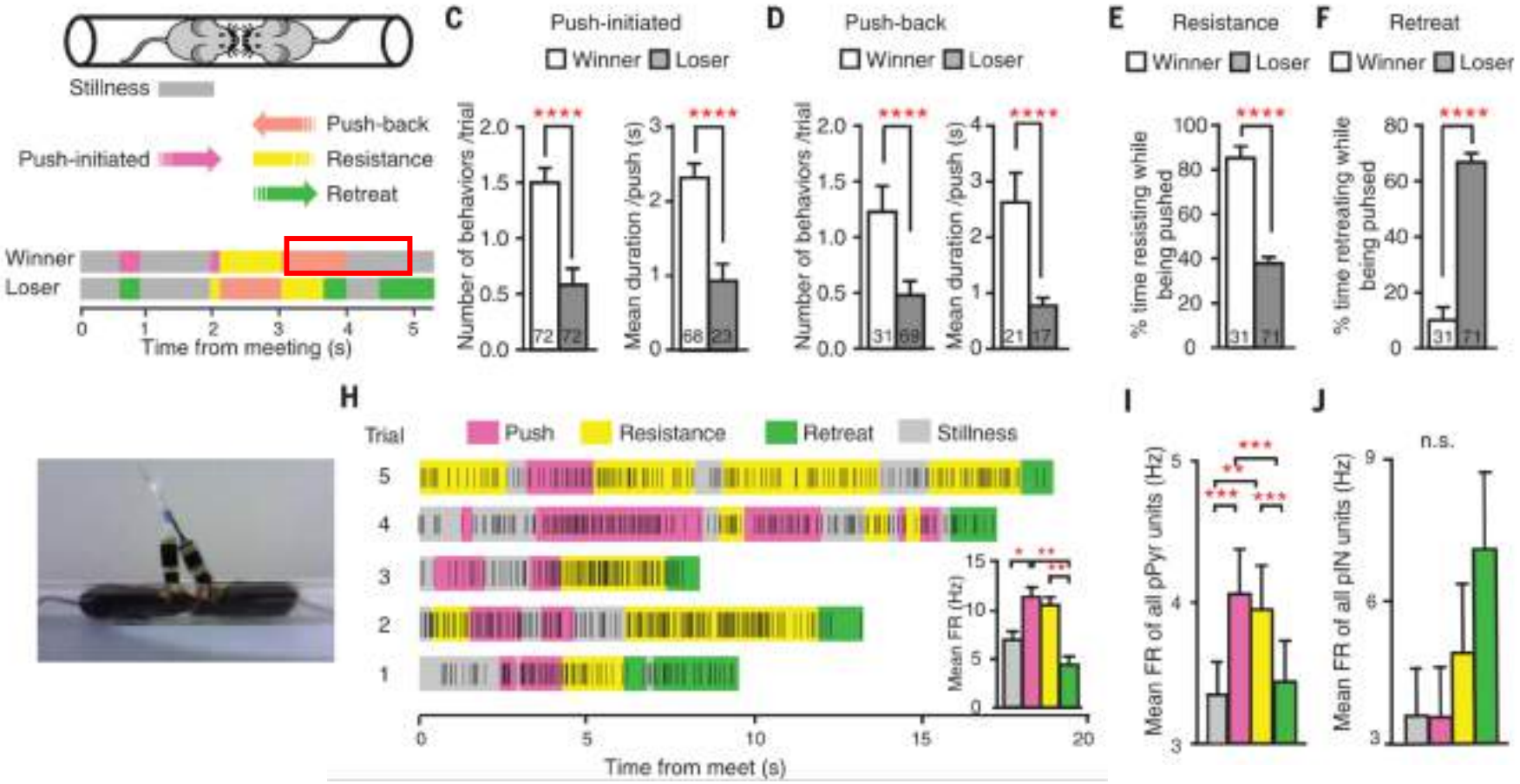
Dominant mice have larger synaptic strength than the subordinate ones



mPFC, as a neural substrate for dominance hierarchy

(Wang F, et al. Science. 2011)

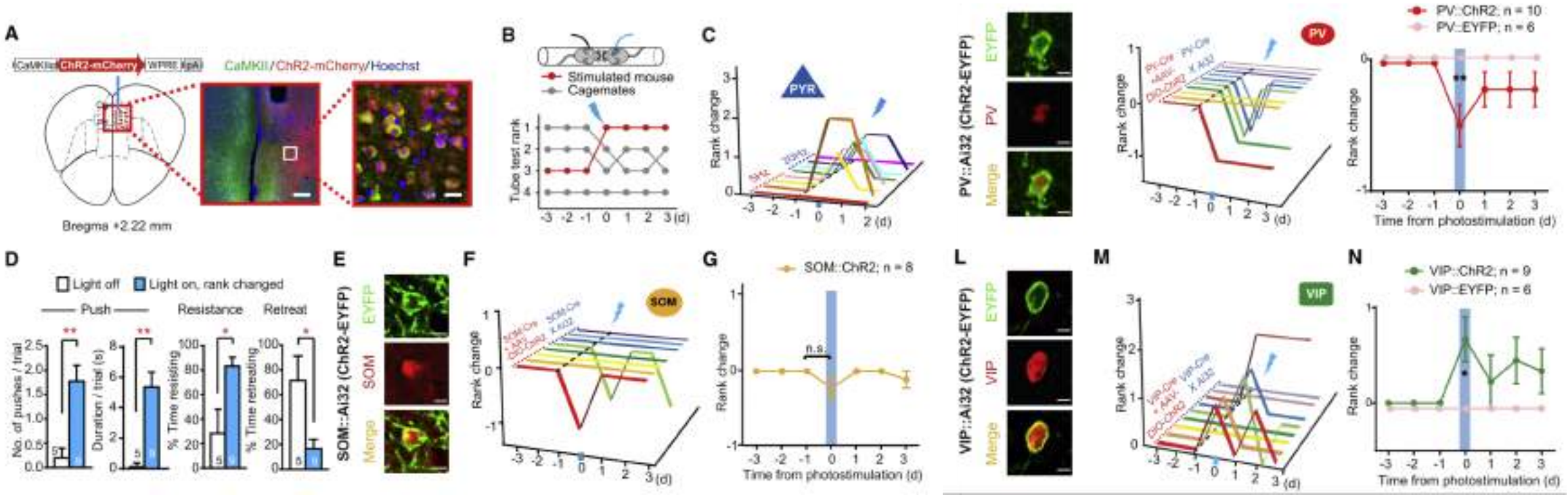
dmPFC neurons are activated during effortful behaviors in the dominance tube test



潜在的锥体神经元(putative pyramidal neurons, **pPyr**)
潜在的中间神经元(putative interneurons, pIN)

(Zhou T, et al. Science. 2017)

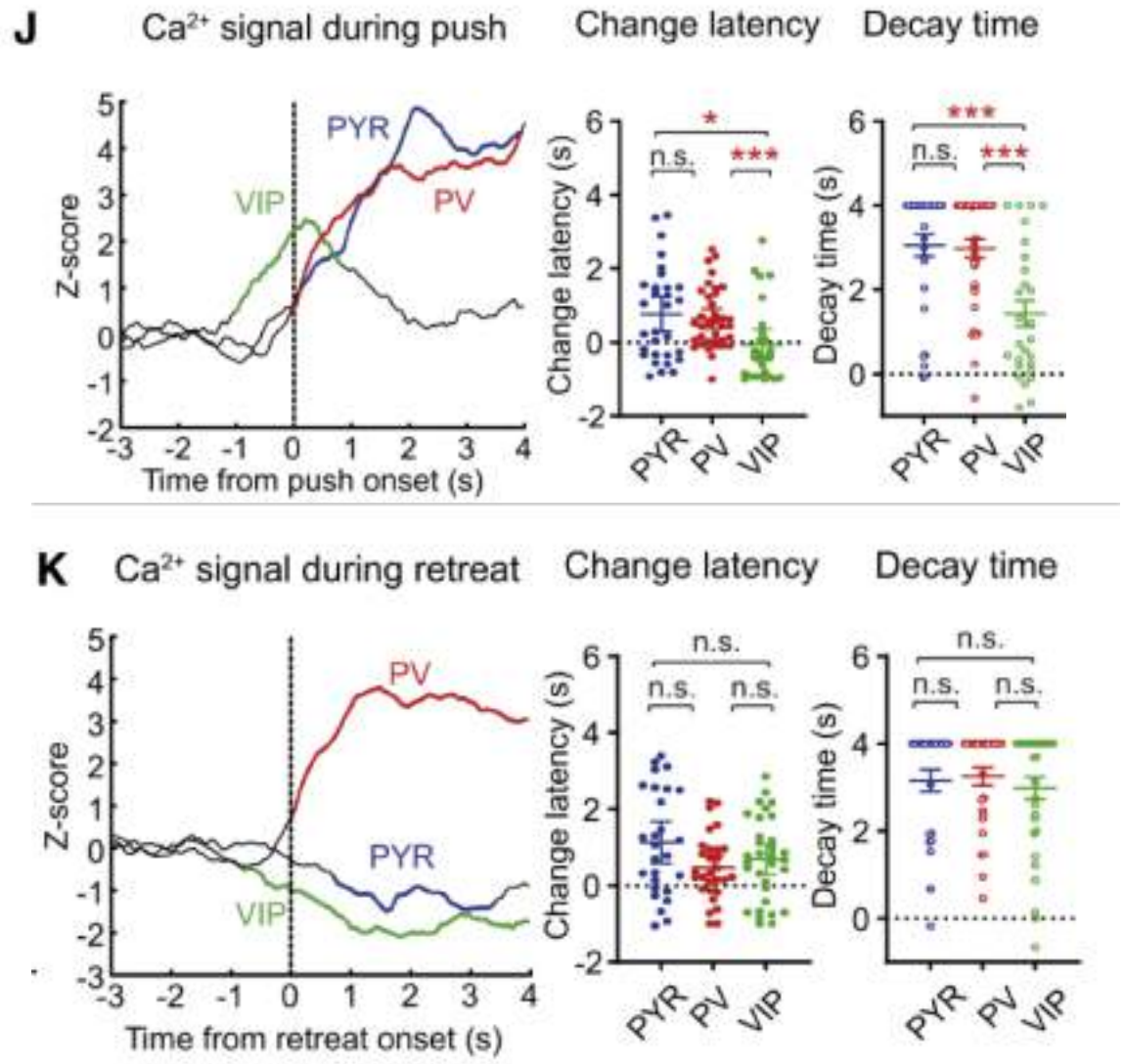
Different types of neurons in the dorsomedial prefrontal cortex play different roles in social competition



dmPFC中PYR神经元和三种主要中间神经元：
血管活性肠肽（VIP）、小清蛋白（PV）和生长抑素（SOM）神经元

(Zhang C, et al. Neuron. 2022)

Different types of neurons in the dorsomedial prefrontal cortex play different roles in social competition

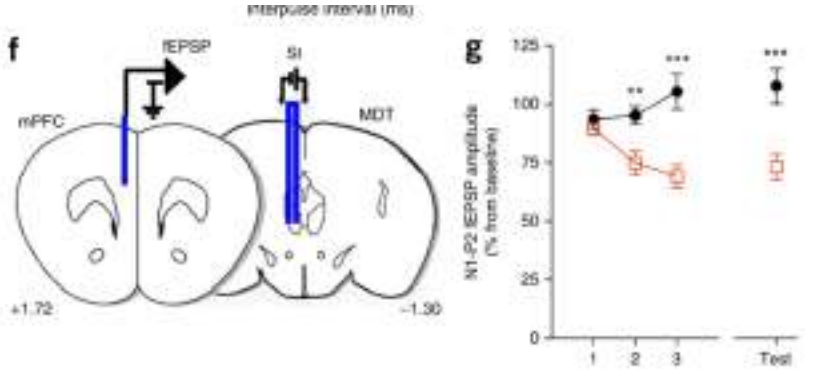


Manipulation on Rank

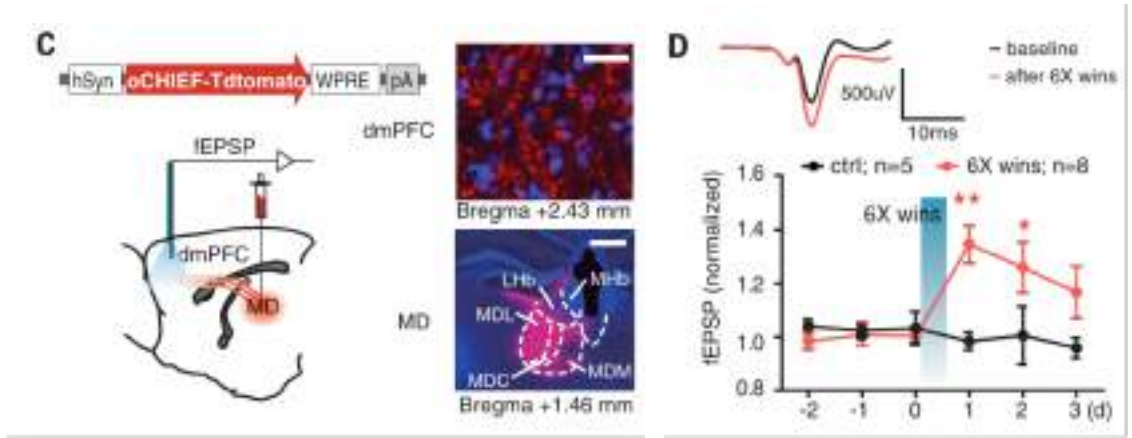
	Activated	Inhibited
PYR	+	N/A
VIP	+	−
PV	−	+
SOM	n.s.	n.s.

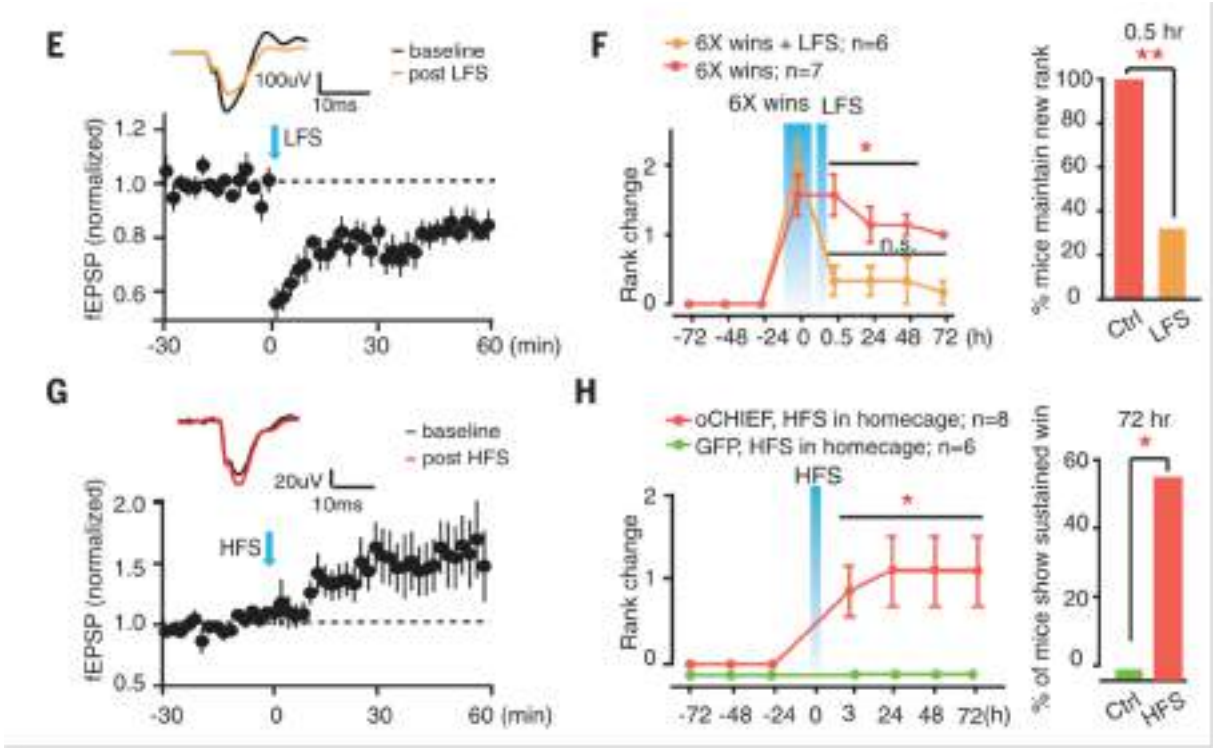
(Zhang C, et al. Neuron. 2022)

Synaptic strength in the MDT-dmPFC circuit underlies the winner effect in the tube test



(Franklin TB, et al. Nat Neurosci. 2017)

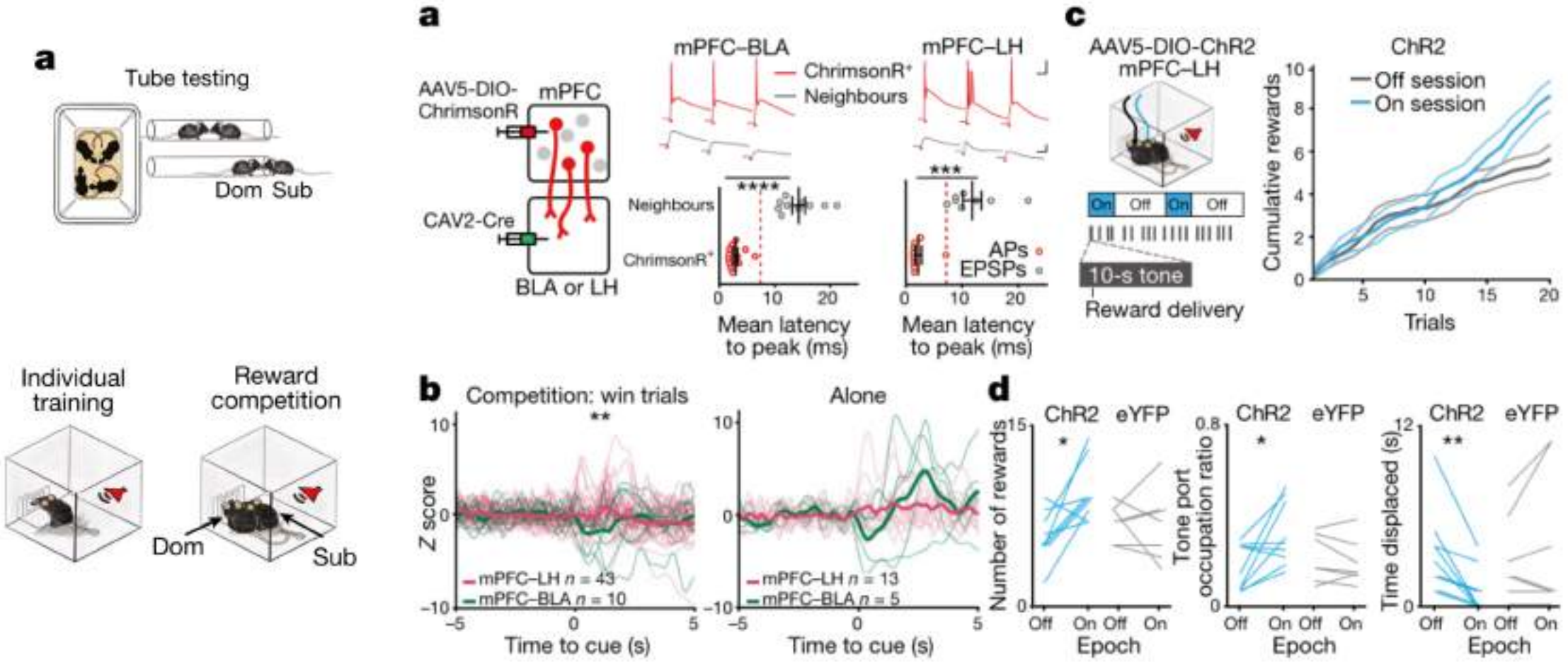




The synaptic connections of the MDT-PFC circuit mediate the "winner effect"

(Zhou T, et al. Science. 2017)

mPFC–LH neurons modulate dominance



(Padilla-Coreano N, et al. Nature. 2022)

Summary

1. Smart decision-making in the competition of biological territories

Chimpanzee, high elevation in territorial contexts

North American passerine, interspecific territoriality

Chemotaxing bacteria, colonizing a habitat

2. Neuron driven social competitive behavior mechanism

- mPFC, as a **neural substrate** for dominance hierarchy
- **dmPFC neurons** are **activated** during effortful behaviors
- Different types of neurons in the dorsomedial prefrontal cortex play **different roles** in social competition
- The synaptic connections of the **MDT-PFC circuit** mediate the "winner effect“
- **mPFC–LH pathway** encodes social competition and modulates social dominance behaviour

Thanks ！