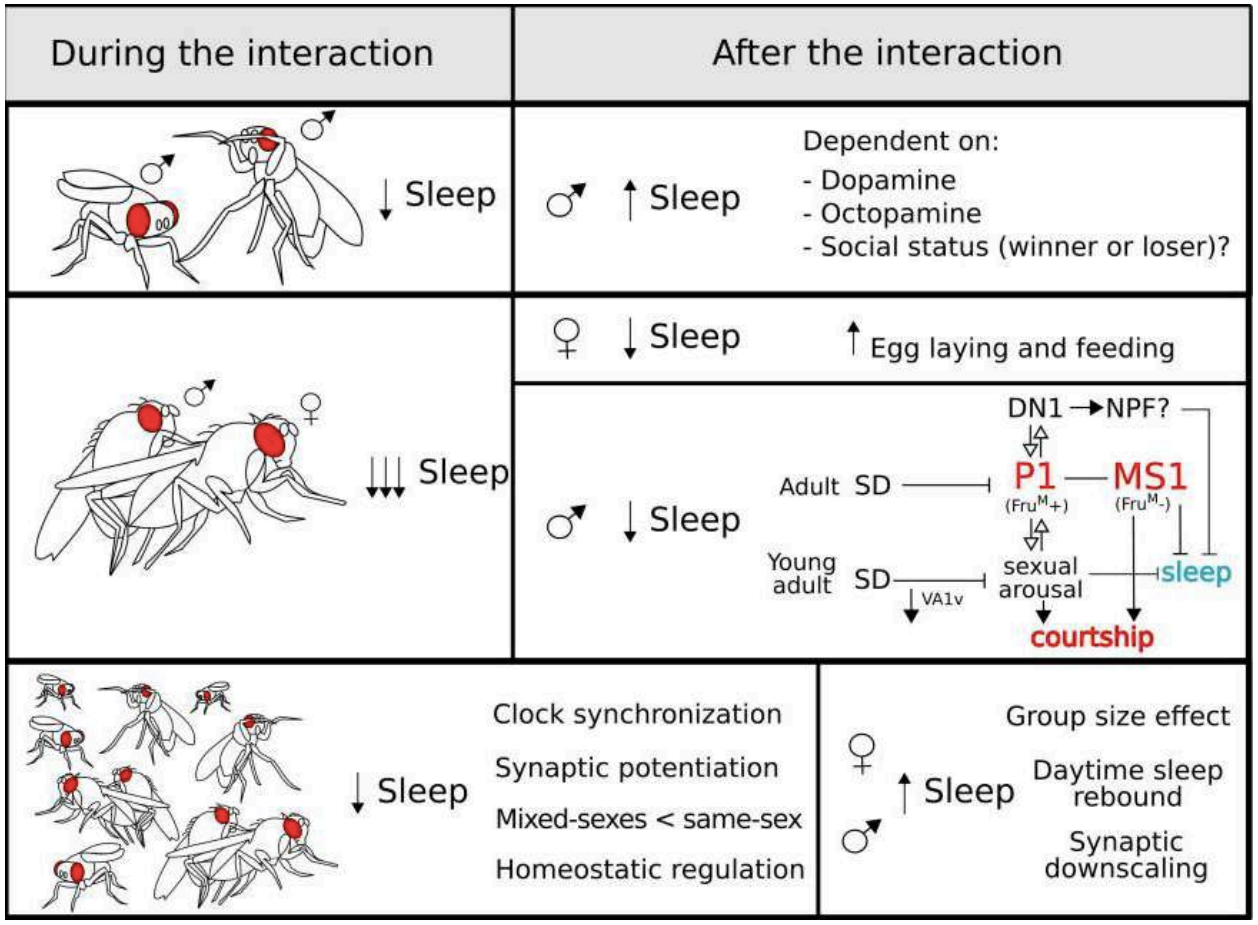
The effect of social experience on *Drosophila* behavior

赵环 马铭泽 王蓉

2022-05-26

How does social environment affet the survival and reproduction behavior?

Social Interactions Have a Profound Effect on Sleep Regulation



→ Cue: Aggression

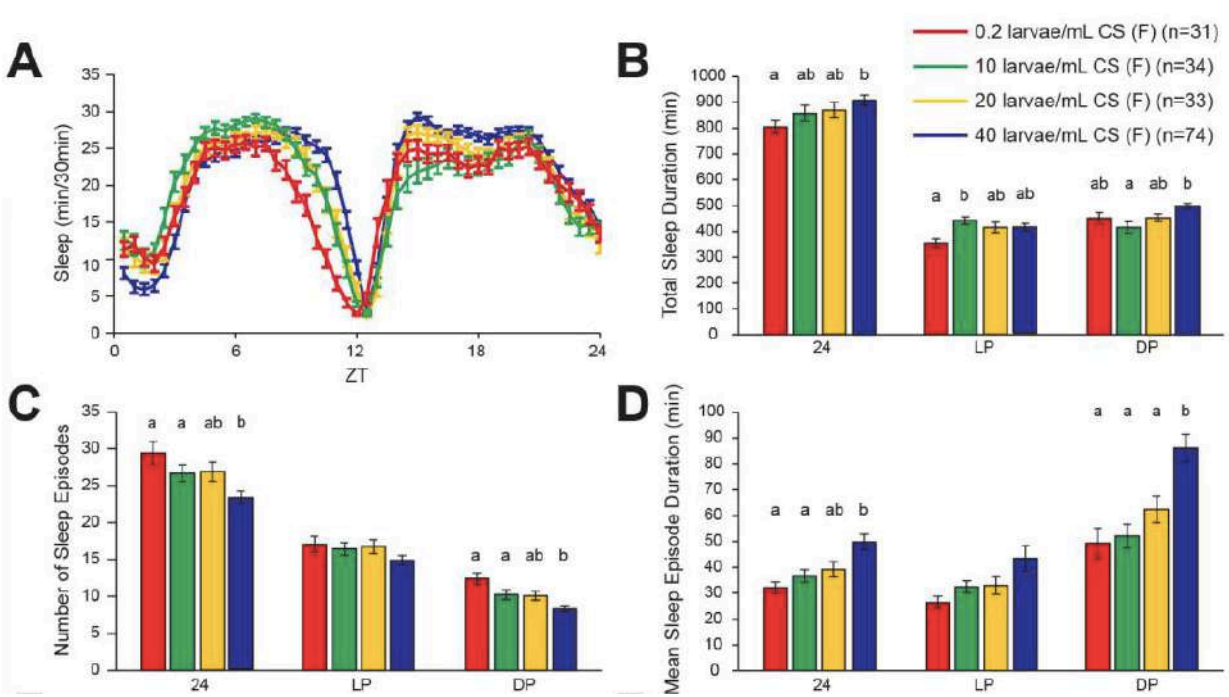
→ Cue: Courtship

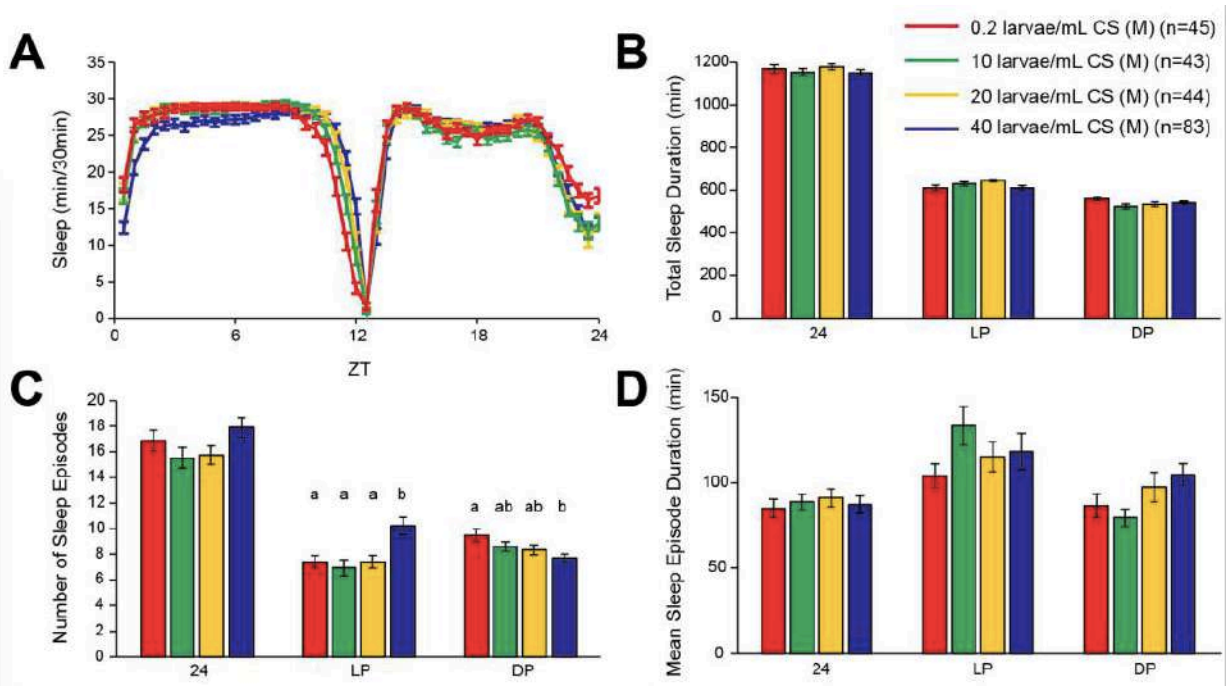
→ Cue: Social environment

Brain Sci. 2014 Aug 11;4(3):453-70. doi: 10.3390/brainsci4030453.

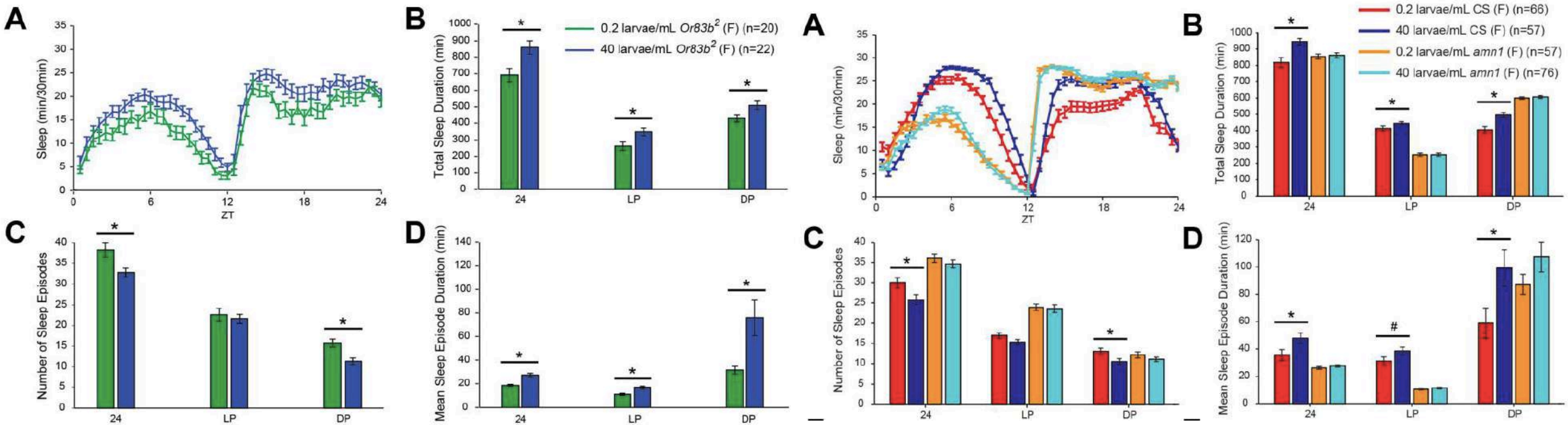
Larval Population Density Alters Adult Sleep in Wild-Type Drosophila melanogaster but Not in Amnesiac Mutant Flies

Michael W Chi [1], Leslie C Griffith [2], Christopher G Vecsey [3]





population density during larval development has an impact on the sleep behavior of adult flies, causing female flies to sleep longer, and in more consolidated bouts.

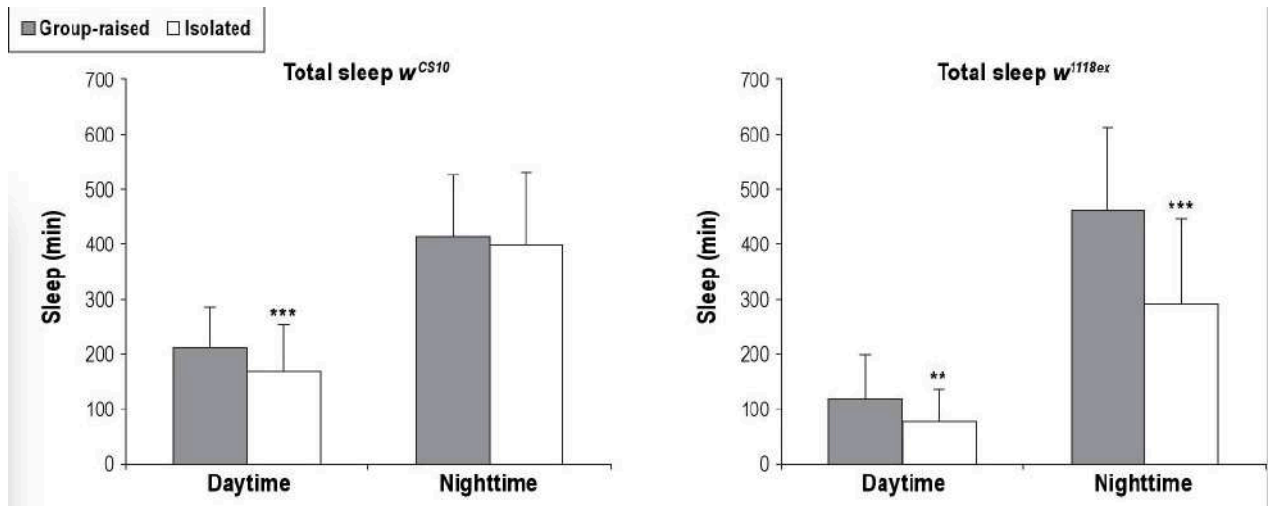


these effects are attenuated in amnesiac mutant flies, but are not affected by mutation to the ubiquitous olfactory receptor or83b.

Sleep. 2012 Apr 1;35(4):545-57. doi: 10.5665/sleep.1744.

Genetic background has a major impact on differences in sleep resulting from environmental influences in Drosophila

John E Zimmerman [1], May T Chan, Nicholas Jackson, Greg Maislin, Allan I Pack

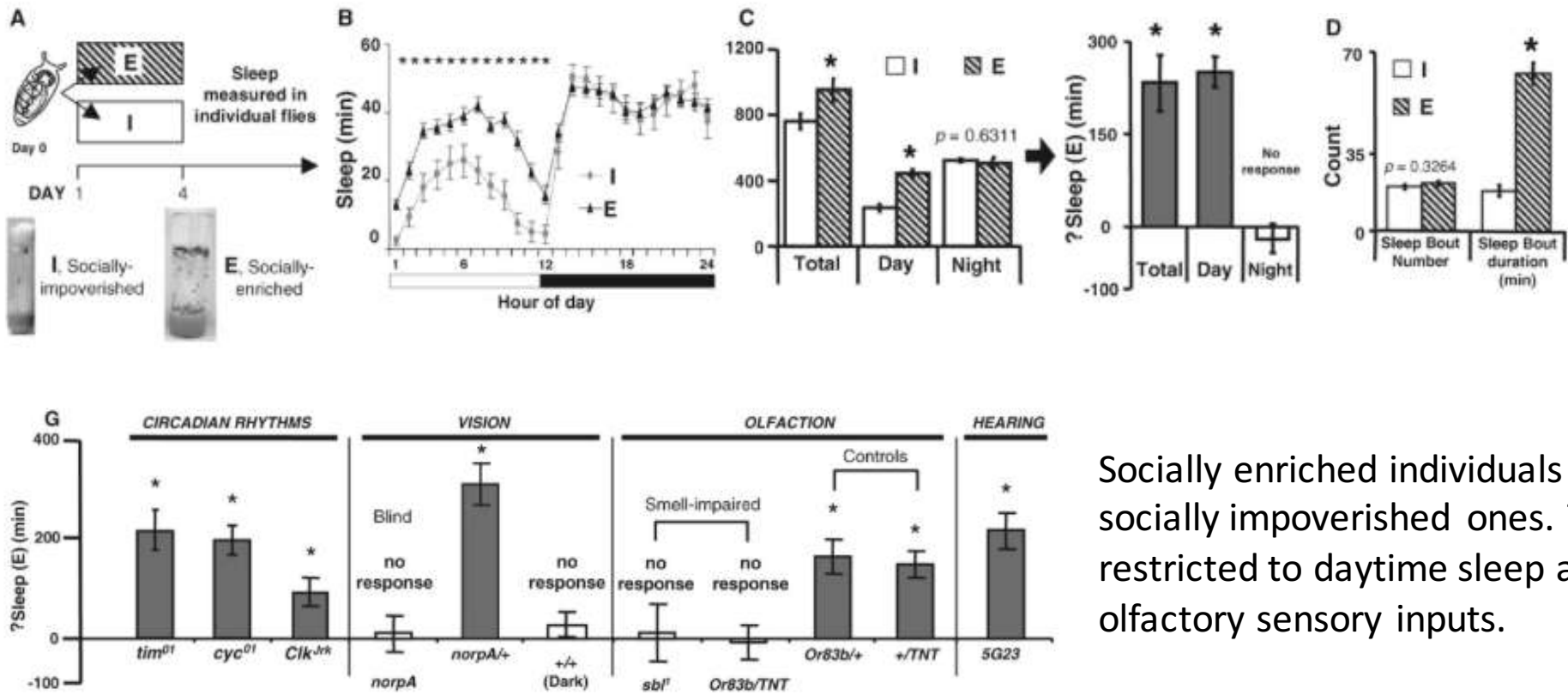


Similar results were shown for groups of females housed in groups of 30 for 9 days .

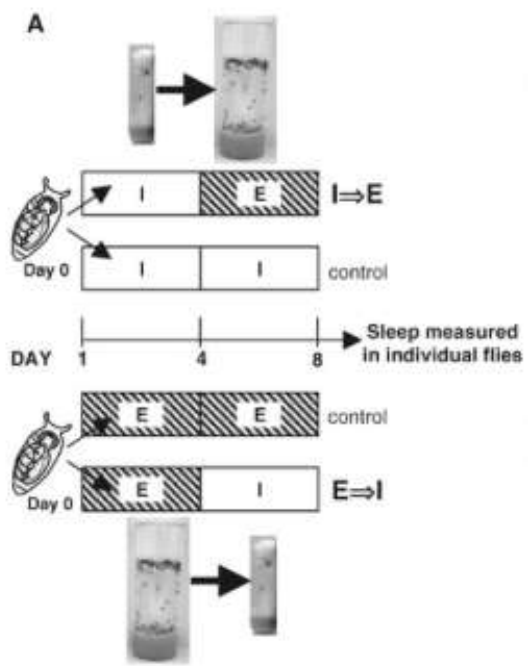
Waking Experience Affects Sleep Need in *Drosophila*

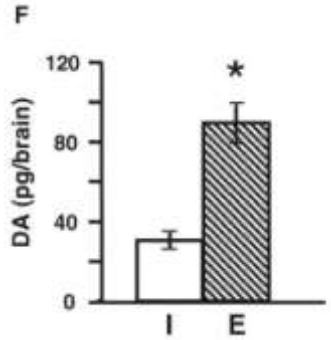
INDRANI GANGULY-FITZGERALD, JEFF DONLEA, AND PAUL J. SHAW

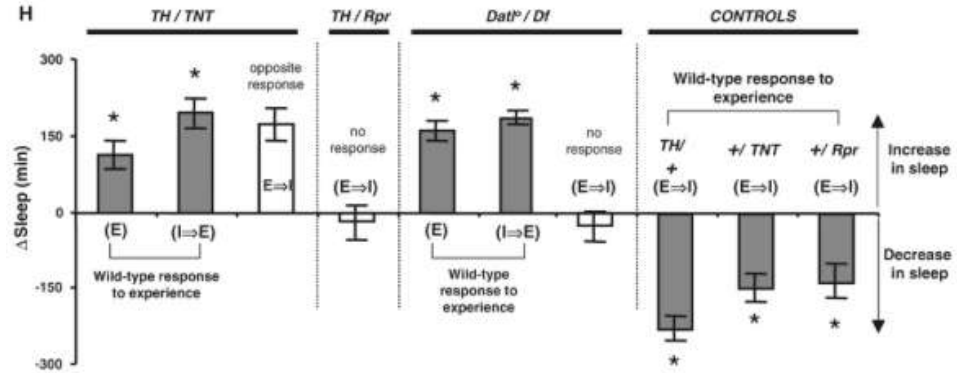
Science • 22 Sep 2006 • Vol 313,Issue 5794 • pp.1775-1781 • DOI: 10.1126/science.1130408

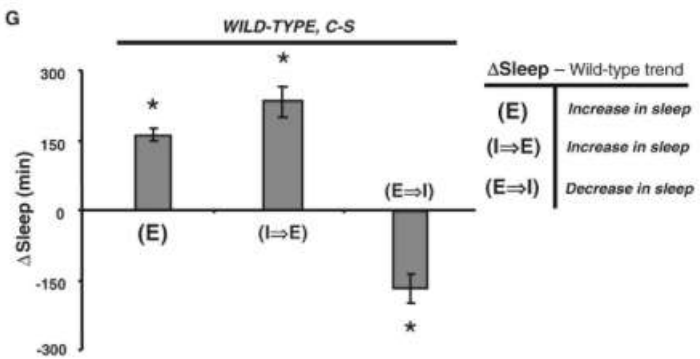


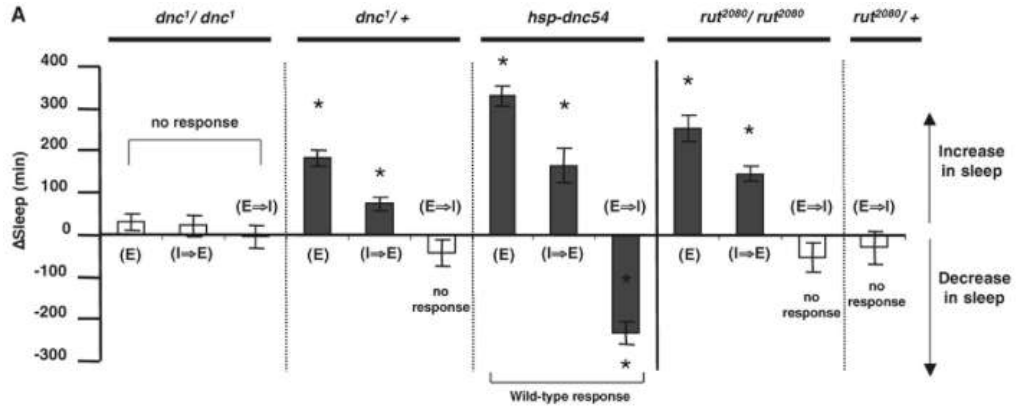
Socially enriched individuals slept significantly more than socially impoverished ones. The difference in sleep was restricted to daytime sleep and depend on visual and olfactory sensory inputs.

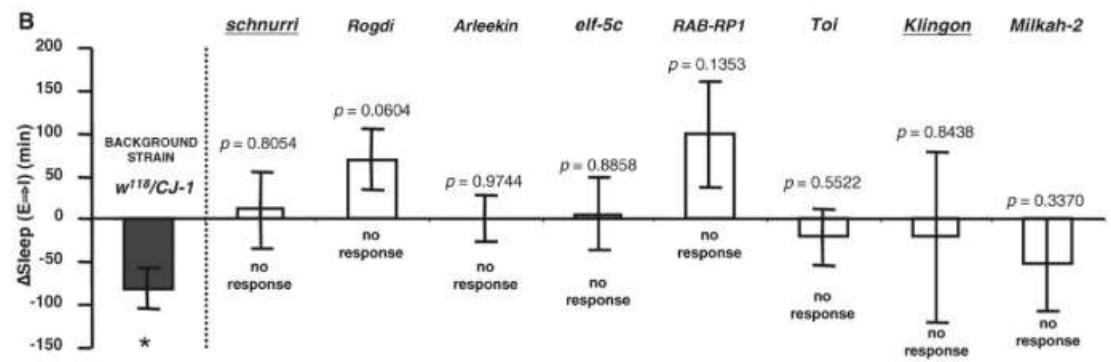










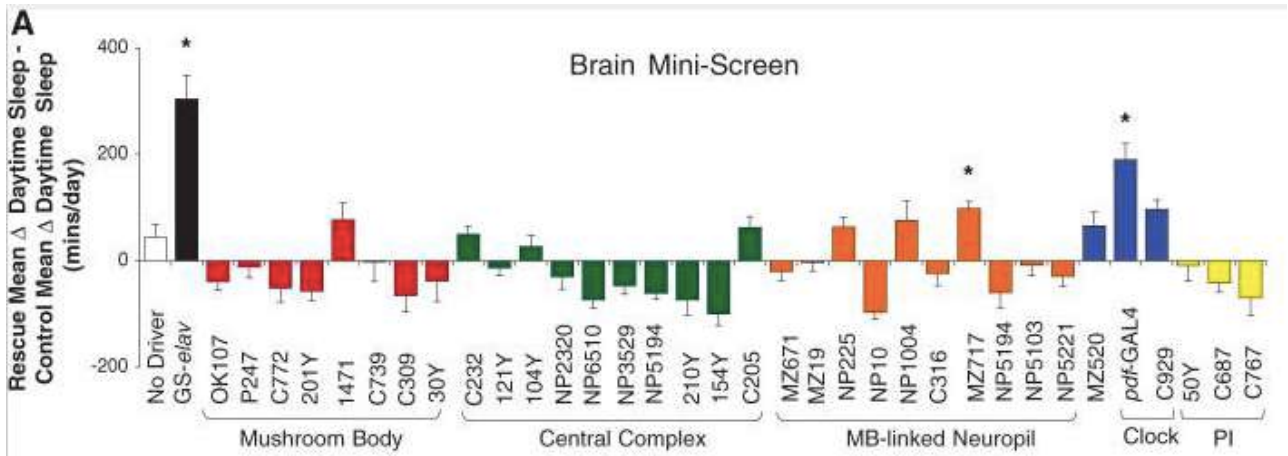


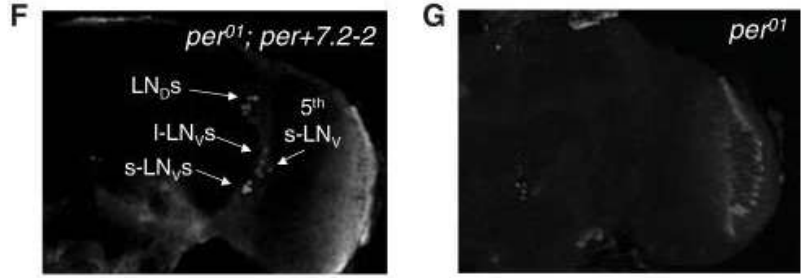
Experience-dependent changes in sleep need require dopaminergic modulation, cAMP signaling, and particular subsets of memory genes.

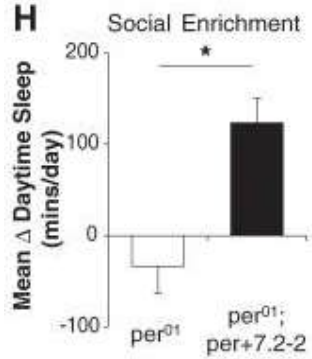
Science. 2009 Apr 3;324(5923):105-8. doi: 10.1126/science.1166657.

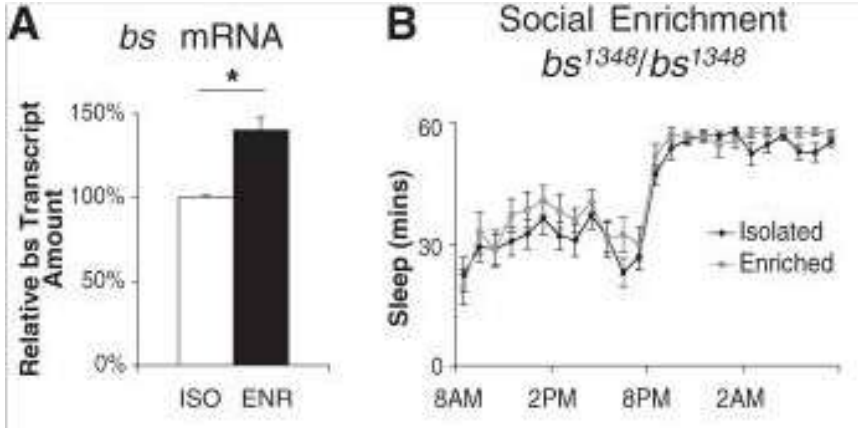
Use-dependent plasticity in clock neurons regulates sleep need in Drosophila

Jeffrey M Donlea [1], Narendrakumar Ramanan, Paul J Shaw

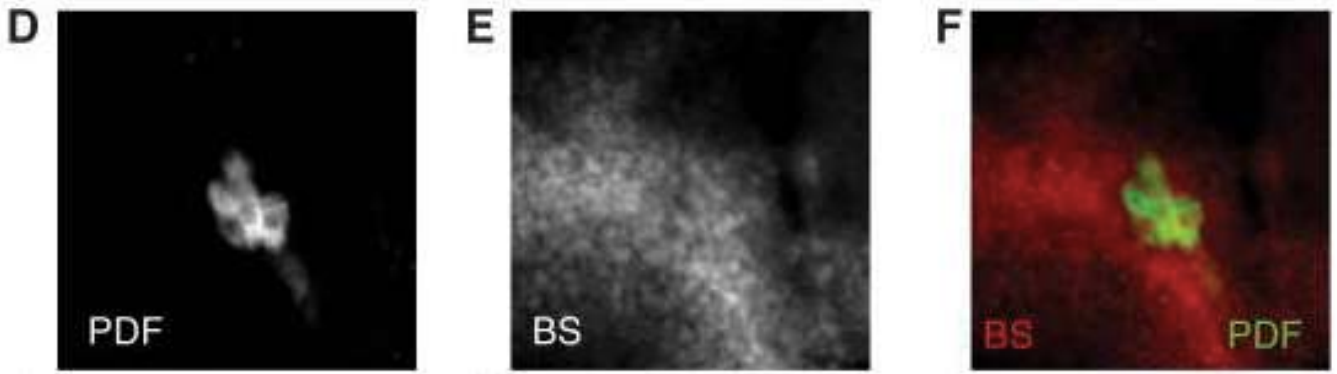


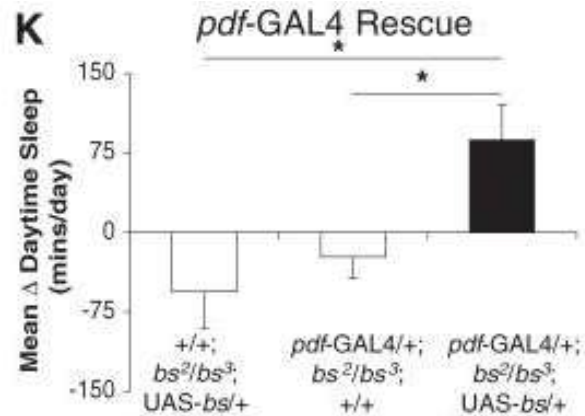






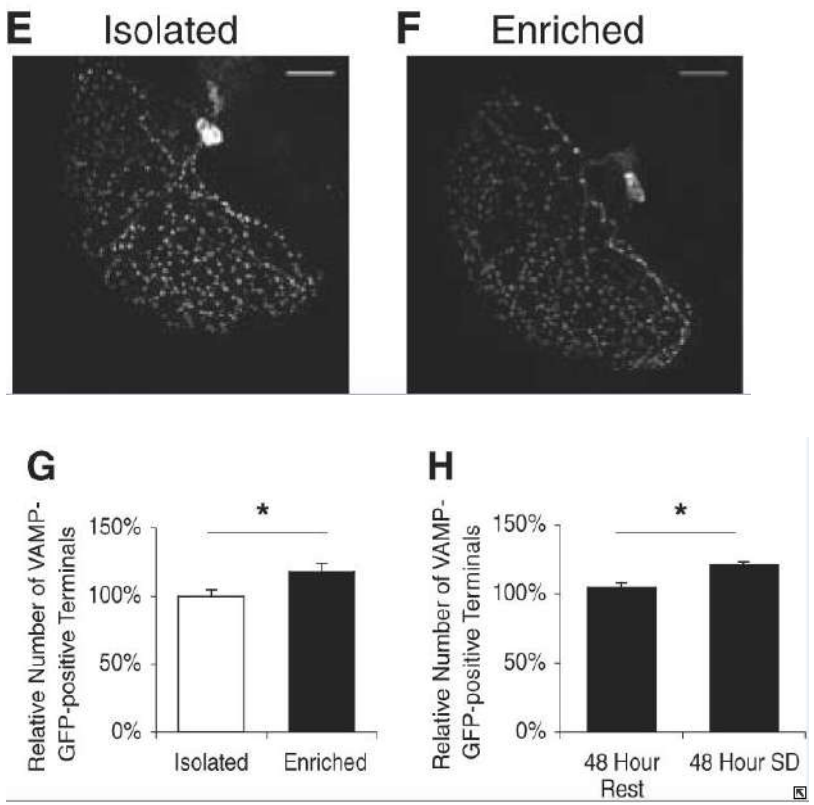
The difference is dependent on the core clock gene *per* but it is independent of other core clock genes like *timeless*, *cycle*, and *clock* . This may indicate that this is a clock-independent process in which *per* has a separate function.





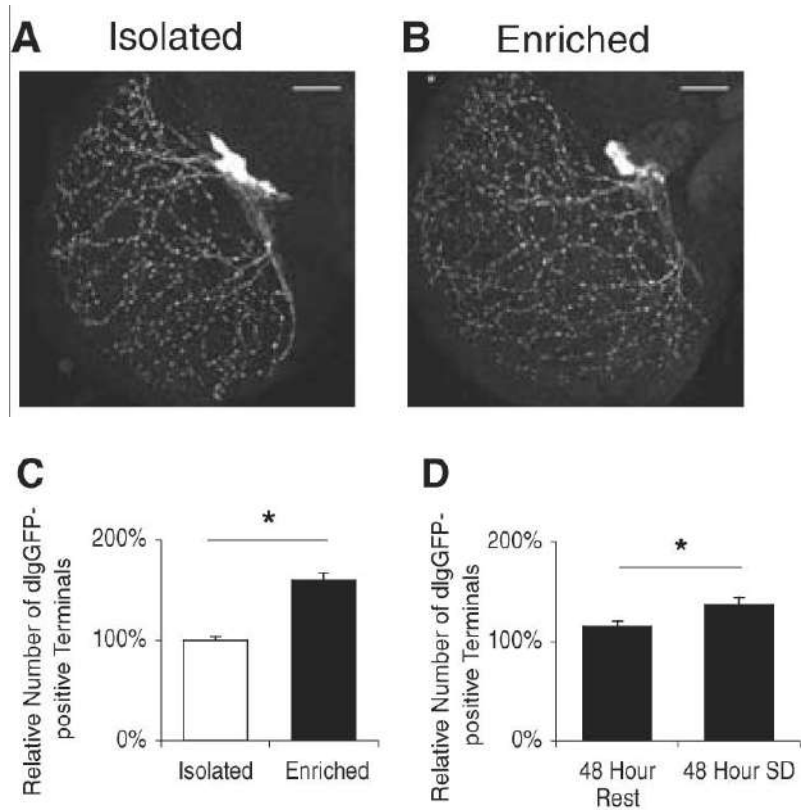
Pre-synaptic signals

pdf-GAL4/+;UAS-VAMP-GFP/+



Post-synaptic signals

pdf-GAL4/+;;UAS-dlgWT-gfp/+



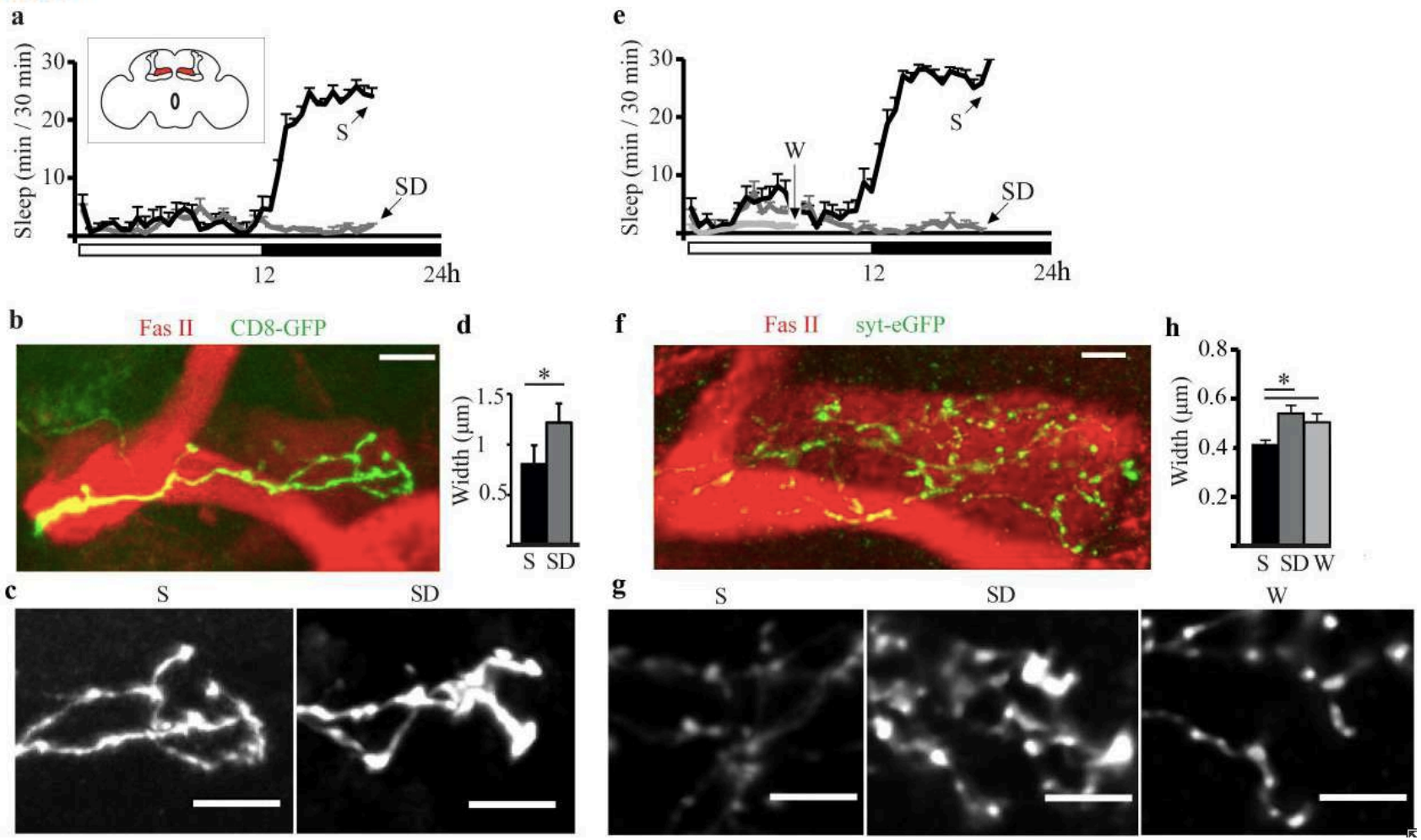
sleep acts to downscale synaptic connections that are potentiated during waking experience.

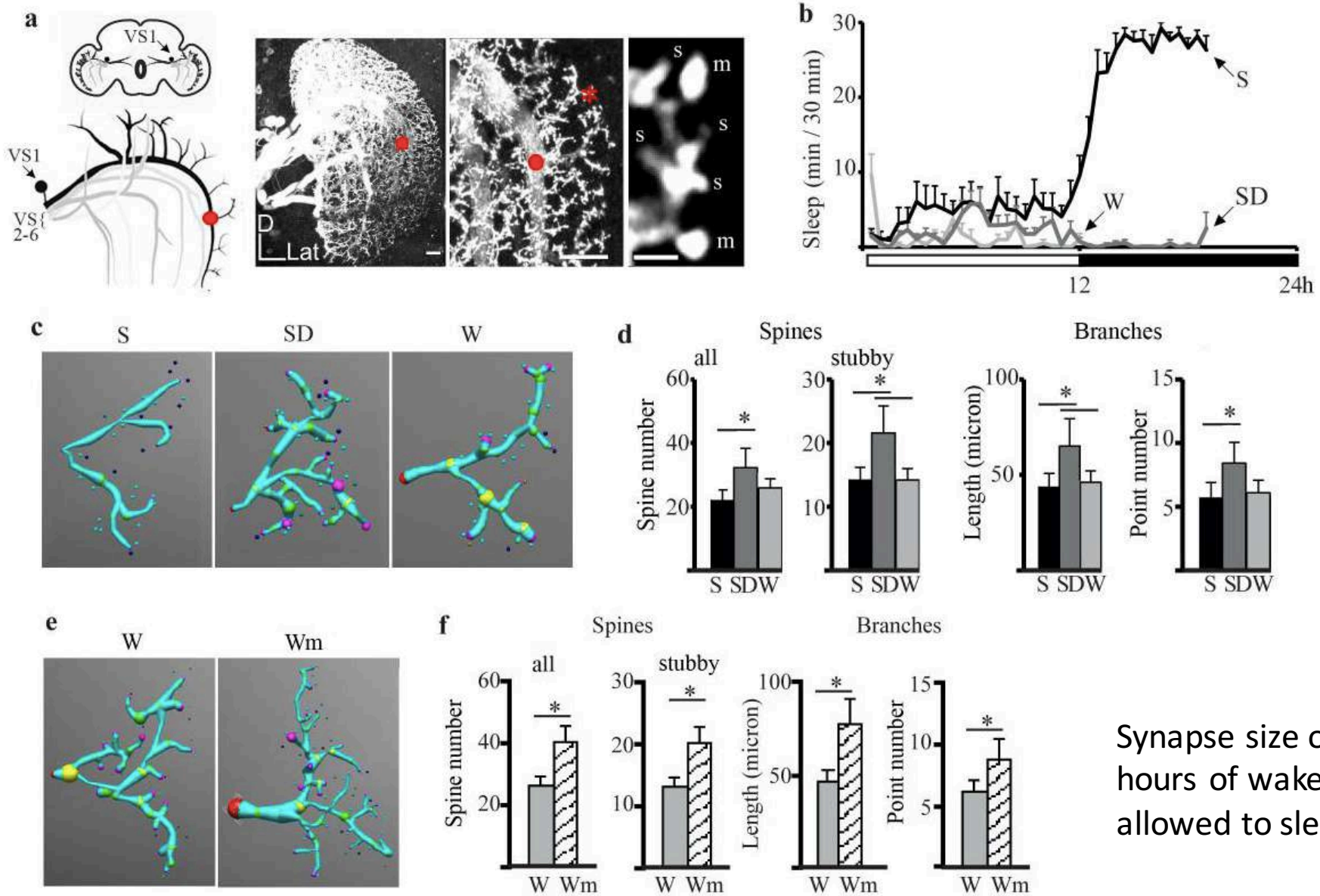
Science. 2011 Jun 24;332(6037):1576-81. doi: 10.1126/science.1202839.

Sleep and synaptic homeostasis: structural evidence in Drosophila

Daniel Bushey [1], Giulio Tononi, Chiara Cirelli

The axonal tips were larger after sleep deprivation than after sleep, consistent with an increase in volume of presynaptic terminals.





Synapse size or number increases after a few hours of wake and decreases only if flies are allowed to sleep.

突触稳态假说：果蝇在觉醒期间，受周围社交信息影响，突触连接数量激增，在睡眠期间对无用突触连接进行修剪，以保持神经环路的可塑性；使得下一次觉醒期间能进行更多的突触连接。

睡眠是作为一种保持神经环路可塑性的代价。关于这个假说最早的实验证据可追溯到1984年的文章：

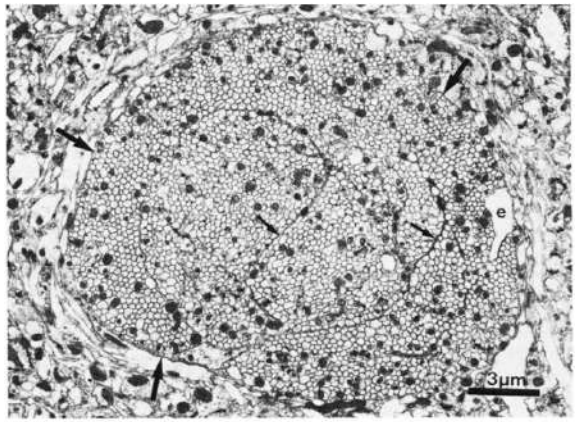


Fig. 1. Electron micrograph of a cross-section through the caudal peduncle of the mushroom body of an adult female fly. Arrows point to glial lamellae enveloping the peduncle (big arrows) and partially separating fiber portions internally (small arrows). e, extrinsic element.

J. Neurogenetics, 21: 183–196

ISSN: 0167-7063 print/1563-5260 online
DOI: 10.1080/01677060701695359

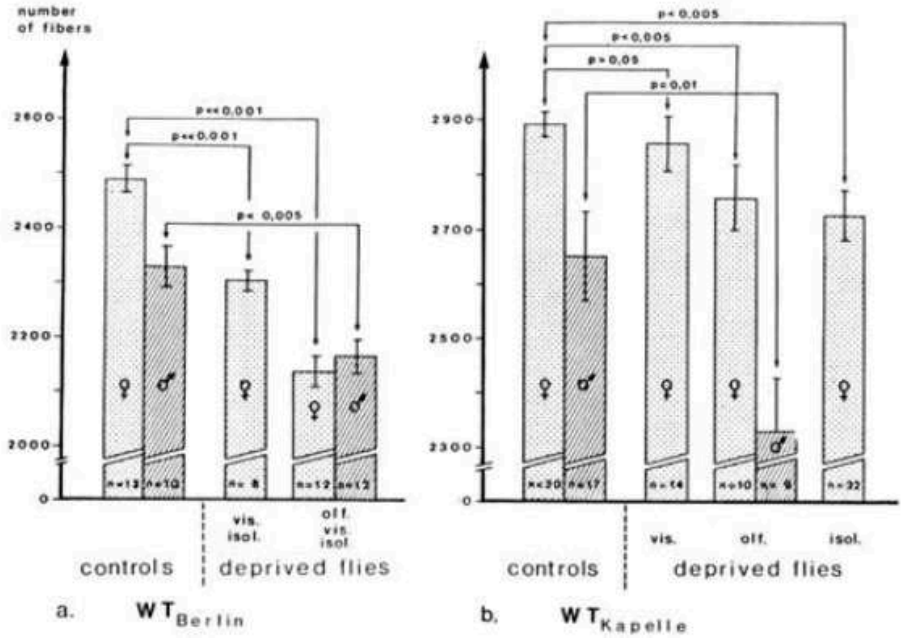
informa
healthcare

Fiber Number in the Mushroom Bodies of Adult *Drosophila melanogaster* depends on Age, Sex and Experience

Gerhard M. Technau*

Institut für Genetik und Mikrobiologie, Röntgenring 11, 8700 Würzburg (F.R.G.)

(Received October 18th, 1983)
(Revised January 3rd, 1984)
(Accepted January 4th, 1984)



Conclusions:

- 社交对睡眠的影响从幼虫时期就开始了
- 幼虫时期的社交环境对成虫睡眠需求的影响，雌蝇比雄蝇更多
- 成虫时期雄蝇比雌蝇受社交环境的影响更多
- 视觉和嗅觉感官输入均能使得睡眠需求增加
- 多巴胺能神经元和学习记忆相关基因调控了依赖于社交环境的睡眠需求的变化
- 依赖于社交信息的睡眠需求主要由节律因子per以一种区别于其他三个节律因子的稳态机制来调控
- 提出一种模型：睡眠—突触稳态假说

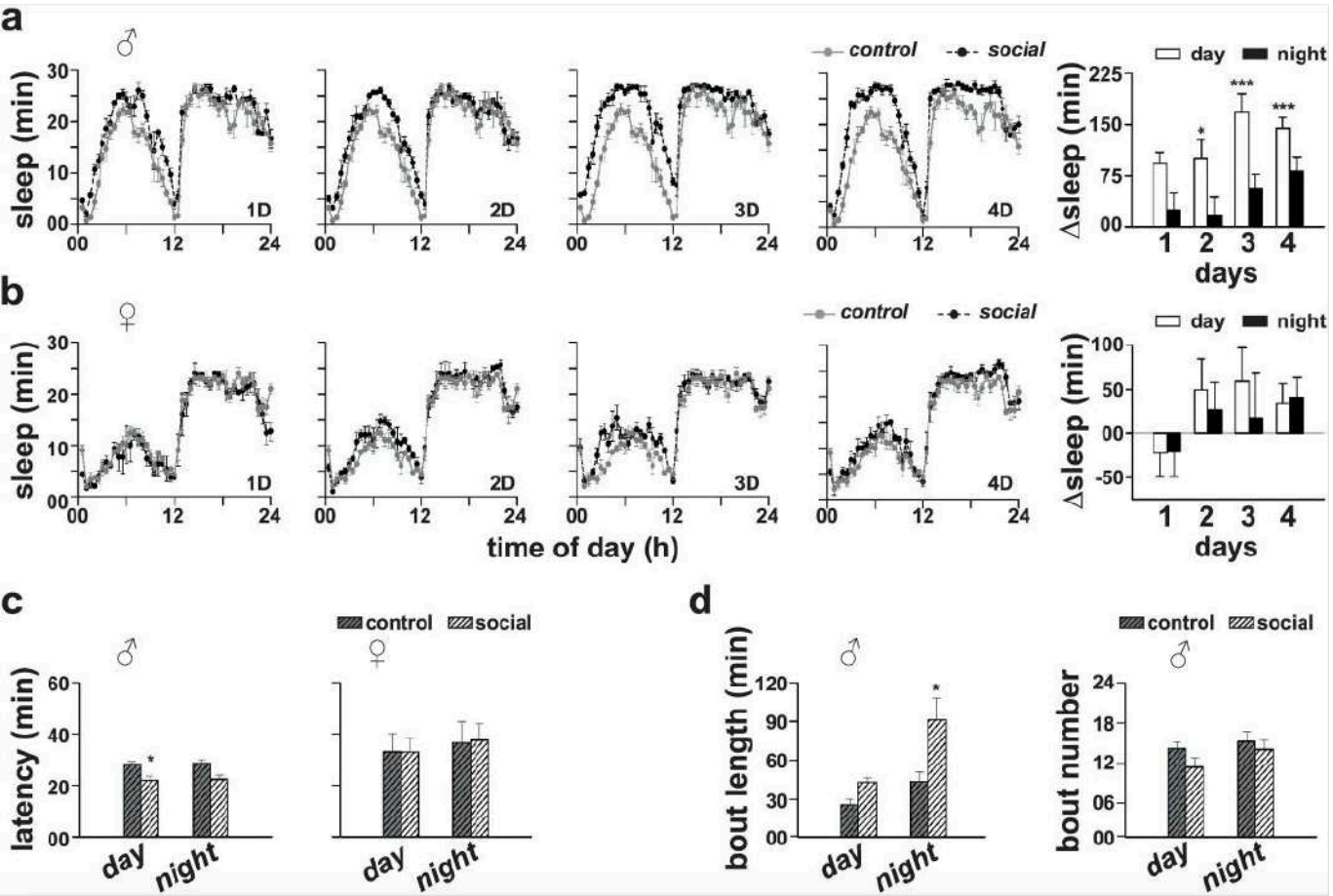
Thank you !

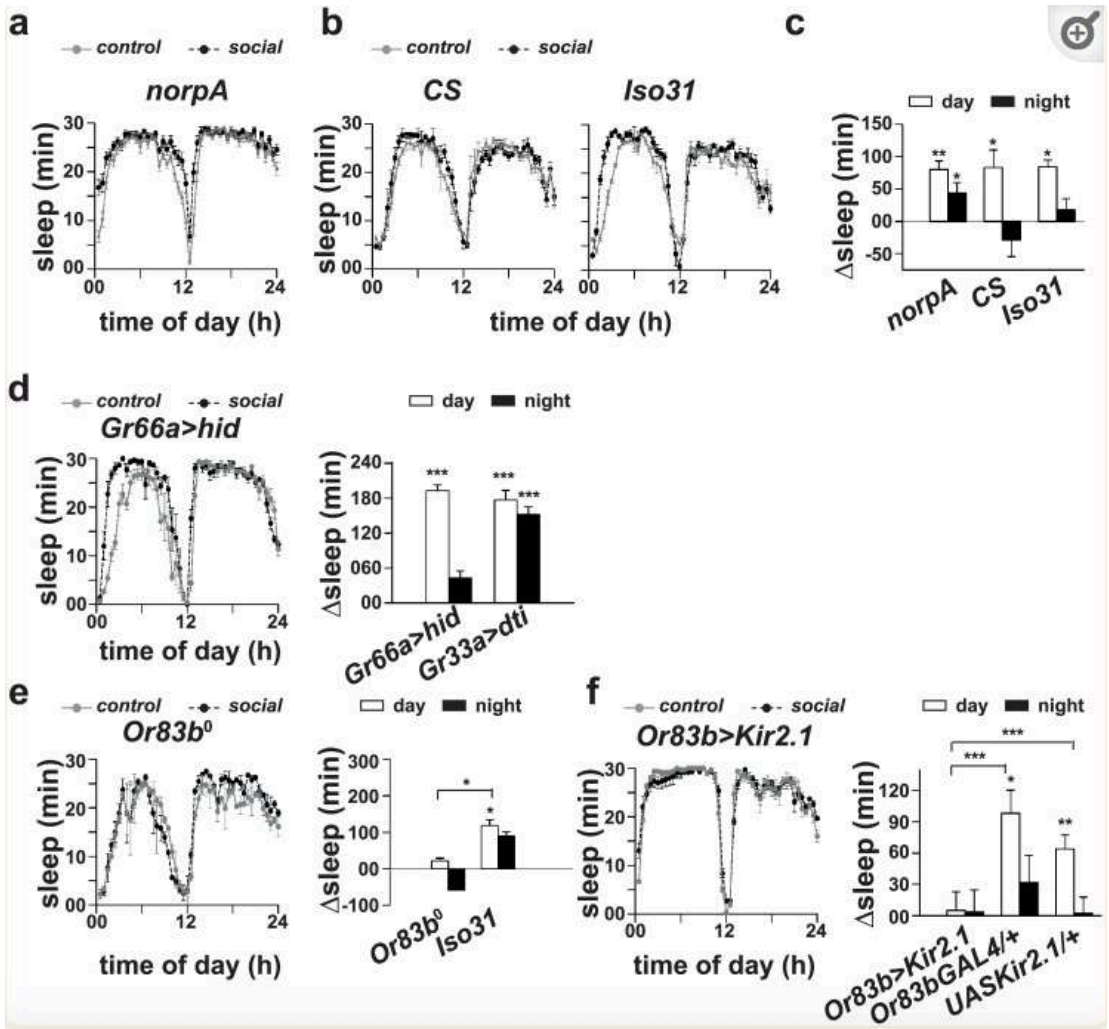
PLoS One. 2016; 11(3): e0150596.
Published online 2016 Mar 3. doi: 10.1371/journal.pone.0150596
PMCID: PMC4777415
PMID: 26938057

Social Experience Is Sufficient to Modulate Sleep Need of *Drosophila* without Increasing Wakefulness

Shahnaz Rahman Lone,[1] Sheetal Potdar,[2] Manishi Srivastava,[1] and Vijay Kumar Sharma[1,*]

嗅觉信息主导了睡眠差异的产生



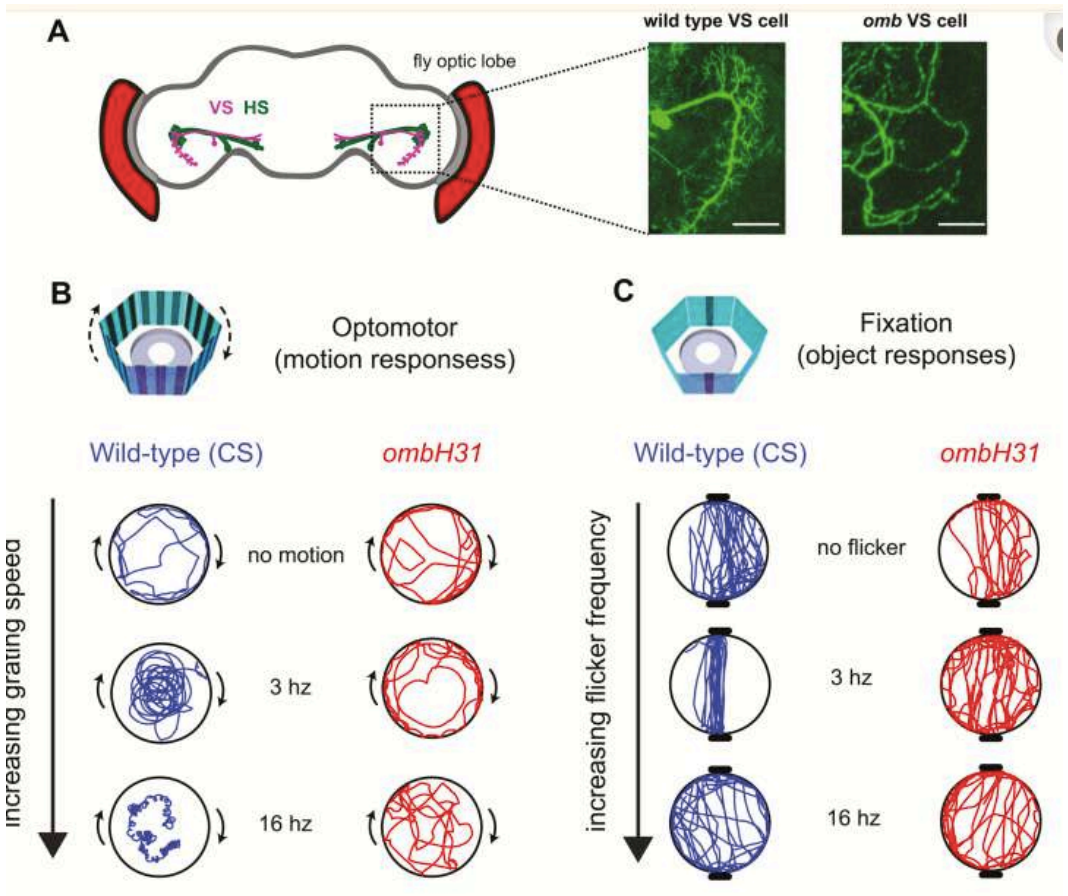


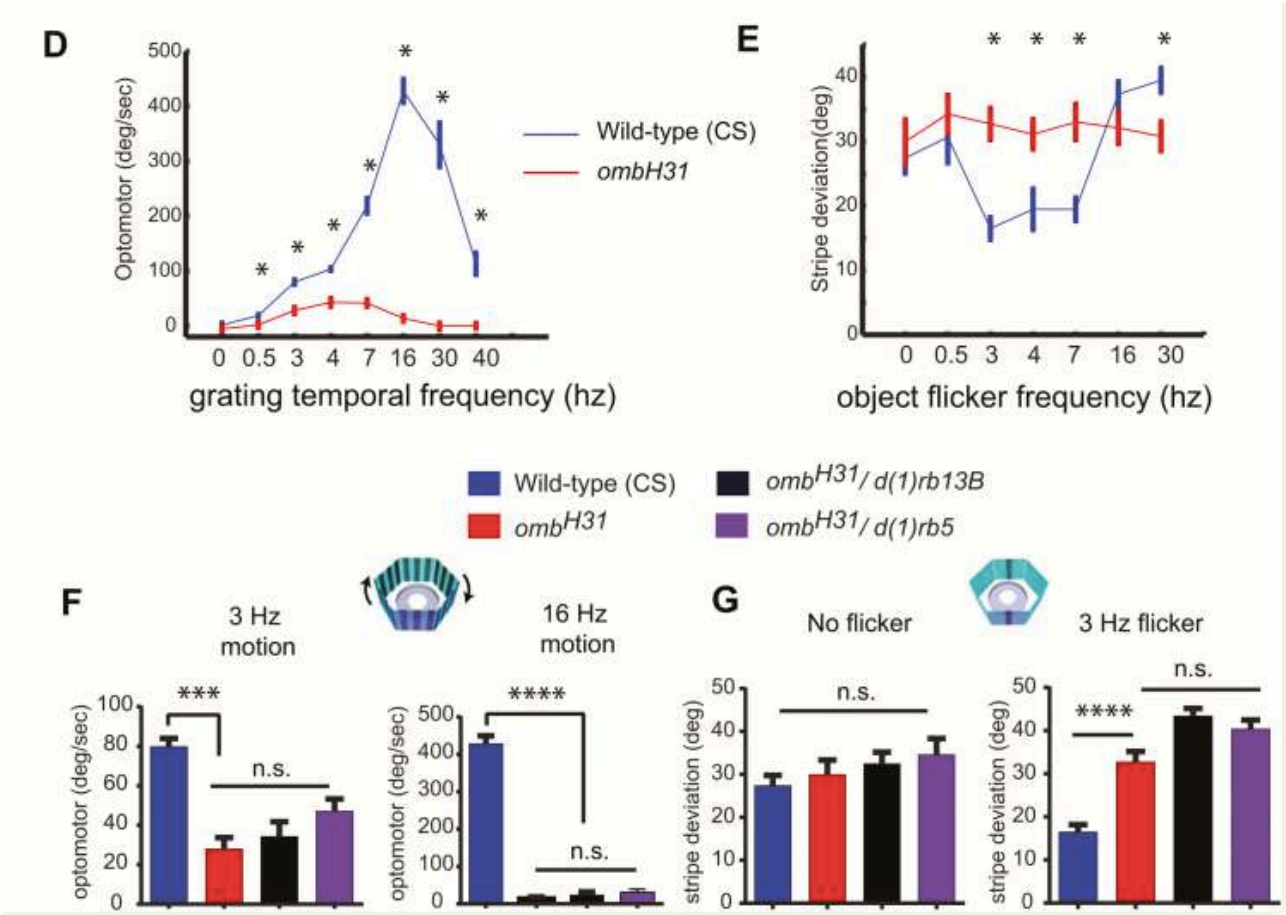
Sleep. 2019 Jul; 42(7): zsz102.
Published online 2019 Apr 23. doi: 10.1093/sleep/zsz102

Visual experience drives sleep need in *Drosophila*

视觉信息经验改变了睡眠需求

Leonie Kirszenblat, Rebecca Yaun, and Bruno van Swinderen



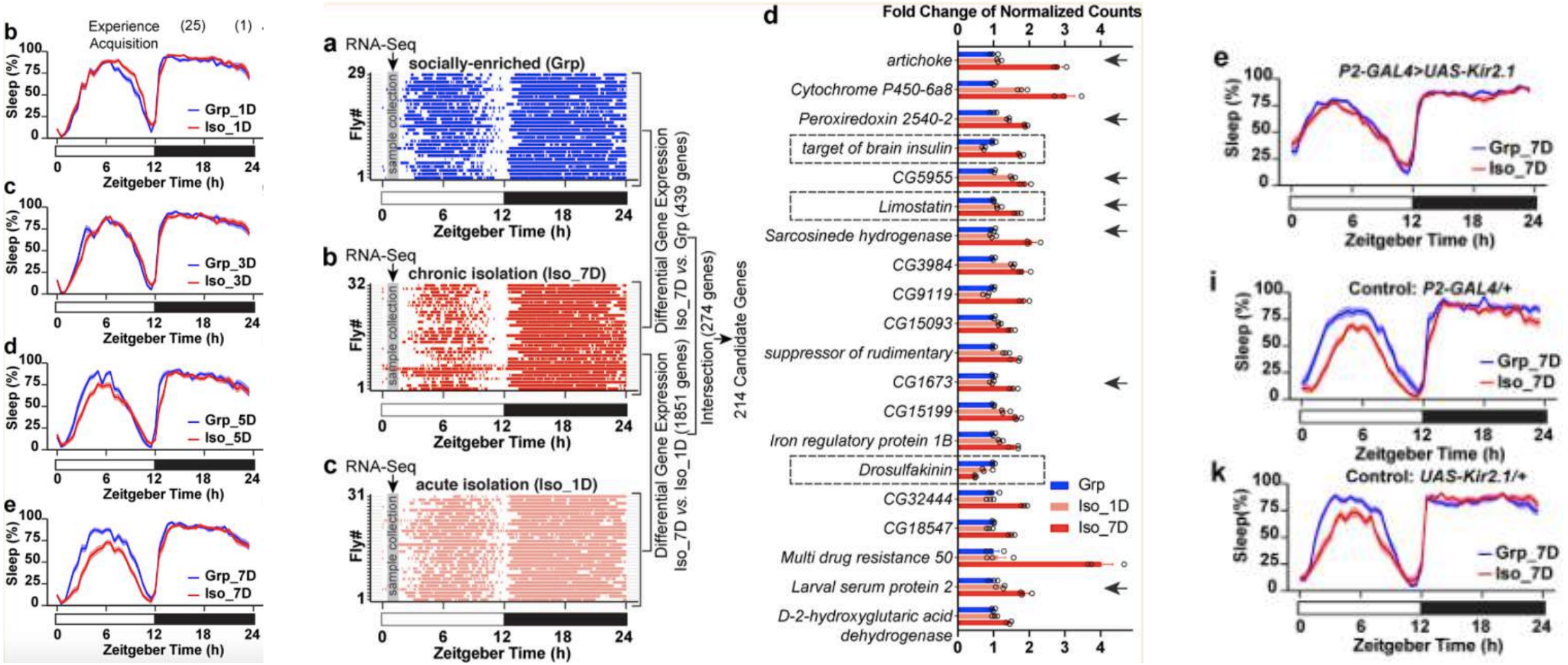


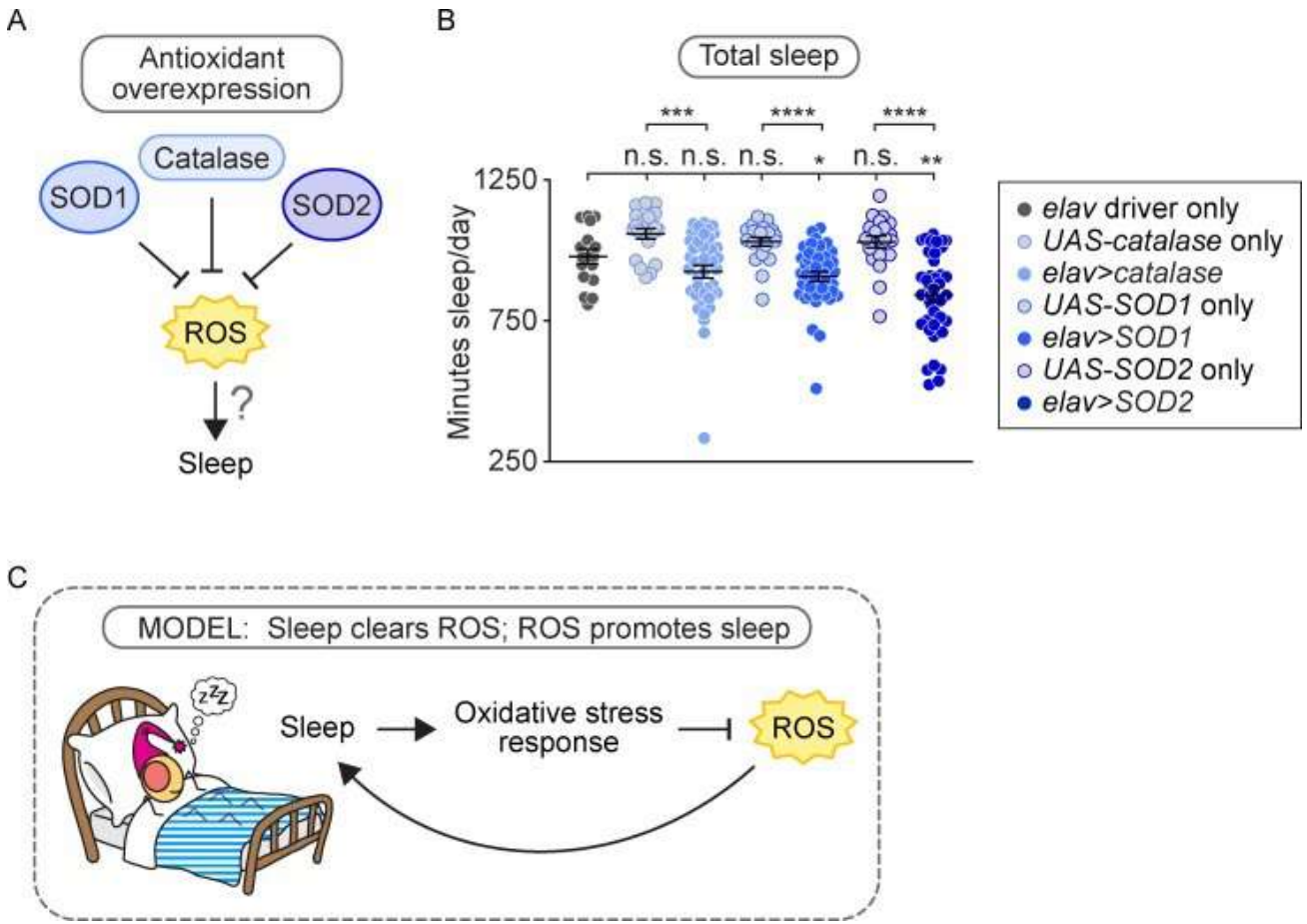
Nature. Author manuscript; available in PMC 2022 Mar 1.
Published in final edited form as:
Nature. 2021 Sep; 597(7875): 239–244.
Published online 2021 Aug 18. doi: 10.1038/s41586-021-03837-0

PMCID: PMC8429171
NIHMSID: NIHMS1731758
PMID: 34408325

Chronic Social Isolation Signals Starvation and Reduces Sleep in *Drosophila*

Wanhe Li,[1,*] Zikun Wang,[1] Sheyum Syed,[2] Cheng Lyu,[3] Samantha Lincoln,[1] Jenna O'Neil,[1] Andrew D. Nguyen,[1] Irena Feng,[1] and Michael W. Young[1,*]




A
Antioxidant overexpression
Catalase
SOD1
SOD2
ROS
?
Sleep
B
Total sleep
***
****
****
n.s. n.s. n.s. * n.s. **
1250
750
250
Minutes sleep/day
elav driver only
UAS-catalase only
elav>catalase
UAS-SOD1 only
elav>SOD1
UAS-SOD2 only
elav>SOD2
C
MODEL: Sleep clears ROS; ROS promotes sleep
Sleep
Oxidative stress response
ROS

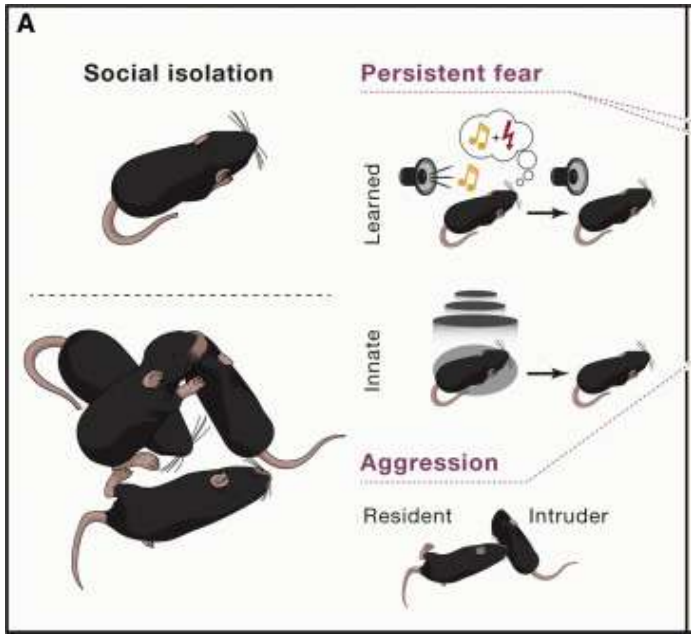
睡眠清除氧自由基假说

Social isolation effect on *Drosophila* aggression

MMZ

20220526

Social isolation induce aggression in many species



- How does social isolation regulate aggression ?
  - Sensory
  - Neuromodulator
- Why *Drosophila* has a higher aggression level after social isolation ?

- How does social isolation regulate aggression ?
  - Sensory
  - Neuromodulator
- Why *Drosophila* has a higher aggression level after social isolation ?

Vision does not involved in the social isolation induced aggression

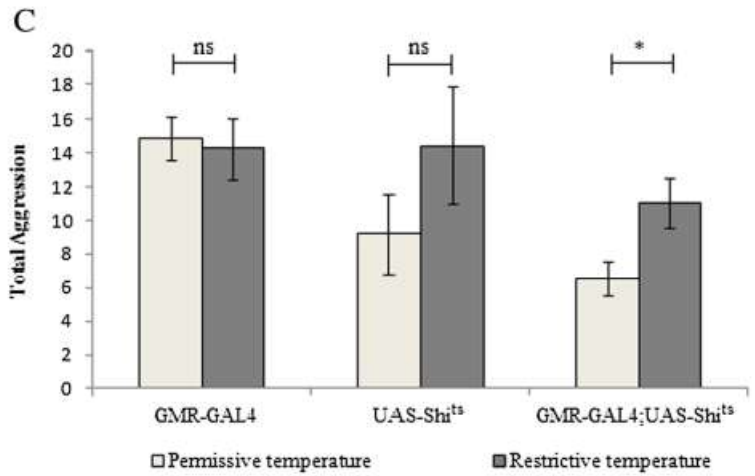
Ramin *et al. Molecular Brain* 2014, 7:55
http://www.molecularbrain.com/content/7/1/55

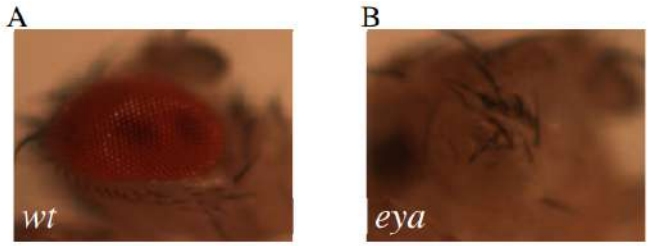
Molecular Brain

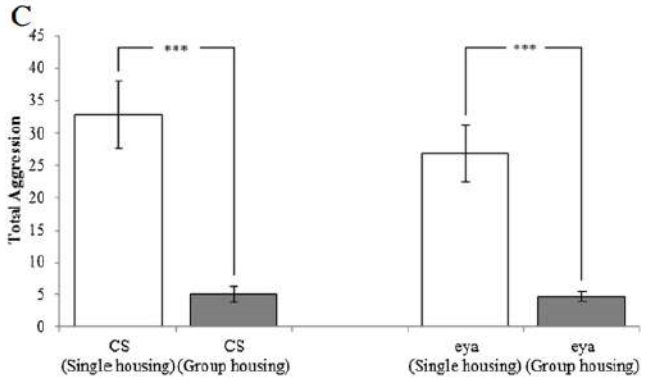
RESEARCH Open Access

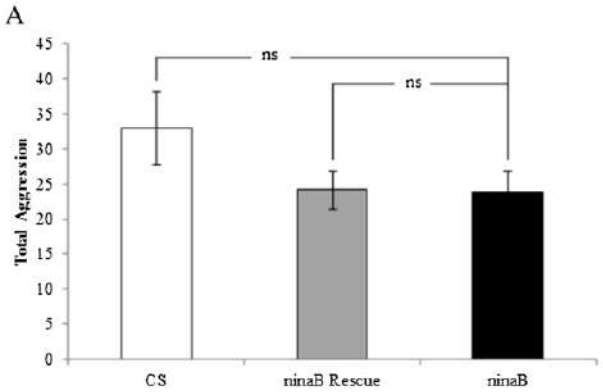
Aggression and social experience: genetic analysis of visual circuit activity in the control of aggressiveness in *Drosophila*

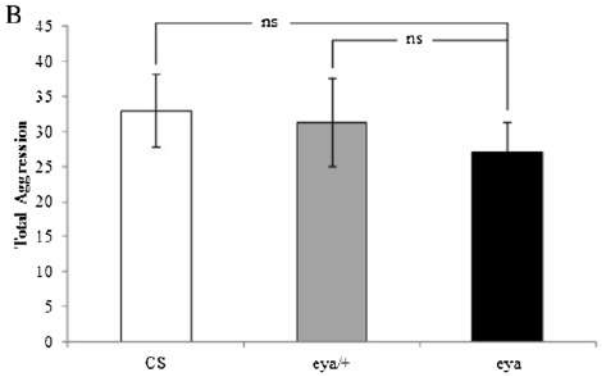
Mahmoudreza Ramin[1,2], Claudiu Domocos[1], David Slawaska-Eng[1] and Yong Rao[1,2,3*]











Social status affected aggression is reversible

PNAS

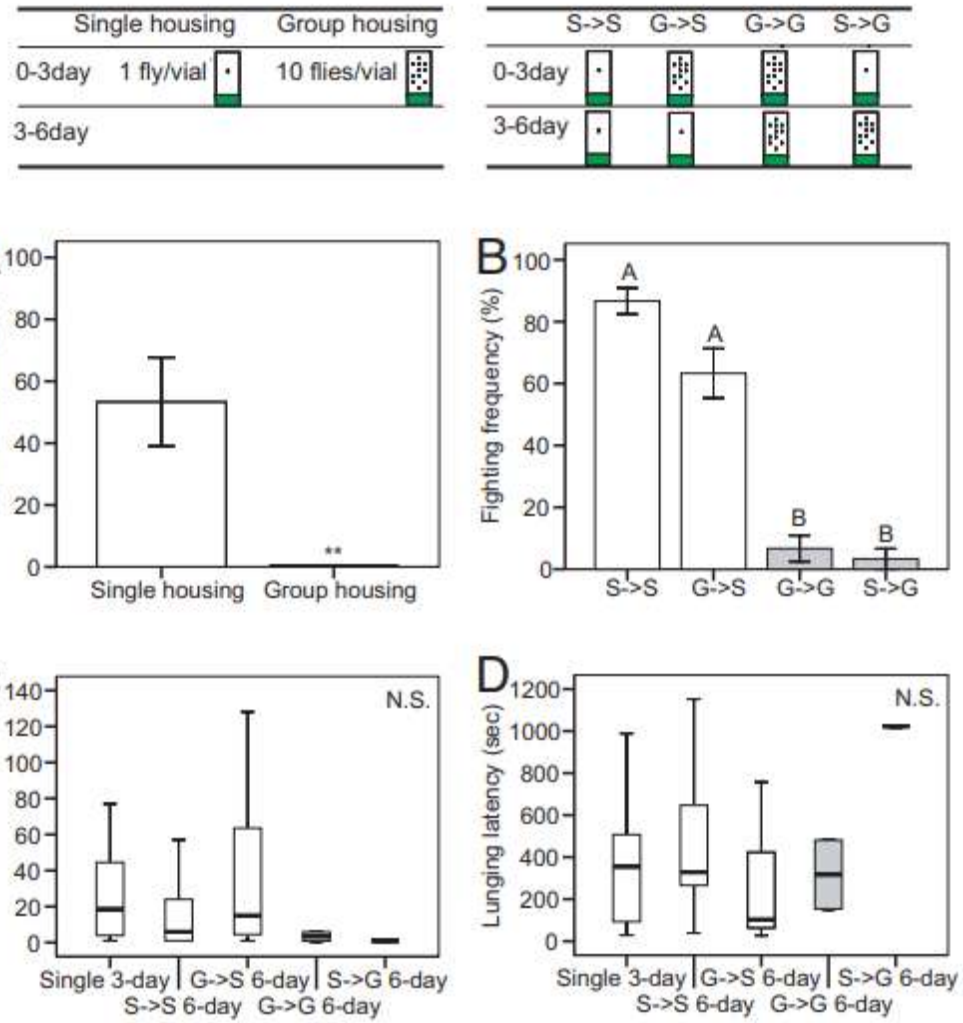
A common genetic target for environmental and heritable influences on aggressiveness in *Drosophila*

Liming Wang*, Heiko Dankert*†, Pietro Perona†, and David J. Anderson*‡§

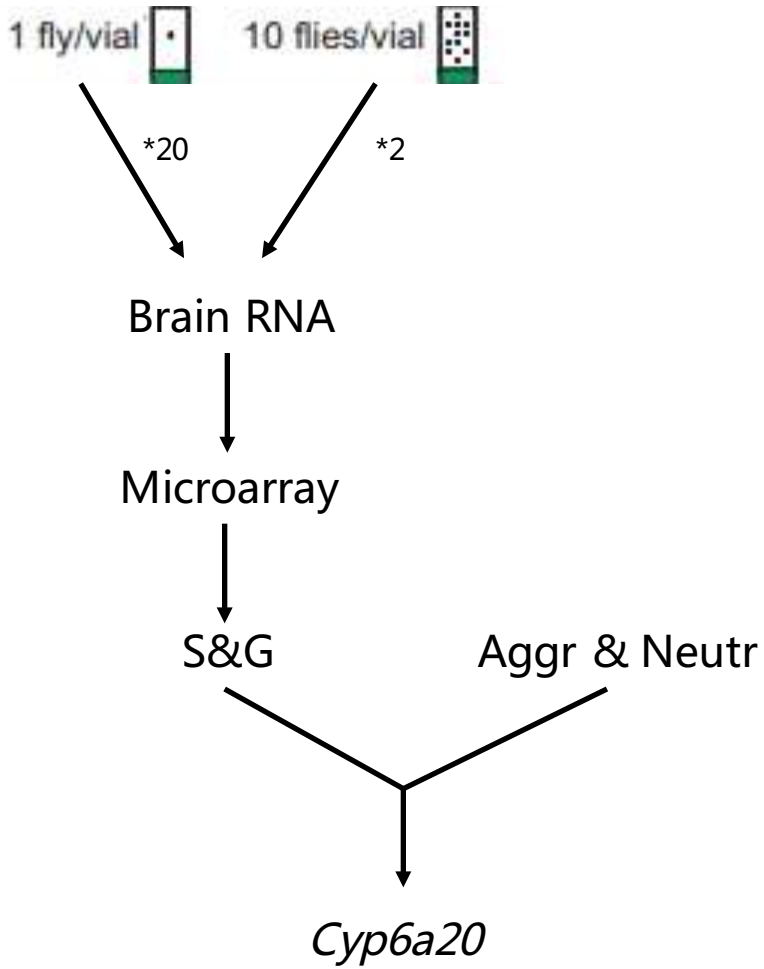
*Division of Biology 216-76 and †Engineering and Applied Sciences 136-93 and ‡Howard Hughes Medical Institute, California Institute of Technology, Pasadena, CA 91125

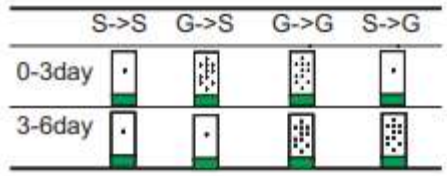
This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected on May 1, 2007.

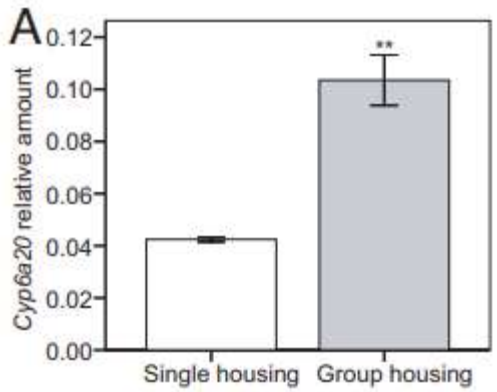
Contributed by David J. Anderson, February 11, 2008 (sent for review November 12, 2007)

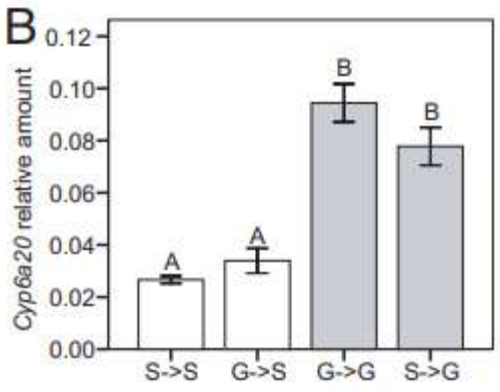


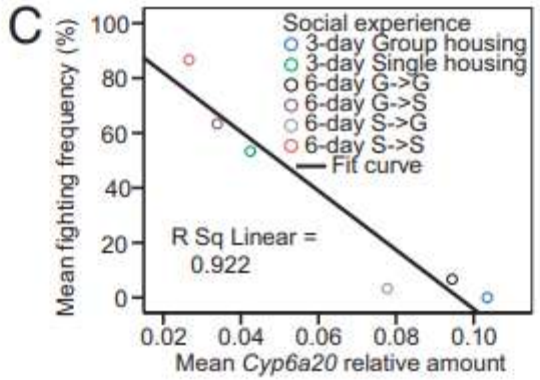
Screening of the associated genes of social isolation and aggression



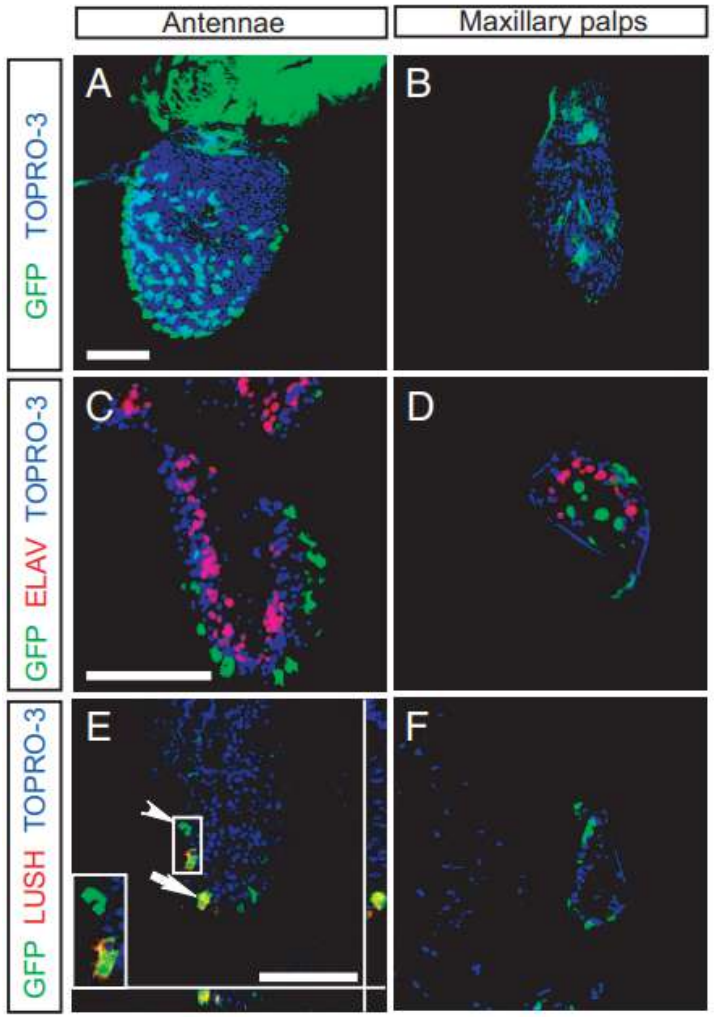


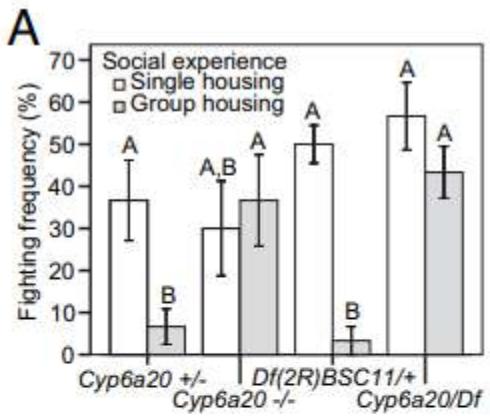


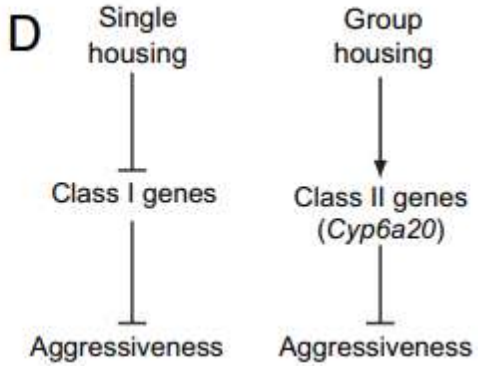


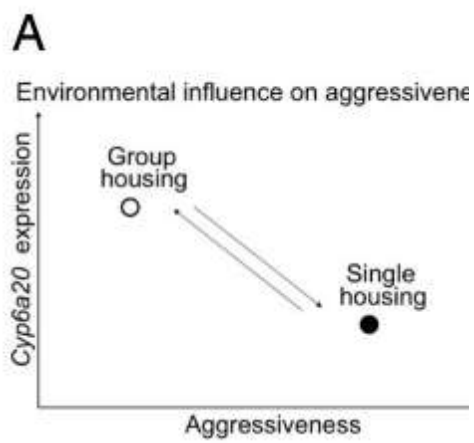


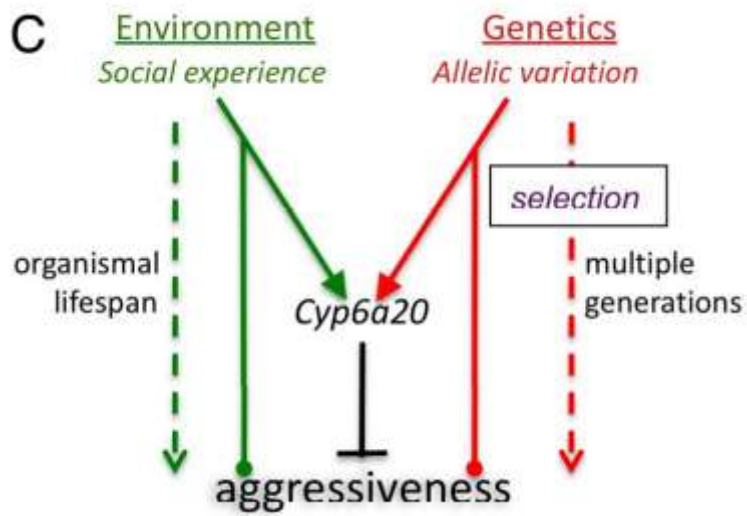
Nonneuronal protein involved in the regulation of aggression by social experience











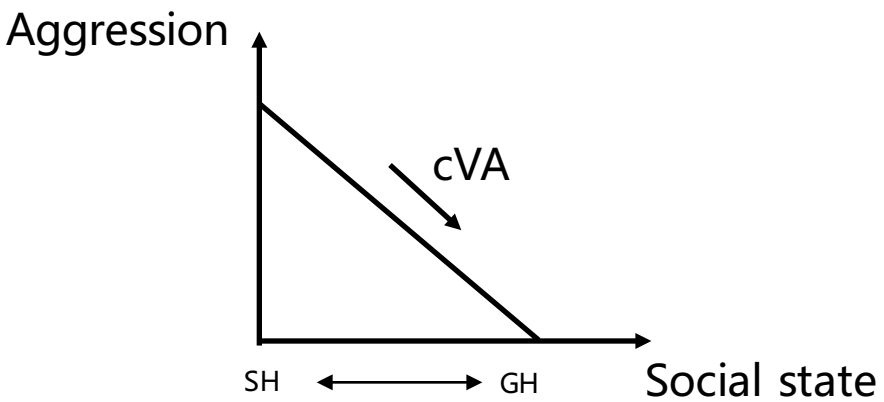
Drosophila gets social information through cVA

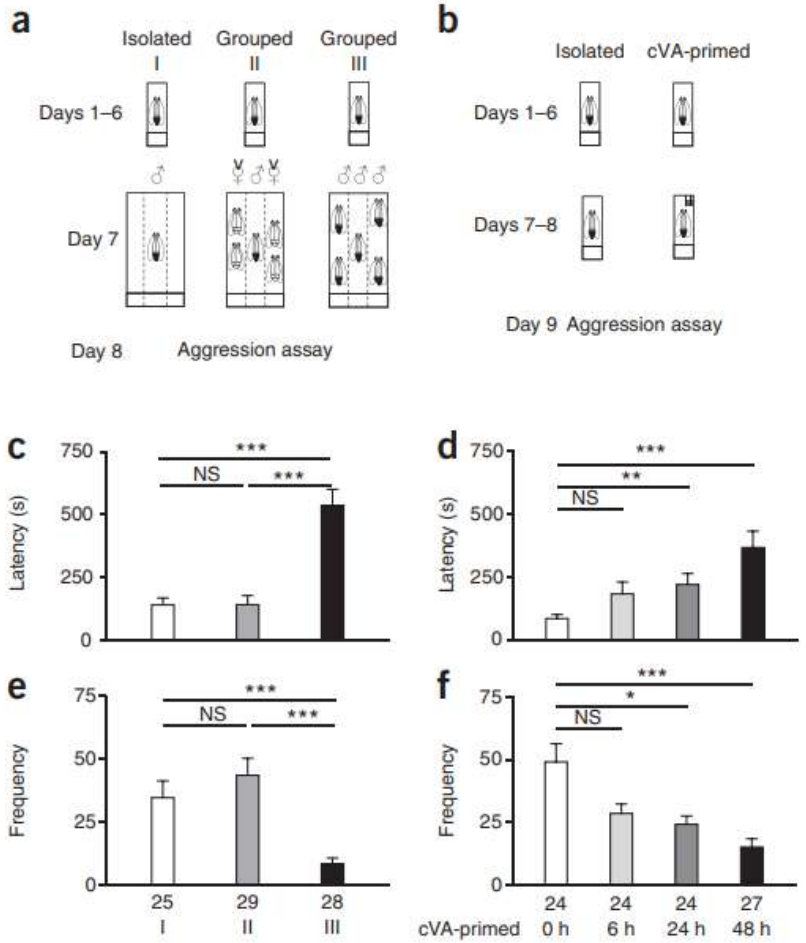
ARTICLES

nature neuroscience

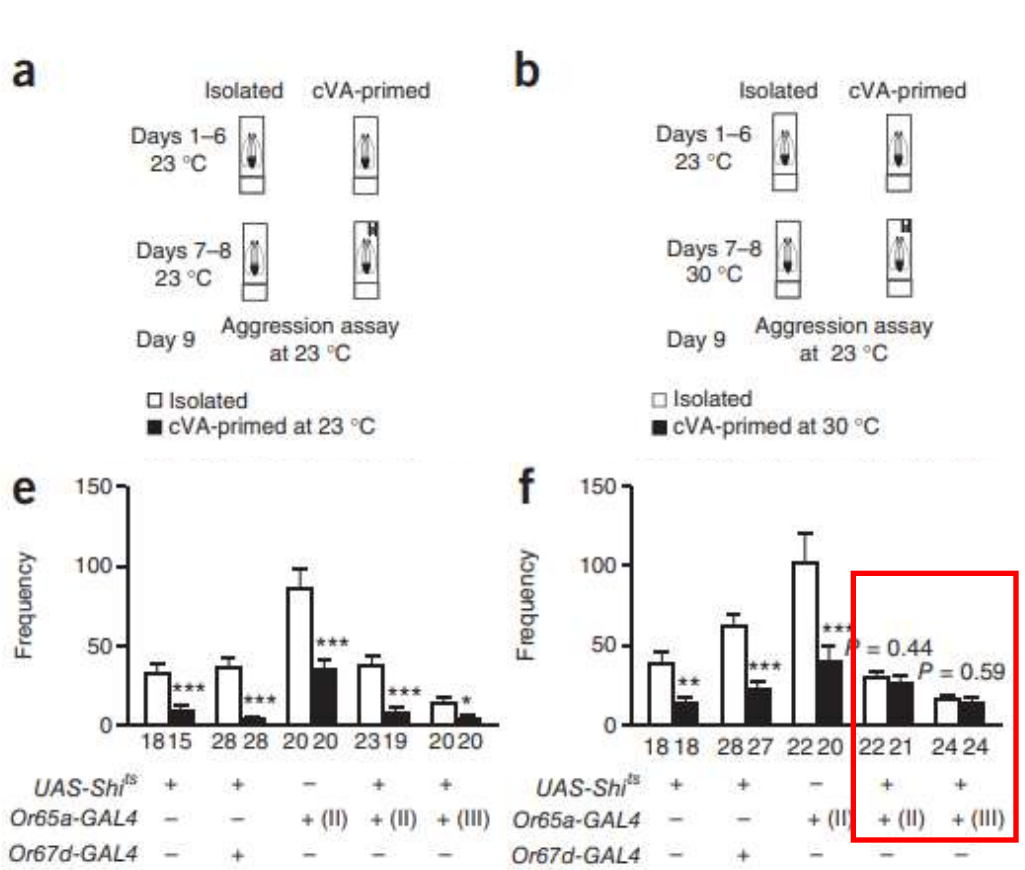
Social regulation of aggression by pheromonal activation of Or65a olfactory neurons in *Drosophila*

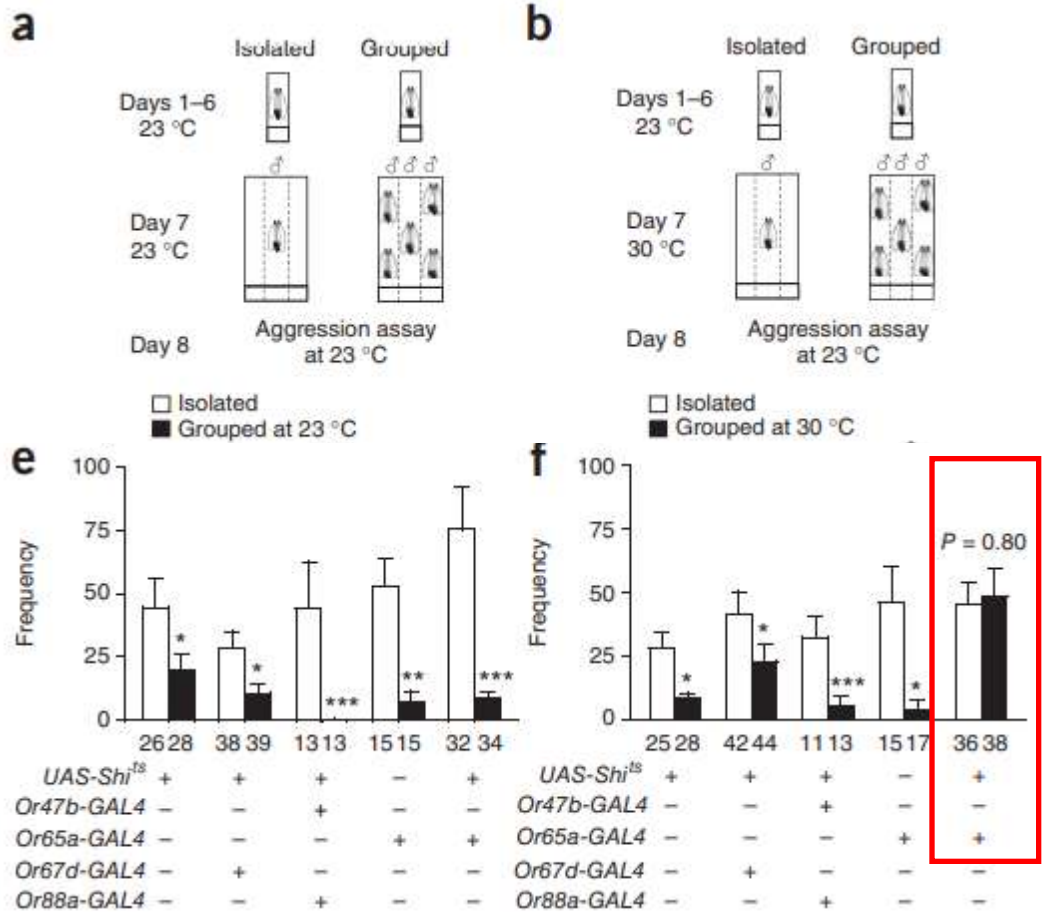
Weiwei Liu[2,3,7], Xinhua Liang[1,3,7], Jianxian Gong[4], Zhen Yang[4], Yao-Hua Zhang[5], Jian-Xu Zhang[5] & Yi Rao[3,6]



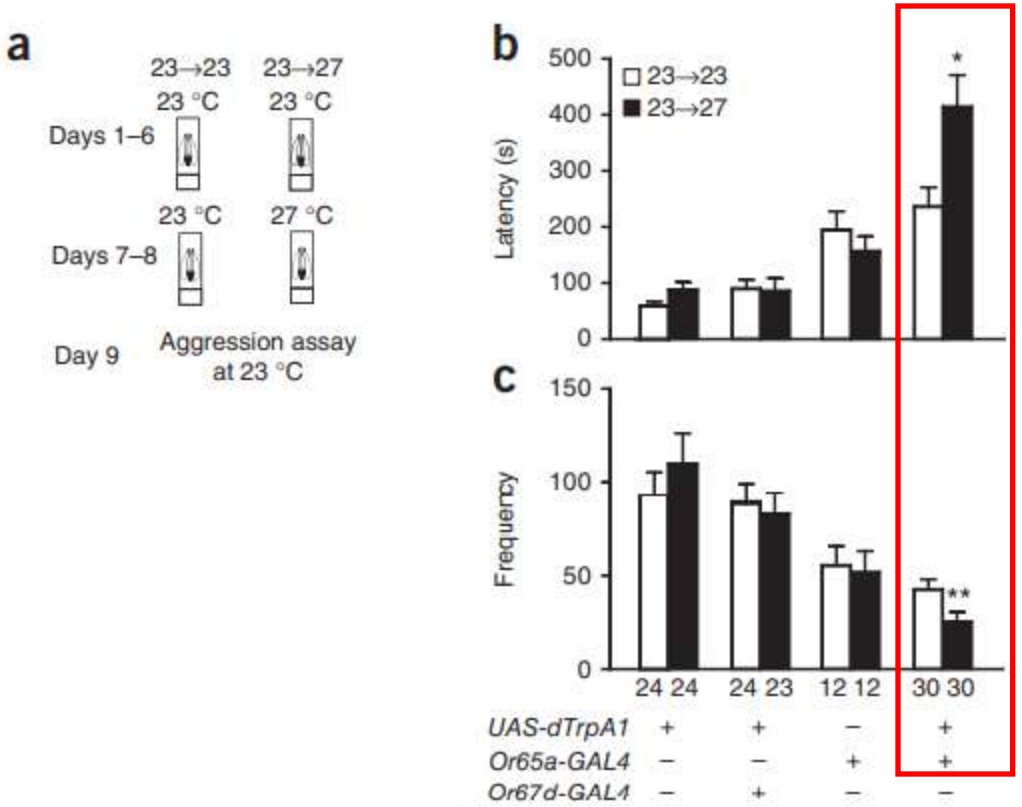


cVA effects aggression in social *Drosophila* via Or65a ORNs





Aggression reduced in *Drosophila* with Or65a ORNs activation experience



In group house files:

cVA level — Or65a ⊣ aggression drive →

cVA enhance aggression of crowded *Drosophila* via the or67d ORNs

hhmi Howard Hughes Medical Institute

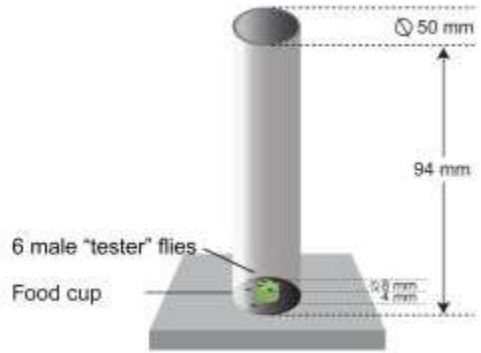
Published as: *Nature*. 2010 January 14; 463(7278): 227–231.

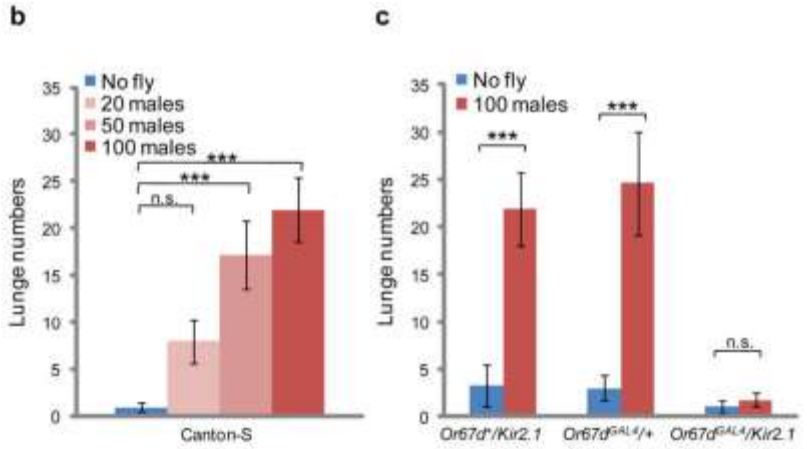
Identification of an aggression-promoting pheromone and its receptor neurons in *Drosophila*

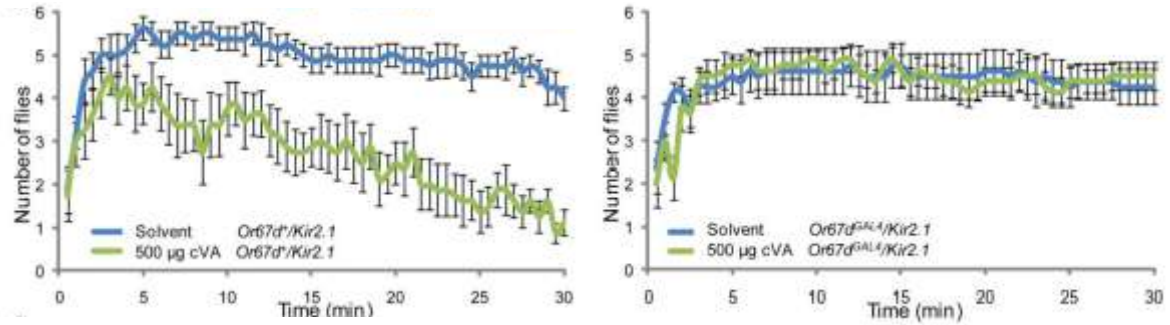
Liming Wang[1] and **David J. Anderson**[1,2,*]

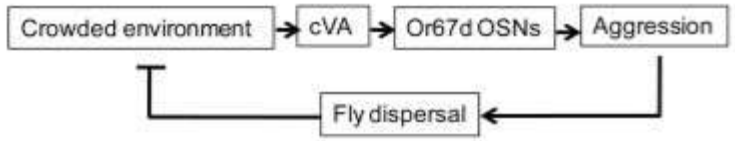
[1]Division of Biology 216-76, California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91125

[2]Howard Hughes Medical Institute, California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91125

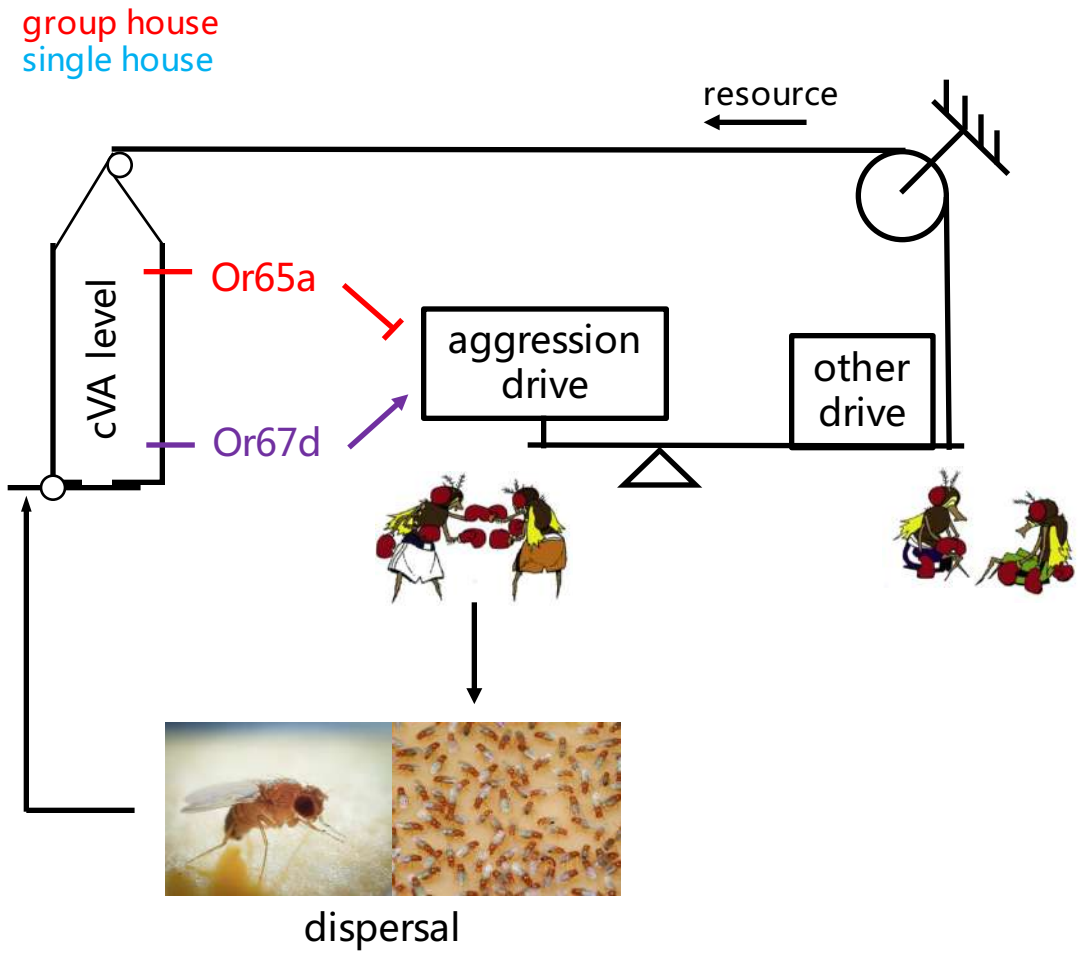








A model of cVA modulates aggression by social experience/status

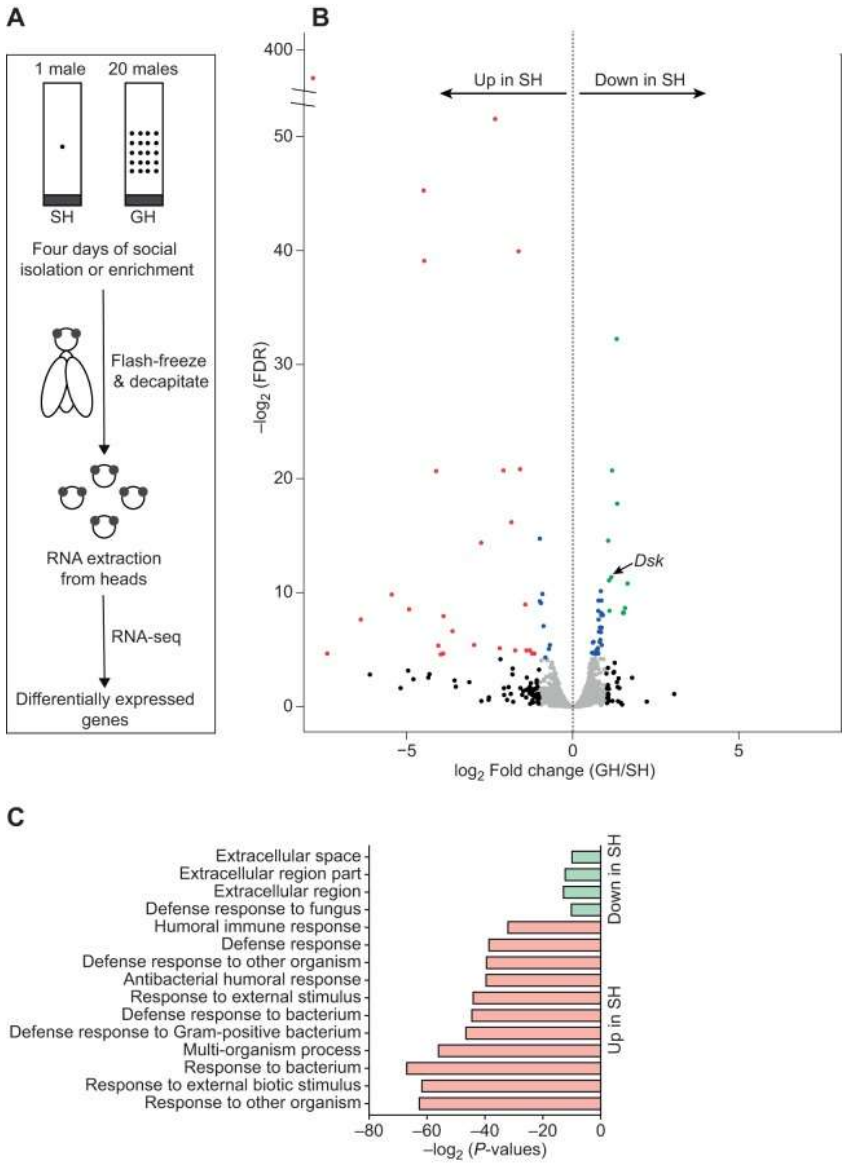


Neuromodulator changes in social isolation induced aggression

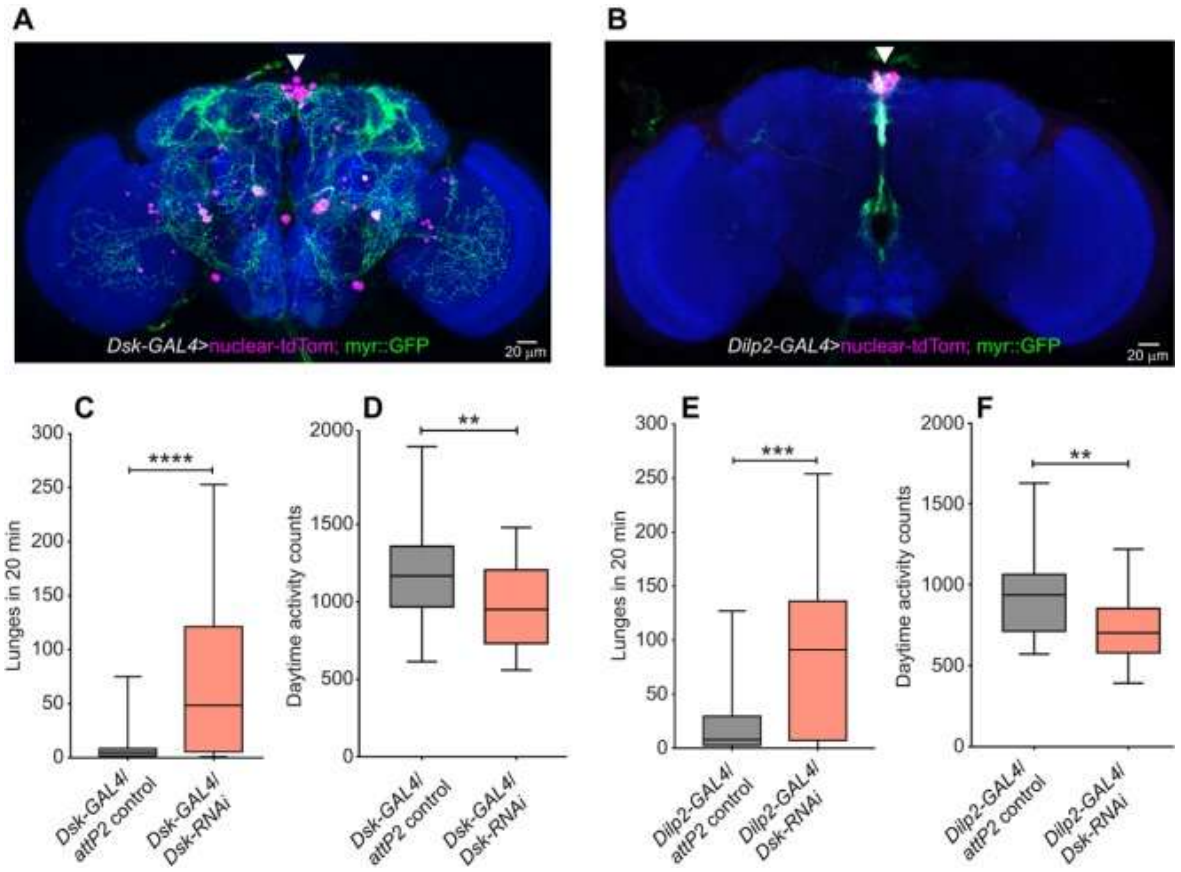
View PDF | About us | Current issue | Submit | Contact us | eTOC
Journal of Experimental Biology | The Company of Biologists

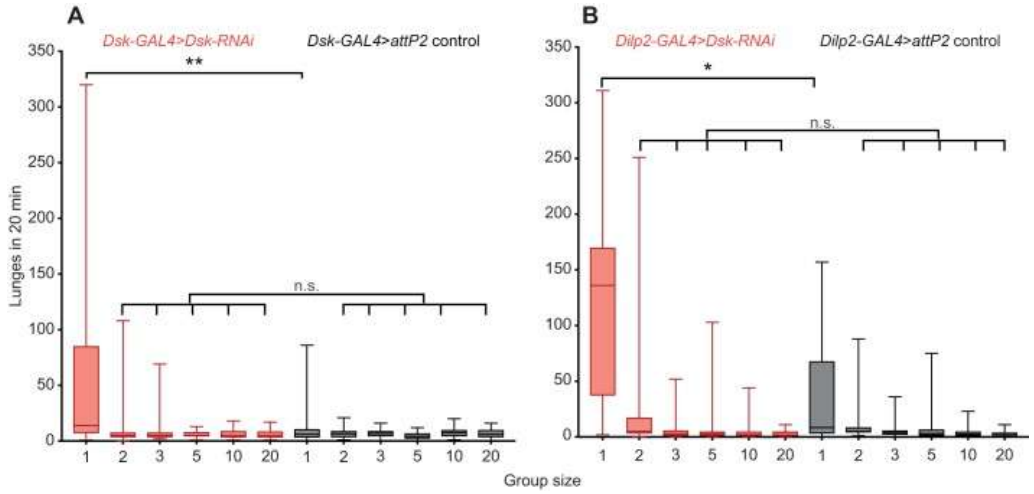
J Exp Biol. 2020 Jan 15; 223(2): jeb207407. PMCID: PMC7033730
Published online 2020 Jan 29. doi: 10.1242/jeb.207407 PMID: 31900346

The neuropeptide Drosulfakinin regulates social isolation-induced aggression in *Drosophila*

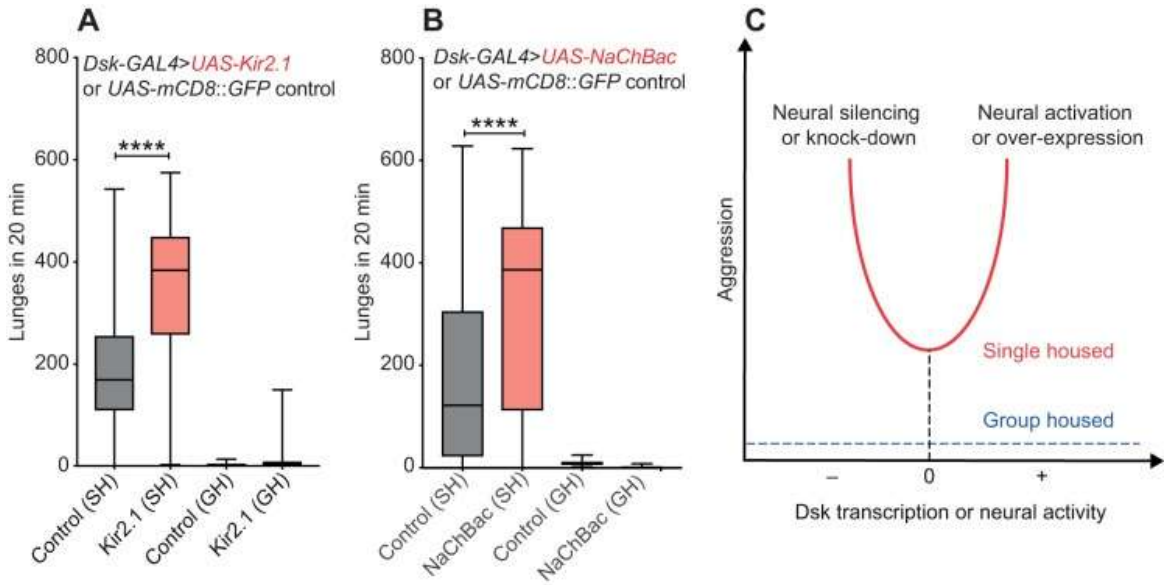


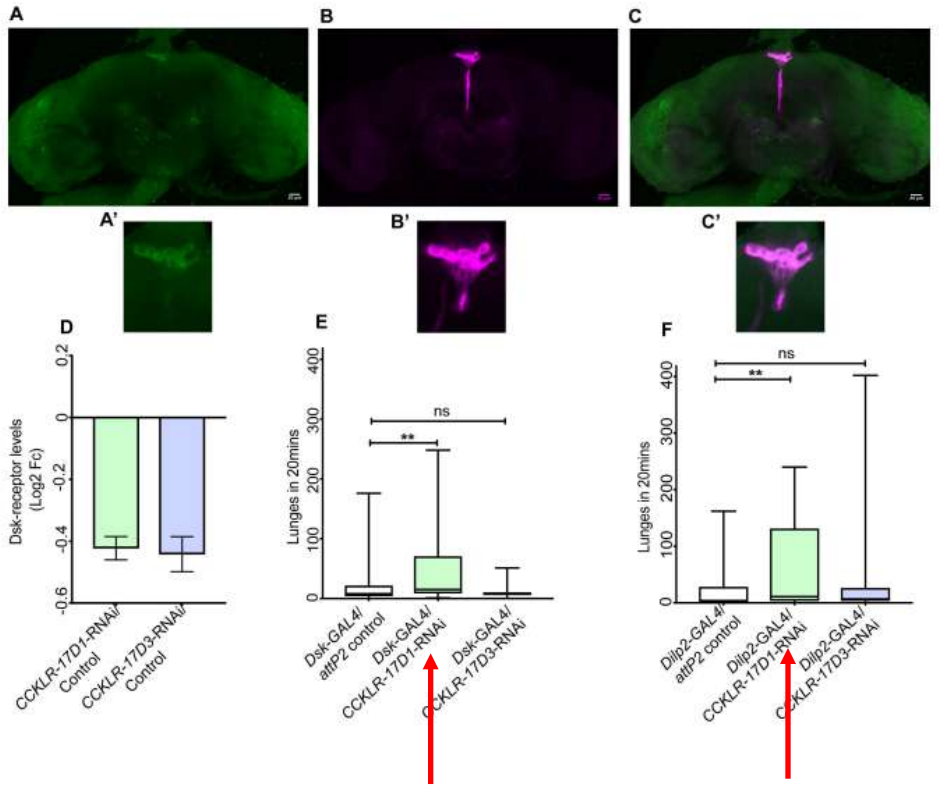
Decreased Dsk Expression increases aggression in social isolation flies





Dsk neurons activity bidirectionally regulates aggression in single housed fly

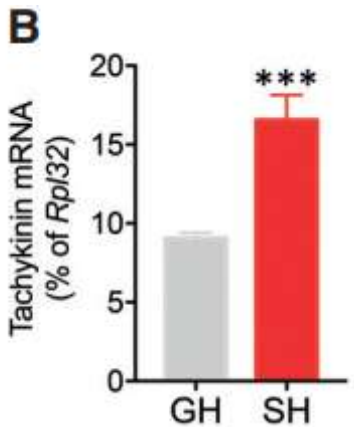


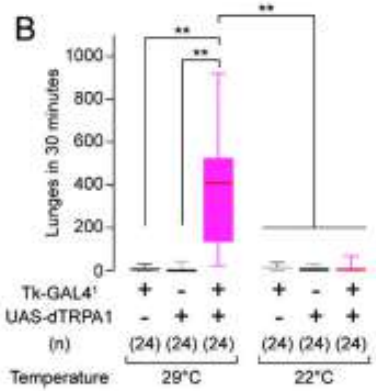


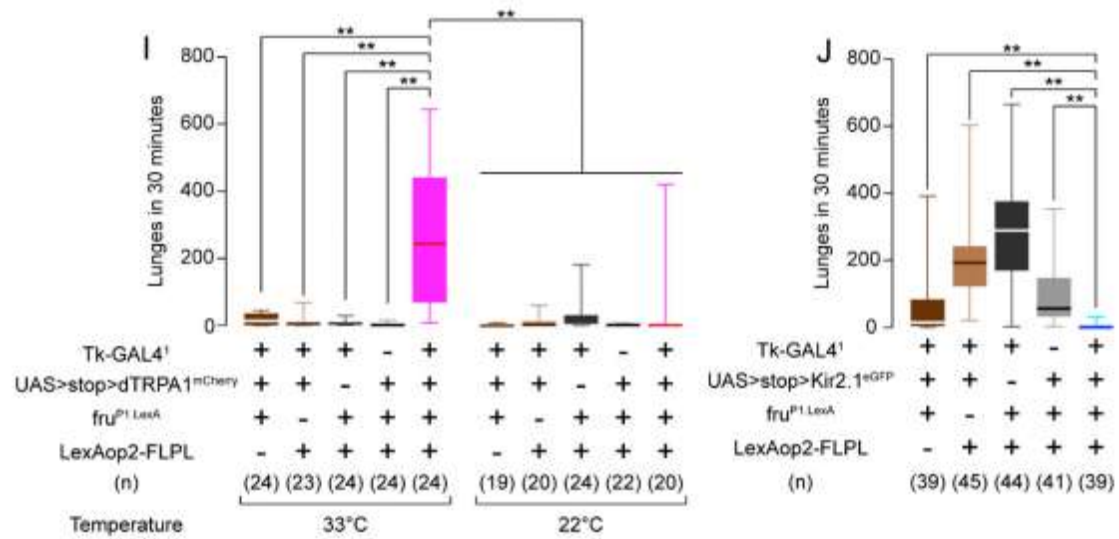
TK∩*fru*^{P1} neuron activity positively correlated with aggression

Tachykinin-Expressing Neurons Control Male-Specific Aggressive Arousal in *Drosophila*

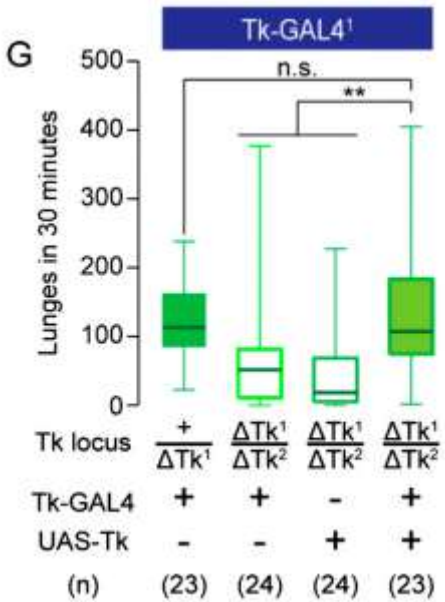
Kenta Asahina,[1,2] Kiichi Watanabe,[1,2] Brian J. Duistermars,[1,2] Eric Hoopfer,[1,2,4] Carlos Roberto González,[3] Eyrún Arna Eyjólfsdóttir,[3] Pietro Perona,[3] and David J. Anderson[1,2,*]
[1]Howard Hughes Medical Institute, California Institute of Technology, 1200 E. California Boulevard, Pasadena, CA 91125, USA
[2]Division of Biology, 156-29, California Institute of Technology, 1200 E. California Boulevard, Pasadena, CA 91125, USA
[3]Division of Engineering and Applied Science, California Institute of Technology, 1200 E. California Boulevard, Pasadena, CA 91125, USA
[4]Janelia Farm Research Campus, HHMI, 19700 Helix Drive, Ashburn, VA 20147, USA
*Correspondence: wuwei@caltech.edu
http://dx.doi.org/10.1016/j.cell.2013.11.045

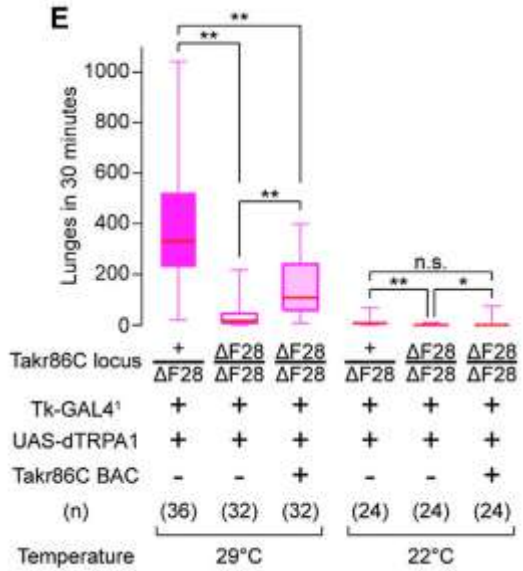


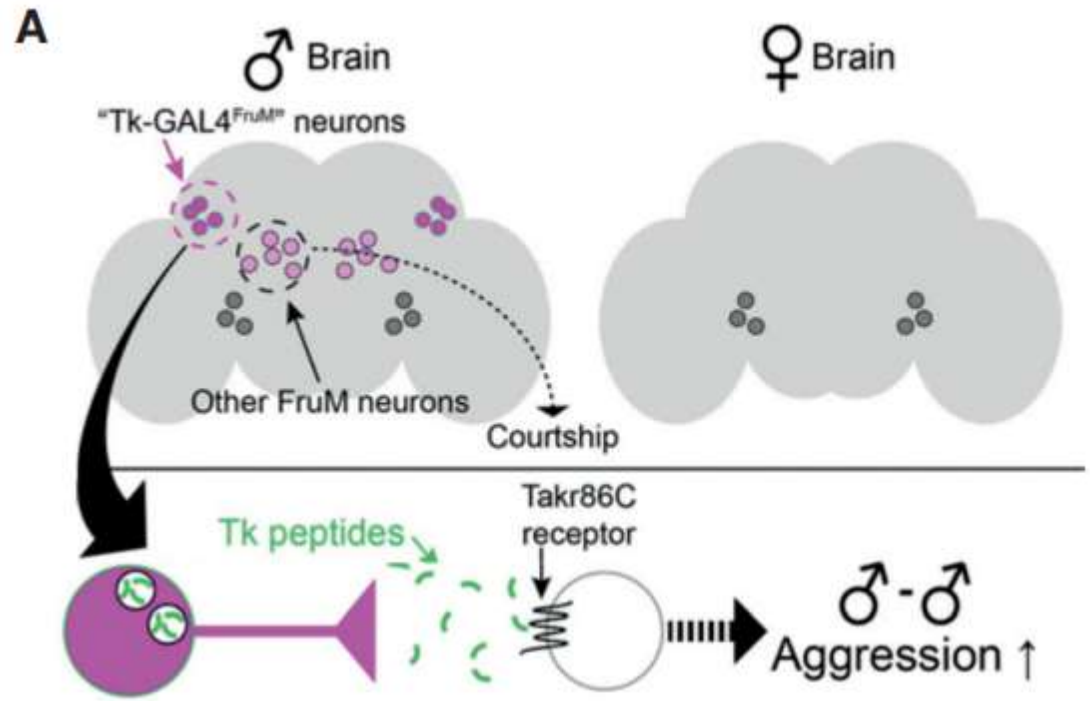




TK regulates aggression through Takr86C in single housed flies







Summary:

- Pheromone is very important for the establishment of social experience and the regulation of social behavior.
- The presence or absence of social experience can be reflected by differences in neuromodulators expression.

- How does social isolation regulate aggression ?
  - Sensory
  - Neuromodulator
- Why *Drosophila* has a higher aggression level after social isolation ?

Social isolation stress increase aggression in rodents

Stress, June 2005; 8(2): 85–93

Taylor & Francis
Taylor & Francis Group

Social isolation stress-induced aggression in mice: A model to study the pharmacology of neurosteroidogenesis

KINZO MATSUMOTO[1], GRAZIANO PINNA[2], GIULI PUIA[3], ALESSANDRO GUIDOTTI[2], & ERMINIO COSTA[2]

[1]*Division of Medicinal Pharmacology, Institute of Natural Medicine, Toyama Medical and Pharmaceutical University, 2630 Sugitani, Toyama 930-0194, Japan,* [2]*Department of Psychiatry, Psychiatric Institute, University of Illinois at Chicago College of Medicine, 1601 W Taylor Street, Chicago, IL 60612 USA, and* [3]*Department of Pharmaceutical Sciences, Universita di Modena, Italy*

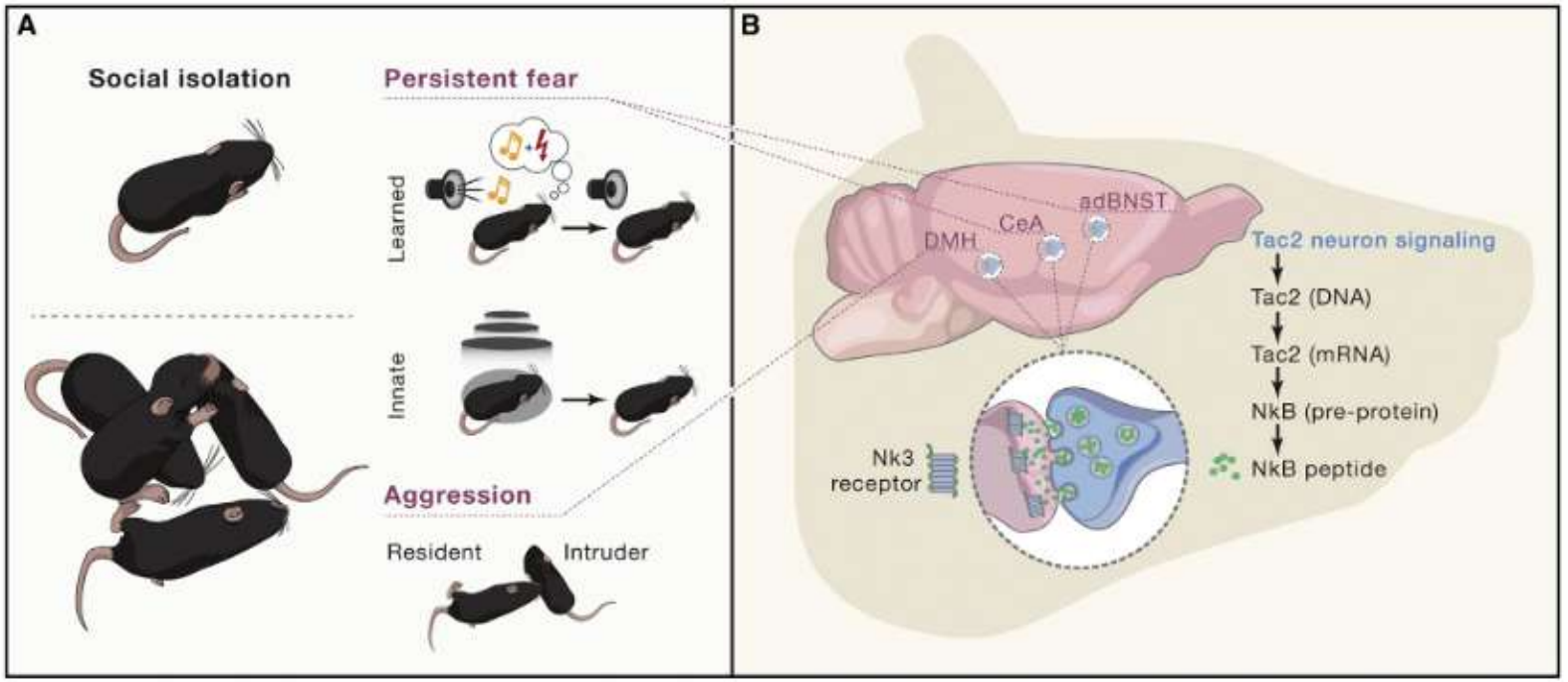
(Received 28 February 2005; revised 29 April 2005; in final form 2 May 2005)

Leading Edge
Previews

Cell

Social Isolation Co-opts Fear and Aggression Circuits

Jose Rodriguez-Romaguera[1] and Garret D. Stuber[1,2,3,*]
[1]Department of Psychiatry, University of North Carolina, Chapel Hill, NC, USA
[2]Department of Cell Biology and Physiology, University of North Carolina, Chapel Hill, NC, USA
[3]Neuroscience Center, University of North Carolina, Chapel Hill, NC, USA
*Correspondence: gstuber@med.unc.edu
https://doi.org/10.1016/j.cell.2018.04.031



Aggression reduced after group feeding in cricket

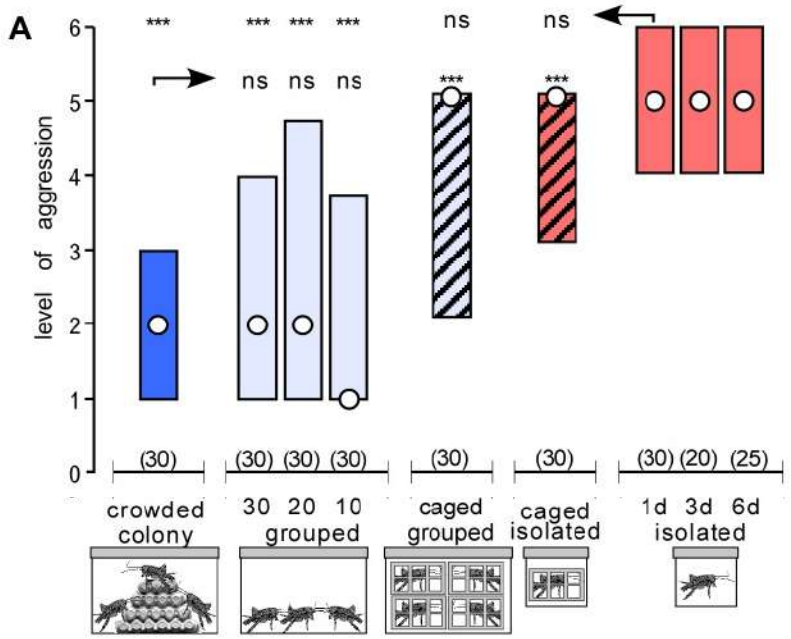
PLOS ONE

PLoS One. 2013; 8(9): e74965.
Published online 2013 Sep 6. doi: 10.1371/journal.pone.0074965

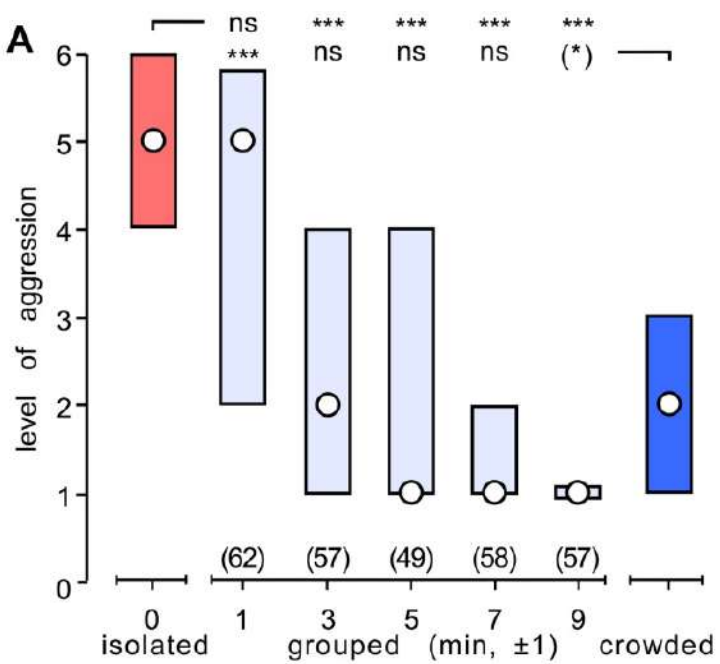
PMCID: PMC3765410
PMID: 24040368

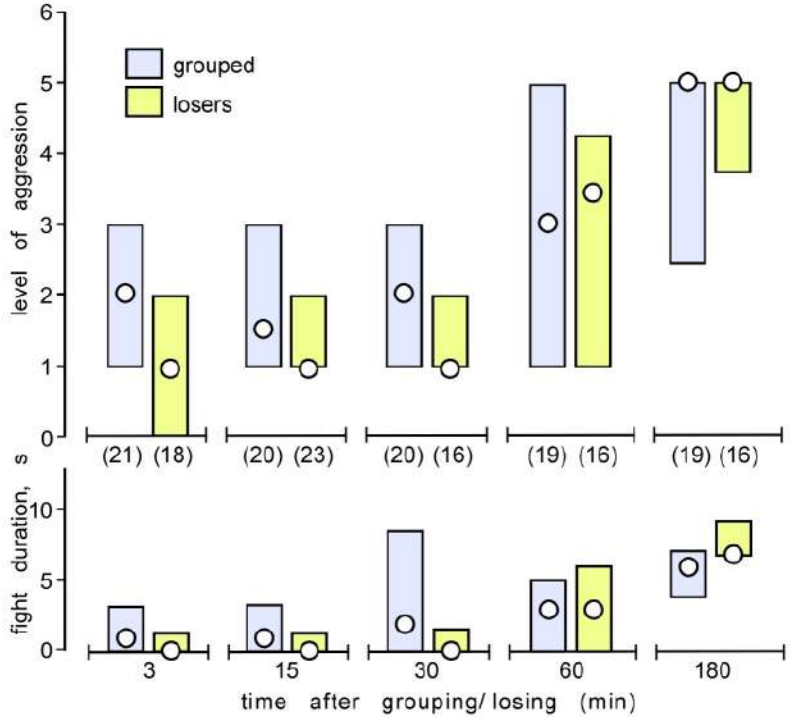
Isolation Associated Aggression – A Consequence of Recovery from Defeat in a Territorial Animal

Paul A. Stevenson [1,*] and Jan Rillich [2]

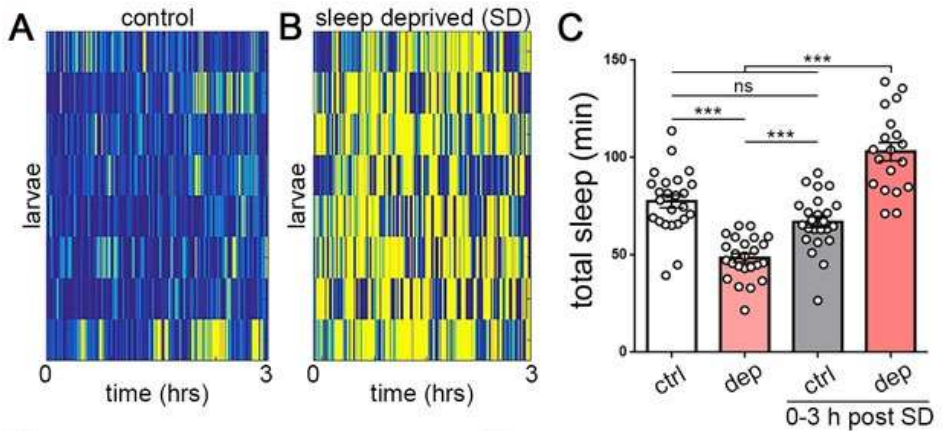


Aggression level is not constant during the normal behavior test

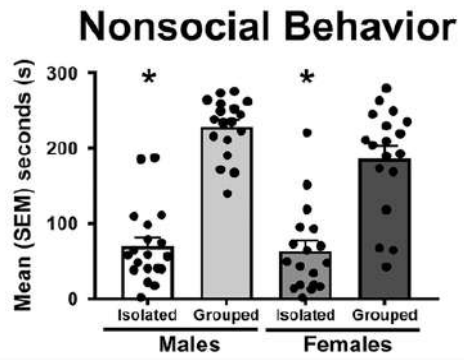




Social rebound after social isolation



Milan Szuperak, et al., *eLife*, 2018.



Ross, Amy P et al., *Hormones and behavior*, 2019.

Take home messages:

- The role of cVA in *Drosophila* aggression regulation.
- Neuromodulator involved in the modulation of social isolation related aggression.
- The significance of higher aggression levels for *Drosophila.*

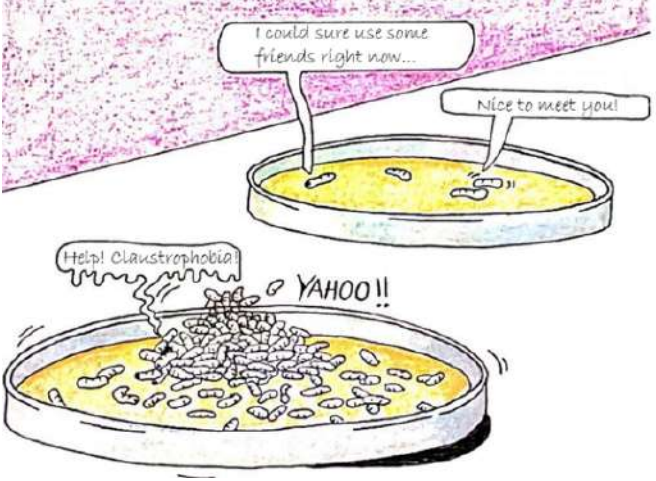
Thanks

Effects of social experience on courtship in Drosophila

WR

2022.5.26

- How social environment affects drosophila mating behavior
- Social experience and courtship behavior of both sexes



How social environment affects drosophila mating behavior?

Published in final edited form as:
Curr Biol. 2019 November 18; 29(22): 3887–3898.e4. doi:10.1016/j.cub.2019.09.045.

Social context enhances hormonal modulation of pheromone detection in *Drosophila*

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

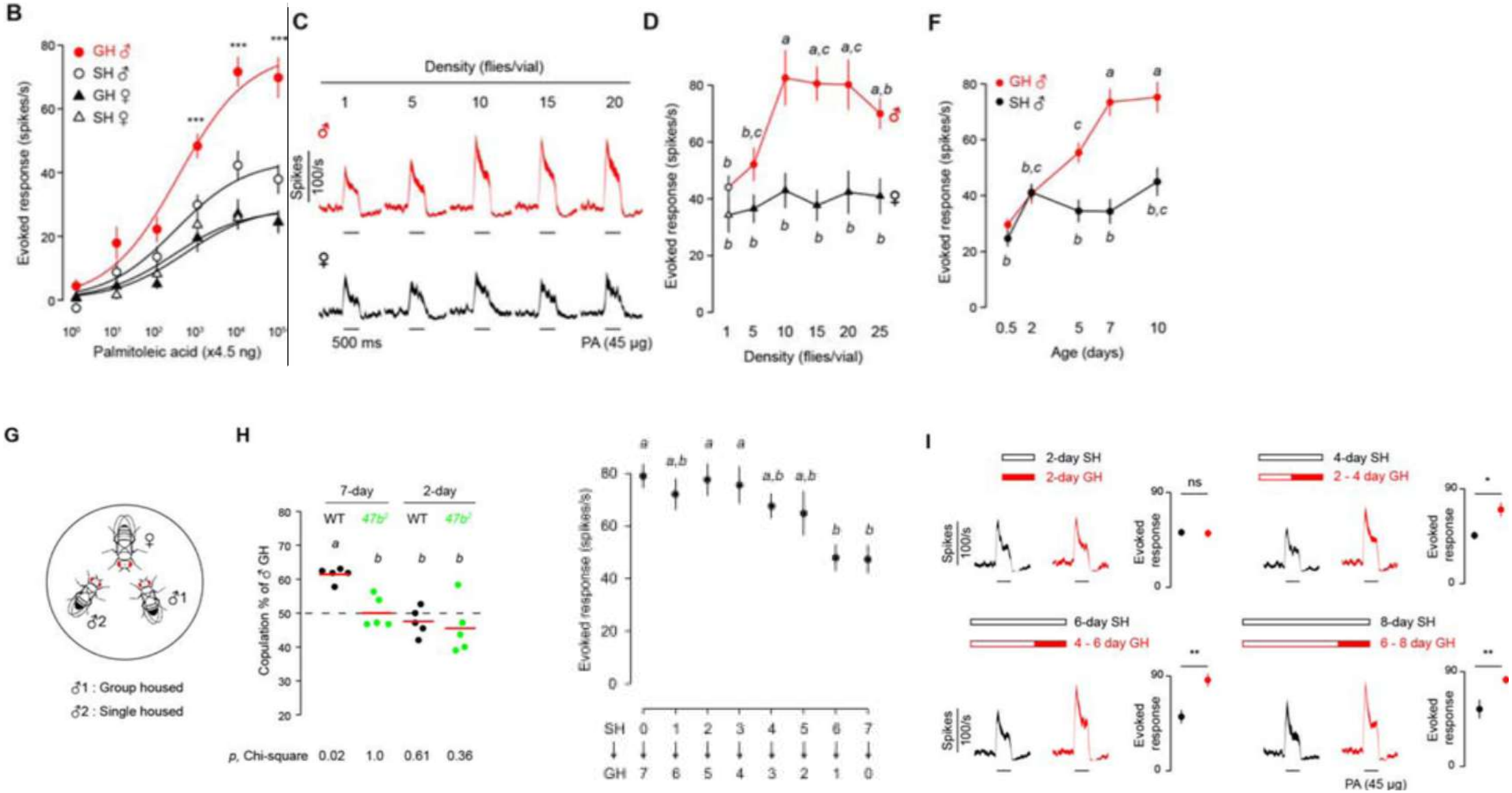
Individual contextual inputs

- mating status
- hormonal state
- population density
- prior experience

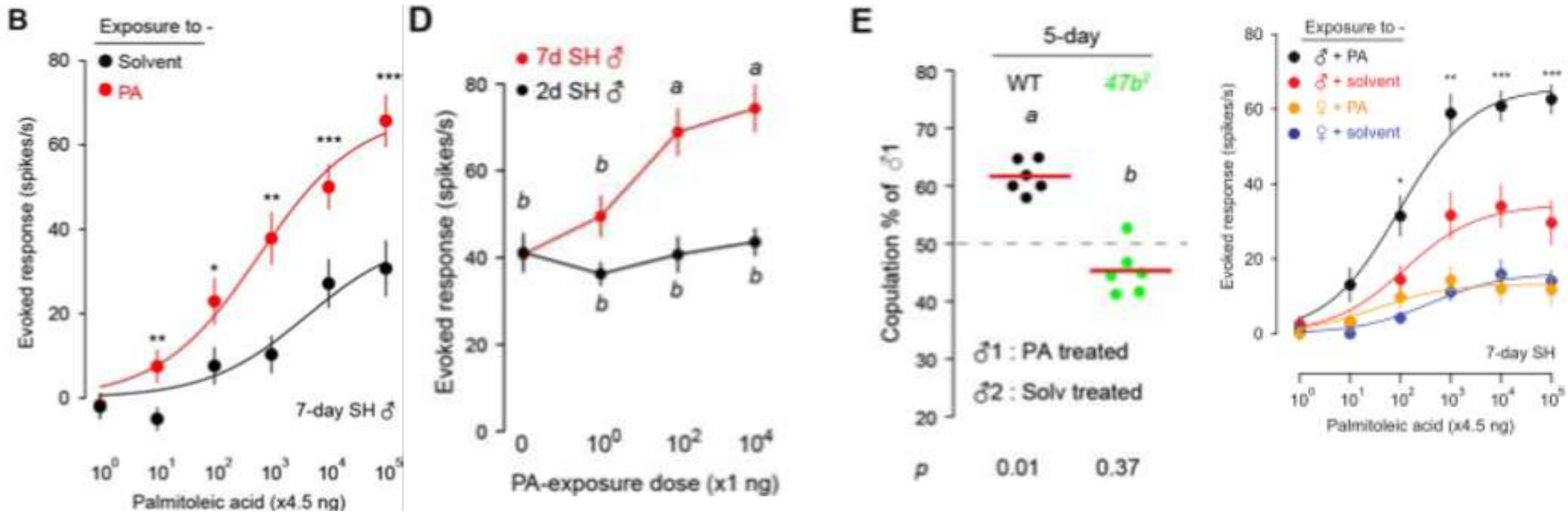
How?

modulate the display of social behaviors

Group housing enhances pheromone response of Or47b neurons in mature males

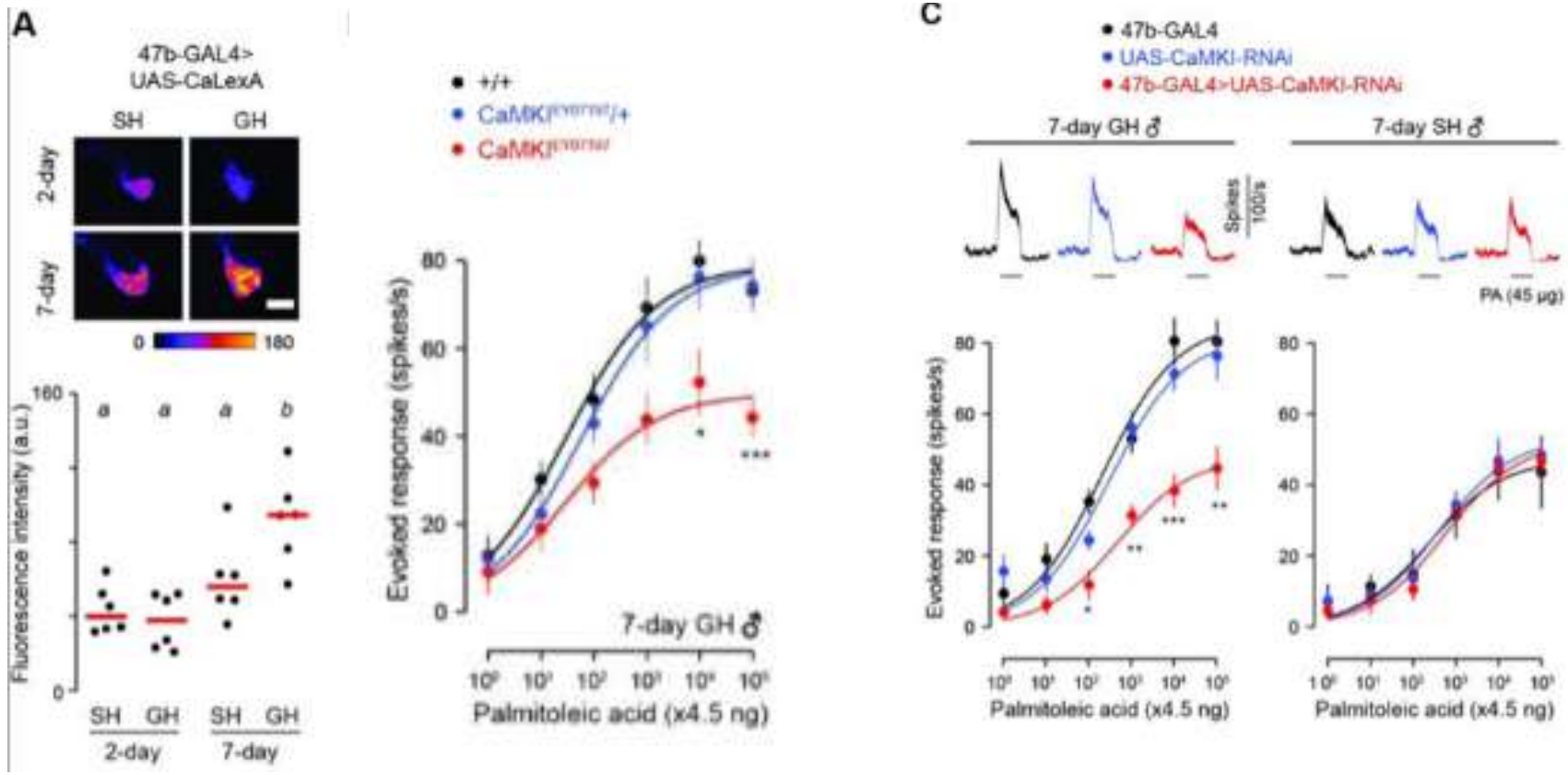


GH elevates Or47b pheromone response by means of activity-dependent CaMKI signaling.

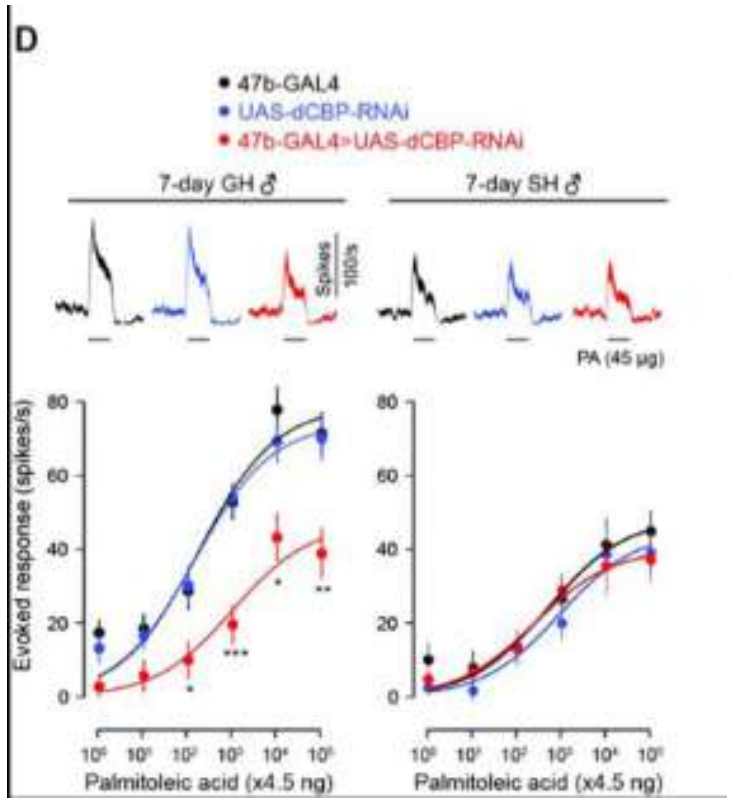


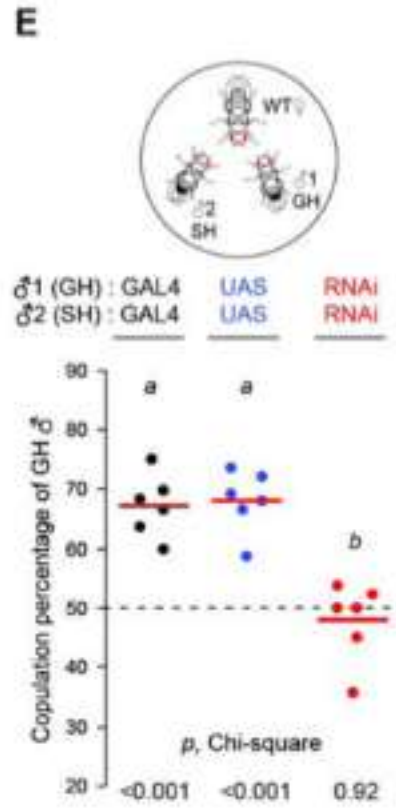
Heightened levels of Or47b ligands in group-housing conditions are sufficient to sensitize Or47b ORNs in mature males.

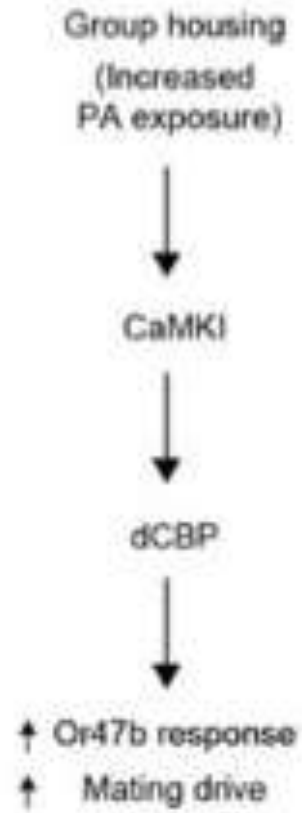
GH elevates Or47b pheromone response by means of activity-dependent CaMKI signaling.



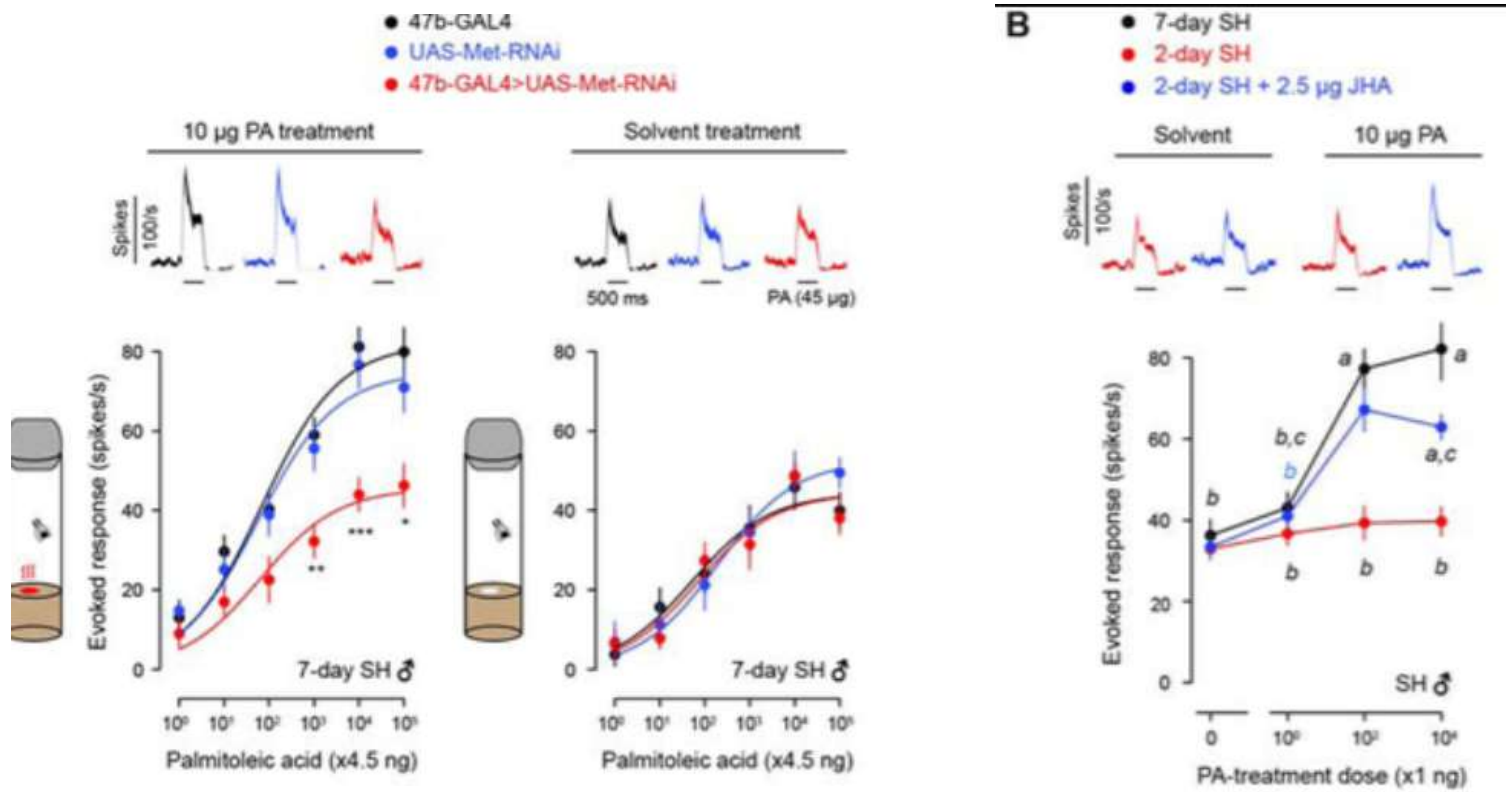
GH enhances courtship behavior by activating a CaMKI-dCBP signaling pathway in male Or47b ORNs





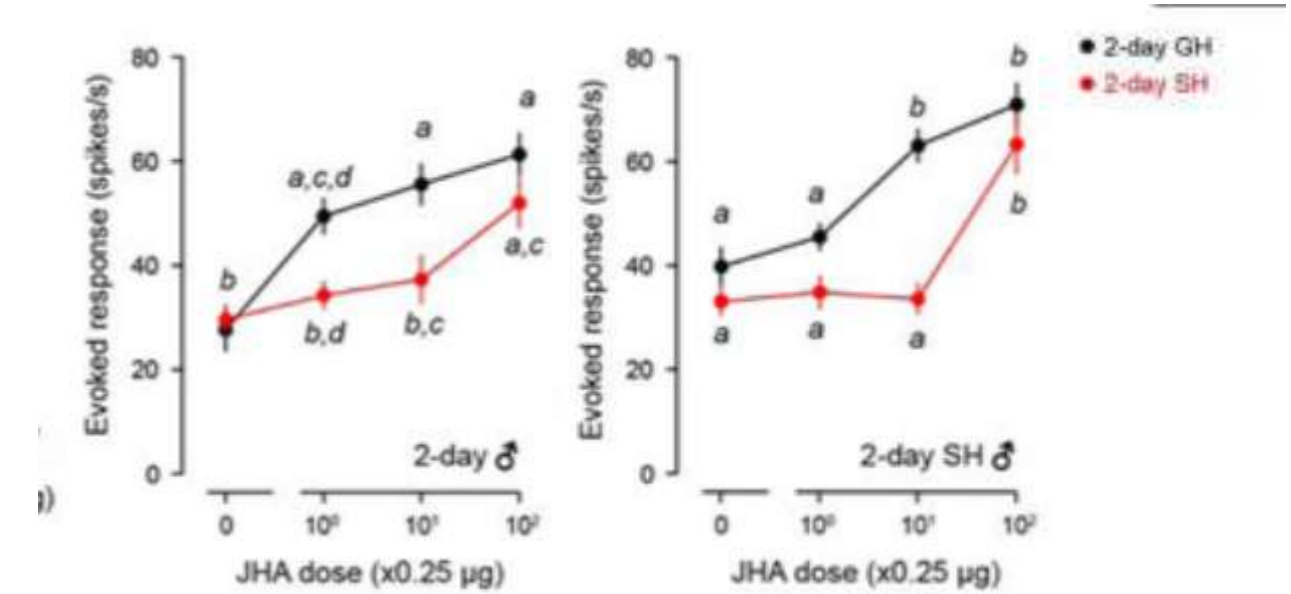


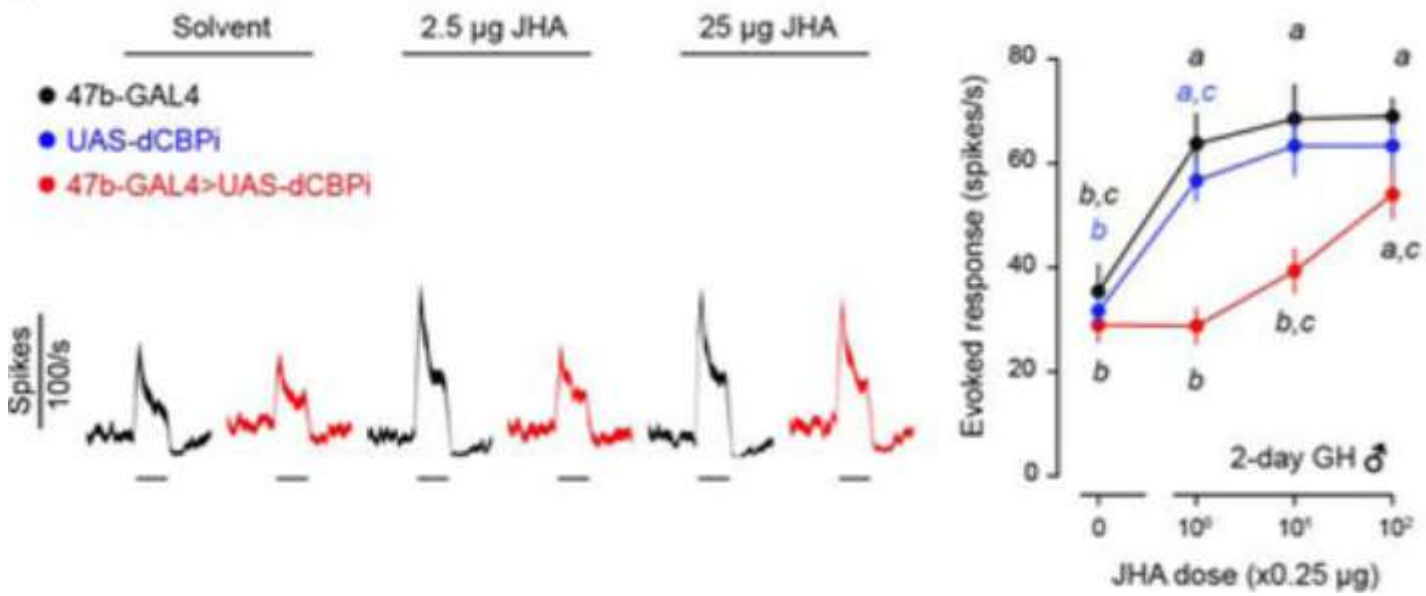
Juvenile hormone signaling is required for the effect of group housing on Or47b ORNs

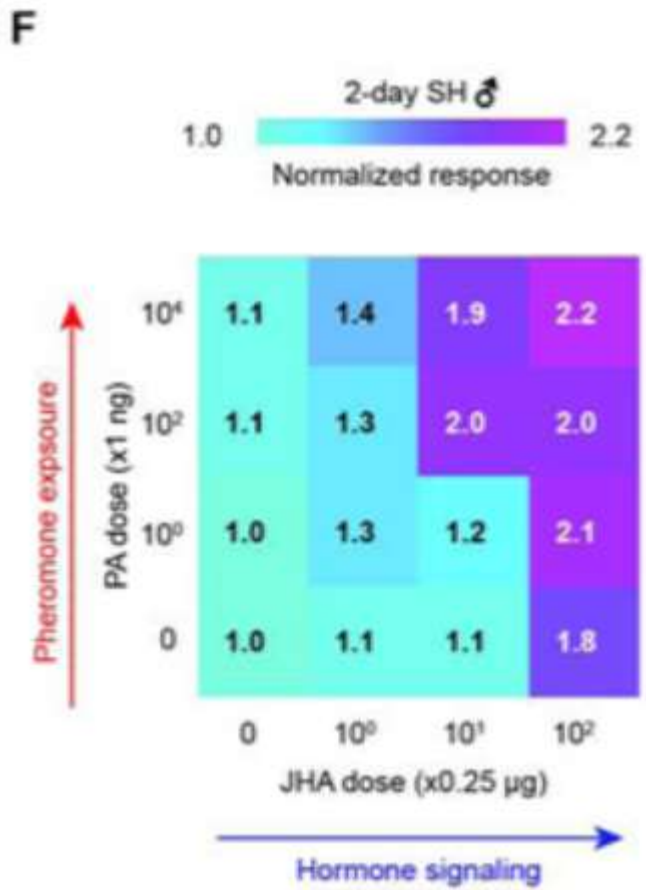


Two molecular pathways—one signaling population density and the other fly age—are both required for the activity-dependent Or47b neuronal plasticity.

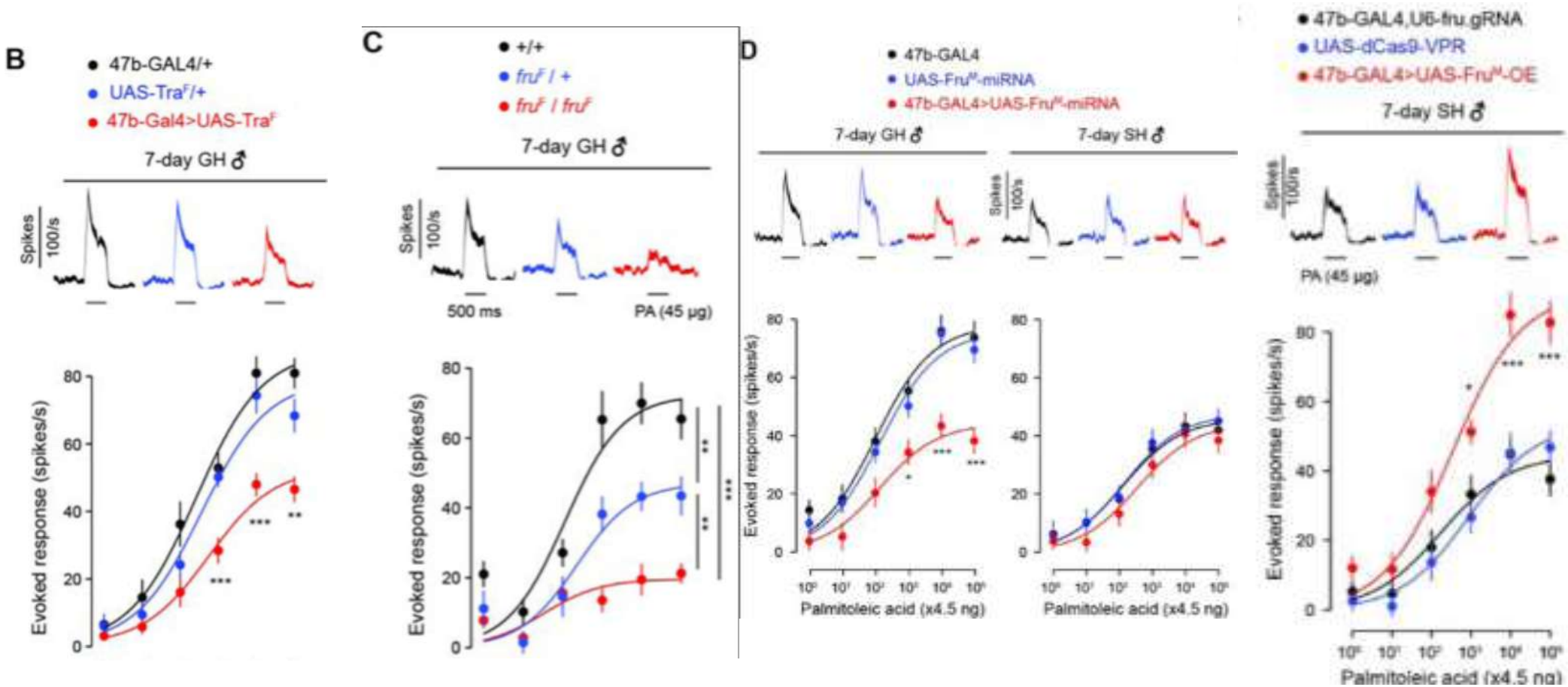
Group housing enhances the efficacy of juvenile hormone signaling



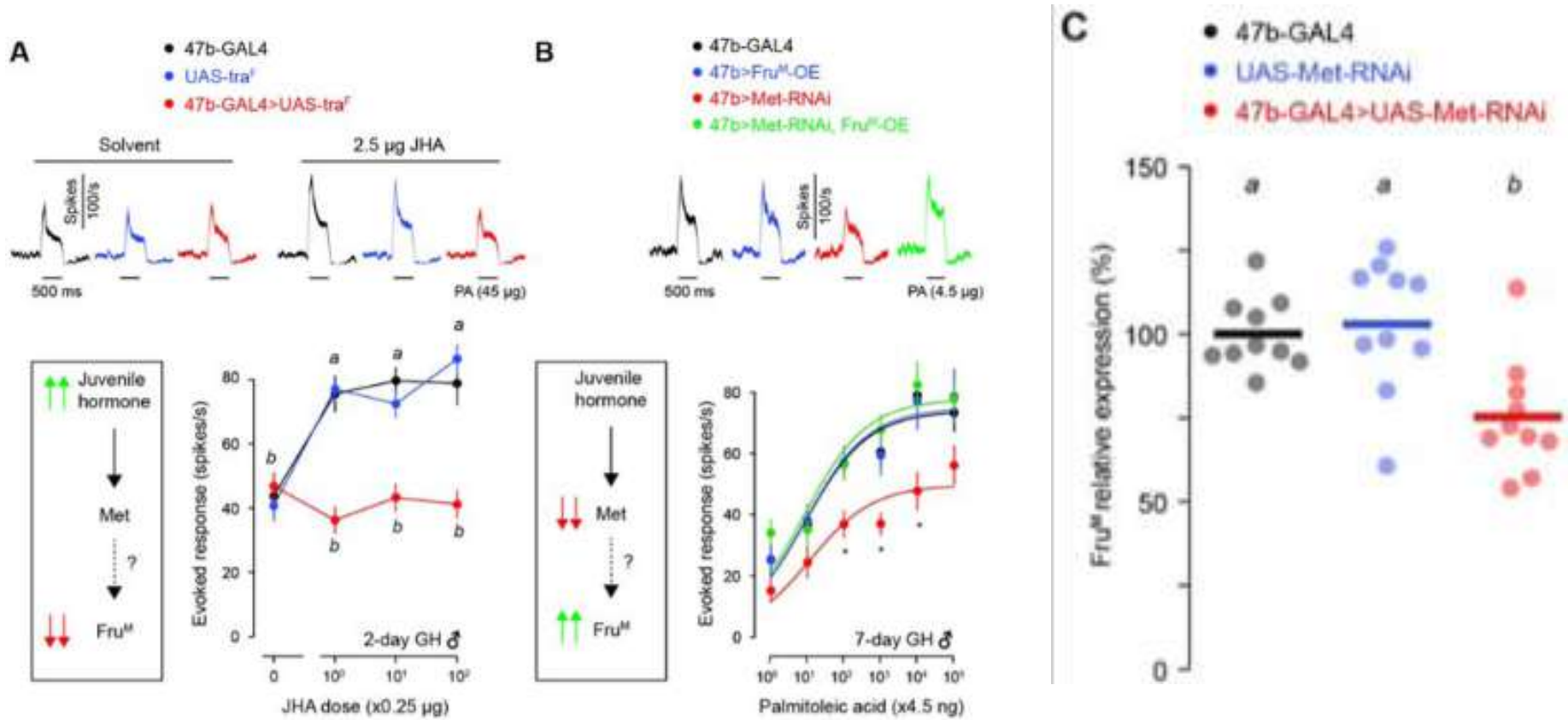




FruM expression levels determine Or47b response



Juvenile hormone signaling require FruM to elevate pheromone responses



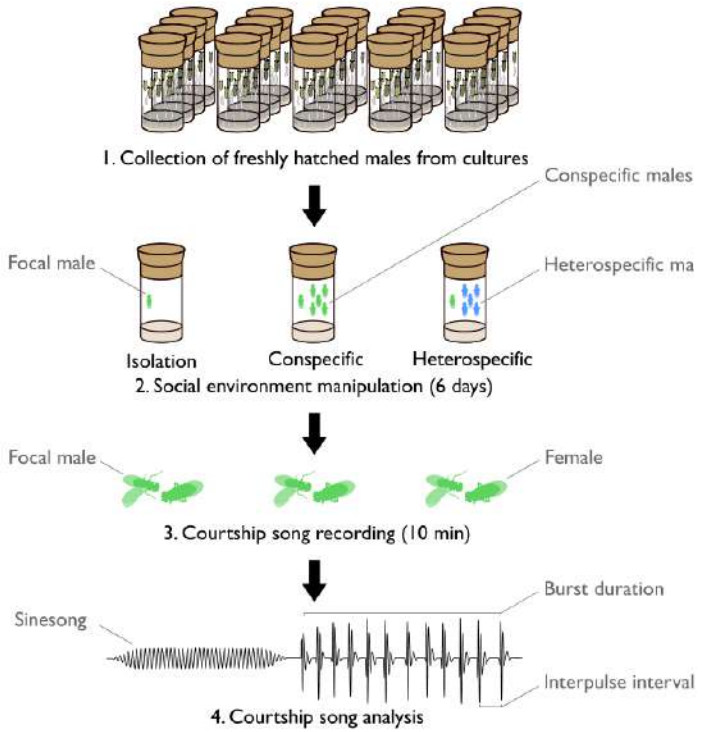
Communicating housing condition and signaling hormonal state—act in concert to regulate the expression of FruM in Or47b ORNs.

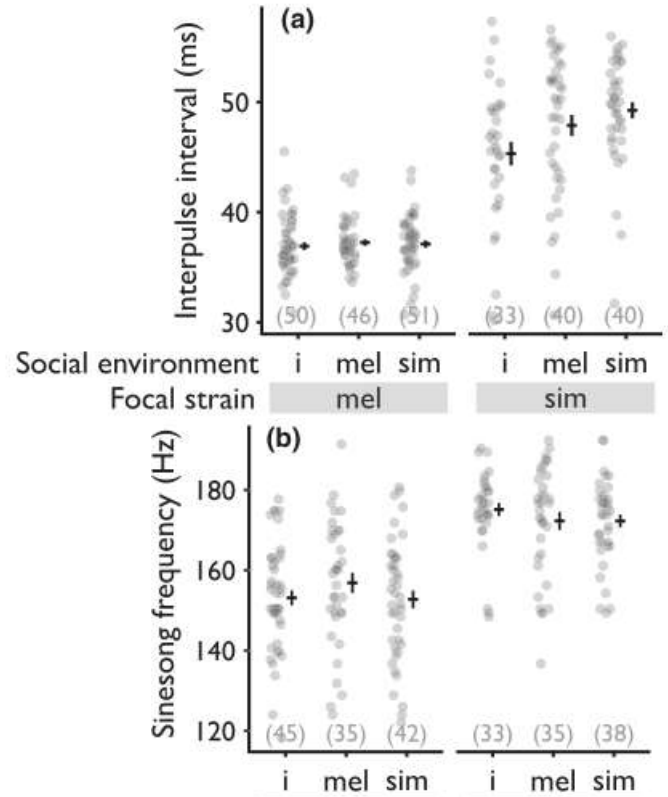
Summary:

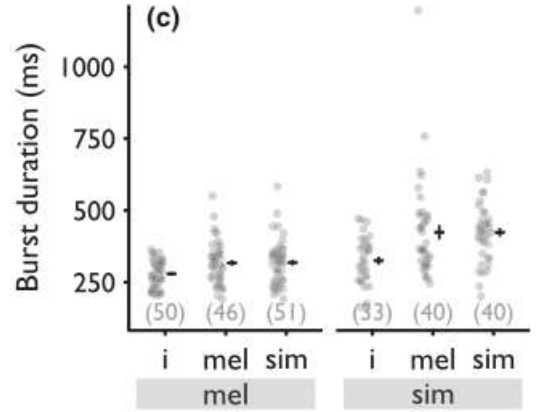
- Group housing enhances courtship motivation in mature but not immature males.
- Group housing elevates the pheromone response of Or47b ORNs only in mature males.
- CaMKI/CBP pathway synergizes with juvenile hormone in sensitizing Or47b ORNs.
- FruM levels fine-tune pheromone sensitivity according to both fly density and age.

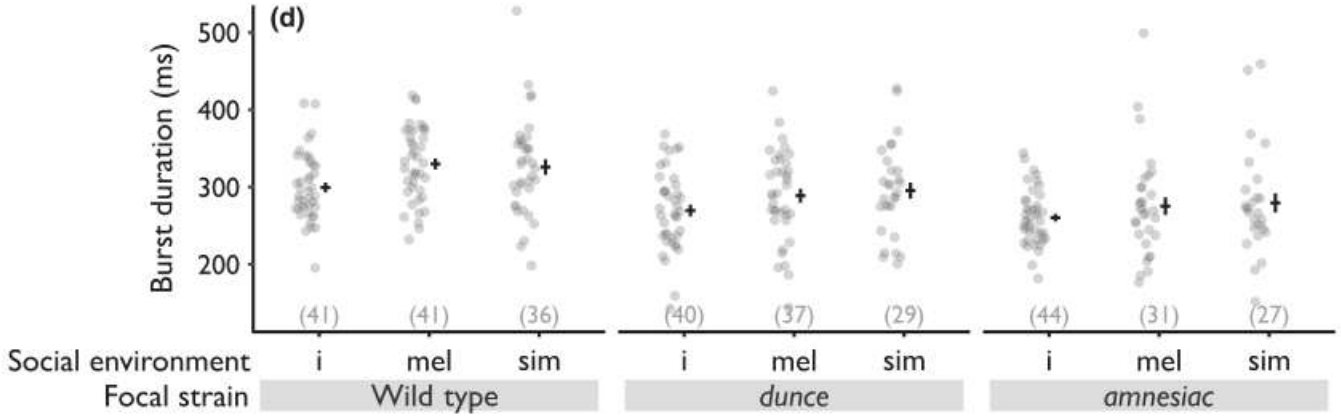
Effects of social experience or environment on male fruit flies

Experimental procedure to test the social plasticity of courtship song.



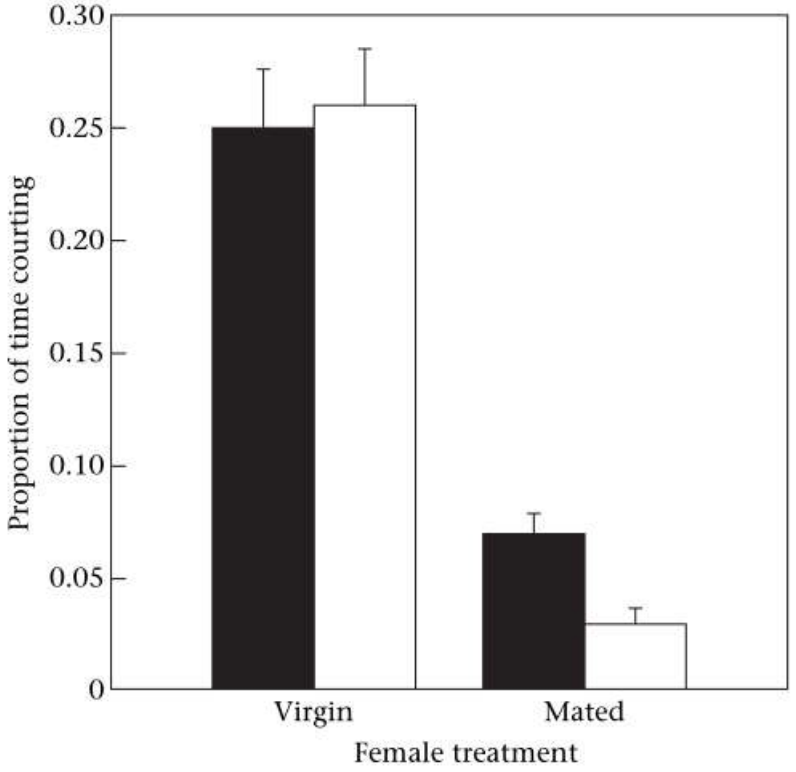


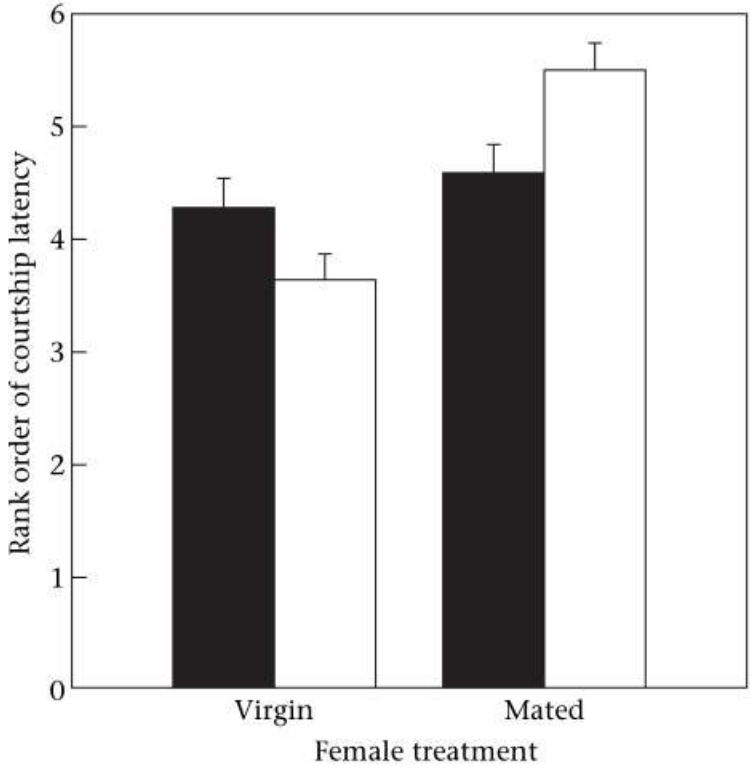




（Lucas Marie-Orleach、Nathan W. Bailey et al.*Ecology and*

Male experience affected the proportion of time males spent courting and the rank order of courtship latencies



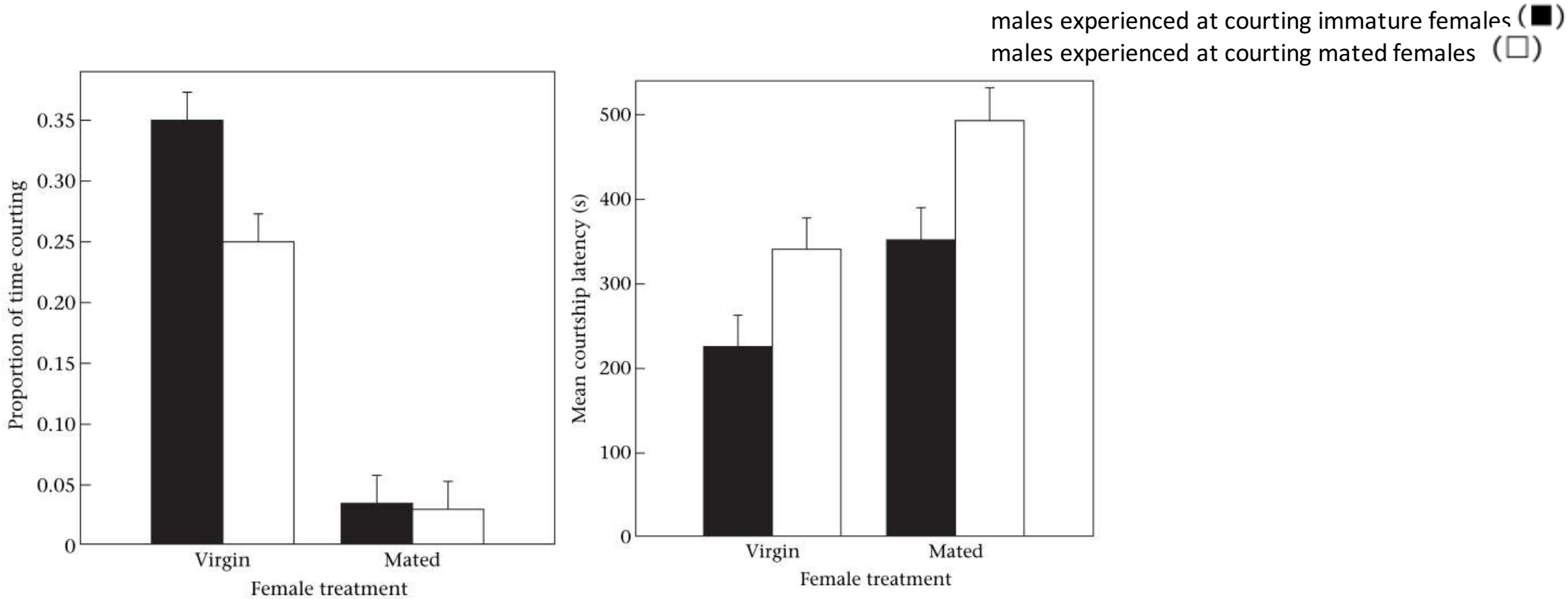


naïve males (■)

experienced (□)

（Department of Psychology, McMaster Universit.*Animal Behaviour*.2004）

Male experience significantly affected both the proportion of time males spent courting and courtship latency



Compared to males experienced with mated females, males experienced with immature females decreased courtship latency towards virgin and mated females and increased courtship duration towards virgin females.

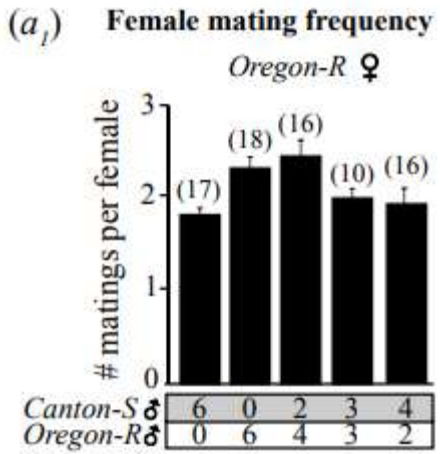
Summary:

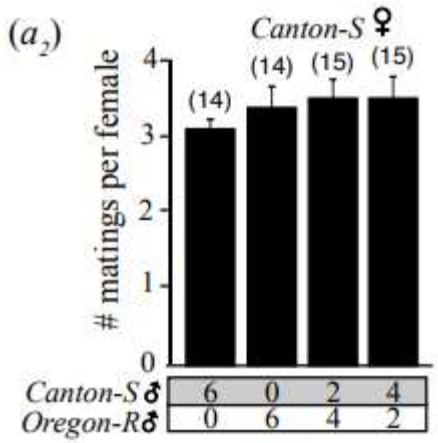
- The courtship song of fruit flies is influenced by social environment.

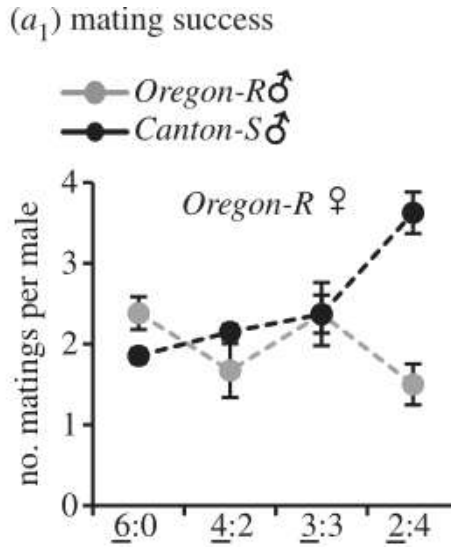
- Male experience affected the proportion of time males spent courting and the rank order of courtship latencies

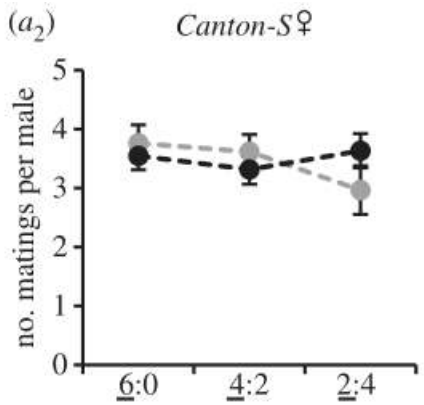
Effects of social experience or environment on female fruit flies

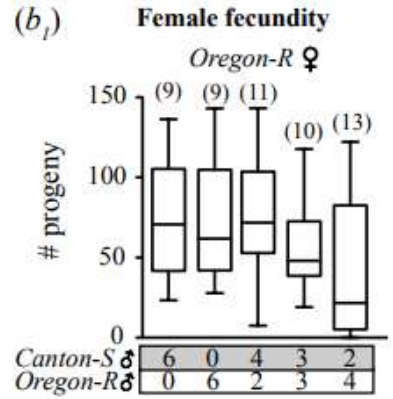
Social environment can influence mate choice and fecundity, and notably genotypic diversity in the next generation.

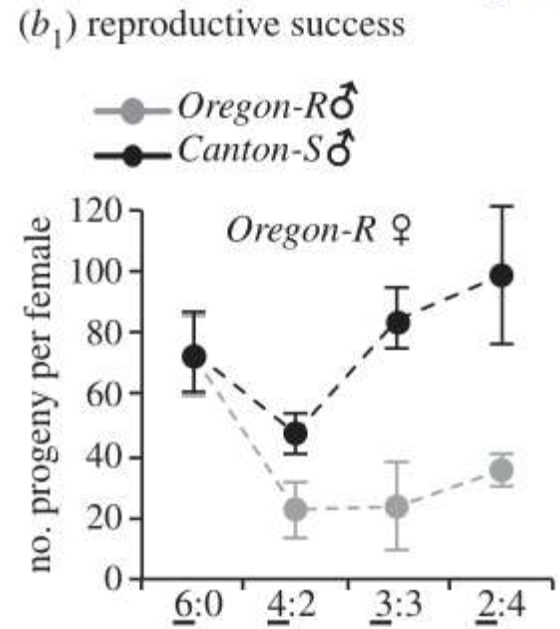


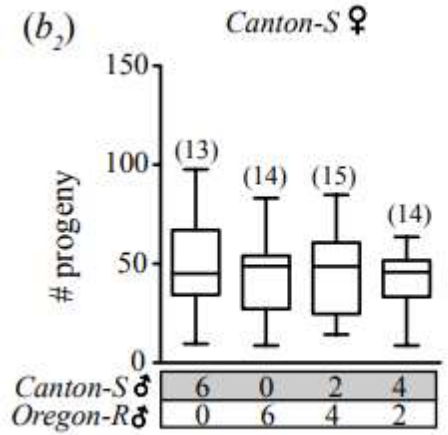


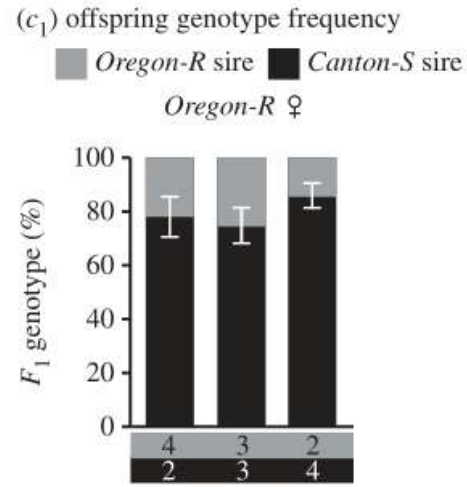


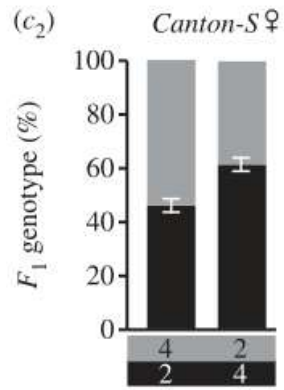






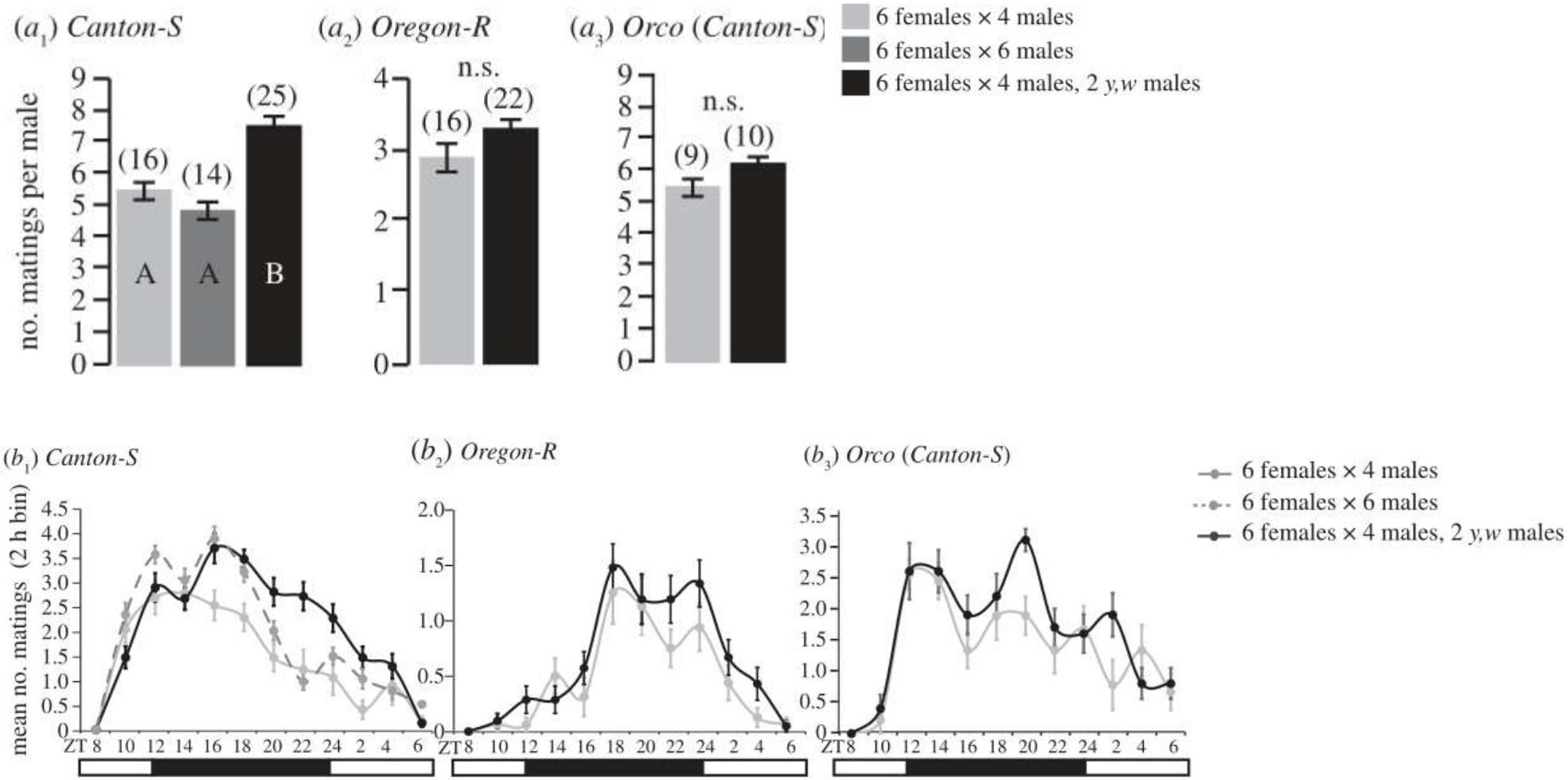






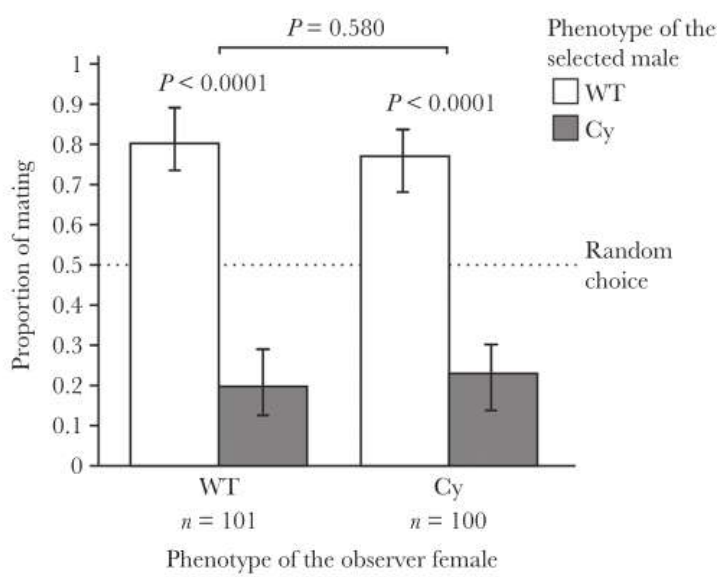
（Department of Biology, University of Toronto, McMaster Universit.*Proc. R. Soc. B* .2012）

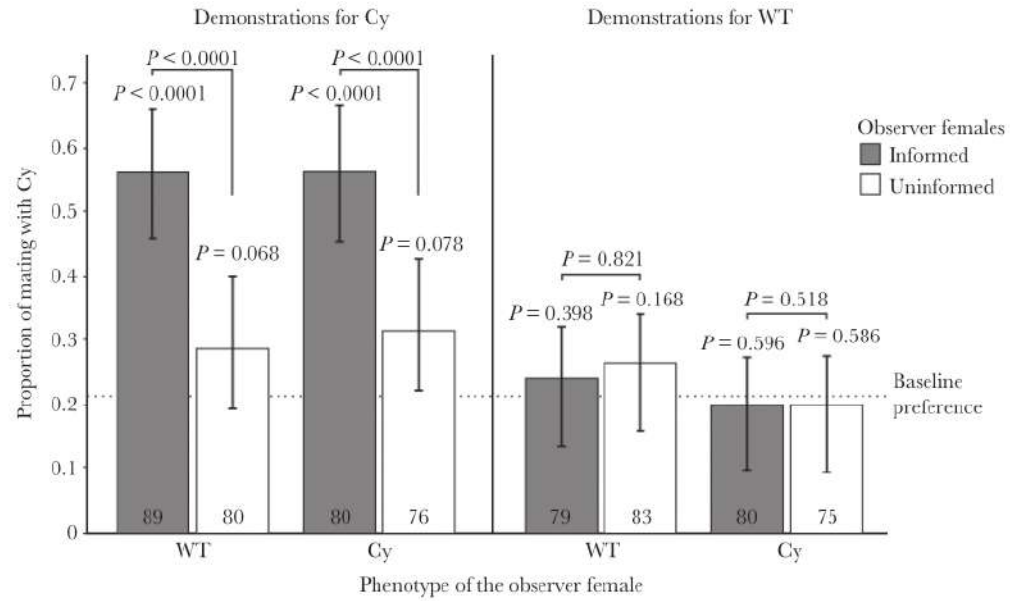
Social heterogeneity affects mating frequency



Influence of social information on mate selection of female fruit flies

Mate-copying





（Sabine Nöbel, Etienne Danchin et al.*Behavioral Ecology.20*18.）

Summary:

•群居增强了成熟雄蝇的求偶动机，提高了 or47b 的信息素反应并且这个过程需要CaMKI-dCBP途径与保幼激素协同；FruM 根据果蝇密度和年龄调整信息素敏感度。

•社交环境影响雄果蝇的求偶歌；雄性经历影响雄性求偶的时间比例和求偶潜伏期的等级顺序。

•黑腹果蝇会根据社会环境改变交配行为和后代生产；社会经验导致雌性果蝇的“配偶复制”。

THANK YOU !

- 社交环境对果蝇的生存繁衍意义重大
- 丰富的社交环境会增加果蝇的睡眠需求，这可能是为了对清醒期间产生的突触连接进行修剪以保持果蝇大脑神经环路的可塑性。
- 社交隔离会使得果蝇的打斗增强，通过信息素和神经调质的改变传递社交信号，打斗提升也可能是社交隔离后的行为反弹。
- 社交环境也会影响果蝇对信息素检测的灵敏度从而改变雄蝇的求偶策略。

参考文献

- Beckwith, Esteban J, and Alice S French. “Sleep in *Drosophila* and Its Context.” *Frontiers in physiology* vol. 10 1167. 11 Sep. 2019, doi:10.3389/fphys.2019.01167
- Donlea, Jeffrey M et al. “Use-dependent plasticity in clock neurons regulates sleep need in Drosophila.” *Science (New York, N.Y.)* vol. 324,5923 (2009): 105-8. doi:10.1126/science.1166657
- Bushey, Daniel et al. “Sleep and synaptic homeostasis: structural evidence in Drosophila.” *Science (New York, N.Y.)* vol. 332,6037 (2011): 1576-81. doi:10.1126/science.1202839
- Liu, Guangda et al. “A simple computer vision pipeline reveals the effects of isolation on social interaction dynamics in Drosophila.” *PLoS computational biology* vol. 14,8 e1006410. 30 Aug. 2018, doi:10.1371/journal.pcbi.1006410
- Chi, Michael W et al. “Larval Population Density Alters Adult Sleep in Wild-Type Drosophila melanogaster but Not in Amnesiac Mutant Flies.” *Brain sciences* vol. 4,3 453-70. 11 Aug. 2014, doi:10.3390/brainsci4030453
- Hill, Vanessa M et al. “A bidirectional relationship between sleep and oxidative stress in Drosophila.” *PLoS biology* vol. 16,7 e2005206. 12 Jul. 2018, doi:10.1371/journal.pbio.2005206

- Li, Wanhe et al. “Chronic social isolation signals starvation and reduces sleep in Drosophila.” *Nature* vol. 597,7875 (2021): 239-244. doi:10.1038/s41586-021-03837-0
- Khlghatyan, Jivan et al. “Fxr1 regulates sleep and synaptic homeostasis.” *The EMBO journal*vol. 39,21 (2020): e103864. doi:10.15252/embj.2019103864
- Lone, Shahnaz Rahman et al. “Social Experience Is Sufficient to Modulate Sleep Need of Drosophila without Increasing Wakefulness.” *PloS one* vol. 11,3 e0150596. 3 Mar. 2016, doi:10.1371/journal.pone.0150596
- Kirszenblat, Leonie et al. “Visual experience drives sleep need in Drosophila.” *Sleep* vol. 42,7 (2019): zsz102. doi:10.1093/sleep/zsz102
- Ramanan N, Shen Y, Sarsfield S, Lemberger T, Schütz G, Linden DJ, Ginty DD. SRF mediates activity-induced gene expression and synaptic plasticity but not neuronal viability. Nat Neurosci. 2005 Jun;8(6):759-67. doi: 10.1038/nn1462. Epub 2005 May 8. PMID: 15880109.
- Kirszenblat, Leonie et al. “Sleep regulates visual selective attention in *Drosophila*.” *The Journal of experimental biology* vol. 221,Pt 24 jeb191429. 14 Dec. 2018, doi:10.1242/jeb.191429

- Ramin, et al. "Aggression and social experience: genetic analysis of visual circuit activity in the control of aggressiveness in Drosophila. " Molecular Brain (2014).
- Ross, Amy P et al. “Sex-dependent effects of social isolation on the regulation of arginine-vasopressin (AVP) V1a, oxytocin (OT) and serotonin (5HT) 1a receptor binding and aggression.” Hormones and behavior vol. 116 (2019).
- Milan Szuperak, Matthew A Churgin, Austin J Borja, David M Raizen, Christopher Fang-Yen, Matthew S Kayser. “A sleep state in Drosophila larvae required for neural stem cell proliferation.” eLife (2018)
- Ueda, A. , and Y. Kidokoro . "Aggressive behaviours of female Drosophila melanogaster are influenced by their social experience and food resources." Physiological Entomology 27.1(2002).
- Agrawal P, Kao D, Chung P, Looger LL. “The neuropeptide Drosulfakinin regulates social isolation-induced aggression in Drosophila.” J Exp Biol. (2020).

- Sachin Sethi, et al. "Social context enhances hormonal modulation of pheromone
- detection in Drosophila " Curr Biol.(2019).
- Lucas Marie-Orleach et al. “Social effects on fruit fly courtship song” Ecology and Revolution. (2018).
- Department of Psychology, McMaster University. “Experience improves courtship in male fruit flies.” Animal Behaviour.(2004)
- epartment of Biology, University of Toronto, McMaster University. "Drosophila melanogaster females change mating behaviour and offspring production
- based on social context." Proc. R. Soc. B(2012).
- Sabine Nöbel, Etienne Danchin et al. “Mate-copying for a costly variant in Drosophila
- melanogaster females”Behavioral Ecology. (2018).