Visual system and *Drosophila* behavior

苏祥彬，陈江涛，朱培雯

2023-03-02

Outline

- Overview of the visual system: from structure to functions —苏祥彬
- Visual system and sexual behavior —陈江涛
- Visual system and avoidance behavior —朱培雯
- Discussion

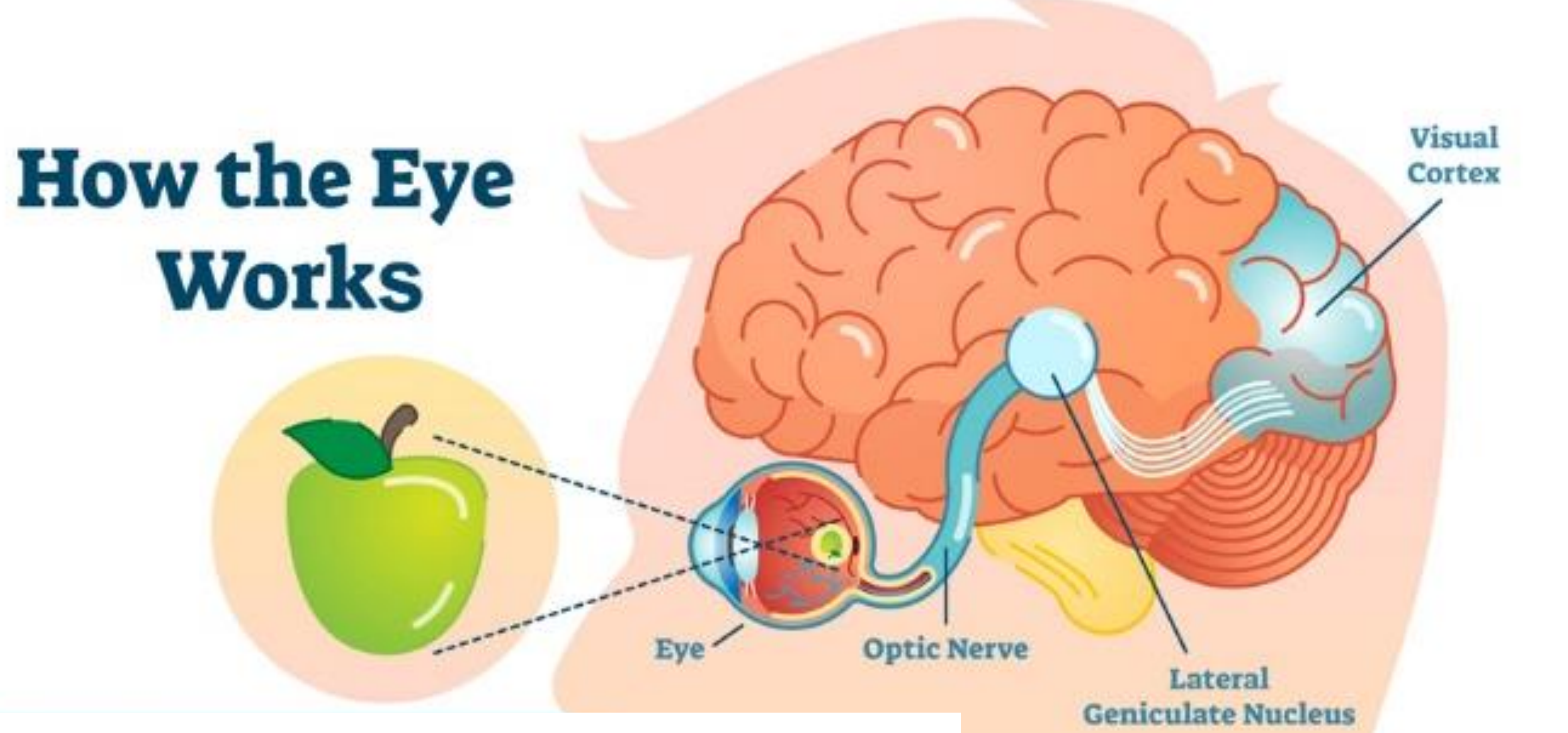
The variety of visual features in animals

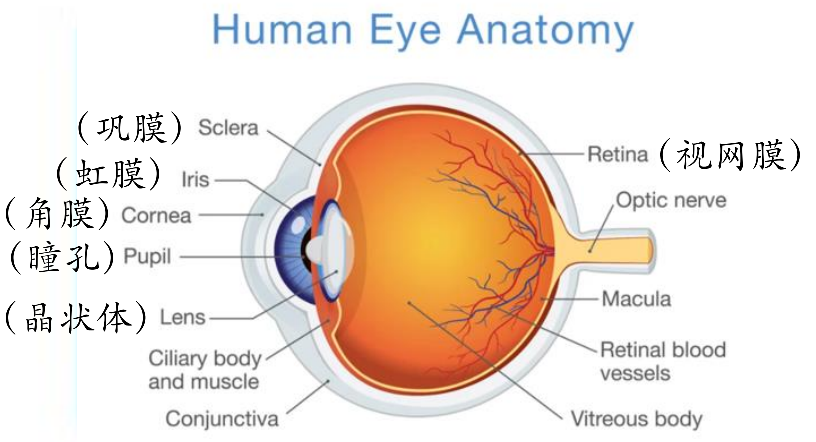
Overview of the visual system: from structure to functions

苏祥彬

2023-03-02

How the human eye works





Questions

How the *Drosophila* eye works?

- What is the structure of the visual system in fruit flies?
- What do fruit flies see?
- How do visual scenes induce appropriate behavior in fruit flies?

Contents

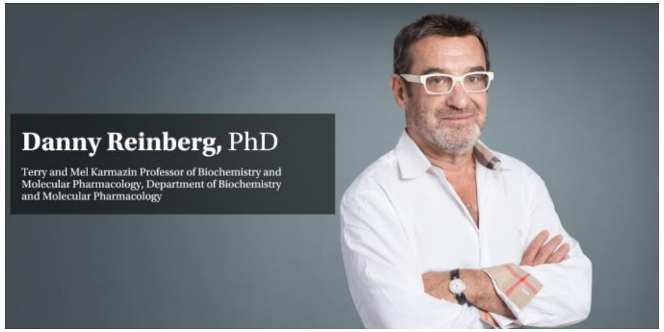
- The *Drosophila* adult visual system
- *Drosophila* larval visual system
- Visual feature-based behavior of *Drosophila*

Contents

A major contributor to this section

RESEARCH

- Stochastic choices in development
- Generation of neural diversity: the development of the optic lobes
- Building the neural pathway for motion vision
- Aging and rejuvenation in a social insect in collaboration with Danny Reinberg



RESEARCH

- Halting the spread of repressive chromatin
- Epigenetics in a model organism(ants)
- Polycomb group (PcG) of epigenetic regulators

› Science. 2022 Sep 2;377(6610):1092-1099. doi: 10.1126/science.abm8767. Epub 2022 Sep 1.

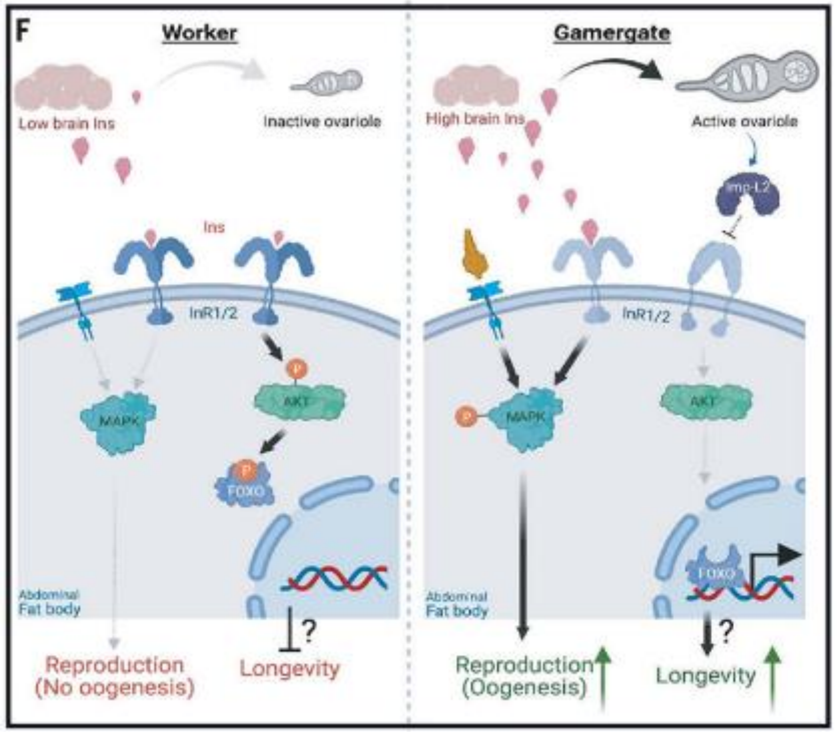
Insulin signaling in the long-lived reproductive caste of ants

Hua Yan [#, 1, 2, 3], Comzit Opachaloemphan [#, 1], Francisco Carmona-Aldana [#, 1], Giacomo Mancini [4], Jakub Mlejnek [4], Nicolas Descostes [1], Bogdan Sieriebriennikov [1, 4], Alexandra Leibholz [4], Xiaofan Zhou [5], Long Ding [4], Maria Traficante [4], Claude Desplan [4], Danny Reinberg [1, 2]

Affiliations + expand

PMID: 36048960 PMCID: PMC9526546 DOI: 10.1126/science.abm8767

Free PMC article



› Cell. 2017 Aug 10;170(4):736-747.e9. doi: 10.1016/j.cell.2017.06.051.

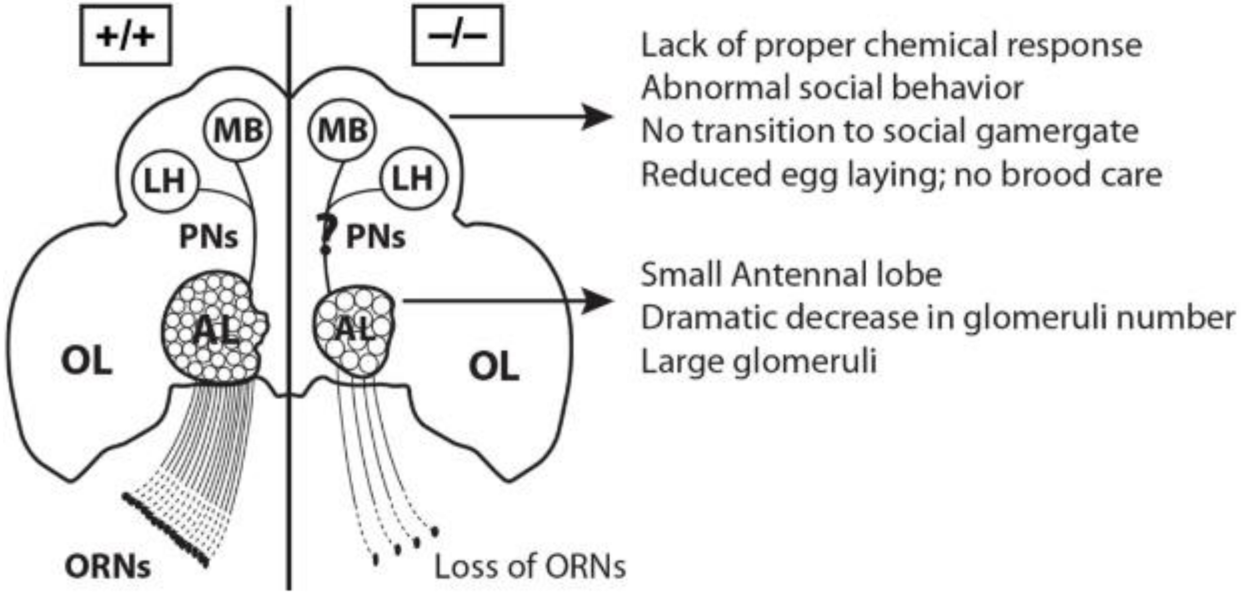
An Engineered orco Mutation Produces Aberrant Social Behavior and Defective Neural Development in Ants

Hua Yan [1], Comzit Opachaloemphan [2], Giacomo Mancini [3], Huan Yang [2], Matthew Gallitto [2], Jakub Mlejnek [3], Alexandra Leibholz [3], Kevin Haight [4], Majid Ghaninia [4], Lucy Huo [3], Michael Perry [3], Jesse Slone [5], Xiaofan Zhou [5], Maria Traficante [3], Clint A Penick [4], Kelly Dolezal [4], Kaustubh Gokhale [4], Kelsey Stevens [3], Ingrid Fetter-Pruneda [6], Roberto Bonasio [7], Laurence J Zwiebel [5], Shelley L Berger [8], Jürgen Liebig [9], Danny Reinberg [10], Claude Desplan [11]

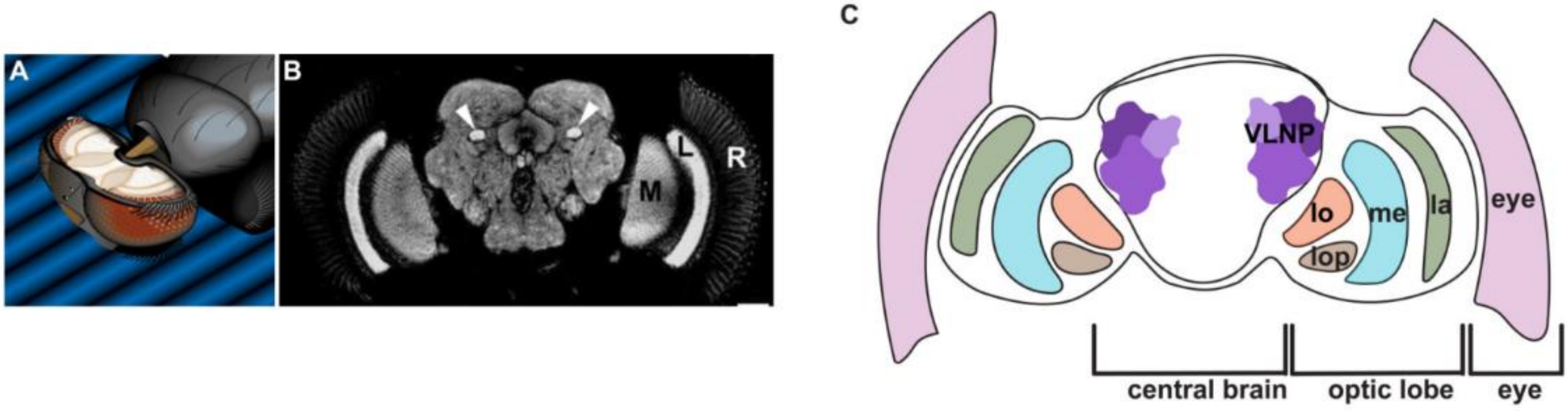
Affiliations + expand

PMID: 28802043 PMCID: PMC5587193 DOI: 10.1016/j.cell.2017.06.051

Free PMC article



The visual system of *Drosophila*

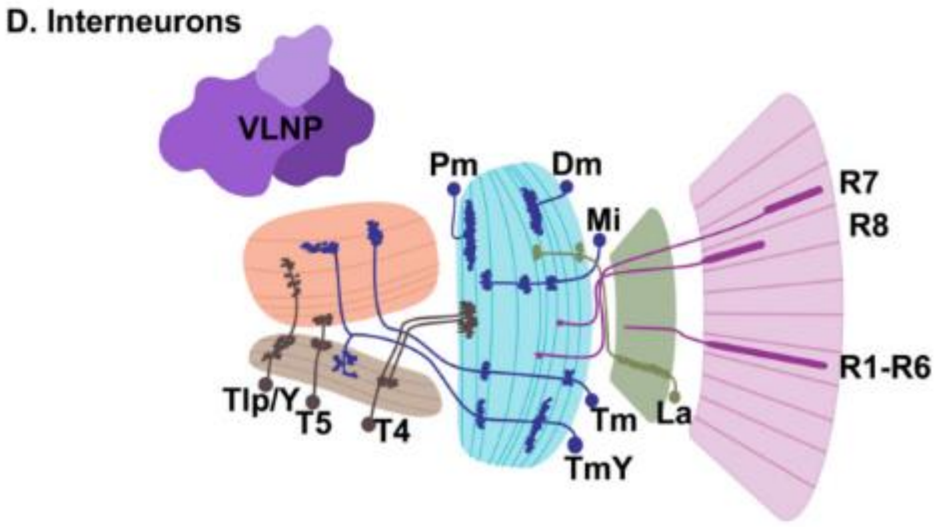


Four of these neuropils form the optic lobe: lamina, medulla, and the lobula complex.

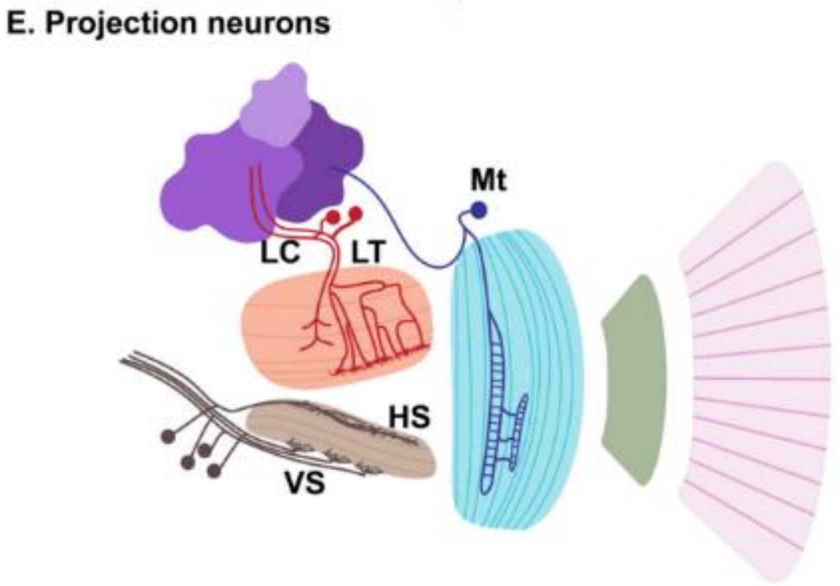
The lobula complex is further subdivided into the lobula and the lobula plate neuropils.

Nathalie Nériec and Claude Desplan, 2016

The visual system of *Drosophila*



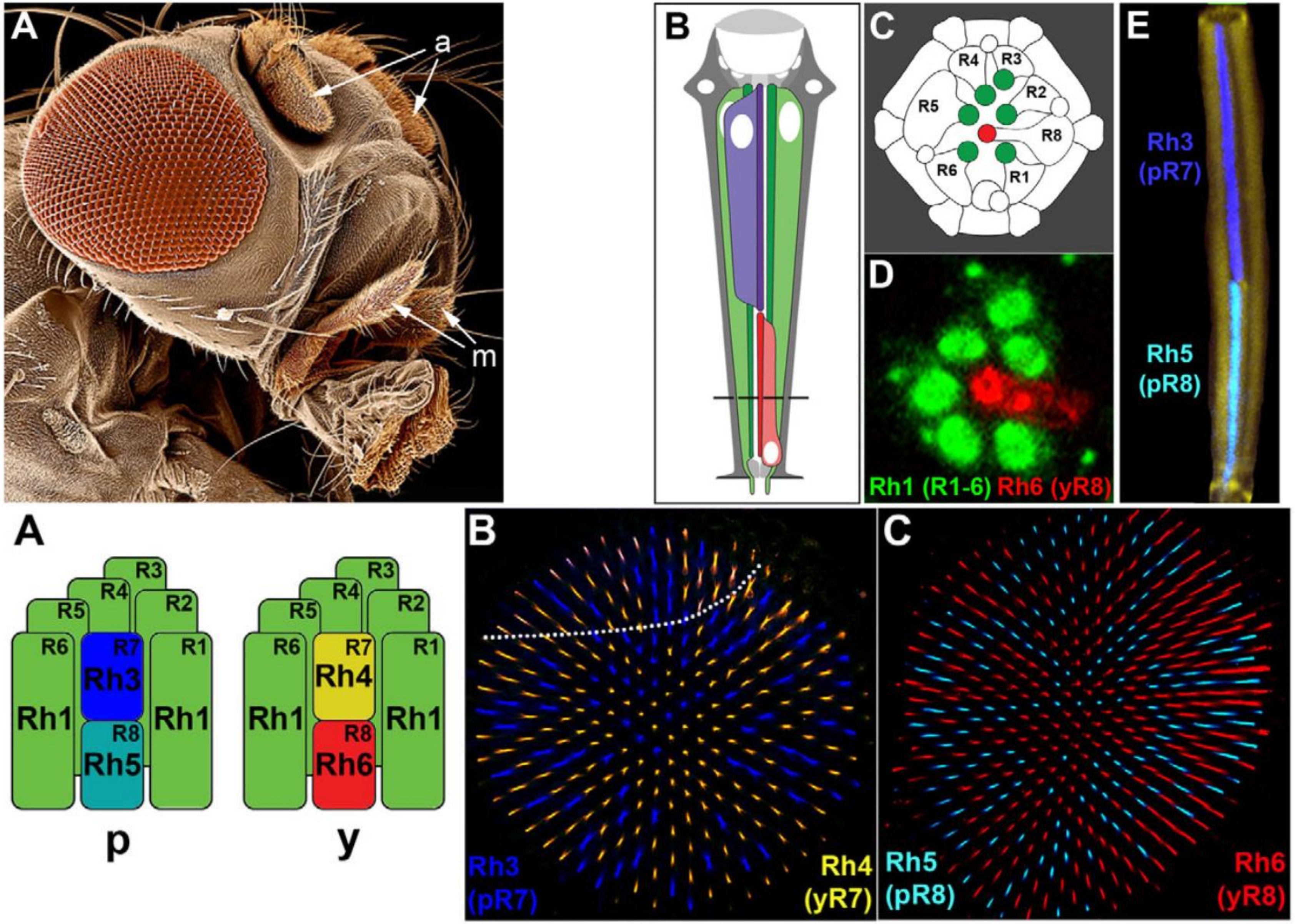
"Interneurons" whose cell bodies and projections remain within the optic lobe.



"projection" neurons, which connect the optic lobe to the CB.

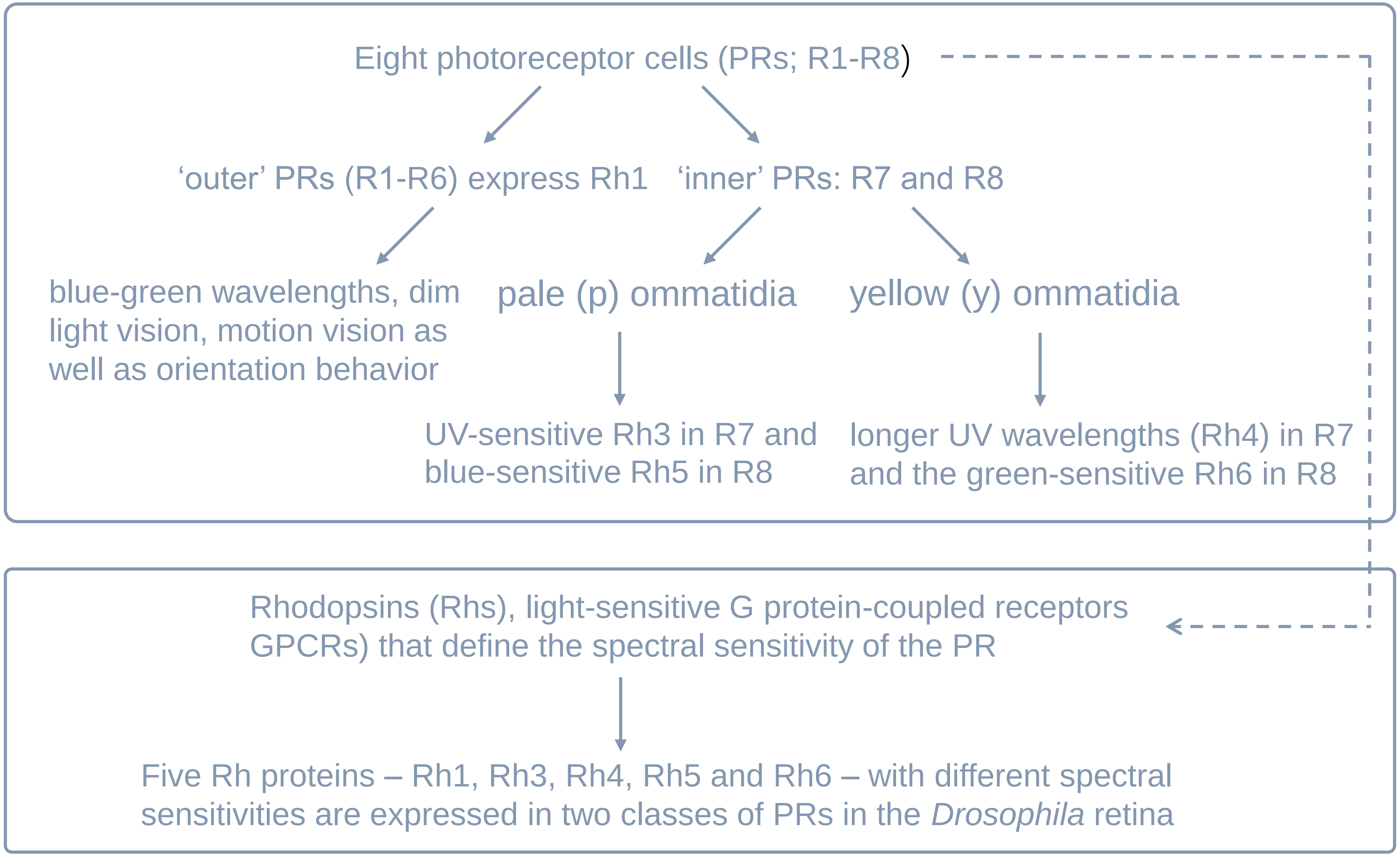
Nathalie Nériec and Claude Desplan, 2016

The compound eye

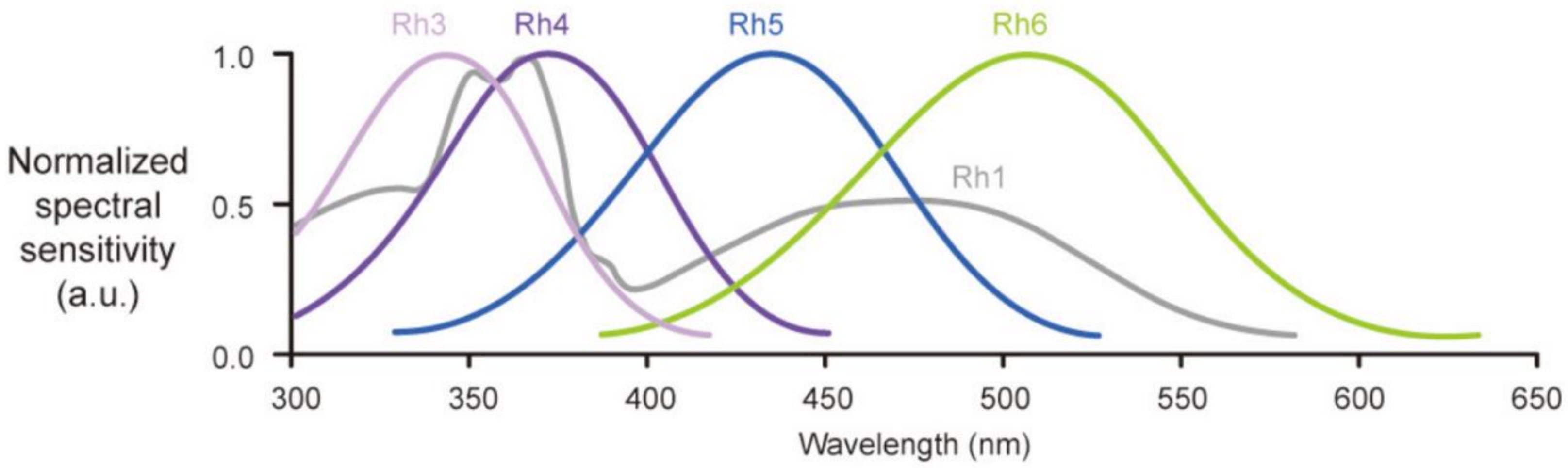


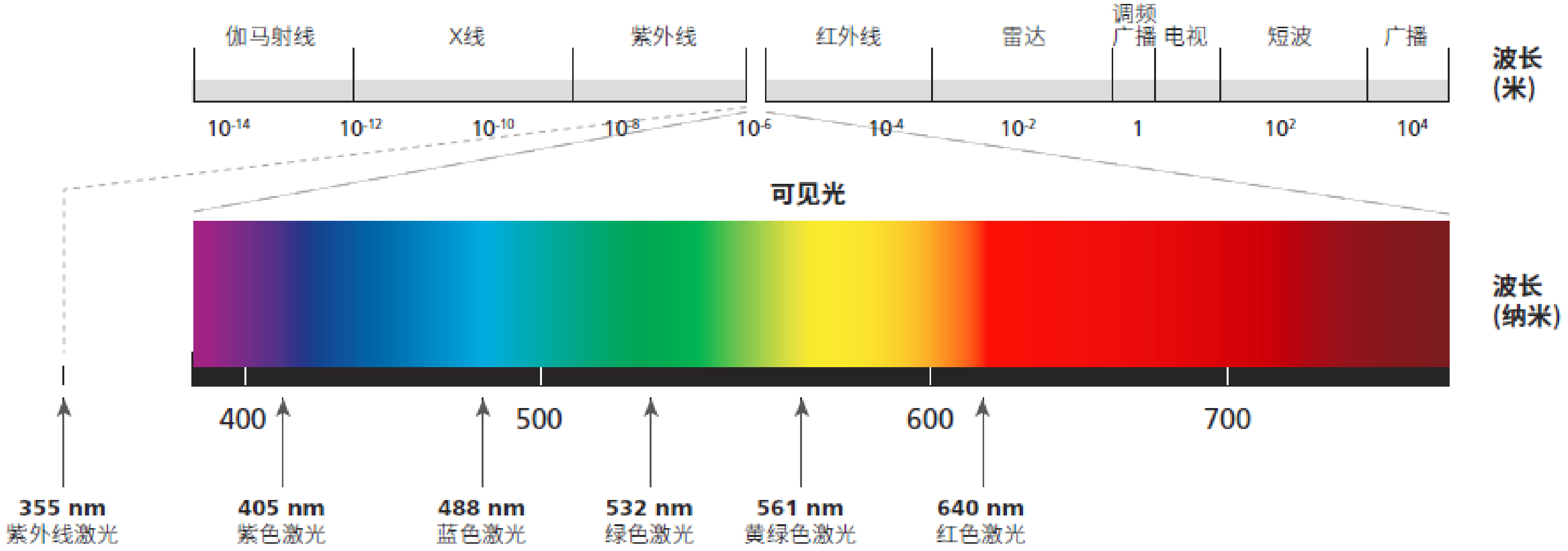
Jens Rister, Claude Desplan and Daniel Vasiliauskas, 2013

The compound eye



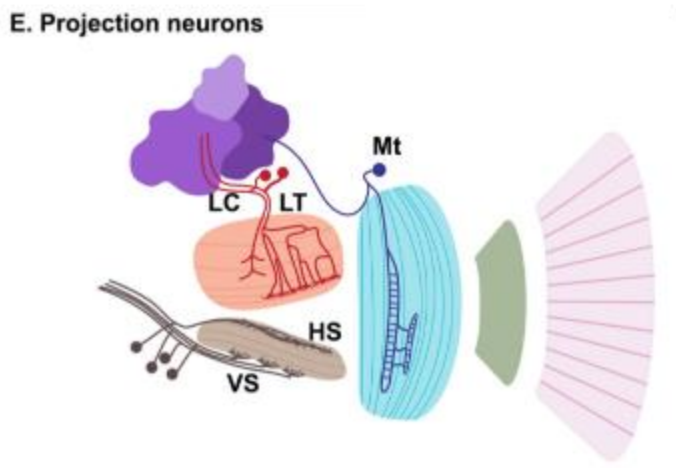
Spectral sensitivity curves of rhodopsins expressed in photoreceptor cells

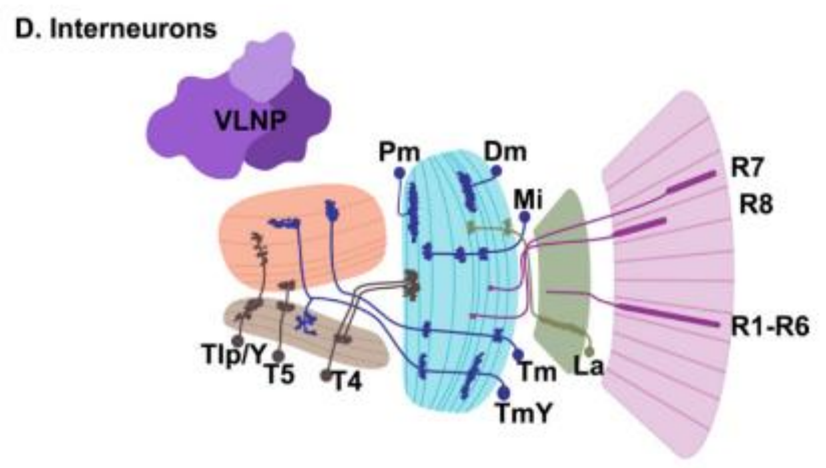




Optic lobe

Structure		Compose	Function	Reference
lamina		interneurons	motion vision	Hofbauer and Campos-Ortega, 1990 Tuthill et al., 2013
medulla		projection neurons interneurons	motion vision, color vision and further computes	Morante and Desplan, 2008 Zhu, 2013 Chin et al., 2014
lobula complex	lobula	projection neurons		Otsuna and Ito 2006 Mu et al., 2012
	lobula plate	projection neurons(LPTCs) interneurons(T4 and T5 cells)	motion detection computation of motion	Behnia and Desplan, 2015 Borst 2014





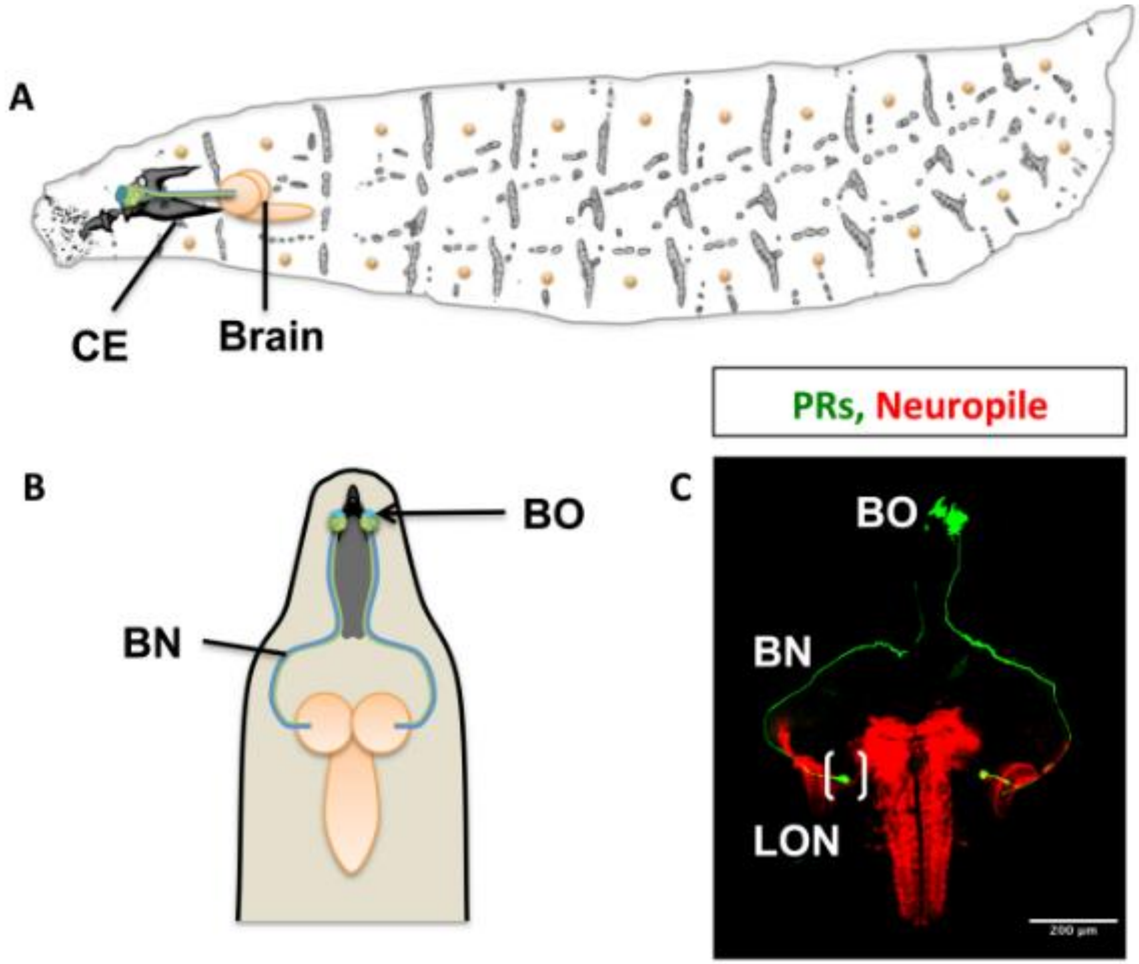
LPTCs, The Lobula Plate Tangential Cells

VLNPs, The Ventrolateral neuropils

Contents

- The *Drosophila* adult visual system
- *Drosophila* larval visual system
- Visual feature-based behavior of *Drosophila*

Differences in visual system between larva and adult



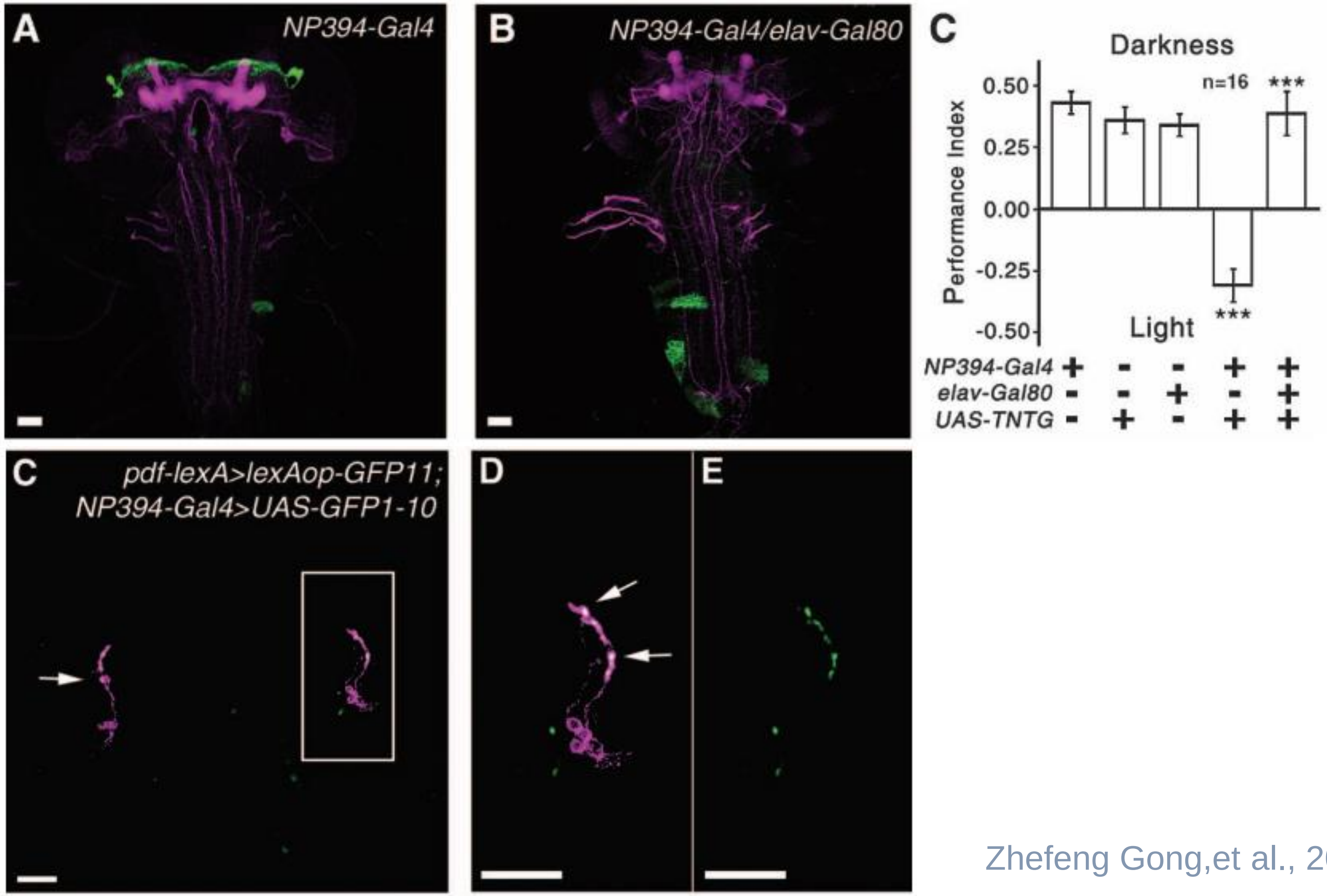
Abud J. Farca-Luna and Simon G. Sprecher, 2013

12 photoreceptors (PRs)

Four PRs express exclusively rhodopsin5 (rh5) and detect blue light

the remaining eight express only rhodopsin6(rh6) detecting green light

Two pairs of neurons in the central brain control *Drosophila* innate light preference



Zhefeng Gong,et al., 2010

Summary 1

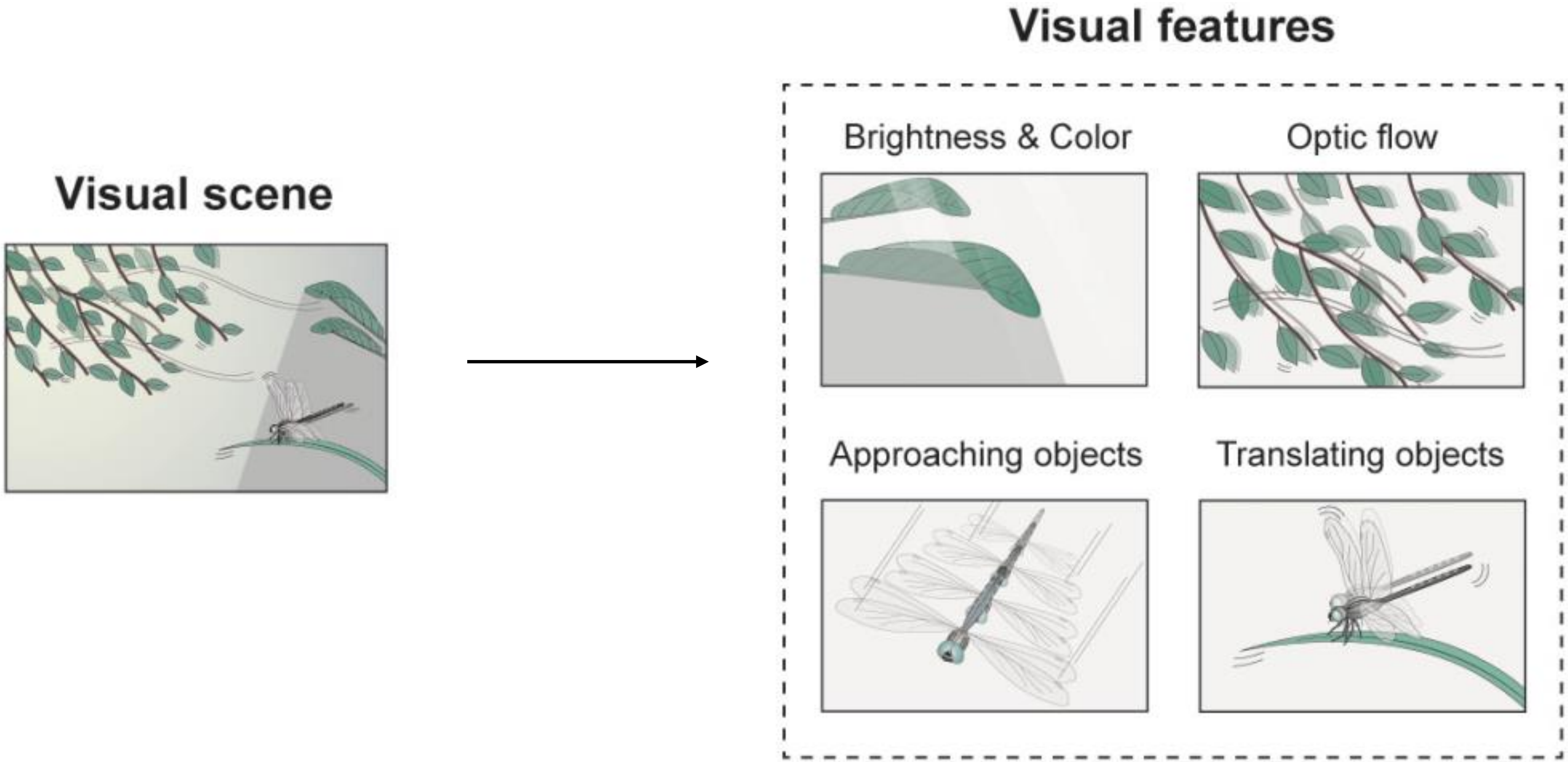
How the *Drosophila* eye works?

- What is the structure of the visual system in fruit flies?
  - eye(compound eye), optic lobe, central brain
- What do fruit flies see?
  - color(UV/blue/green) ,based on photoreceptors
- How do visual scenes induce appropriate behavior in fruit flies?

Contents

- The *Drosophila* adult visual system
- *Drosophila* larval visual system
- Visual feature-based behavior of *Drosophila*
  (such as phototaxis and optic flow)

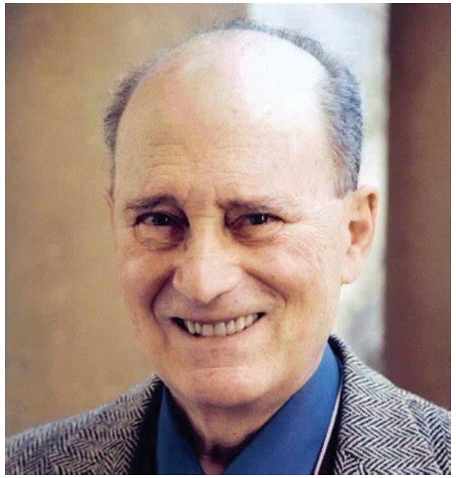
Spatiotemporal features in visual scenes



Leesun Ryu, Sung Yong Kim and Anmo J. Kim, 2022

Brightness, color, and phototaxis

> Proc Natl Acad Sci U S A. 1967 Sep;58(3):1112-9. doi: 10.1073/pnas.58.3.1112.



BEHAVIORAL MUTANTS OF Drosophila ISOLATED BY COUNTERCURRENT DISTRIBUTION

S Benzer [1]

Affiliations + expand

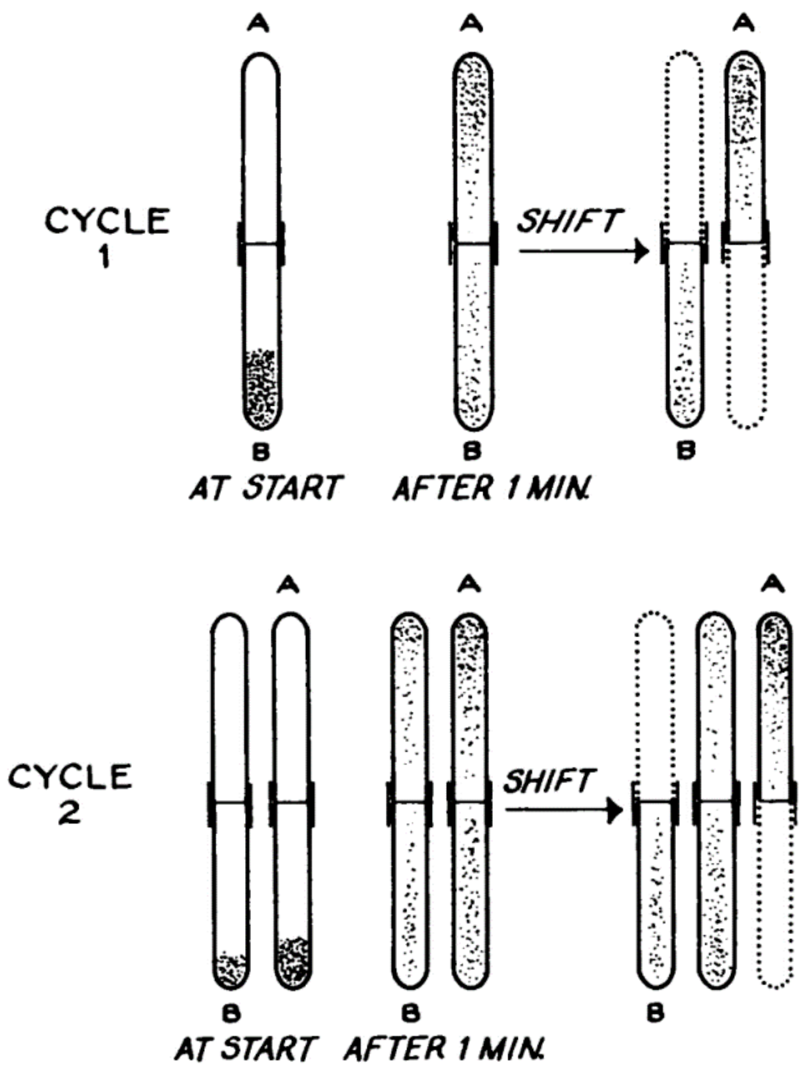
PMID: 16578662 PMCID: PMC335755 DOI: 10.1073/pnas.58.3.1112

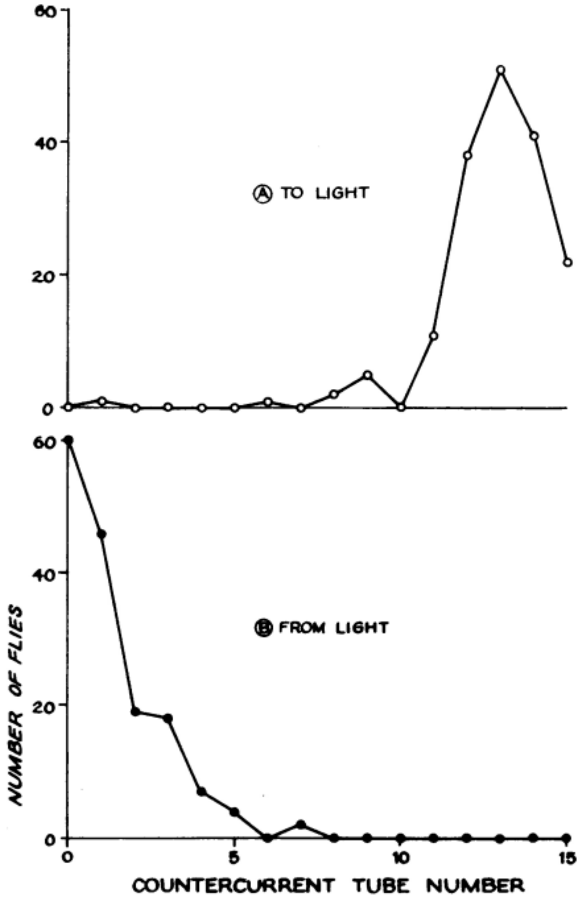
Free PMC article

Benzer was a unique figure who made seminal contributions to physics, molecular biology and behavioural genetics.

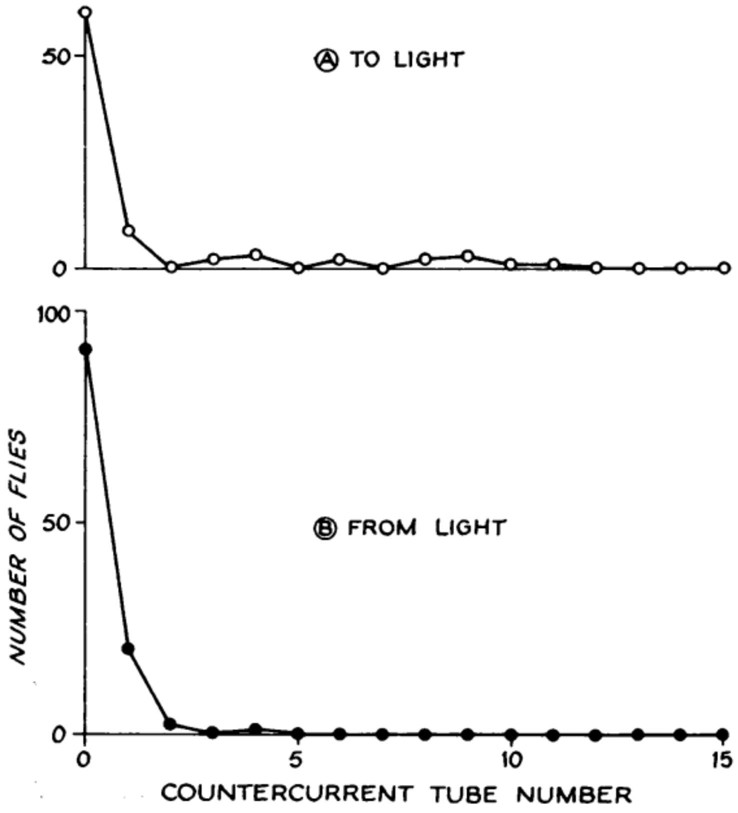
- Using bacteriophage T4, he proved that genes are not indivisible units, but are composed of a linear array of chemical building-blocks, or bases, each of which can be subject to alteration.
- Benzer screened large numbers of flies to discover rare mutants with specific behavioural defects. (*fruitless, per, dunce, Shaker......*)
- Benzer built counter-current apparatus for measuring phototaxis

Behavioral mutants of *Drosophila* isolated by countercurrent distribution



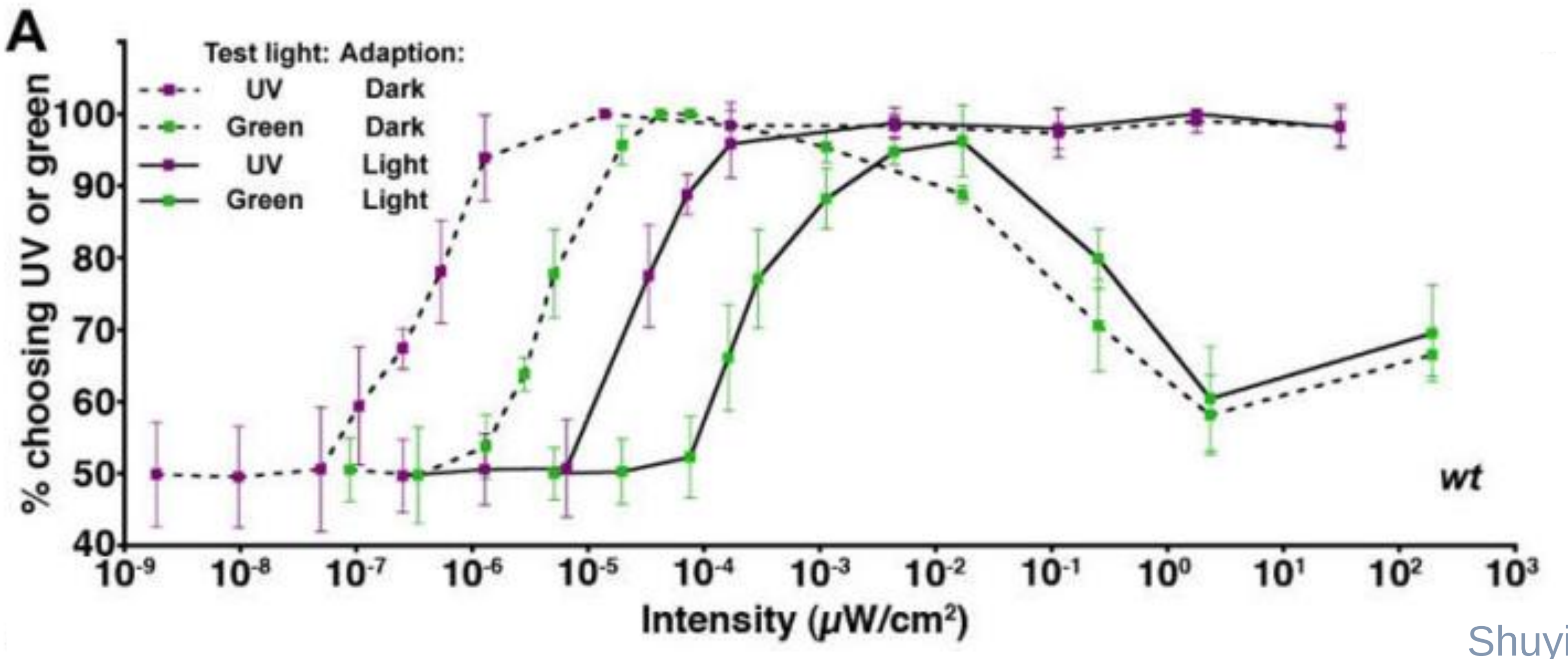


Canton S

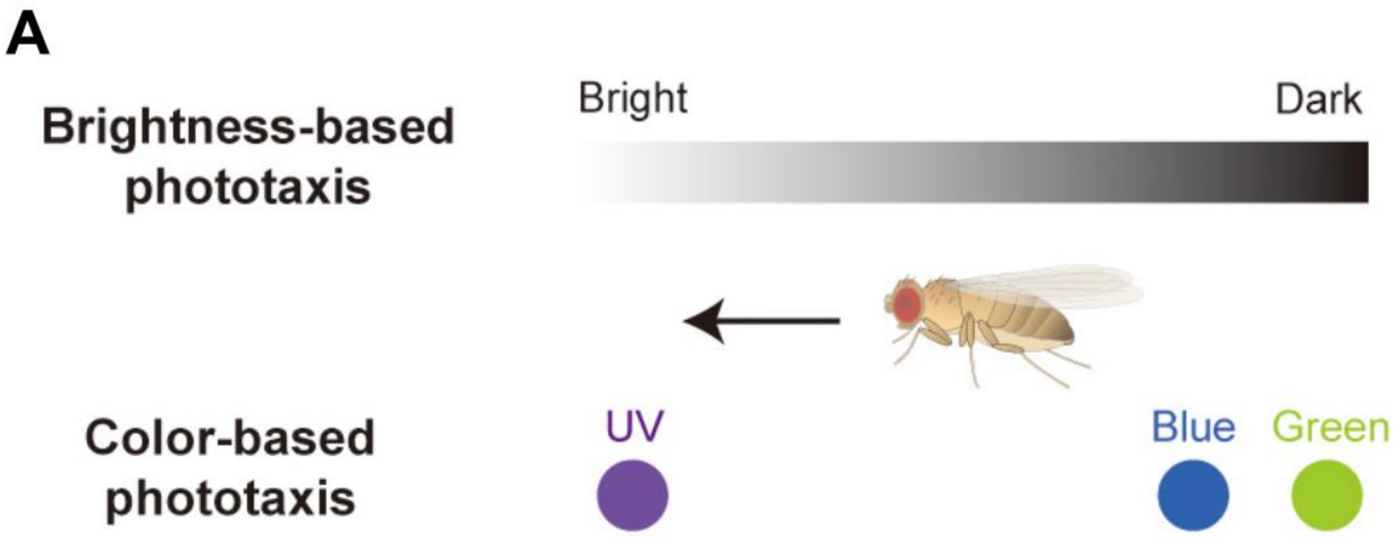


mutant

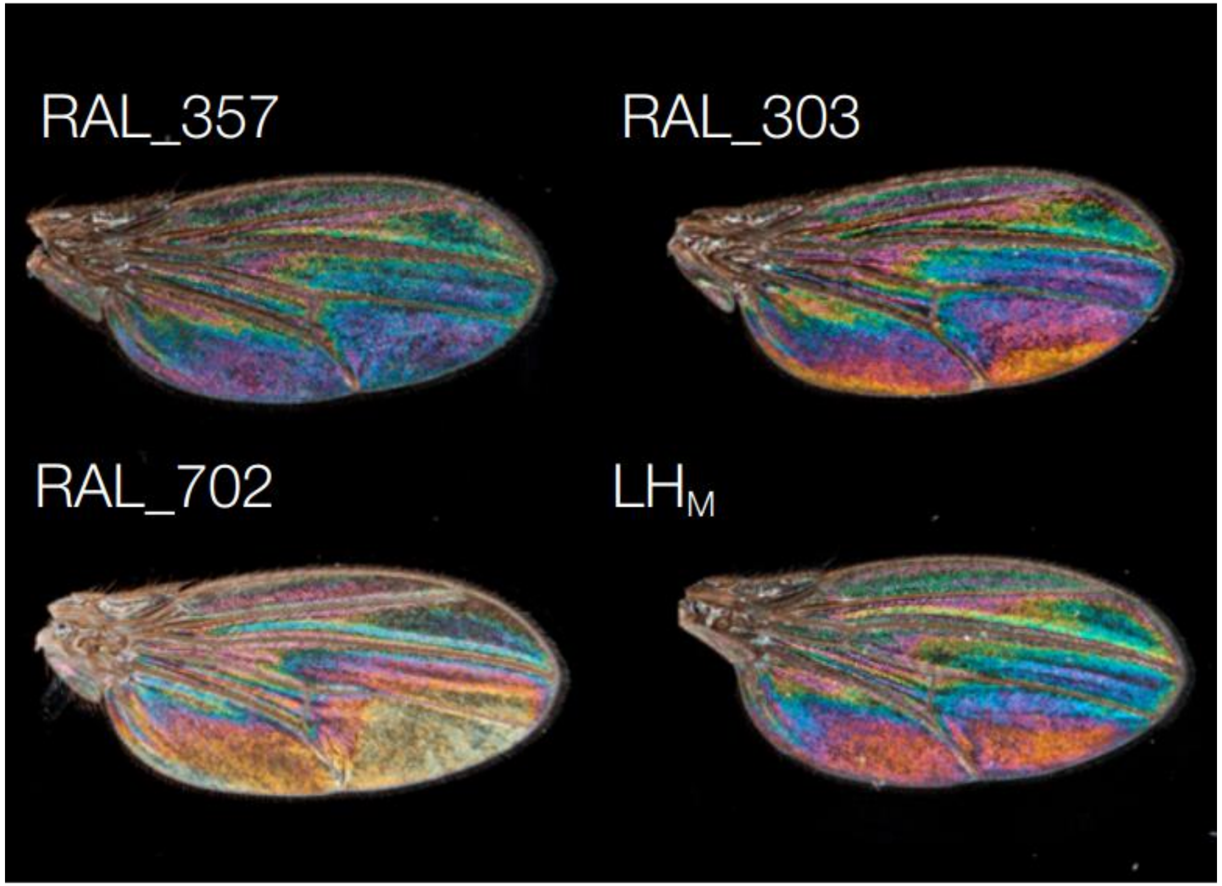
Wild-type flies were tested for fast phototaxis towards UV or green light

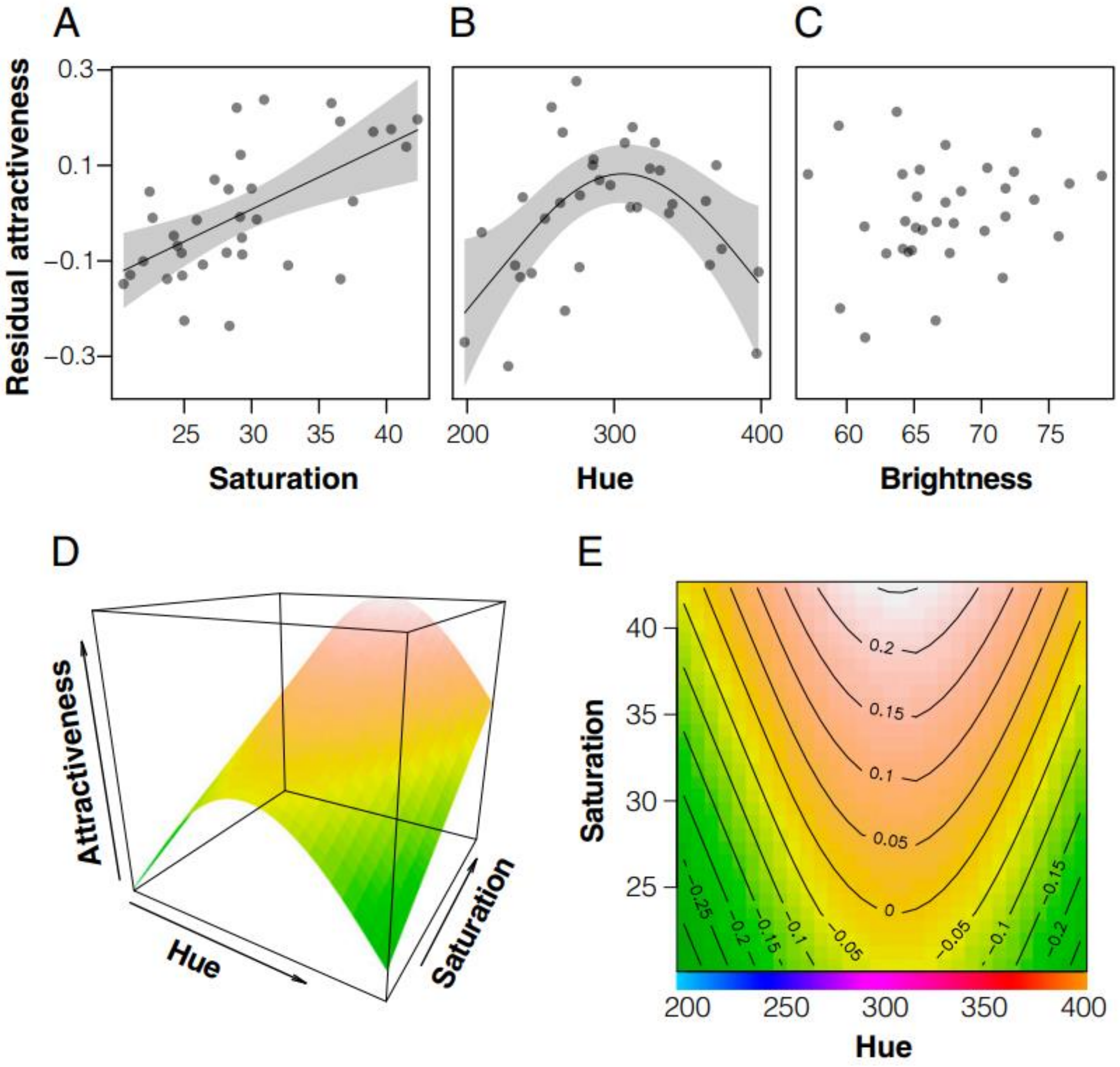


Shuying Gao, et al., 2008



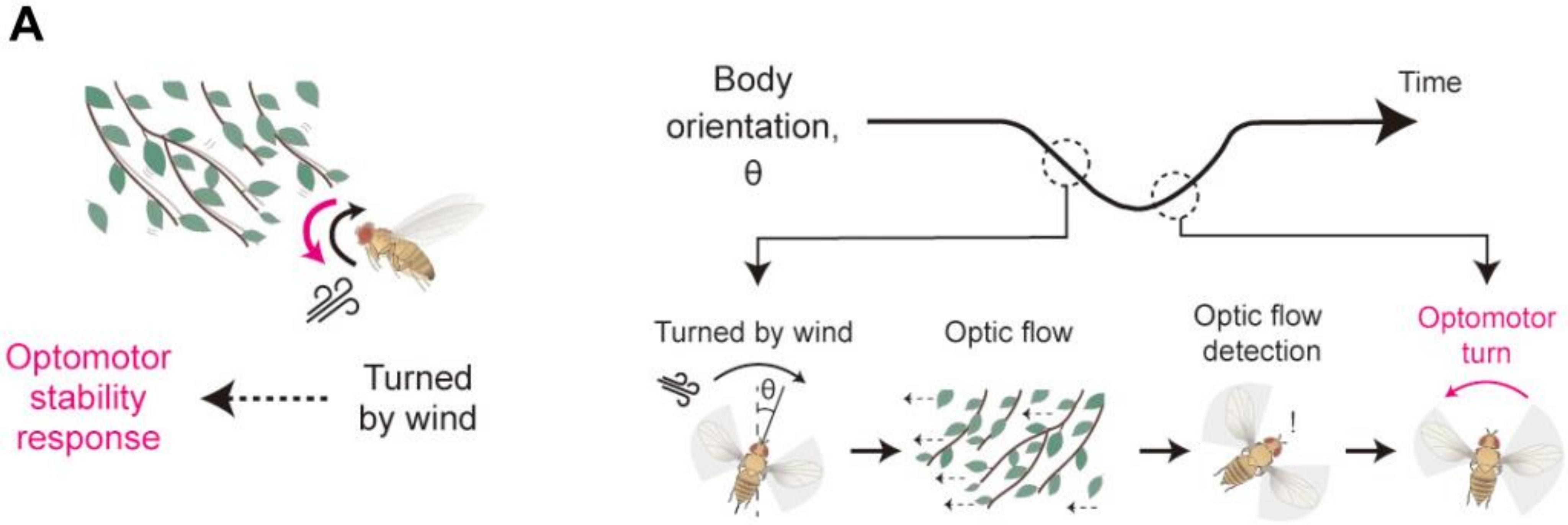
Sexual selection on wing interference patterns in *Drosophila*





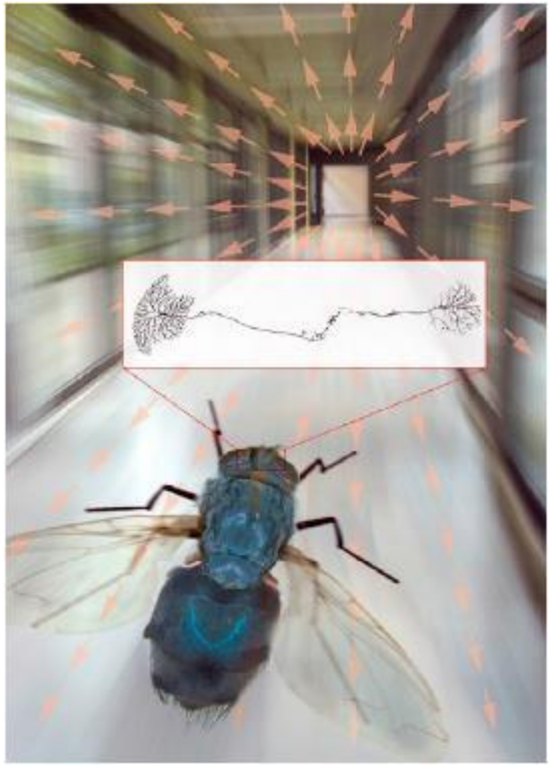
Natsu Katayama et al., 2014

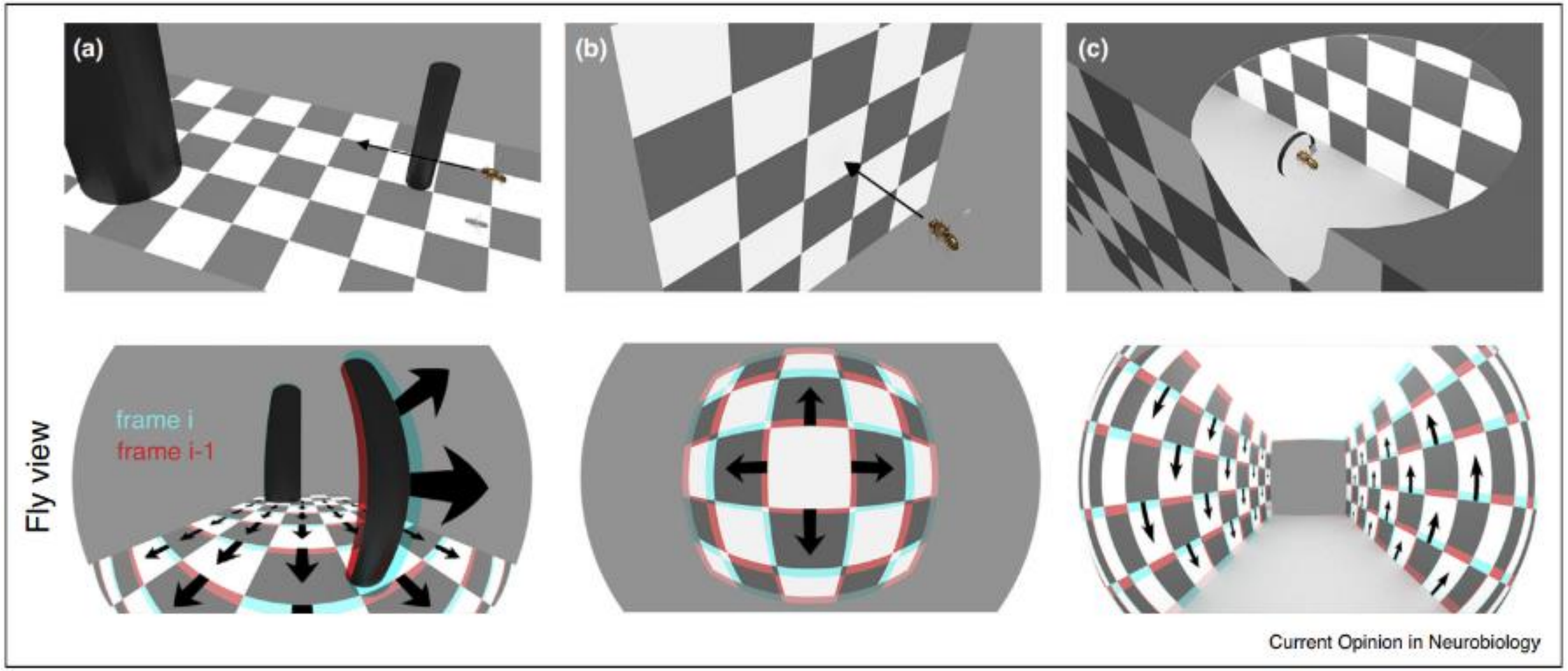
Optic flow detection and optomotor response



What is optic flow?

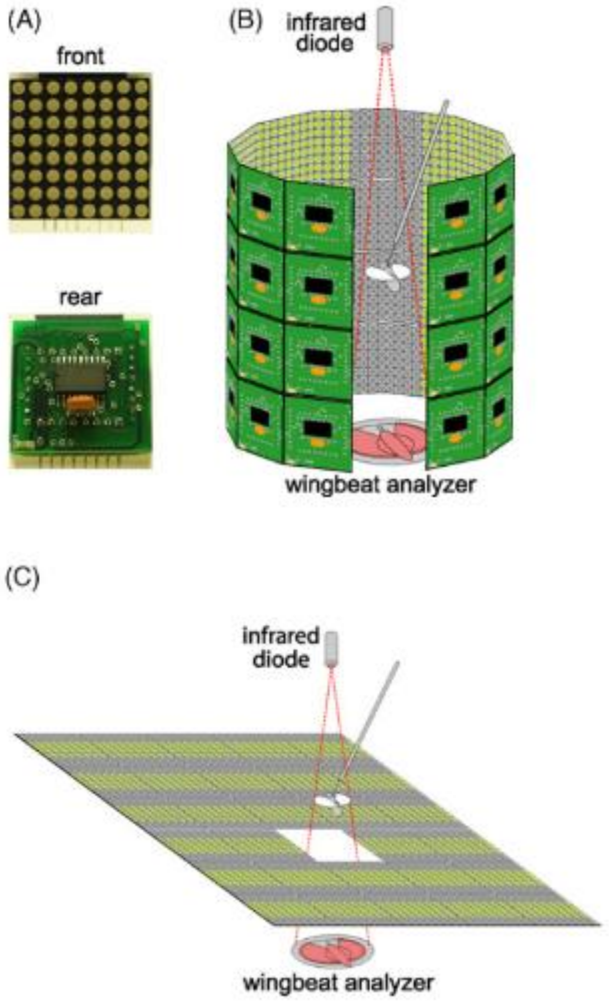
Visual feedback from self-motion as perceived by a flying insect

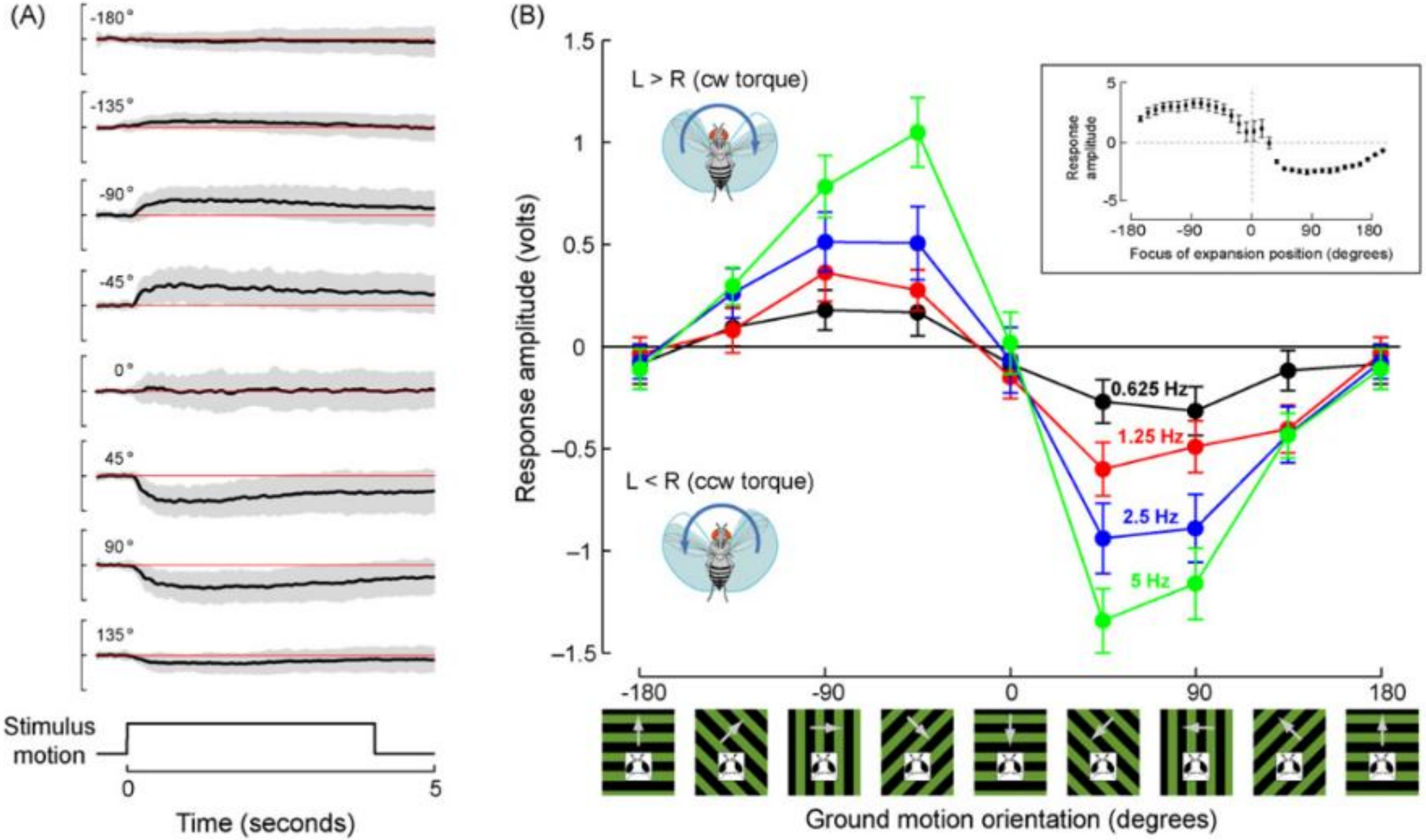




Alex S Mauss and Alexander Borst, 2020

The steering response of *Drosophila* to ground motion of varying speeds and orientations, presented under open-loop conditions





Michael B.Reiser and Michael H Dickinson, 2008

Other visual feature-based behaviors in *Drosophila*

1, approaching (looming) visual objects

—avoidance behavior(朱培雯)

2, translating object

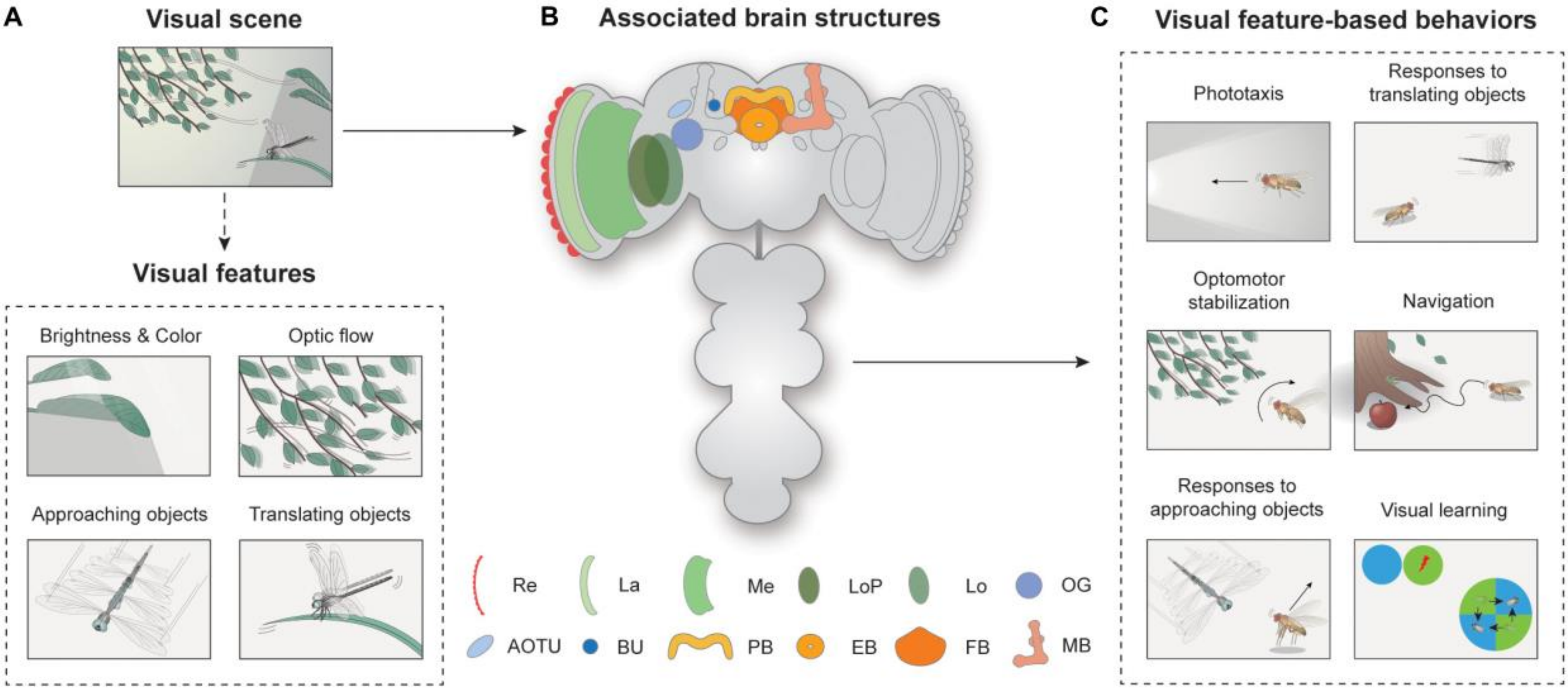
—courtship behavior(陈江涛)

More complex behavior

3, visually-guided spatial navigation

4, visually learning

Summary 1



Leesun Ryu, Sung Yong Kim and Anmo J. Kim, 2022

How neural circuits are implemented for major visual feature-based behaviors in *Drosophila*?

Visual system and courtship behavior(陈江涛)

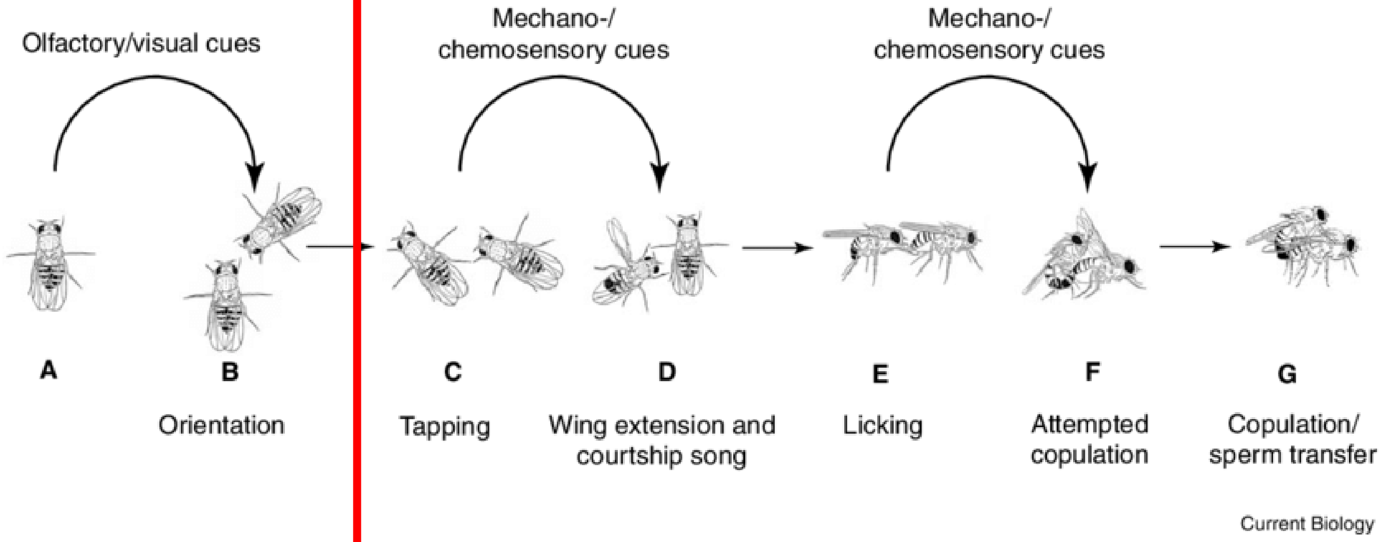
Thanks!

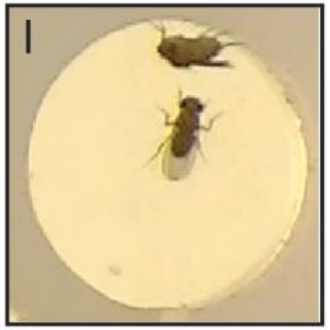
Visual system and sexual behavior

Chen Jiangtao

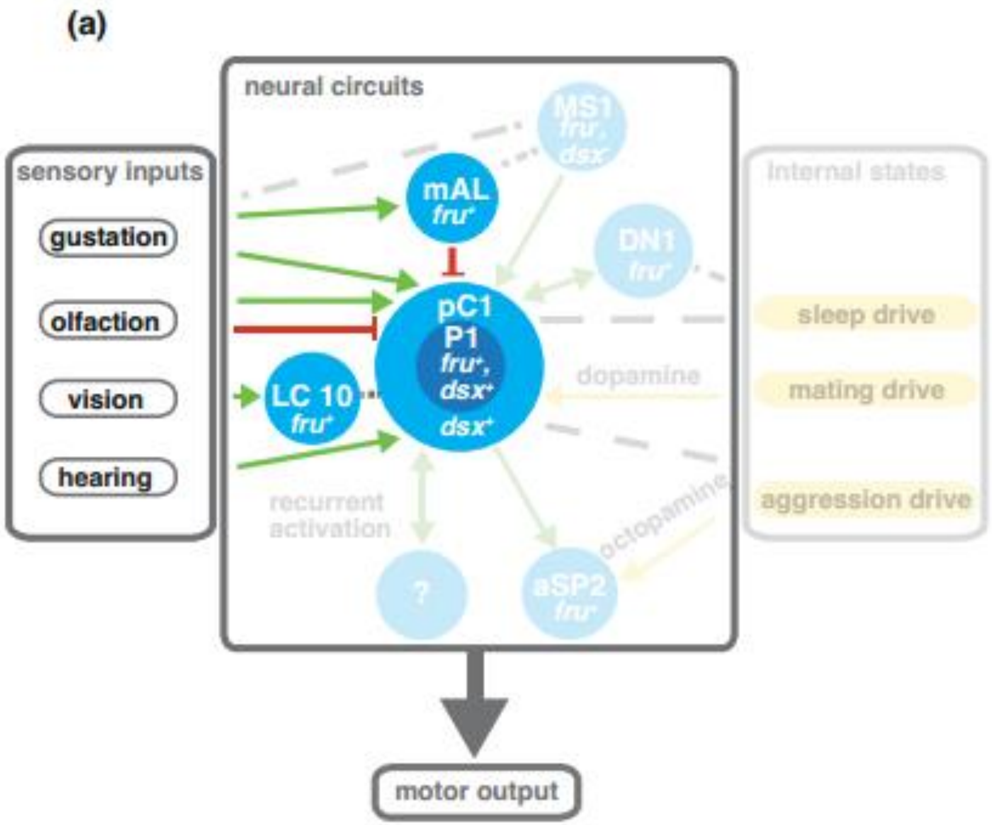
2023/03/02

Courtship steps performed by male *Drosophila*– *Visual system*





orienting

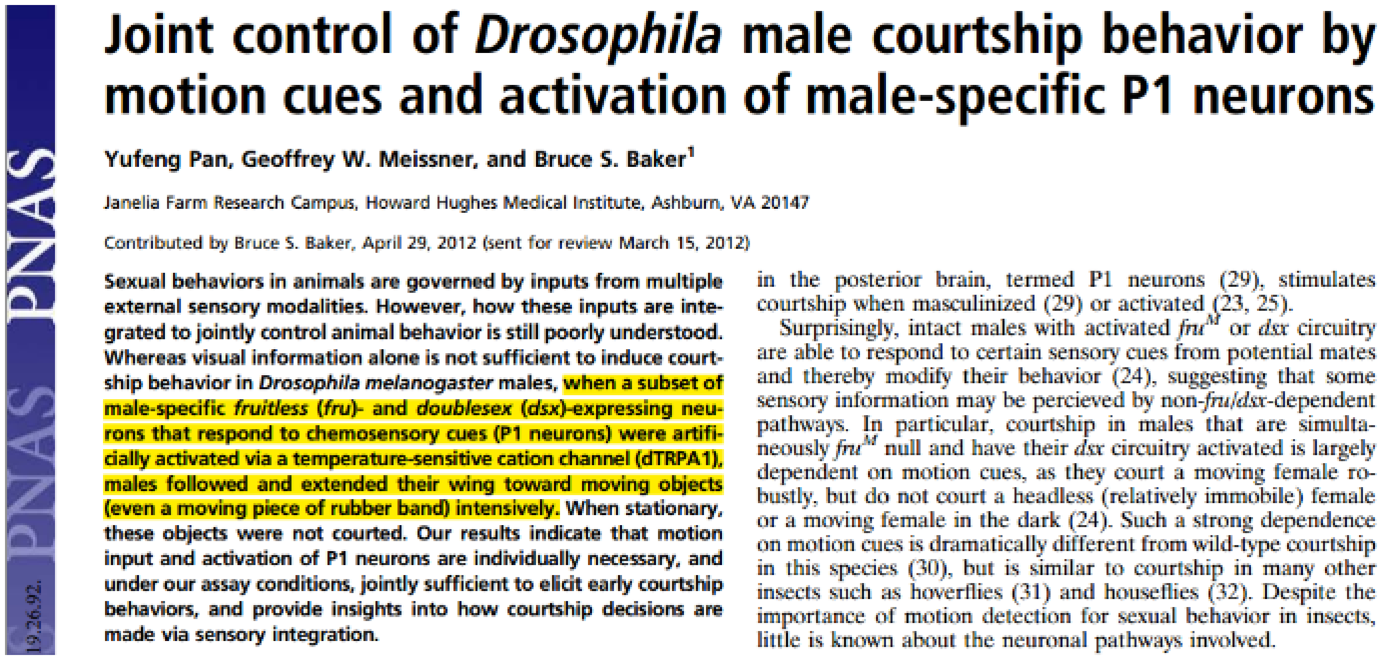


Schematic illustration of inputs to the courtship command cluster pC1/P1

Jean-Christophe Billeter et al. *Curr Biol* . 2006 Sep 5

Annika Rings et al. *Curr Opin Insect Sci . 2019 Oct*

Sensory information and internal states areintegrated ensuring appropriate action selection– P1



PNAS

Joint control of *Drosophila* male courtship behavior by motion cues and activation of male-specific P1 neurons

Yufeng Pan, Geoffrey W. Meissner, and Bruce S. Baker[1]

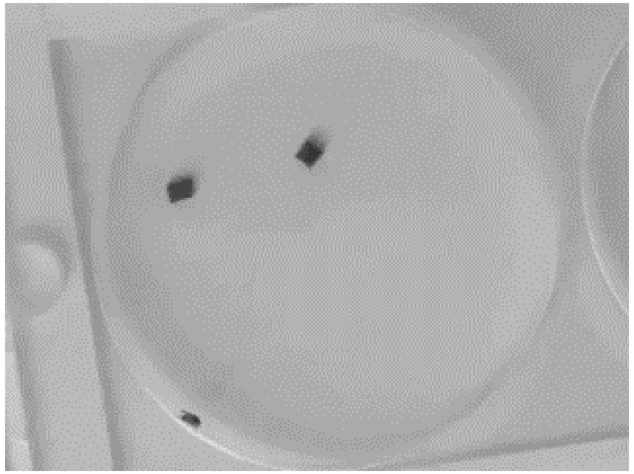
Janelia Farm Research Campus, Howard Hughes Medical Institute, Ashburn, VA 20147

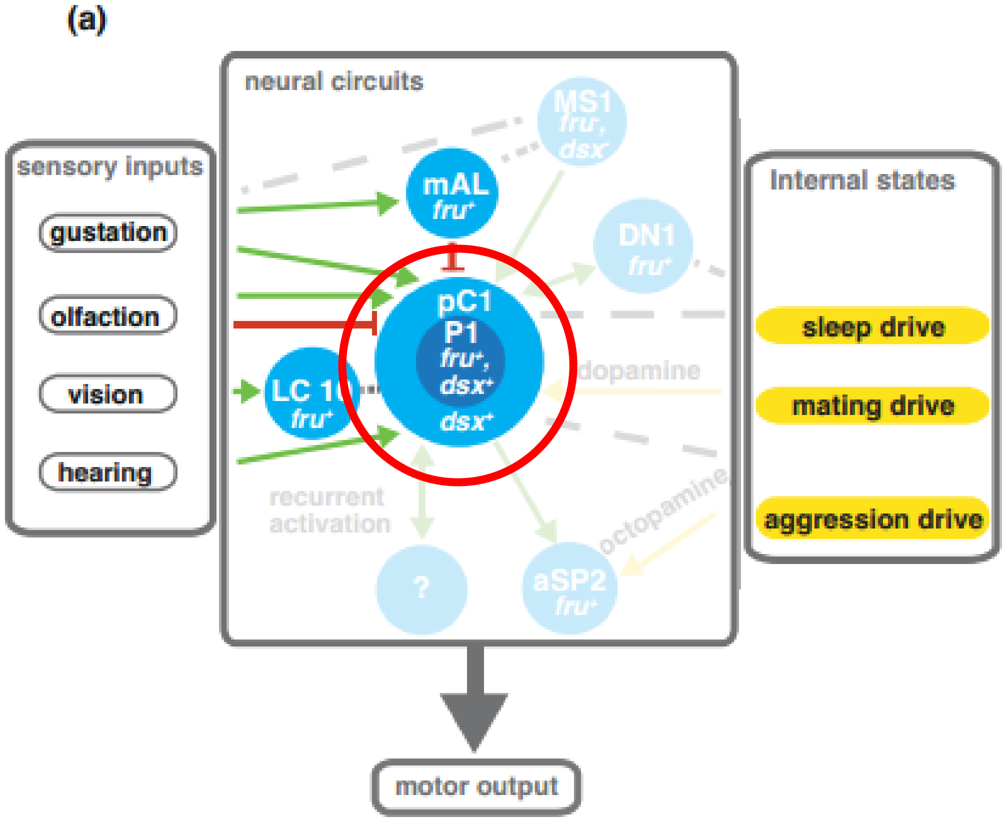
Contributed by Bruce S. Baker, April 29, 2012 (sent for review March 15, 2012)

Sexual behaviors in animals are governed by inputs from multiple external sensory modalities. However, how these inputs are integrated to jointly control animal behavior is still poorly understood. Whereas visual information alone is not sufficient to induce courtship behavior in *Drosophila melanogaster* males, when a subset of male-specific *fruitless* (*fru*)- and *doublesex* (*dsx*)-expressing neurons that respond to chemosensory cues (P1 neurons) were artificially activated via a temperature-sensitive cation channel (dTRPA1), males followed and extended their wing toward moving objects (even a moving piece of rubber band) intensively. When stationary, these objects were not courted. Our results indicate that motion input and activation of P1 neurons are individually necessary, and under our assay conditions, jointly sufficient to elicit early courtship behaviors, and provide insights into how courtship decisions are made via sensory integration.

in the posterior brain, termed P1 neurons (29), stimulates courtship when masculinized (29) or activated (23, 25).

Surprisingly, intact males with activated *fru*^{M} or *dsx* circuitry are able to respond to certain sensory cues from potential mates and thereby modify their behavior (24), suggesting that some sensory information may be percieved by non-*fru*/*dsx*-dependent pathways. In particular, courtship in males that are simultaneously *fru*^{M} null and have their *dsx* circuitry activated is largely dependent on motion cues, as they court a moving female robustly, but do not court a headless (relatively immobile) female or a moving female in the dark (24). Such a strong dependence on motion cues is dramatically different from wild-type courtship in this species (30), but is similar to courtship in many other insects such as hoverflies (31) and houseflies (32). Despite the importance of motion detection for sexual behavior in insects, little is known about the neuronal pathways involved.





Schematic illustration of inputs to the courtship command cluster pC1/P1

Annika Rings et al. *Curr Opin Insect Sci . 2019 Oct*

Content

1. **雄蝇求偶过程中视觉系统如何发挥作用？涉及到哪些关键神经元？**

   LC10

2. **视觉相关神经元与雄蝇求偶中枢 P1神经元是否存在直接或间接的相互作用？**

   P1 neurons regulate LC10a signalling

3. **求偶相关视觉神经元在雌雄神经系统中是否存在性别二态性的功能？雌蝇在性行为中的视觉响应是怎样的？**

   aDNs；accelerated mating behavior

1. 雄蝇求偶过程中视觉系统如何发挥作用？涉及到哪些关键神经元？

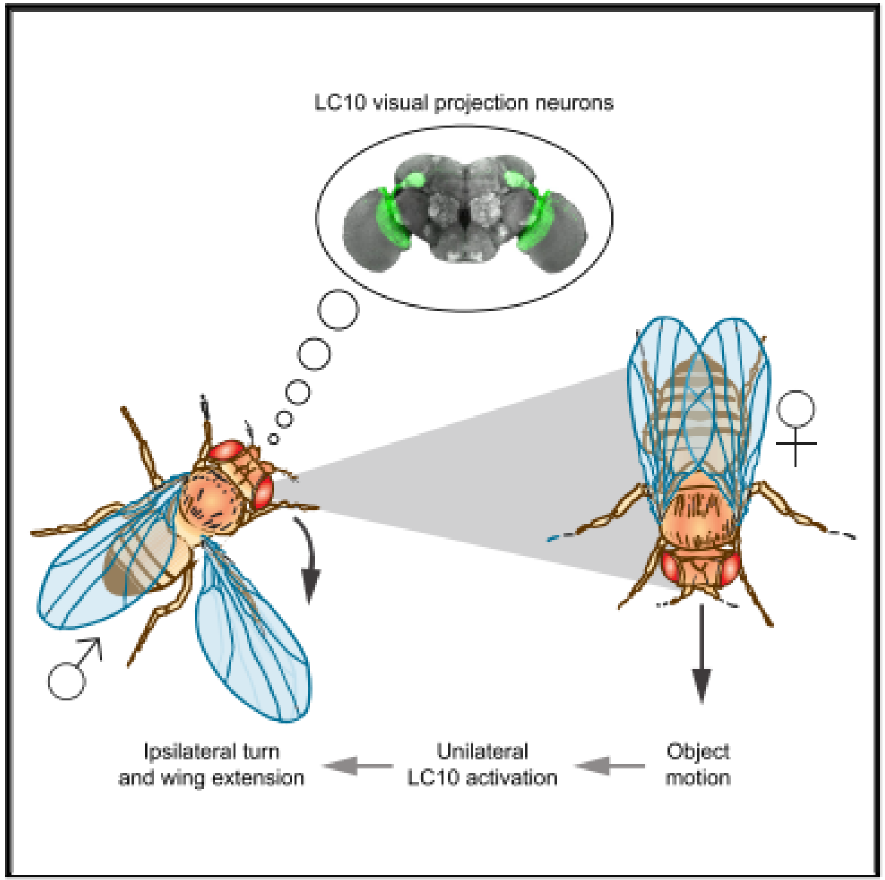
LC10

Cell

Article

Visual Projection Neurons Mediating Directed Courtship in *Drosophila*

Graphical Abstract



Authors

Inês M.A. Ribeiro, Michael Drews, Armin Bahl, Christian Machacek, Alexander Borst, Barry J. Dickson

Correspondence

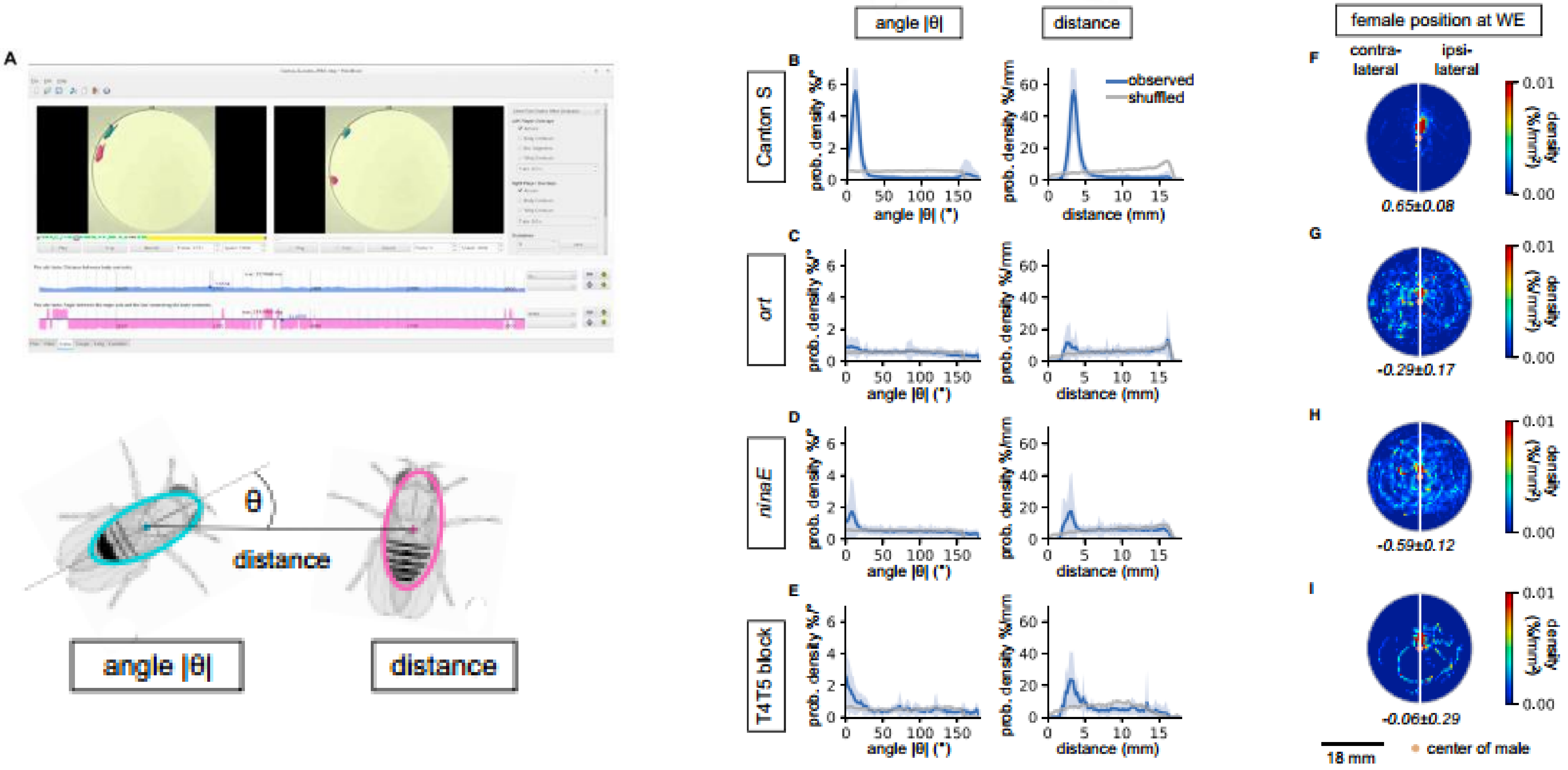
aborst@neuro.mpg.de (A.B.), dicksonb@janelia.hhmi.org (B.J.D.)

In Brief

A specific class of visual projection neurons are dedicated to guiding courtship behaviors in *Drosophila*.

Q: 处理与求偶相关的视觉信号的神经元及神经回路是怎样的?

1、Visual Input Mediates Directed Courtship



视觉对于雄蝇在求偶开始时对雌蝇的定向、追随以及靠近雌性一侧翅膀振动的求偶歌是至关重要的

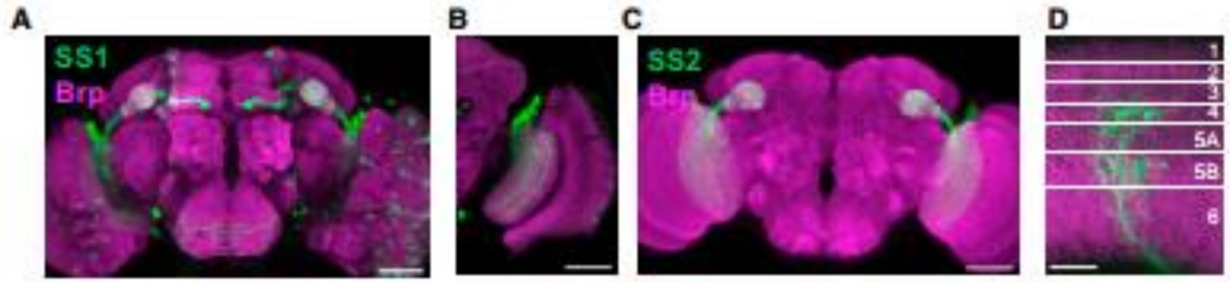
Inês M A Ribeiro et al. *Cell*. 2018 Jul 26

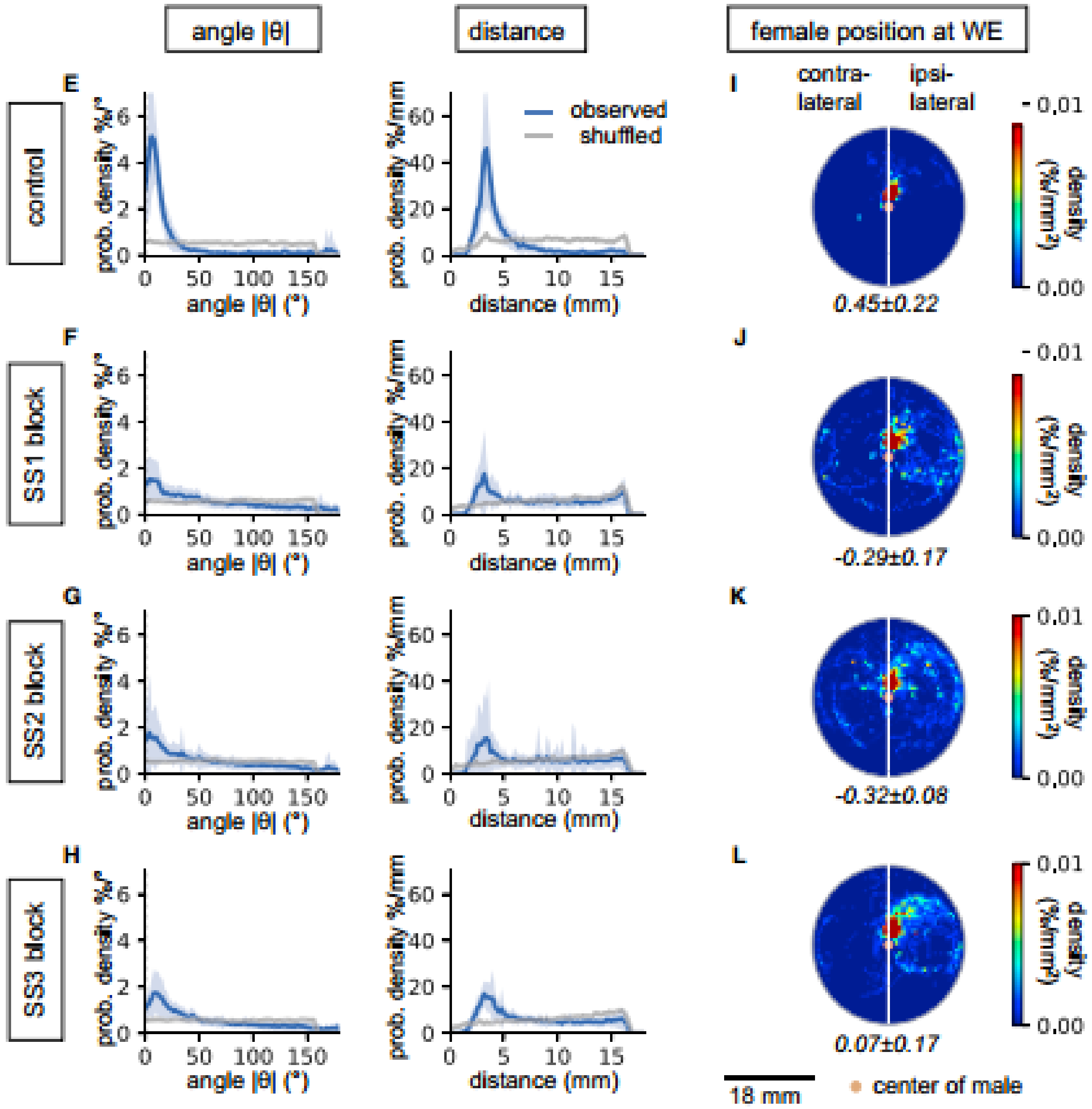
2、LC10 Visual Projection Neurons Are Required for Directed Courtship

courtship deficits flies

in which TNT was expressed in cells co-labeled by fru-FLP and various VT enhancer GAL4 lines

LC10　　（LC10-SS1、 LC10-SS2、 LC10-SS3 ）

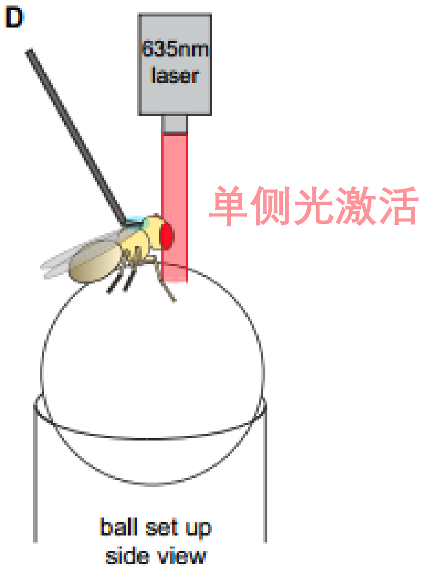


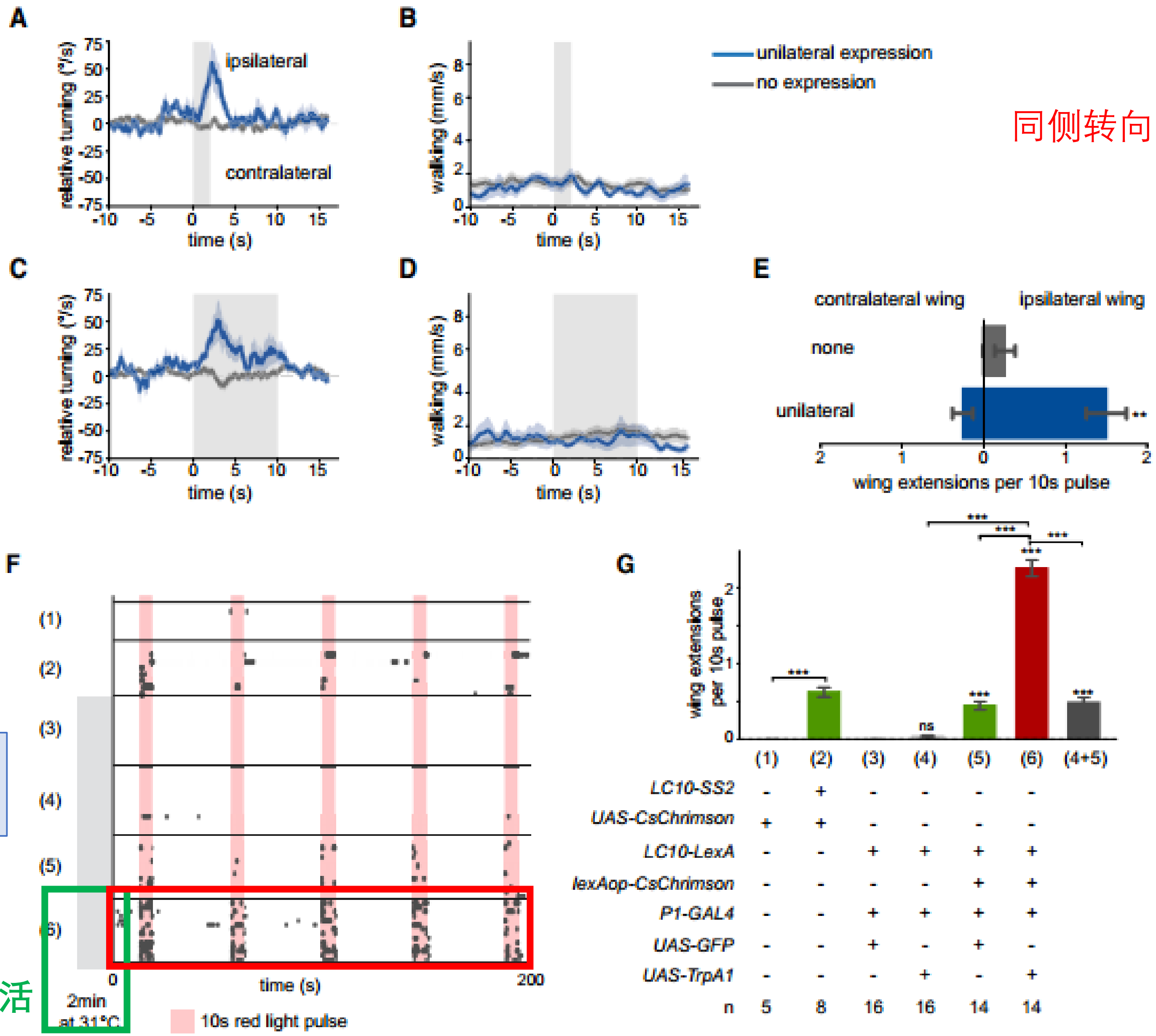


LC10神经元沉默的雄性无法定位或保持与雌性的接近，在唱歌时主要不使用同侧翅膀

Inês M A Ribeiro et al. *Cell* . 2018 Jul 26

3、Activation of LC10 Neurons Elicits Directed Courtship Actions





同侧转向

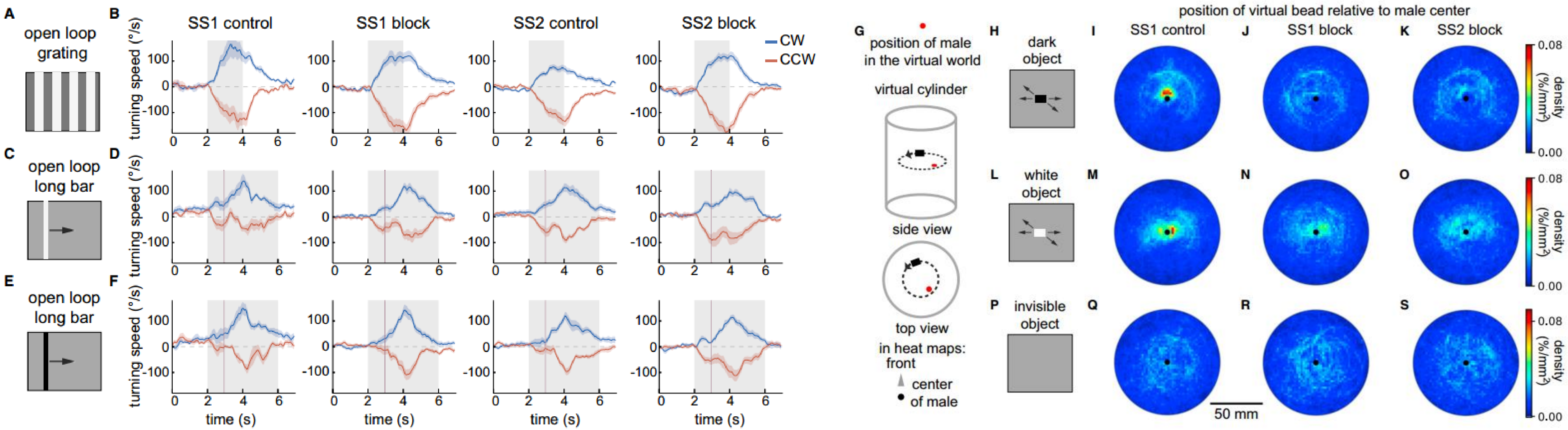
同侧翅膀延伸

LC10的激活能够引起定向求偶行为，并通过求偶唤醒而增强。

Inês M A Ribeiro et al. *Cell*. 2018 Jul 26

4、LC10 Neurons Are Sensitive to Small, Moving Visual Objects

虚拟目标相对于雄蝇中心的位置

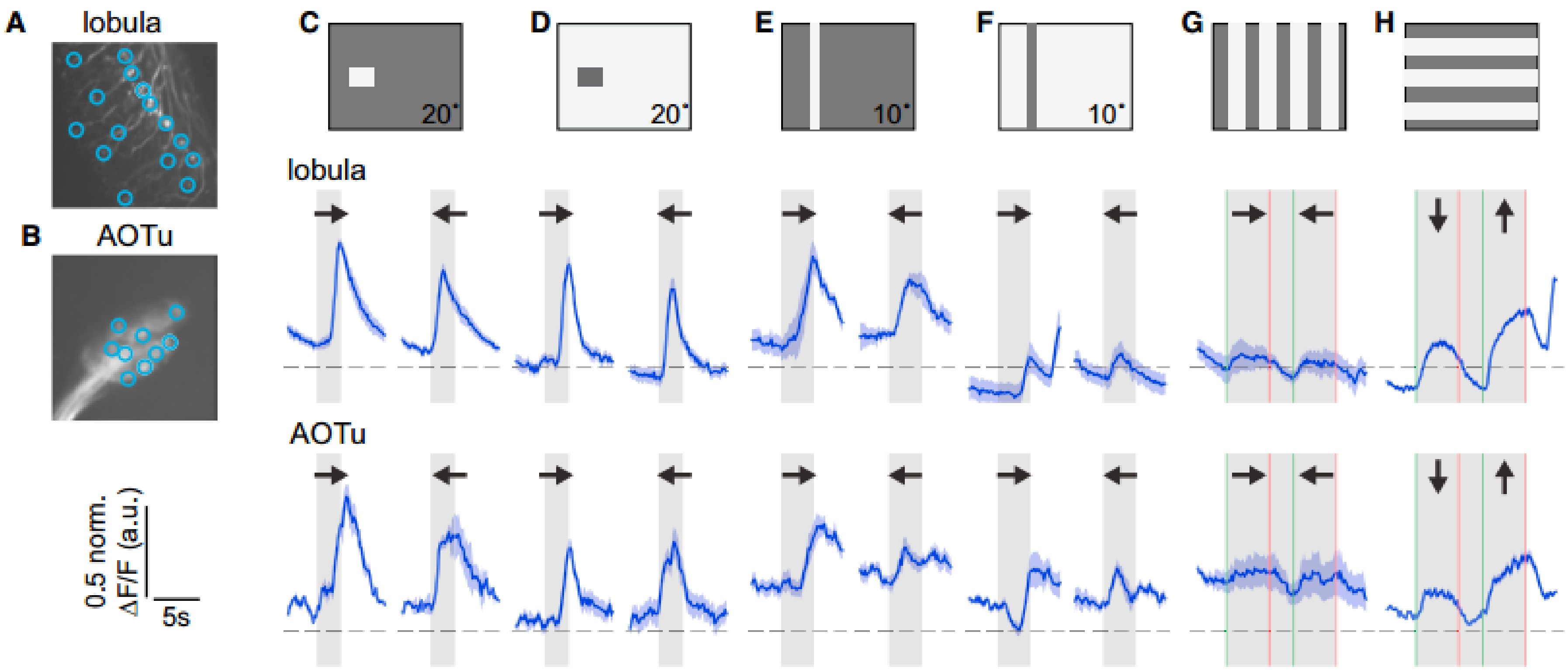


LC10神经元对具有自然角度大小和速度的物体敏感

Inês M A Ribeiro et al. *Cell*. 2018 Jul 26

4、LC10 Neurons Are Sensitive to Small, Moving Visual Objects

LC10对类似果蝇的运动物体的反应比对整个视野的变化更强烈



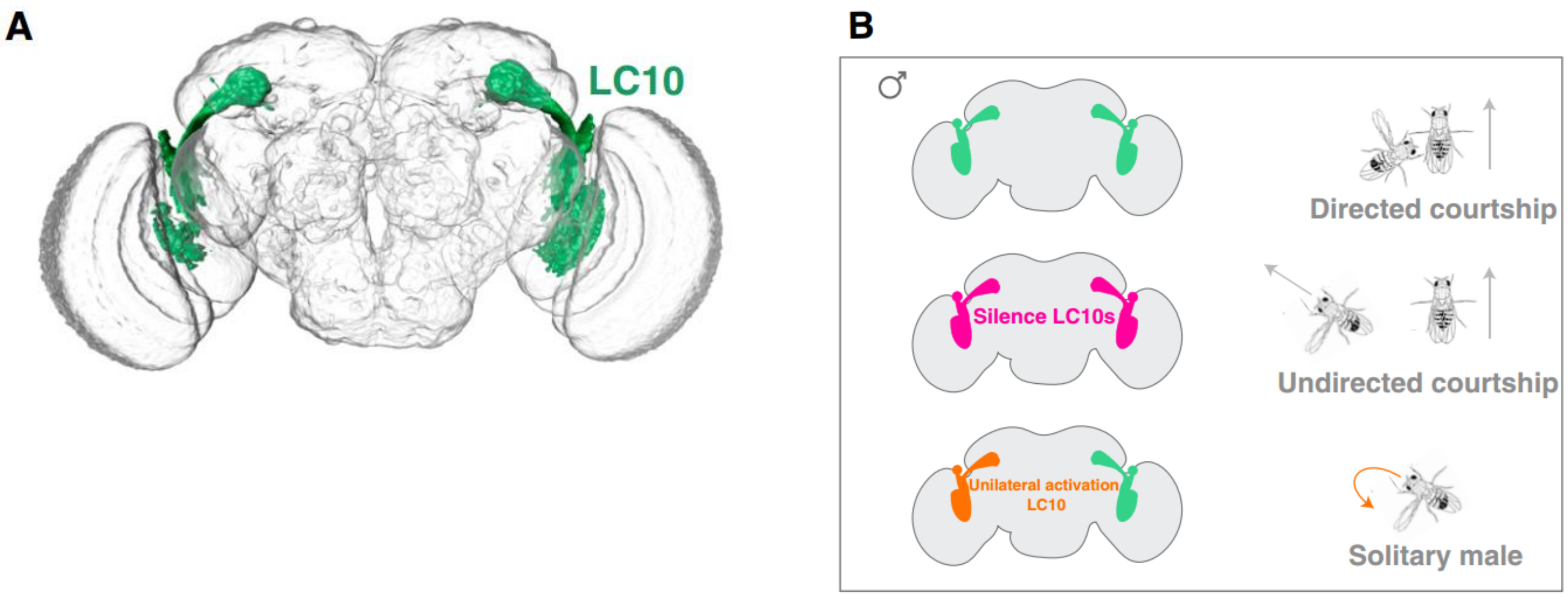
LC10神经元对具有自然角度大小和速度的物体敏感

Inês M A Ribeiro et al. *Cell* . 2018 Jul 26

Summary

1. **雄蝇求偶过程中视觉系统如何发挥作用？涉及到哪些关键神经元？**

LC10是负责雄蝇在求偶开始时对雌蝇的定向、追随以及靠近雌性一侧翅膀振动求偶歌行为的视觉投射神经元;
LC10主要感知移动的、类似于果蝇大小的小目标，这有助于雄蝇更好地寻找雌蝇交配。



Tetsuya Nojima et al. *Curr Biol* . 2018 Aug 6

2. 视觉相关神经元与雄蝇求偶中枢 P1神经元是否存在直接或间接的相互作用?

P1 neurons regulate LC10a signalling

Article

Sexual arousal gates visual processing during *Drosophila* courtship

https://doi.org/10.1038/s41586-021-03714-w
Received: 4 September 2020
Accepted: 9 June 2021
Published online: 7 July 2021
Check for updates

Tom Hindmarsh Sten[1], Rufei Li[1], Adriane Otopalik[1] & Vanessa Ruta[1]✉

Long-lasting internal arousal states motivate and pattern ongoing behaviour, enabling the temporary emergence of innate behavioural programs that serve the needs of an animal, such as fighting, feeding, and mating. However, how internal states shape sensory processing or behaviour remains unclear. In *Drosophila*, male flies perform a lengthy and elaborate courtship ritual that is triggered by the activation of sexually dimorphic P1 neurons[1-5], during which they faithfully follow and sing to a female[6,7]. Here, by recording from males as they court a virtual 'female', we gain insight into how the salience of visual cues is transformed by a male's internal arousal state to give rise to persistent courtship pursuit. The gain of LC10a visual projection neurons is selectively increased during courtship, enhancing their sensitivity to moving targets. A concise network model indicates that visual signalling through the LC10a circuit, once amplified by P1-mediated arousal, almost fully specifies a male's tracking of a female. Furthermore, P1 neuron activity correlates with ongoing fluctuations in the intensity of a male's pursuit to continuously tune the gain of the LC10a pathway. Together, these results reveal how a male's internal state can dynamically modulate the propagation of visual signals through a high-fidelity visuomotor circuit to guide his moment-to-moment performance of courtship.

在果蝇求偶过程中性唤醒影响视觉处理的具体神经环路

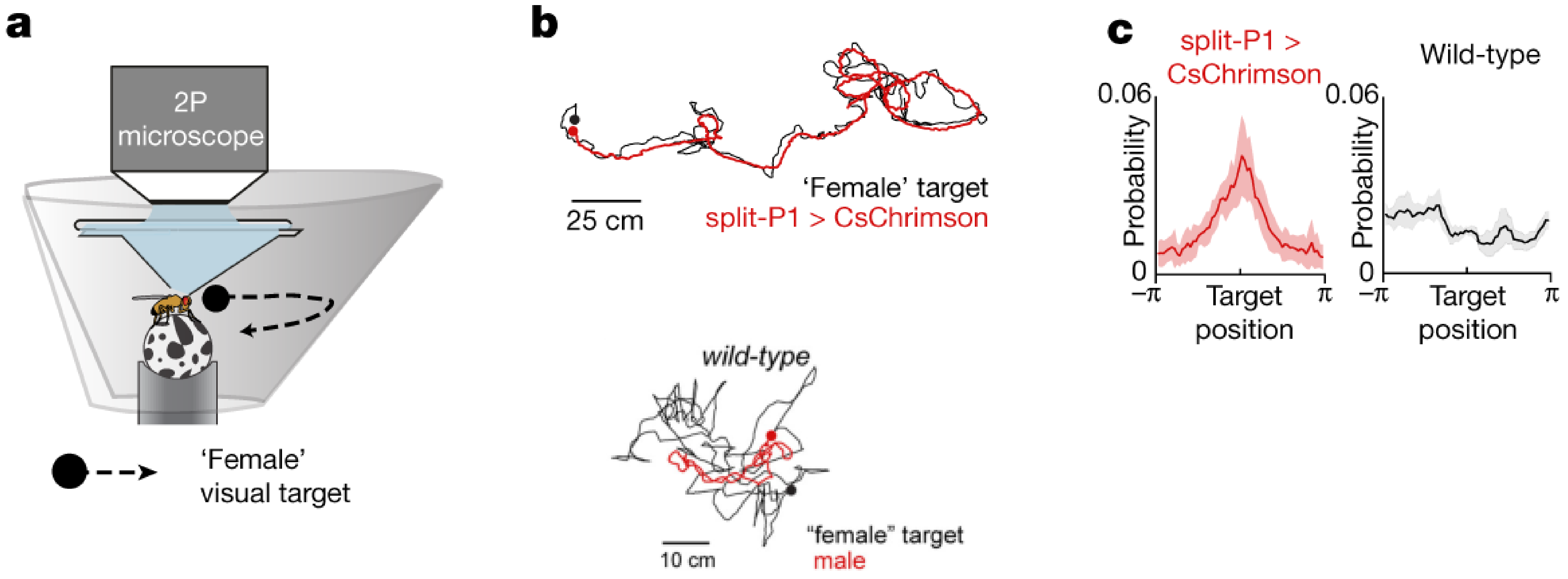
Vanessa Ruta, PhD——The Rockefeller University

黑腹果蝇求偶神经回路;

昆虫嗅觉受体气味识别的结构基础;

多巴胺受体相关通路与联想学习的关系

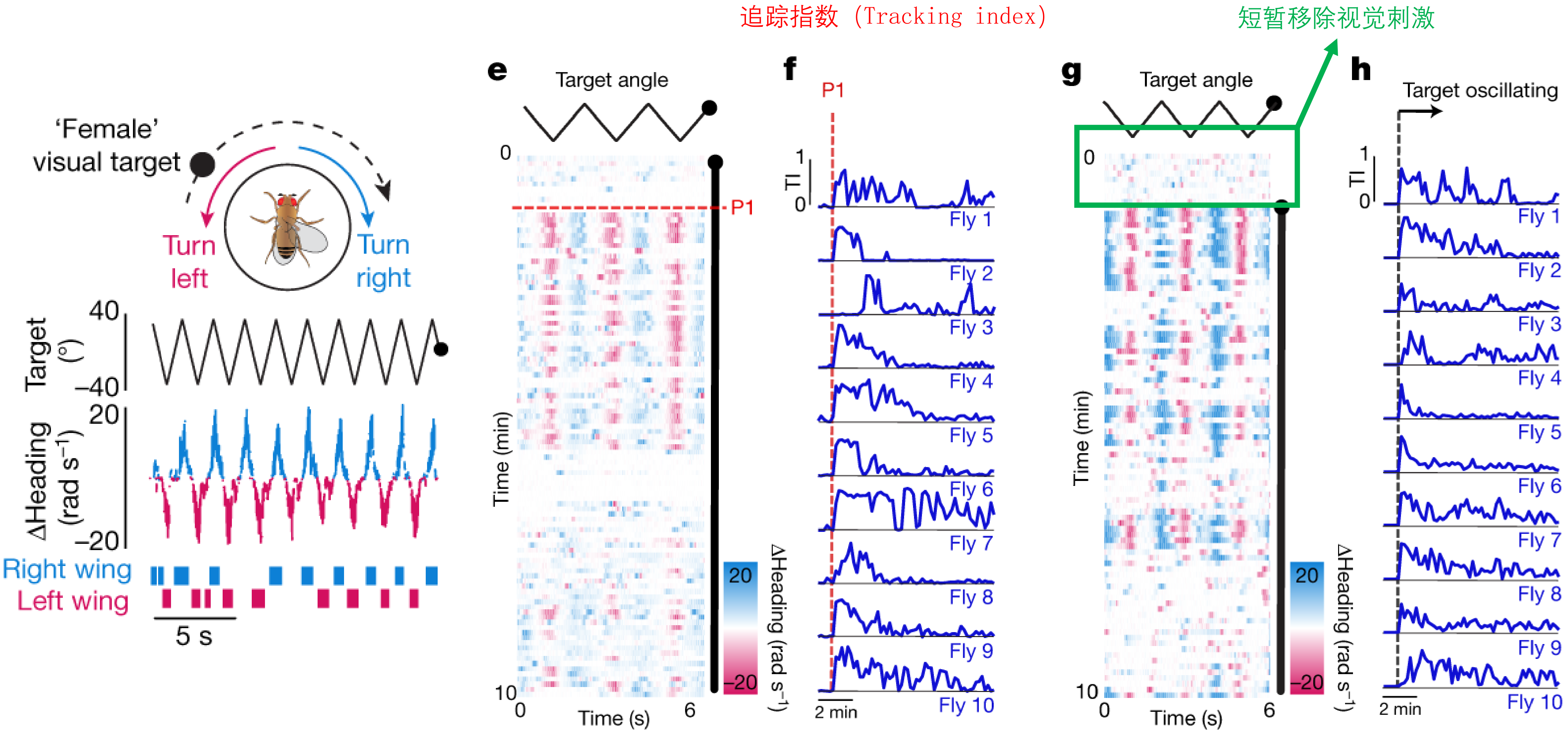
1、P1 neurons release and reflect a dynamic state of sexual arousal



Schematic of behavioural setup

Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

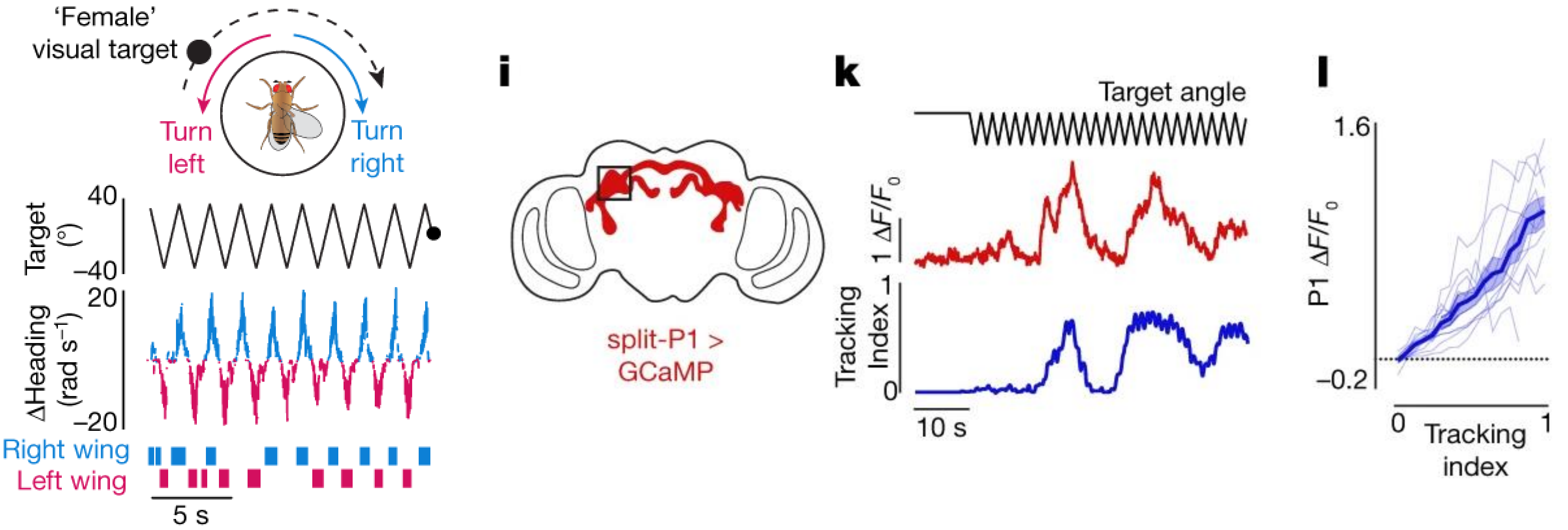
1、P1 neurons release and reflect a dynamic state of sexual arousal



P1激活的雄蝇反应了一种动态、潜在的持续性唤醒状态

Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

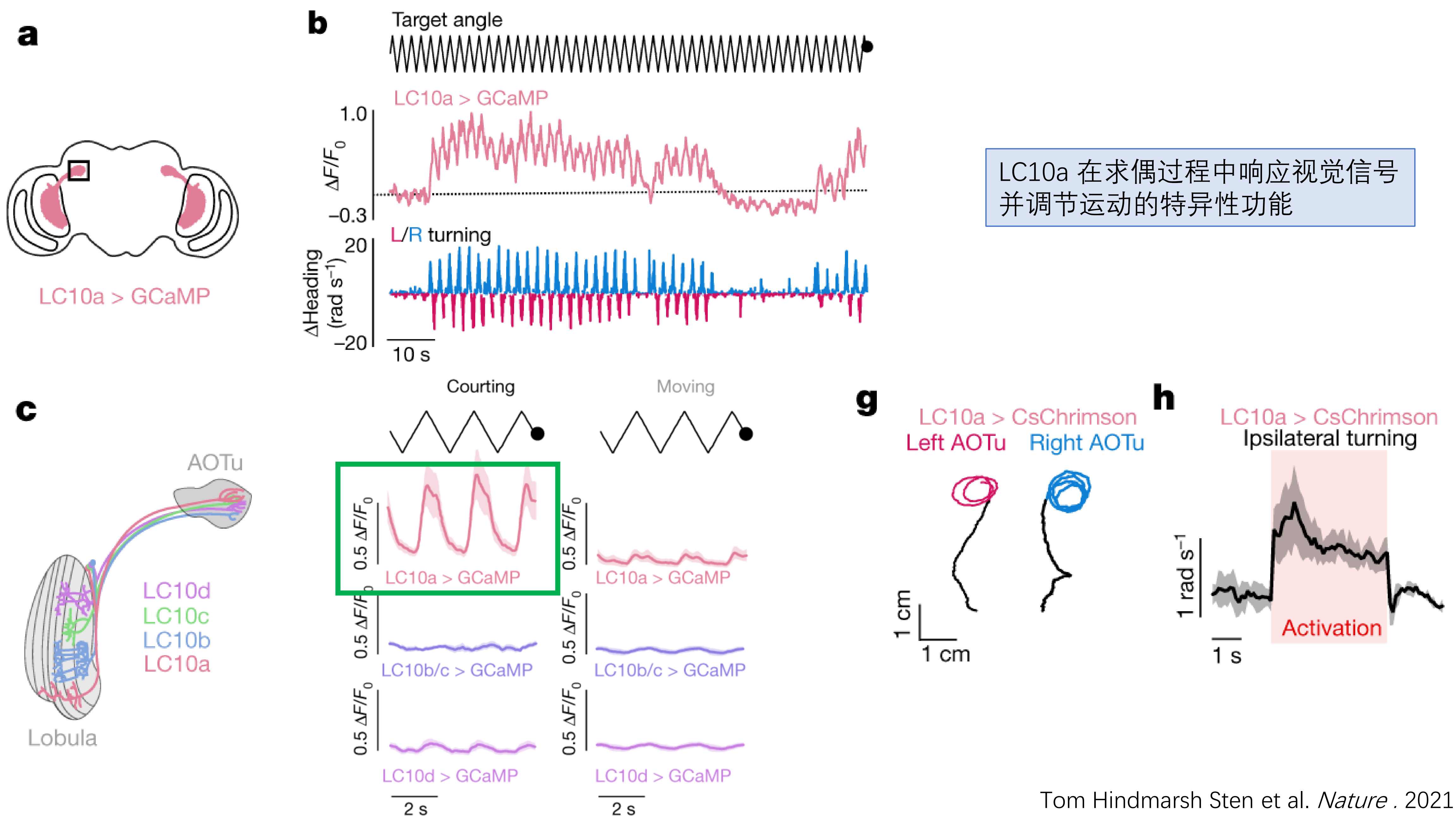
1、P1 neurons release and reflect a dynamic state of sexual arousal



P1激活的雄蝇反应了一种动态、潜在的持续性唤醒状态

Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

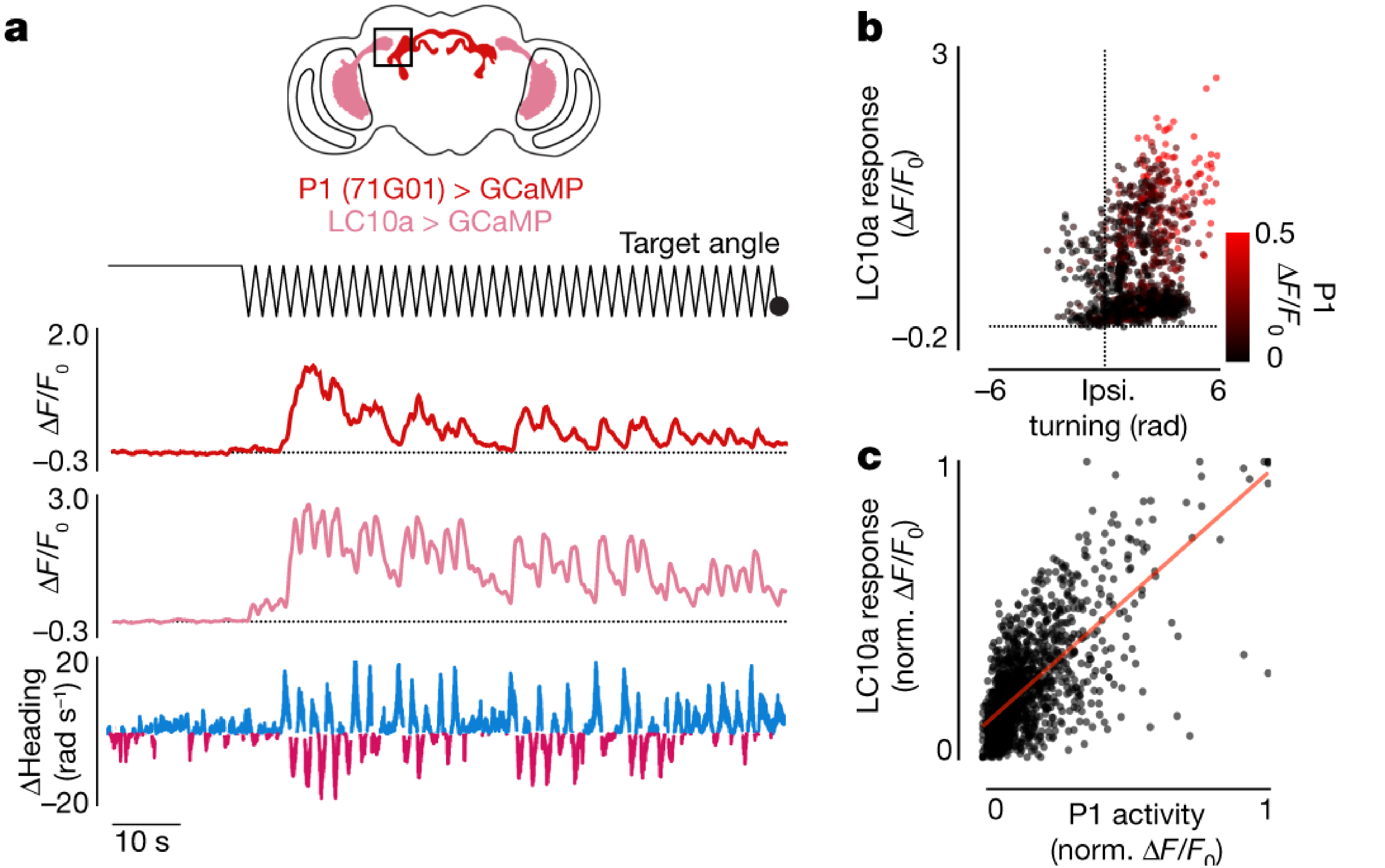
2、Modulation of LC10a neurons during courtship



LC10a 在求偶过程中响应视觉信号
并调节运动的特异性功能

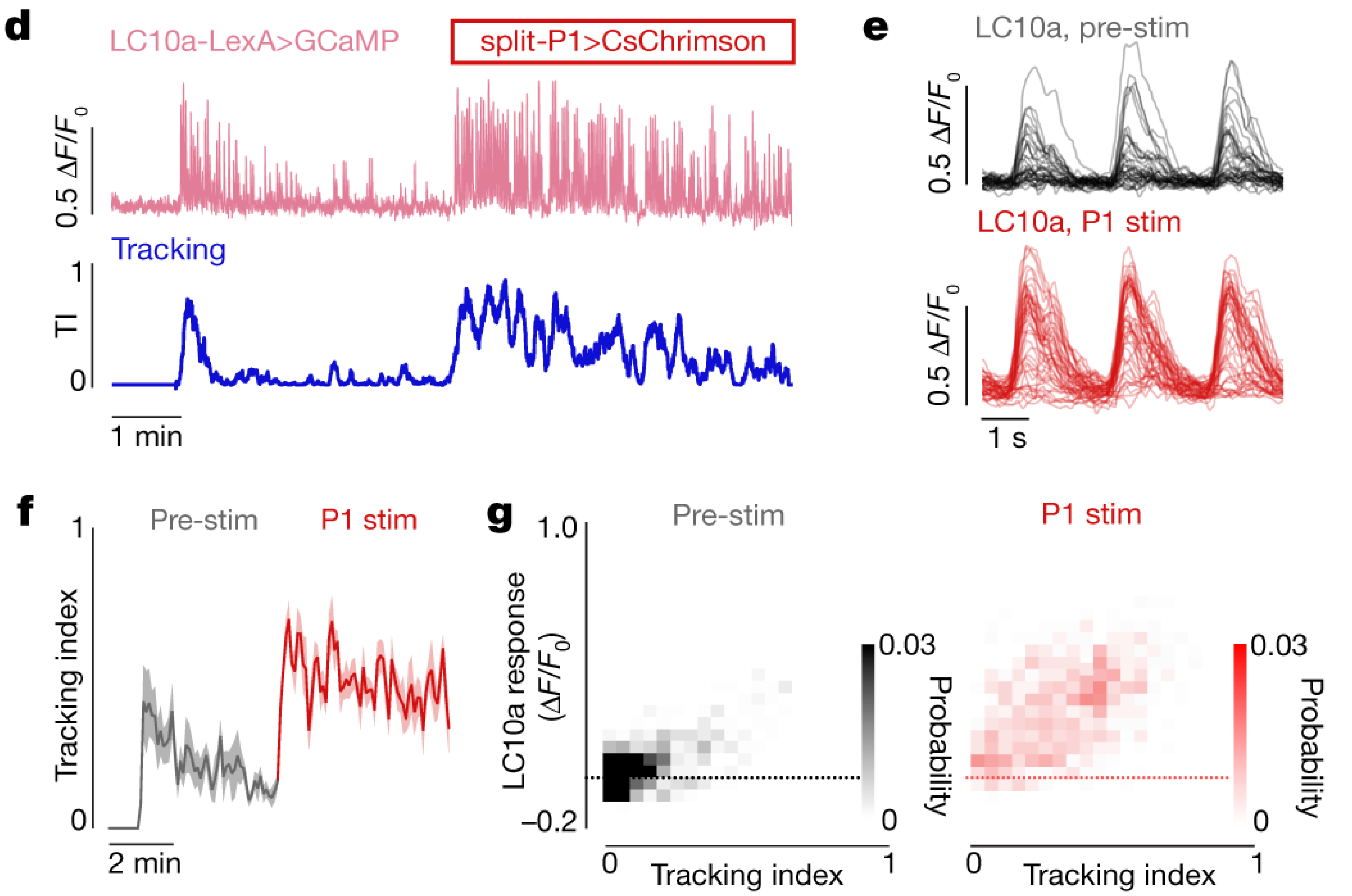
Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

3、P1 neurons regulate LC10a signalling



Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

3、P1 neurons regulate LC10a signalling



Tom Hindmarsh Sten et al. *Nature* . 2021 Jul

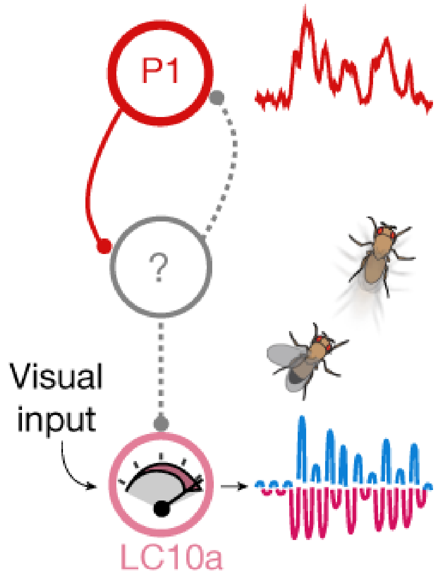
Summary

1. **雄蝇求偶过程中视觉系统如何发挥作用? 涉及到哪些关键神经元?**

LC10是负责雄蝇在求偶开始时对雌蝇的定向、追随以及靠近雌性一侧翅膀振动求偶歌行为的视觉投射神经元;
LC10主要感知移动的、类似于果蝇大小的小目标，这有助于雄蝇更好地寻找雌蝇交配。

2. **视觉相关神经元与雄蝇求偶中枢 P1神经元是否存在直接或间接的相互作用?**

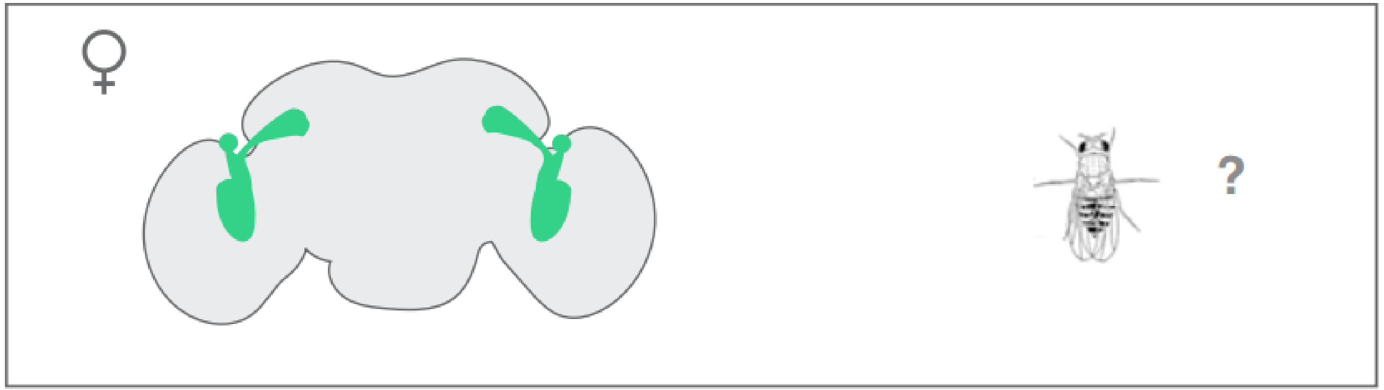
视觉回路中LC10a神经元在很大程度上足以解释雄蝇在性唤醒后对雌蝇的定位和持续追踪;
P1作为求偶中枢，以高度保真的方式动态调节视觉运动神经环路，以指导雄蝇的求偶行为。



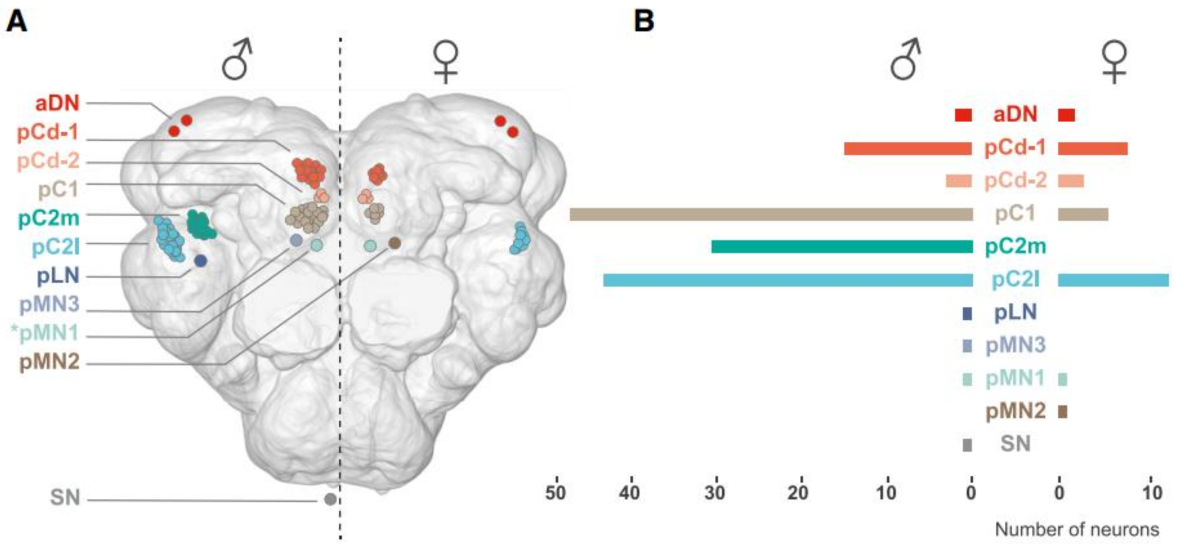
3. 求偶相关视觉神经元在雌雄神经系统中是否存在性别二态性的功能?

雌蝇在性行为中的视觉响应是怎样的?

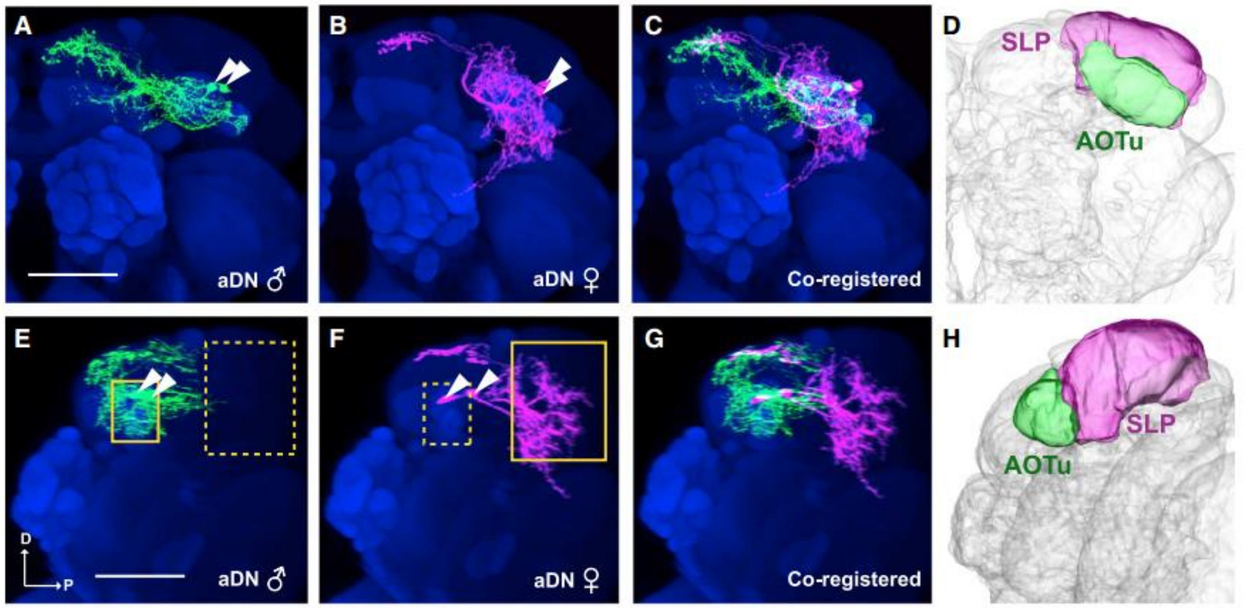
aDNs；accelerated mating behavior

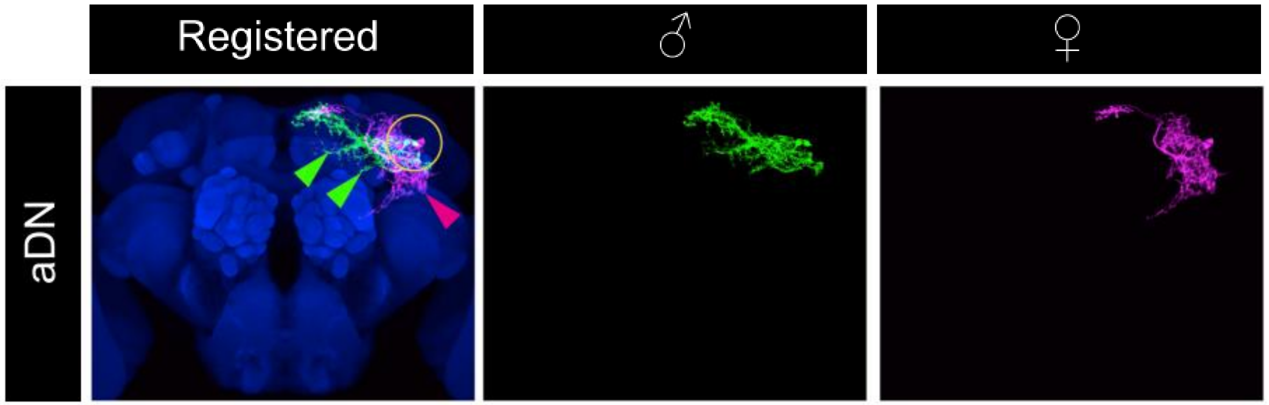


1、*dsx*+ aDNs have sexually dimorphic dendritic input sites



A schematic drawing of *dsx*-expressing neurons in the male (left) and female (right) brain

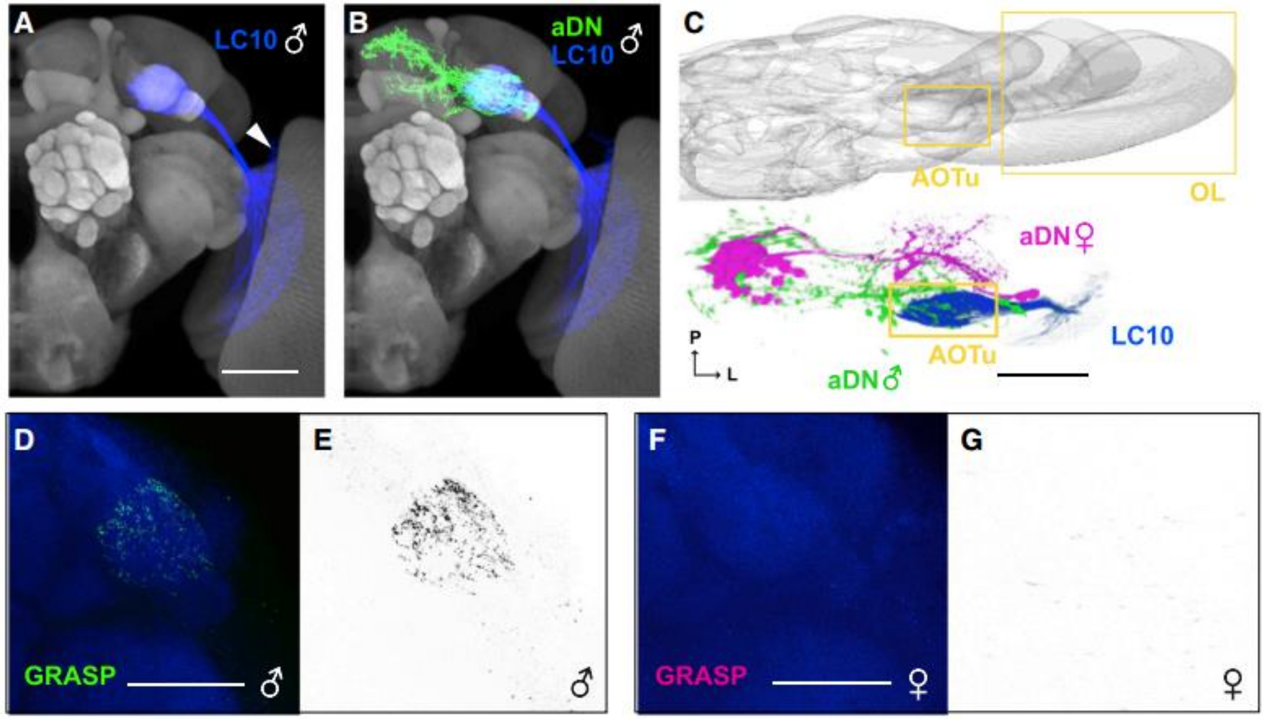


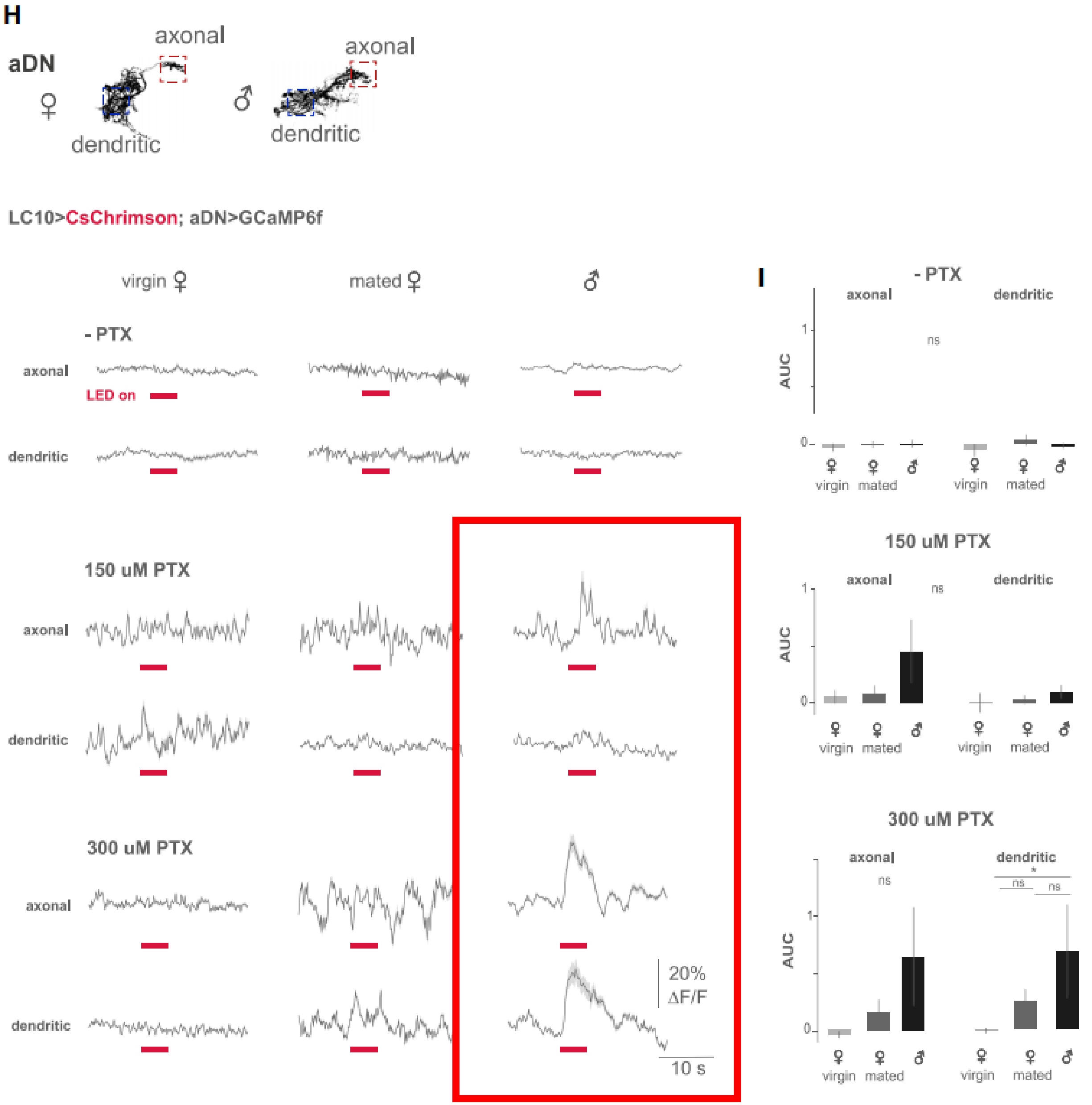


Male neurites	anterior optic tubercle (AOTu)
Female neurites	superior lateral protocerebrum (pSLP)

Tetsuya Nojima et al. *Curr Biol* . 2021 Mar 22

2、Male, but not female, aDN is a downstream cluster of LC10a



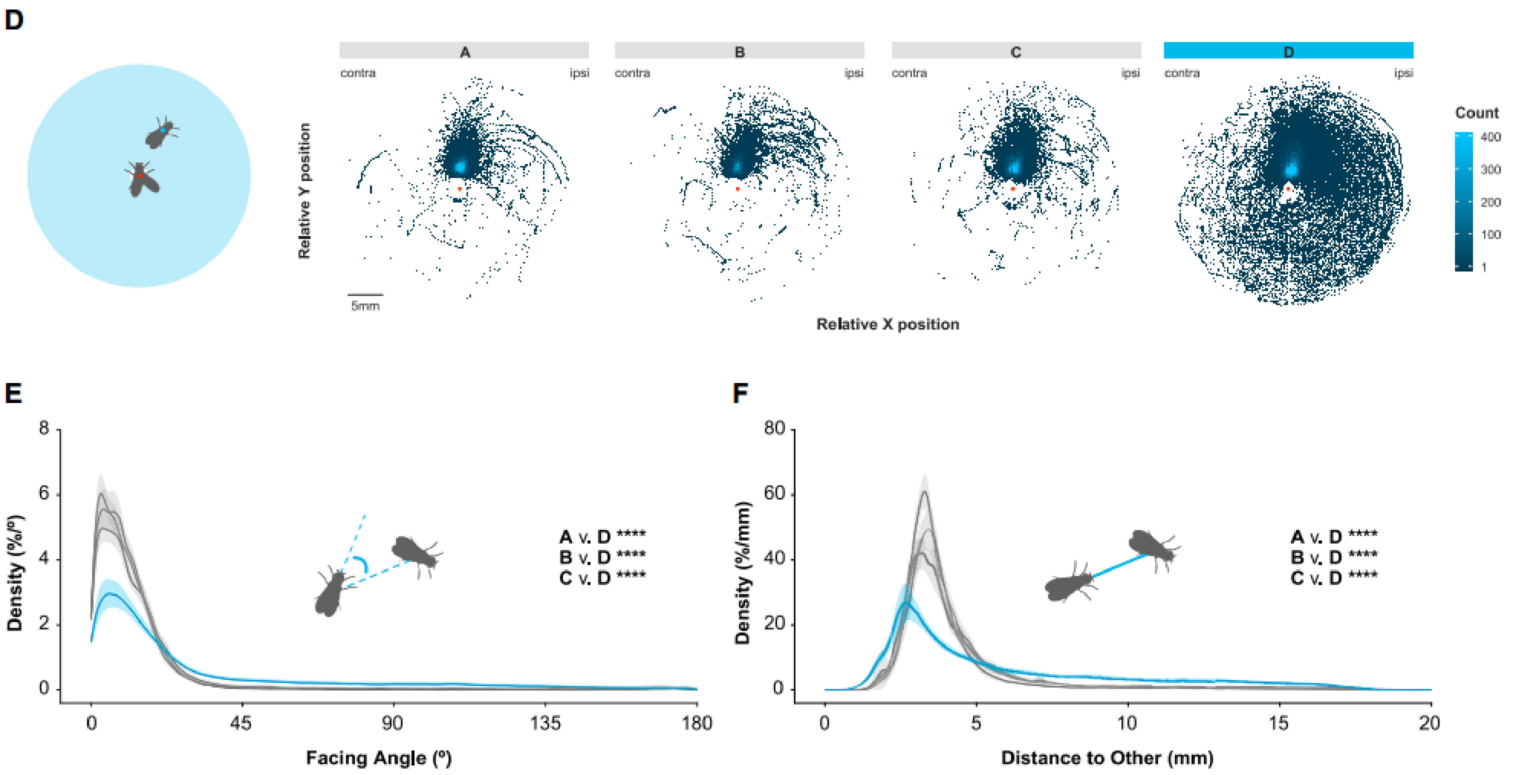


Male aDNs receive inputs from visual projection neurons

Tetsuya Nojima et al. *Curr Biol* . 2021 Mar 22

3、Silencing male aDN alters visually guided courtship behavior

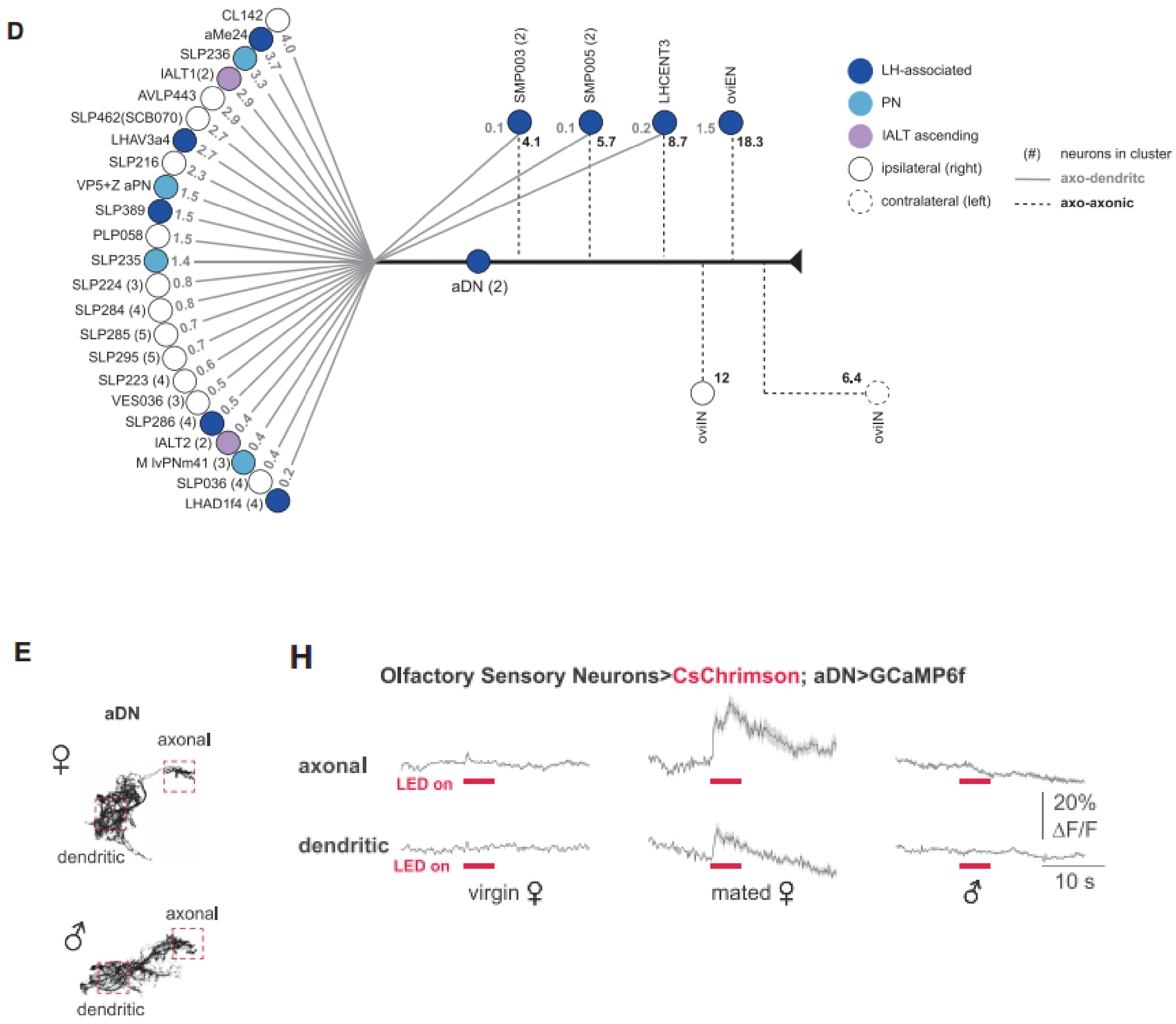
- **A** Parental Control 1
- **B** Parental Control 2
- **C** no *Otd-FLP*
- **D** aDN>*TNT*

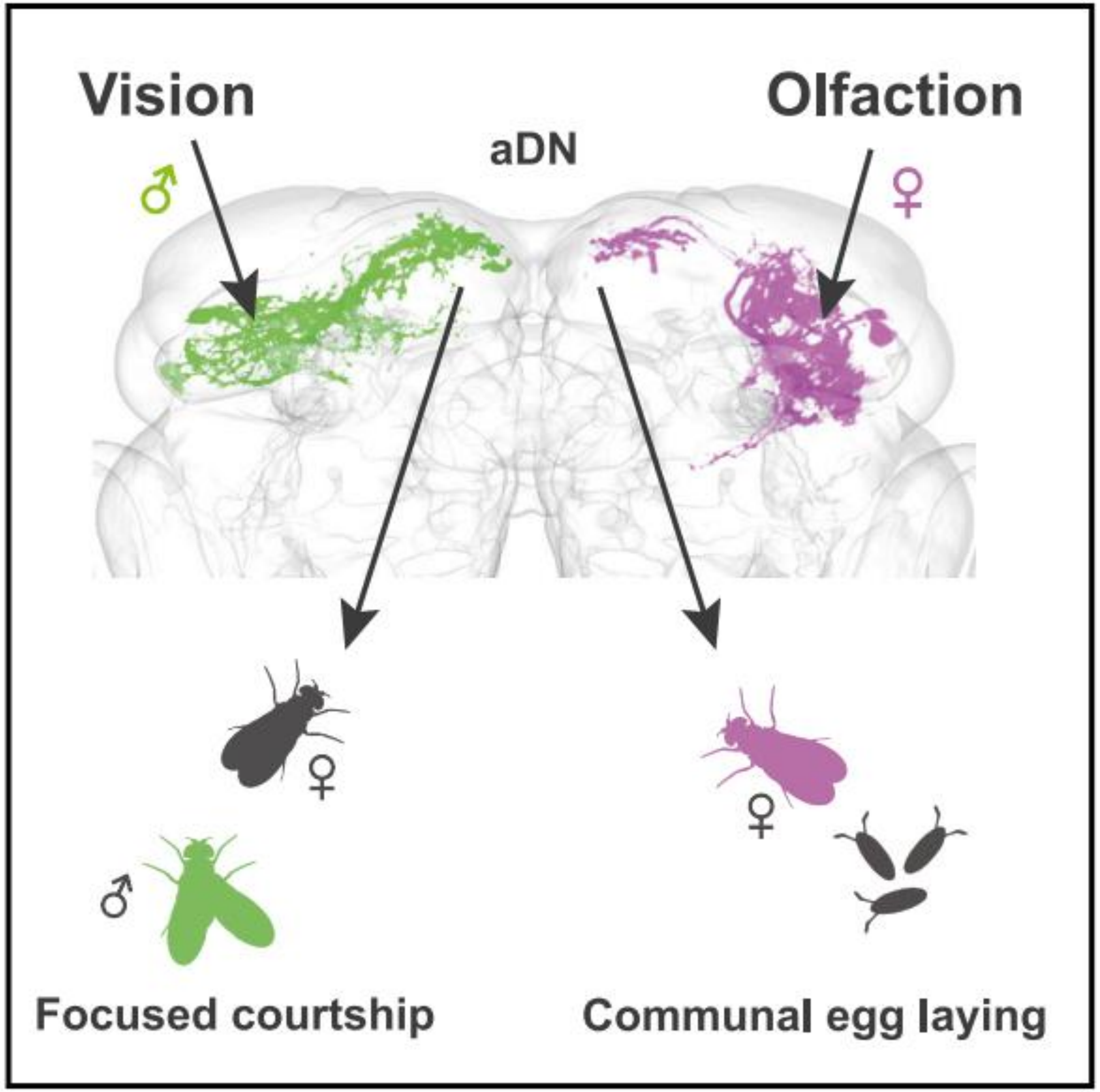


aDN silenced male

Tetsuya Nojima et al. *Curr Biol* . 2021 Mar 22

4、Female aDNs receive functionally relevant olfactory inputs





Tetsuya Nojima et al. *Curr Biol* . 2021 Mar 22

nature COMMUNICATIONS

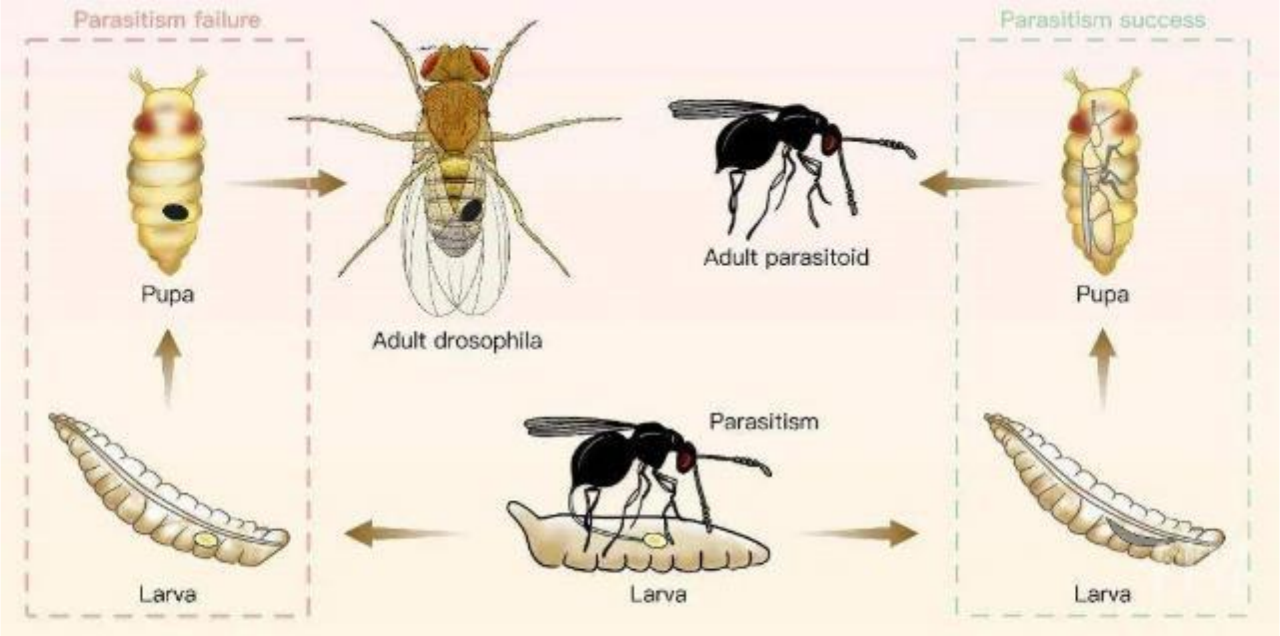
ARTICLE

Check for updates

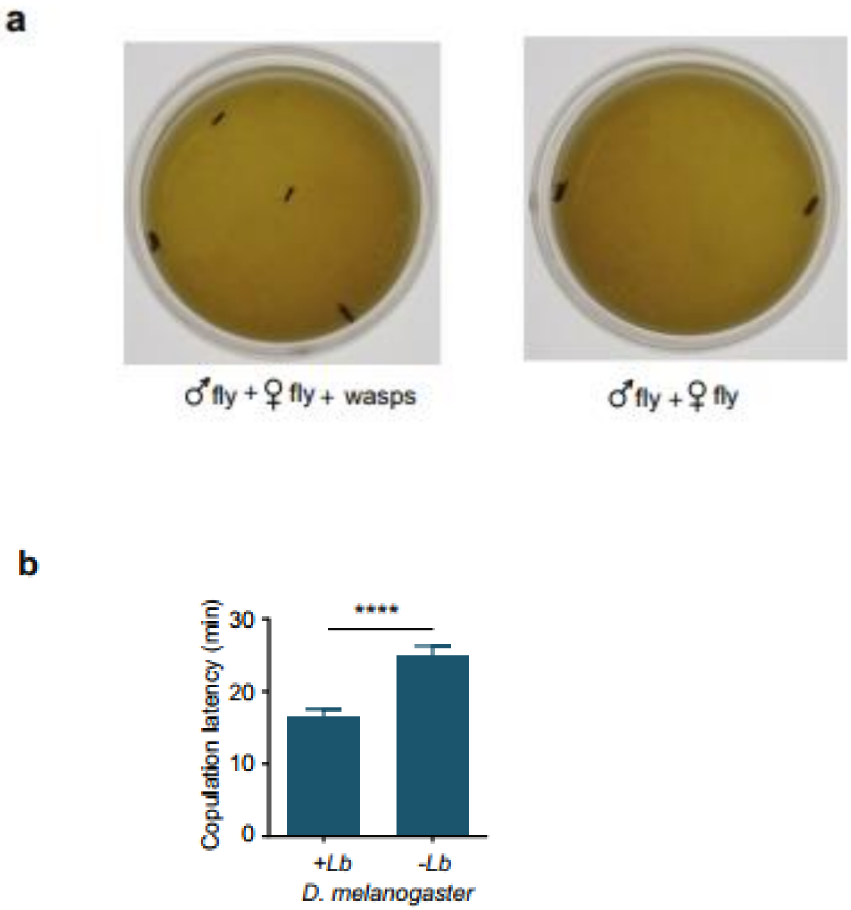
https://doi.org/10.1038/s41467-021-22712-0 OPEN

Sight of parasitoid wasps accelerates sexual behavior and upregulates a micropeptide gene in *Drosophila*

Shimaa A. M. Ebrahim [1], Gaëlle J. S. Talross [1] & John R. Carlson [1✉]

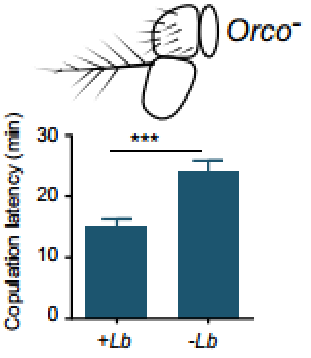


Yang, L et al. *Insect Science.* 2020

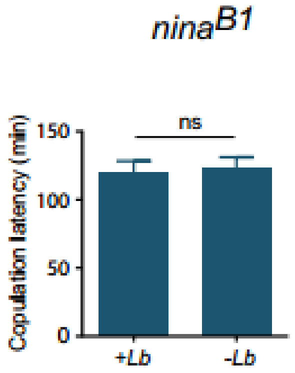


Shimaa A M Ebrahim et al. *Nat Commun* . 2021 Apr 27

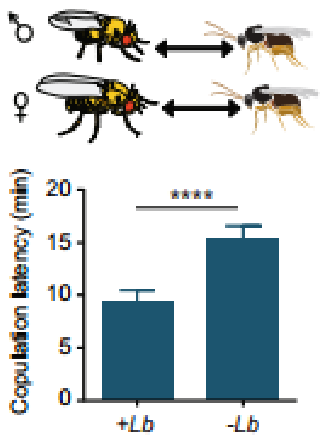
a



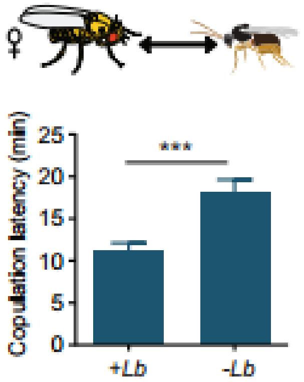
e



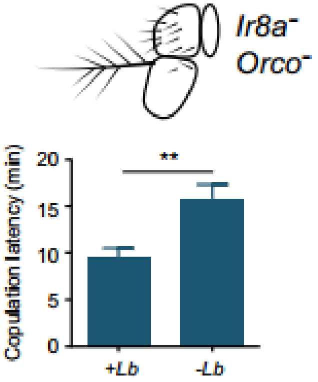
a



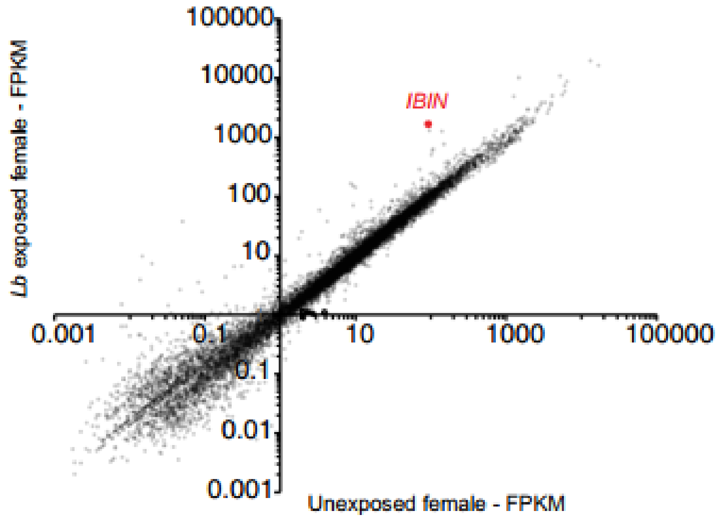
b



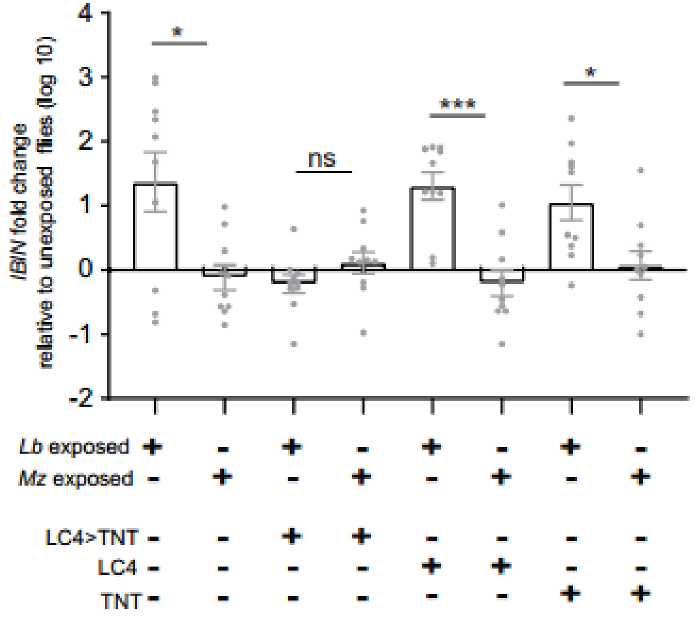
c



a



b



Shimaa A M Ebrahim et al. *Nat Commun* . 2021 Apr 27

Summary

1. **雄蝇求偶过程中视觉系统如何发挥作用？涉及到哪些关键神经元？**

   LC10是负责雄蝇在求偶开始时对雌蝇的定向、追随以及靠近雌性一侧翅膀振动求偶歌行为的视觉投射神经元；
   LC10主要感知移动的、类似于果蝇大小的小目标，这有助于雄蝇更好地寻找雌蝇交配。

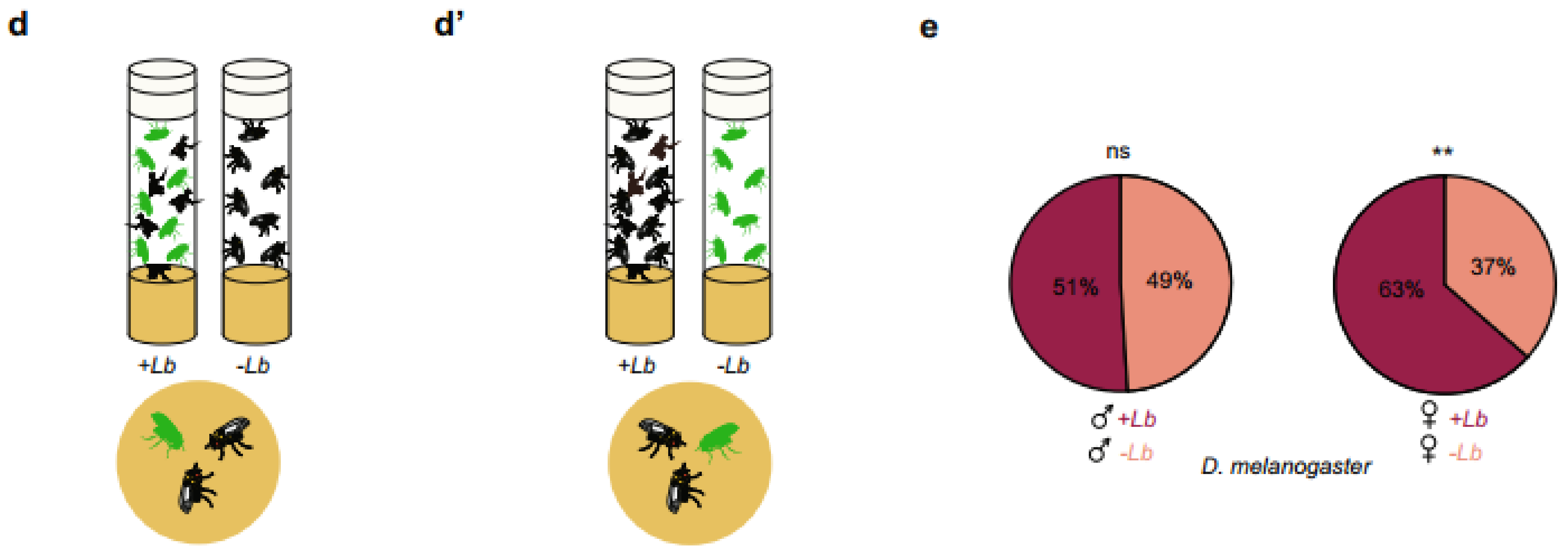
2. **视觉相关神经元与雄蝇求偶中枢 P1神经元是否存在直接或间接的相互作用？**

   视觉回路中LC10a神经元在很大程度上足以解释雄蝇在性唤醒后对雌蝇的定位和持续追踪；
   P1作为求偶中枢，以高度保真的方式动态调节视觉运动神经环路，以指导雄蝇的求偶行为。

3. **求偶相关视觉神经元在雌雄神经系统中是否存在性别二态性的功能？雌蝇在性行为中的视觉响应是怎样的？**

   aDNs作为一种独特的性别二态神经元，通过在雌雄果蝇的感觉通路中接受不同的感觉信息，介导两性之间不同行为（雄蝇求偶期间视觉追踪、雌蝇产卵地点选择偏好）；
   果蝇看到黄蜂会出现加速交配的防御反应，这种行为是由雌蝇的视觉感知介导的。

THANKS!



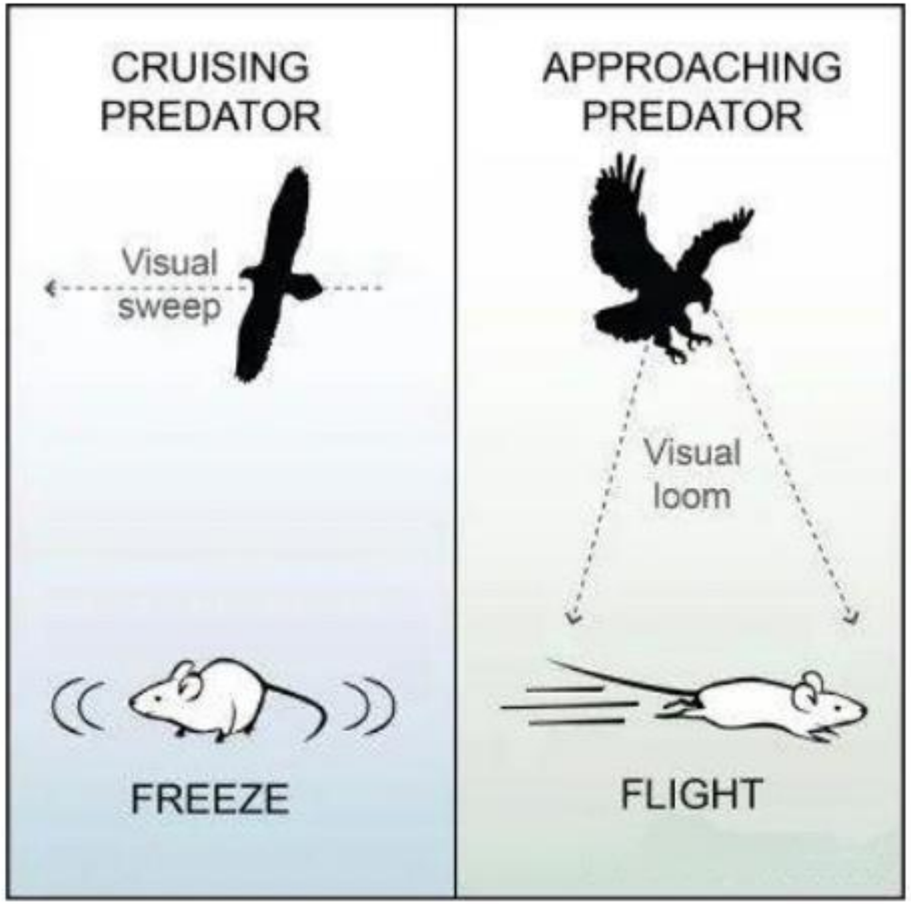
Shimaa A M Ebrahim et al. *Nat Commun* . 2021 Apr 27

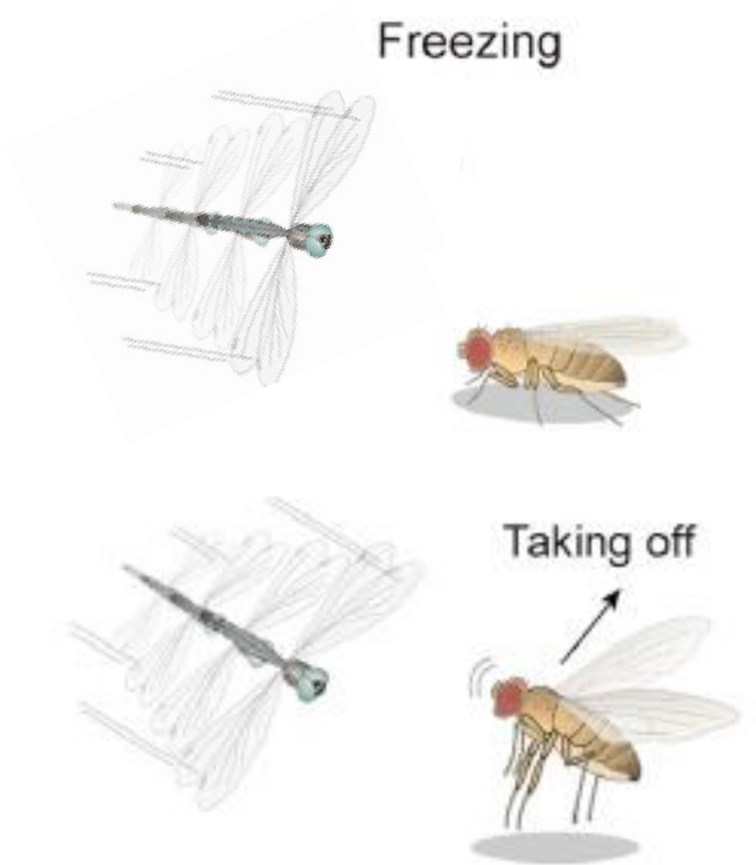
Visual system and avoidance behavior

朱培雯

2023.03.02

Looming can induce avoidance behavior in animals





Drosophila

Zebrafish

Rodents

Nonhuman primates

Humans

Leader in visual system and avoidance behavior

Gwyneth Card, PhD

Investigator / 2022—Present

Dr. Card is an associate professor of neuroscience at Columbia University and a principal investigator at Columbia's Mortimer B. Zuckerman Mind Brain Behavior Institute. She was a group leader at HHMI's Janelia Research Campus from 2010-2022.

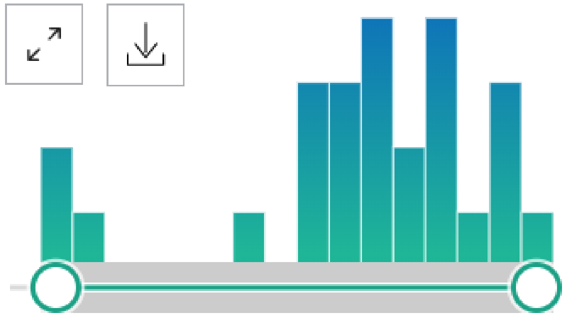
INSTITUTION
Columbia University

SCIENTIFIC DISCIPLINE
Neuroscience

Card Lab / We study the neural mechanisms and circuit architectures that underlie behavior choice for ecologically relevant, visually-guided behaviors of the fly. Our work combines high-throughput, high-resolution behavioral quantification with genetic, electrophysiological, and functional imaging techniques.

Leader in visual system and avoidance behavior

RESULTS BY YEAR



2008 2023

CURRENT RESEARCH

Neural Circuits Underlying *Drosophila* Escape Behavior

Current Biology

CellPress

Volume 18, Issue 17, 9 September 2008, Pages 1300-1307

Report

Visually Mediated Motor Planning in the Escape Response of *Drosophila*

Gwyneth Card [1], Michael H. Dickinson [1]

nature

Explore content About the journal Publish with us

nature > articles > article

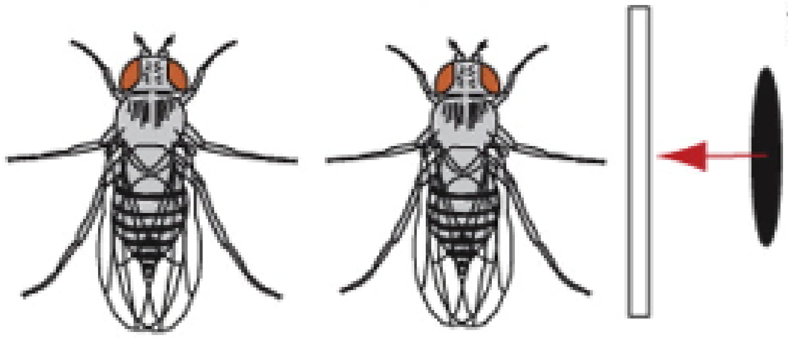
Article | Open Access | Published: 04 January 2023

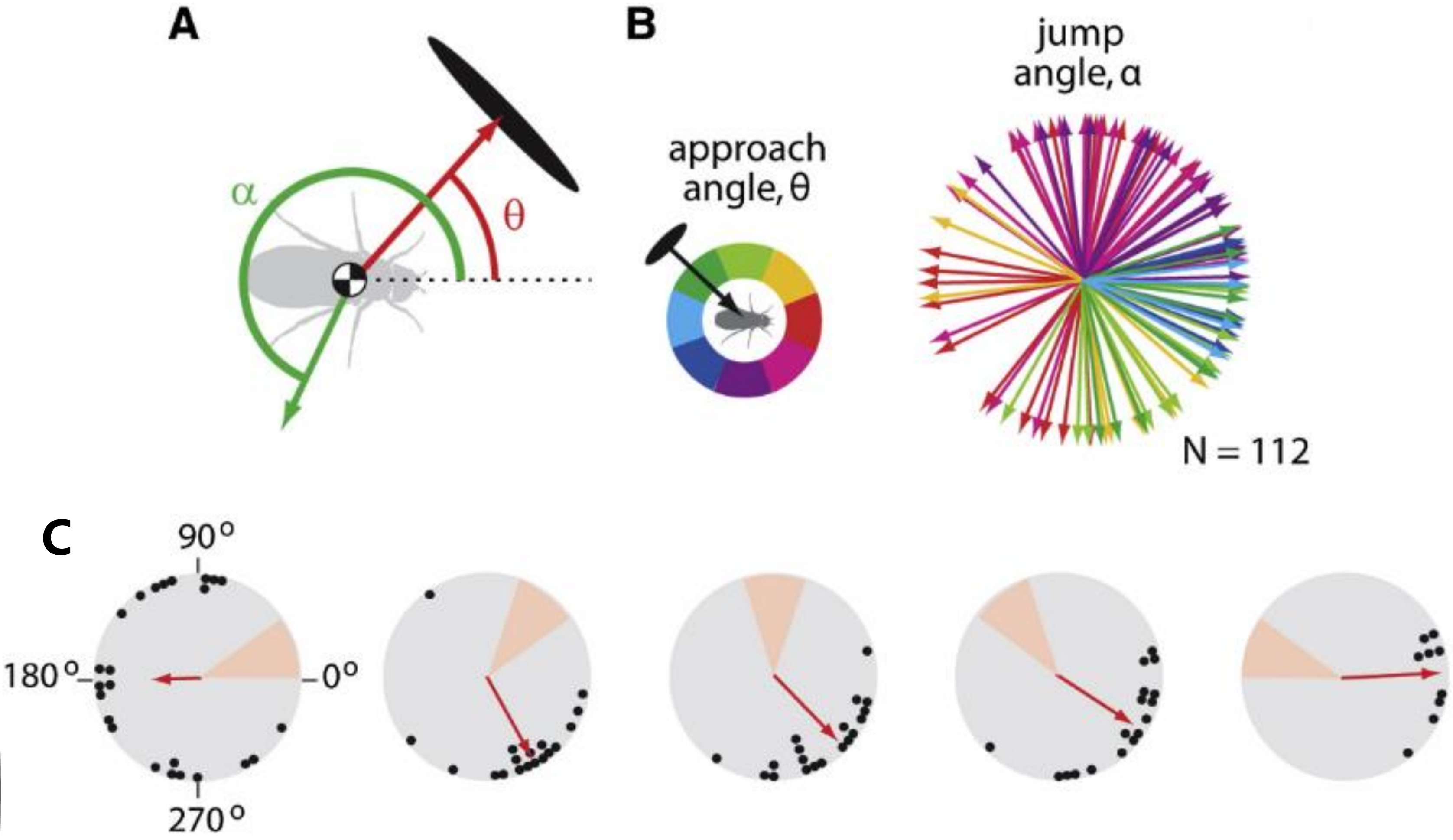
Synaptic gradients transform object location to action

Mark Dombrovski, Martin Y. Peek, Jin-Yong Park, Andrea Vaccari, Marissa Sumathipala, Carmen Morrow, Patrick Breads, Arthur Zhao, Yerbol Z. Kurmangaliyev, Piero Sanfilippo, Aadil Rehan, Jason Polsky, Shada Alghailani, Emily Tenshaw, Shigehiro Namiki, S. Lawrence Zipursky & Gwyneth M. Card

2008.09 → 2023.01

Visual information alone is sufficient for a fly to determine the direction of an approaching threat





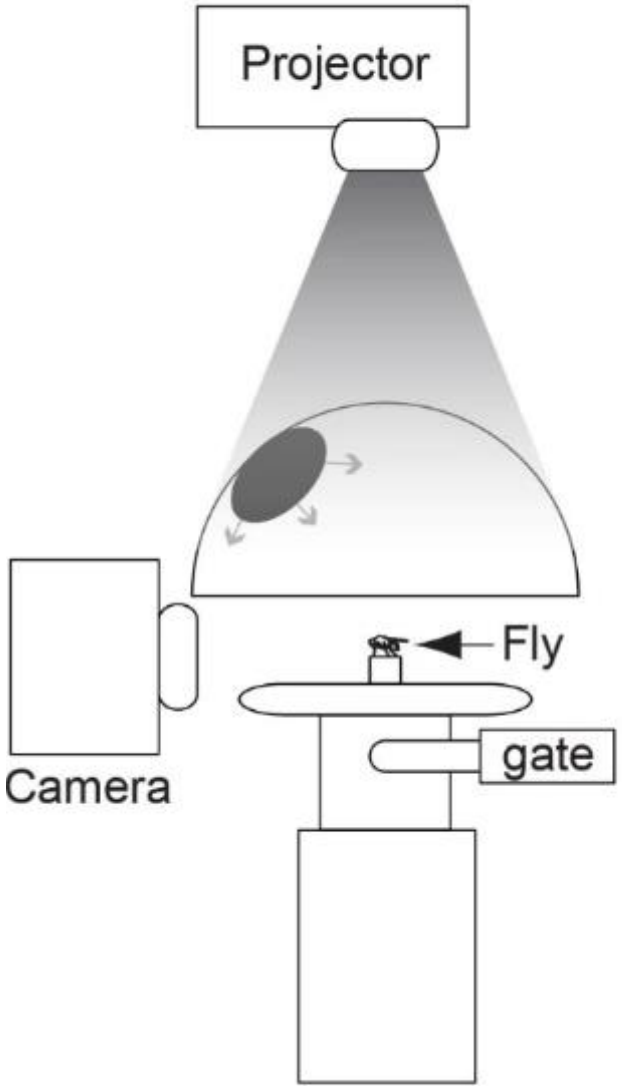
(Gwyneth Card & Michael H. Dickinson. Current Biology, 2008)

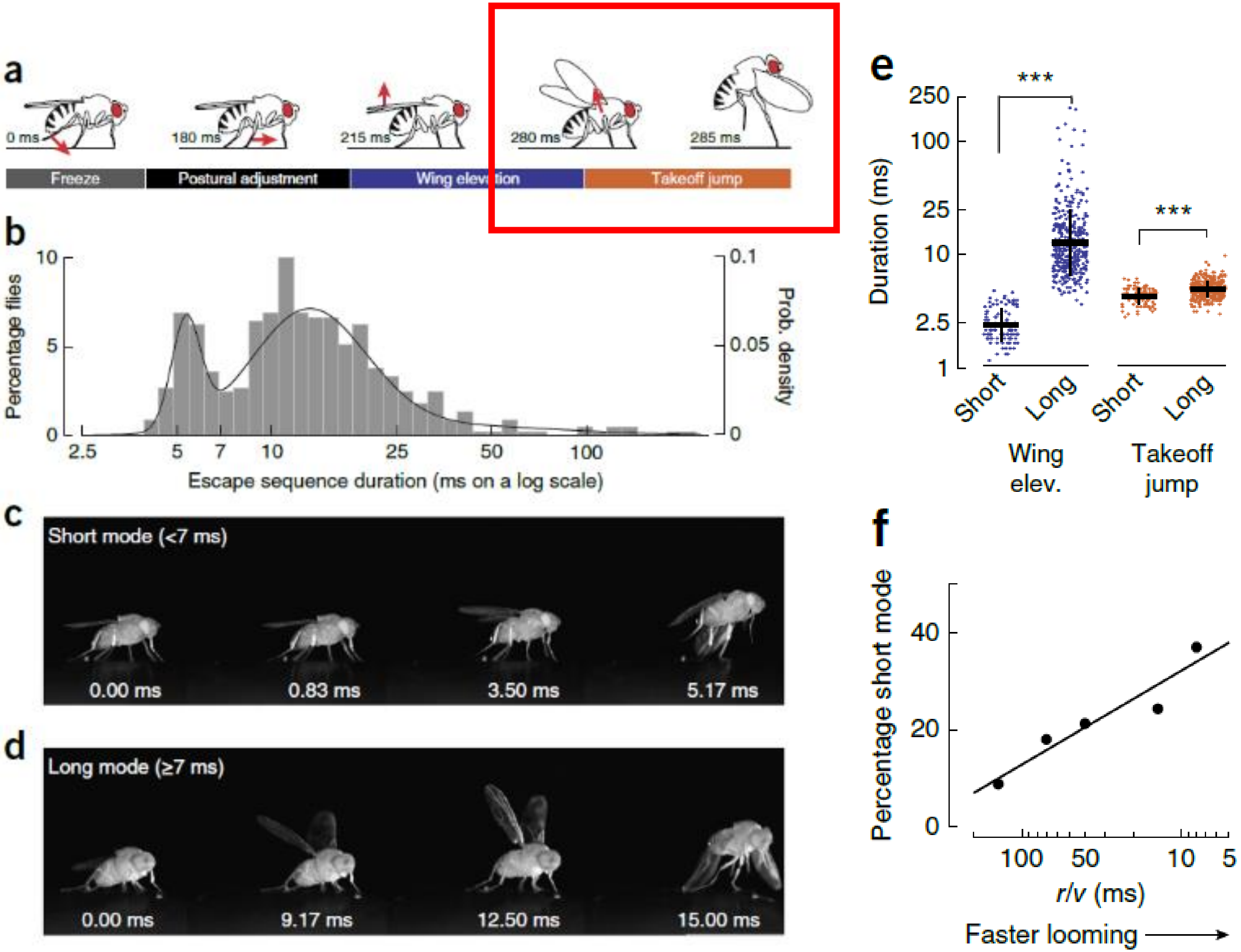
What are the neural circuits responsible for avoidance behavior to approaching (looming) visual objects?

- Do flies choose different ways of avoidance when confronted with different visual objects?
  - When confronted with a fast-approaching object, such as a fly swatter
  - When confronted with a slowly approaching object

- Do flies in different behavioral states choose completely different ways of avoidance?
  - Resting or walking flies
  - Flies in flight

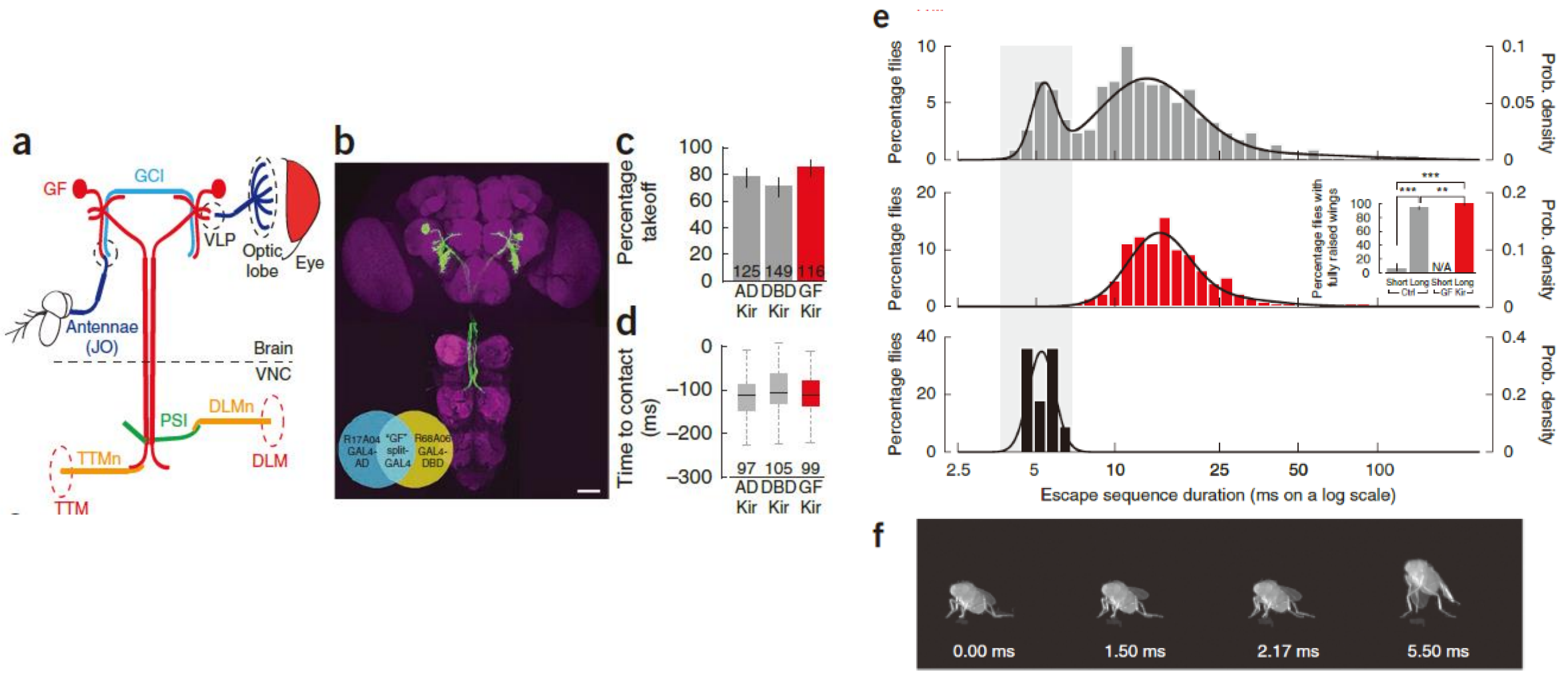
Flies select between two escape sequences when confronted by a looming stimulus





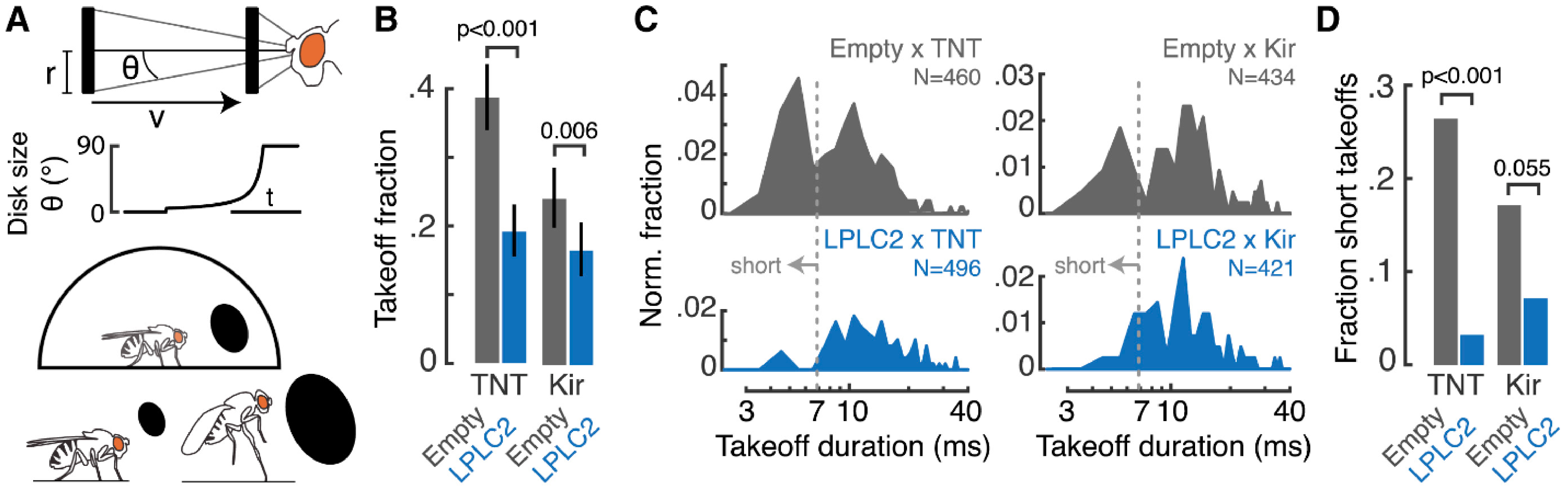
(Catherine R von Reyn, Gwyneth Card, et al. Nature Neuroscience, 2014)

The GFs are necessary and sufficient for eliciting short-mode escapes



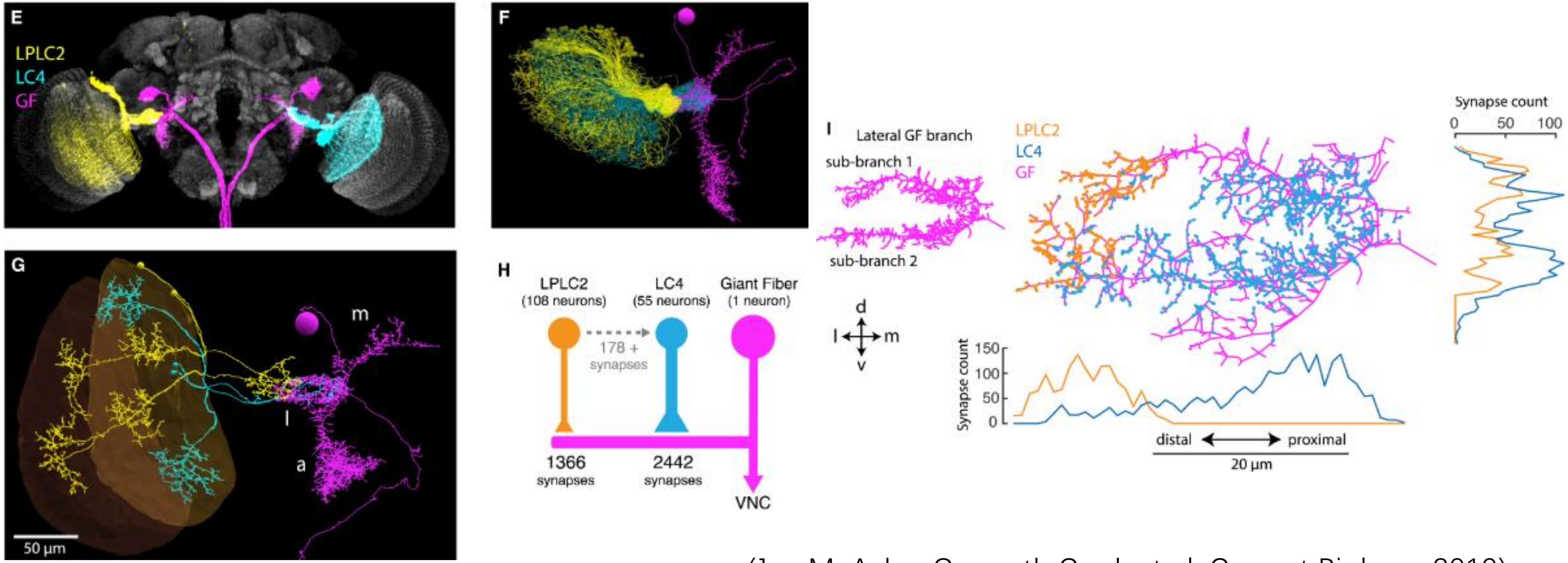
(Catherine R von Reyn, Gwyneth Card, et al. Nature Neuroscience, 2014)

LPLC2 visual projection neurons are required for giant fiber (GF)



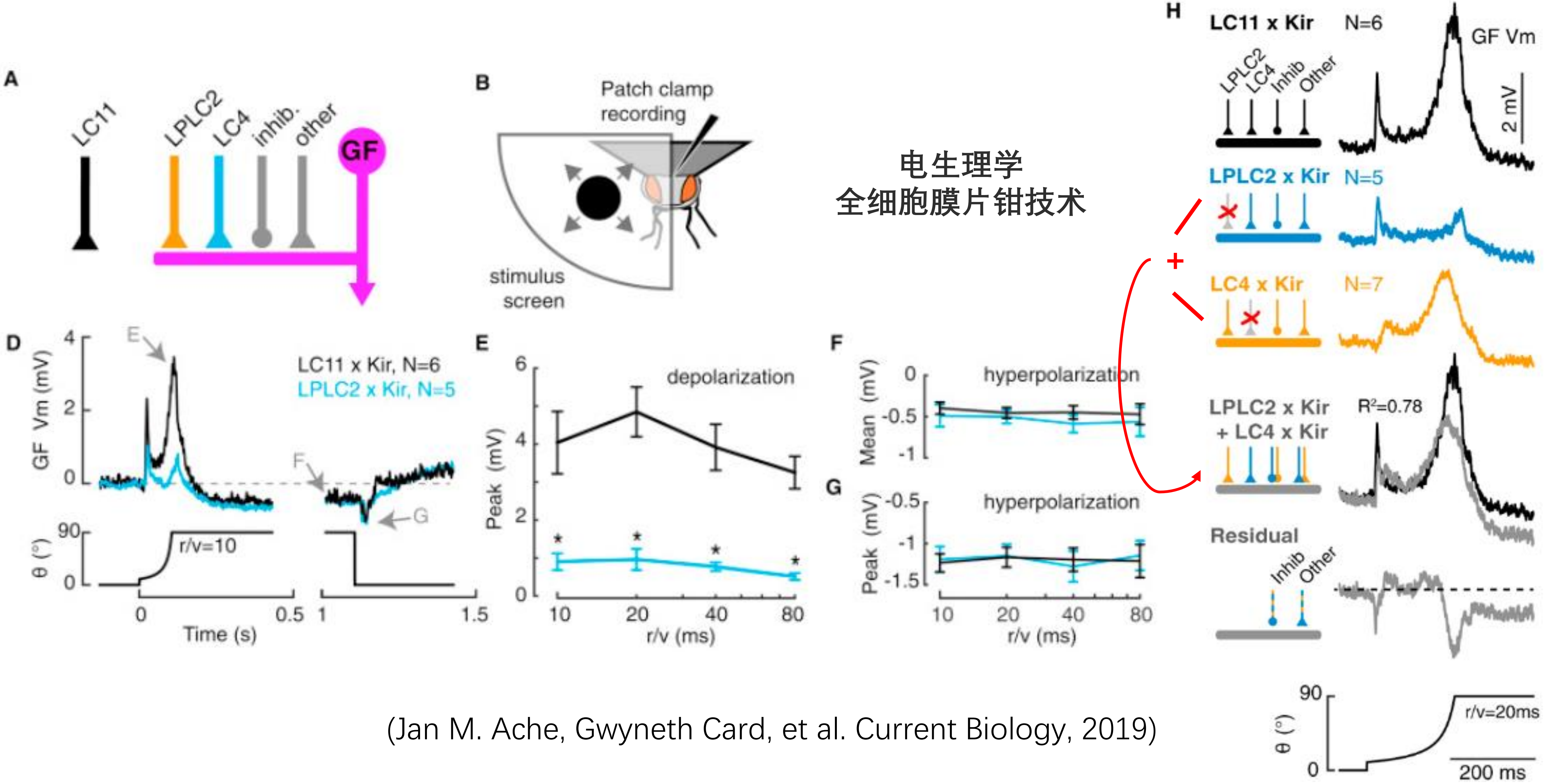
(Jan M. Ache, Gwyneth Card, et al. Current Biology, 2019)

LPLC2 and LC4 visual projection neurons are directly presynaptic to the GF



(Jan M. Ache, Gwyneth Card, et al. Current Biology, 2019)

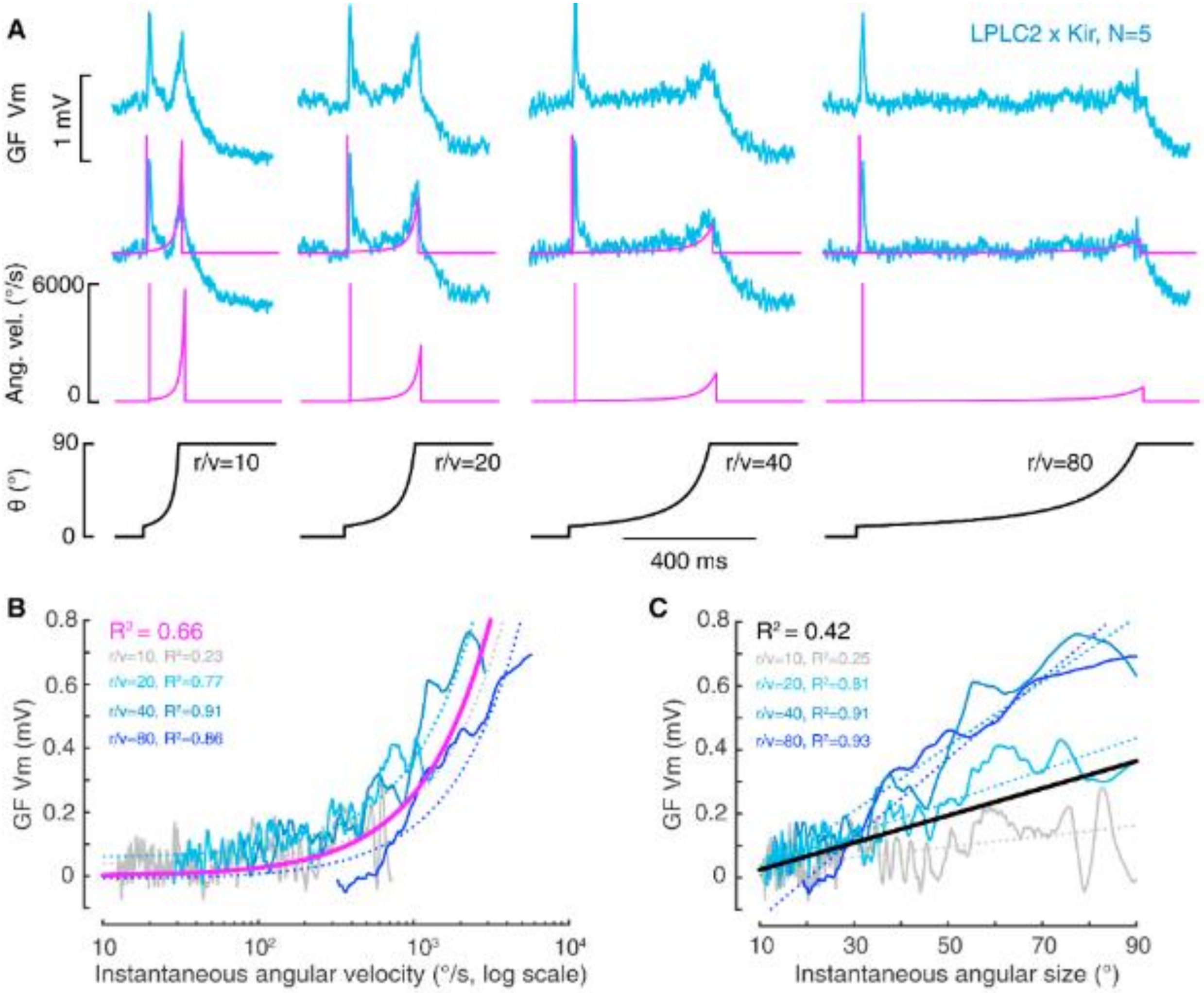
LPLC2 and LC4 provide all primary excitatory input to GF during visual looming



电生理学
全细胞膜片钳技术

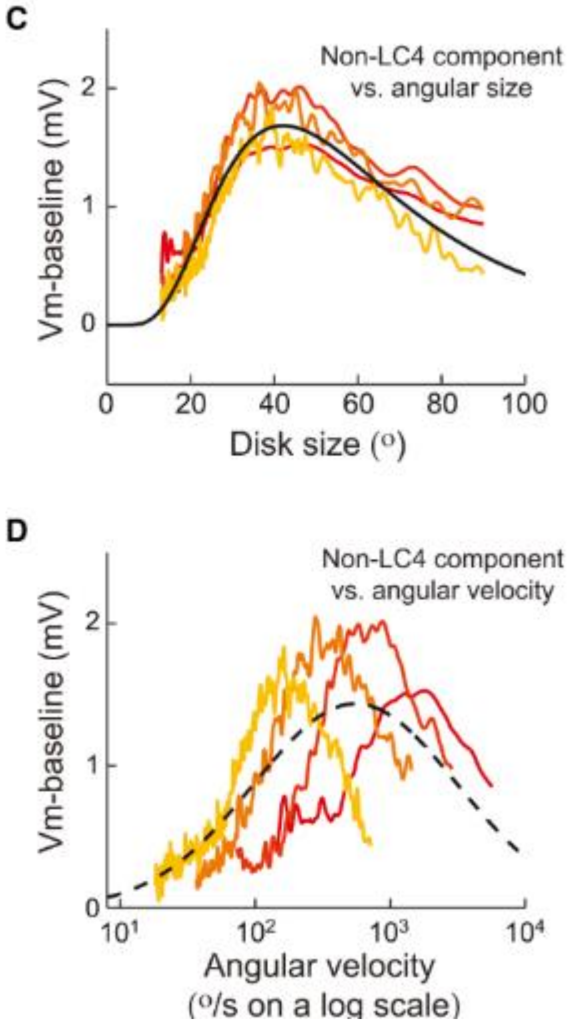
(Jan M. Ache, Gwyneth Card, et al. Current Biology, 2019)

The GF receives angular-size input from LPLC2 and angular-velocity input from LC4 during looming



LC4
（失活LPLC2）

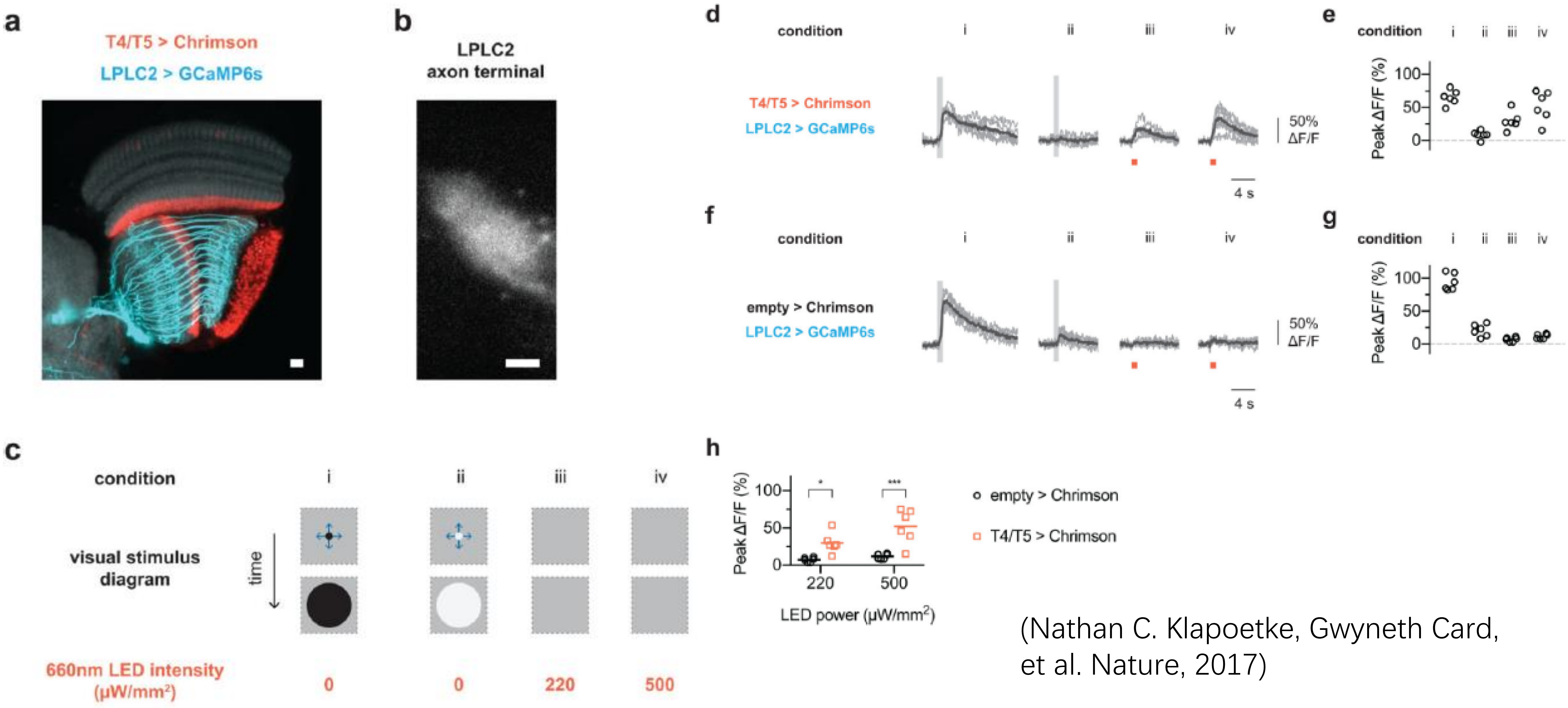
(Jan M. Ache, Gwyneth Card, et al. Current Biology, 2019)



LPLC2
（失活LC4）

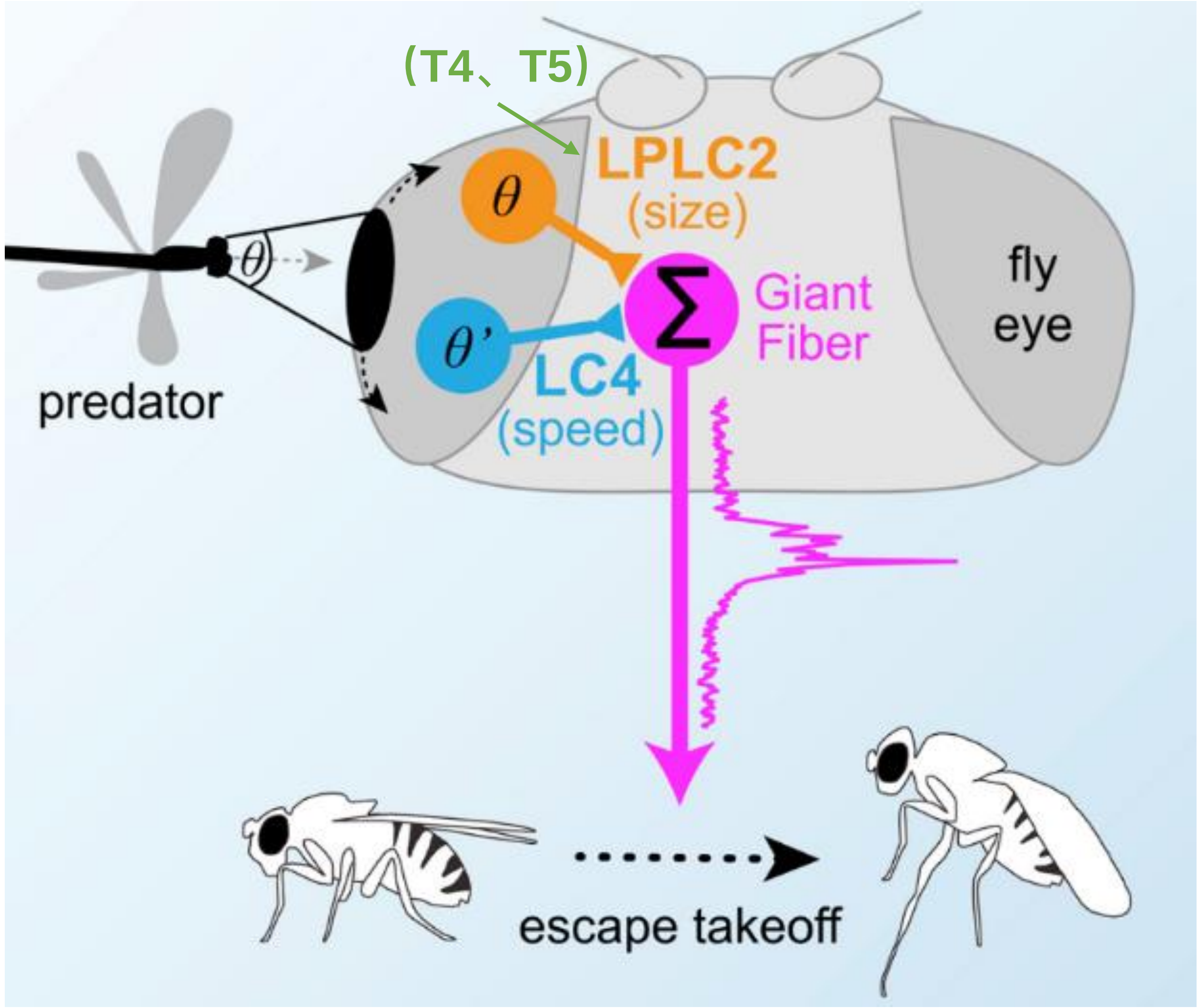
(Catherine R. von Reyn, Gwyneth Card, et al. Neuron, 2017)

T4/T5 cells provide direct excitatory inputs to LPLC2 neurons



(Nathan C. Klapoetke, Gwyneth Card, et al. Nature, 2017)

When confronted with a fast-approaching object, such as a fly swatter, resting or walking flies execute a rapid, stereotyped take-off action

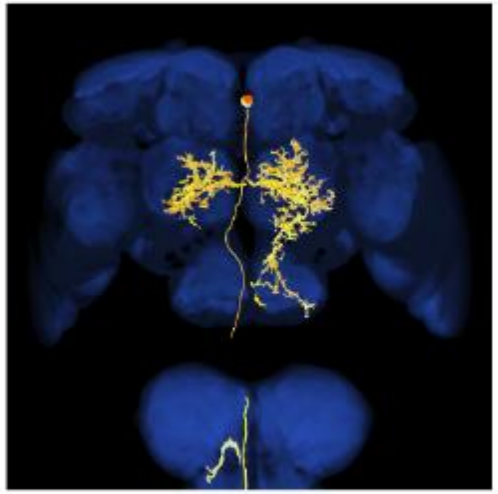


(Jan M. Ache, Gwyneth Card, et al. Current Biology, 2019)

Leader in locomotor circuits in Drosophila

Professor Barry Dickson

Professorial Research Fellow
Queensland Brain Institute
+61 7 334 66328
b.dickson@uq.edu.au
View researcher profile

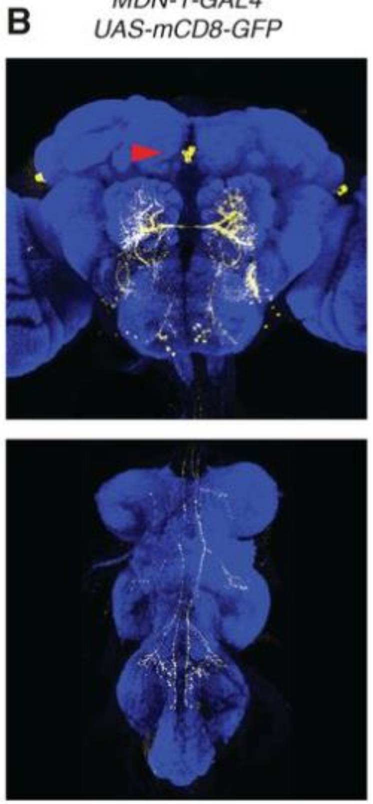


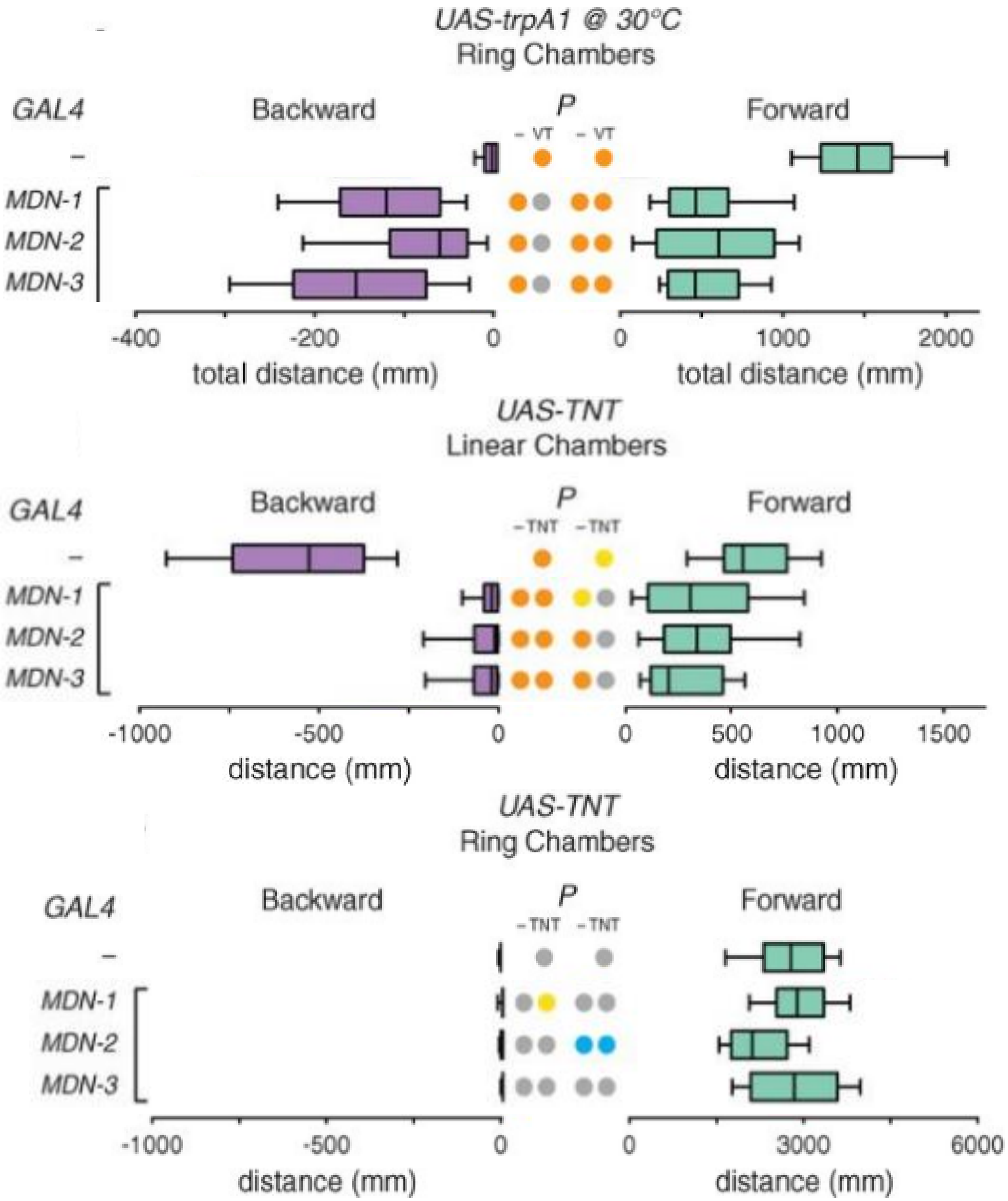
Professor Barry Dickson: Locomotor Circuits in Drosophila

The Dickson laboratory investigates the neural circuits that control walking in the fruit fly, *Drosophila melanogaster*. The goal is to understand how local circuits in the nerve cord produce rhythmic motor patterns, how these patterns are co-ordinated across each leg joint and all six legs, and how descending signals from the brain modulate these operations to alter the fly's direction, speed and gait.

Find out more

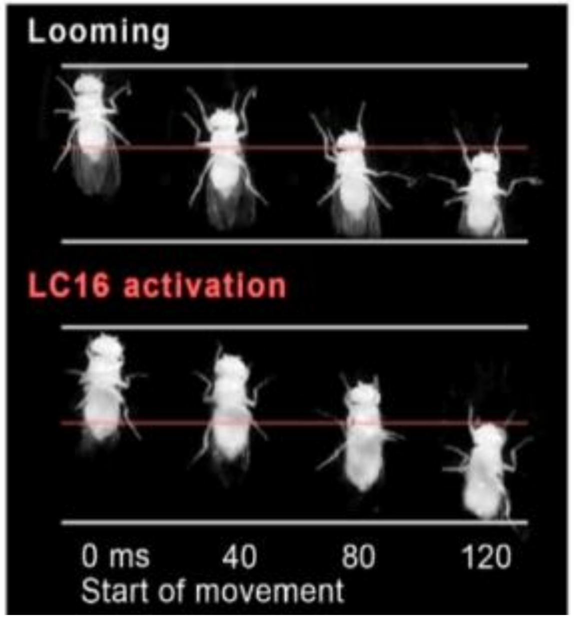
Descending neurons for backward walking in Drosophila—the moonwalker descending neuron (MDN) neurons

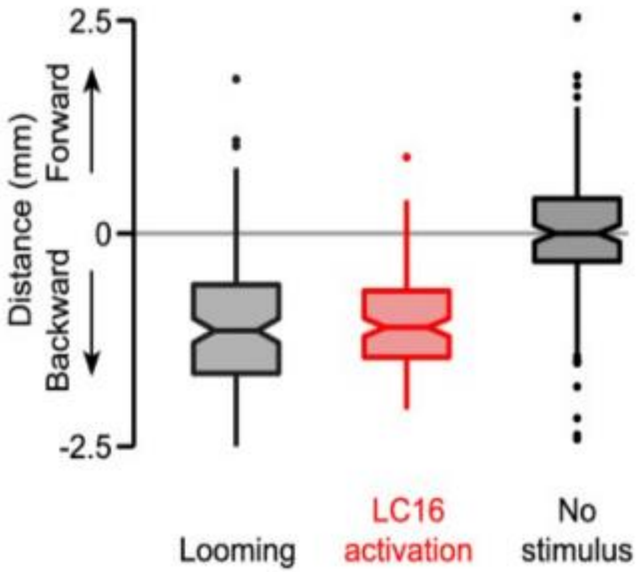


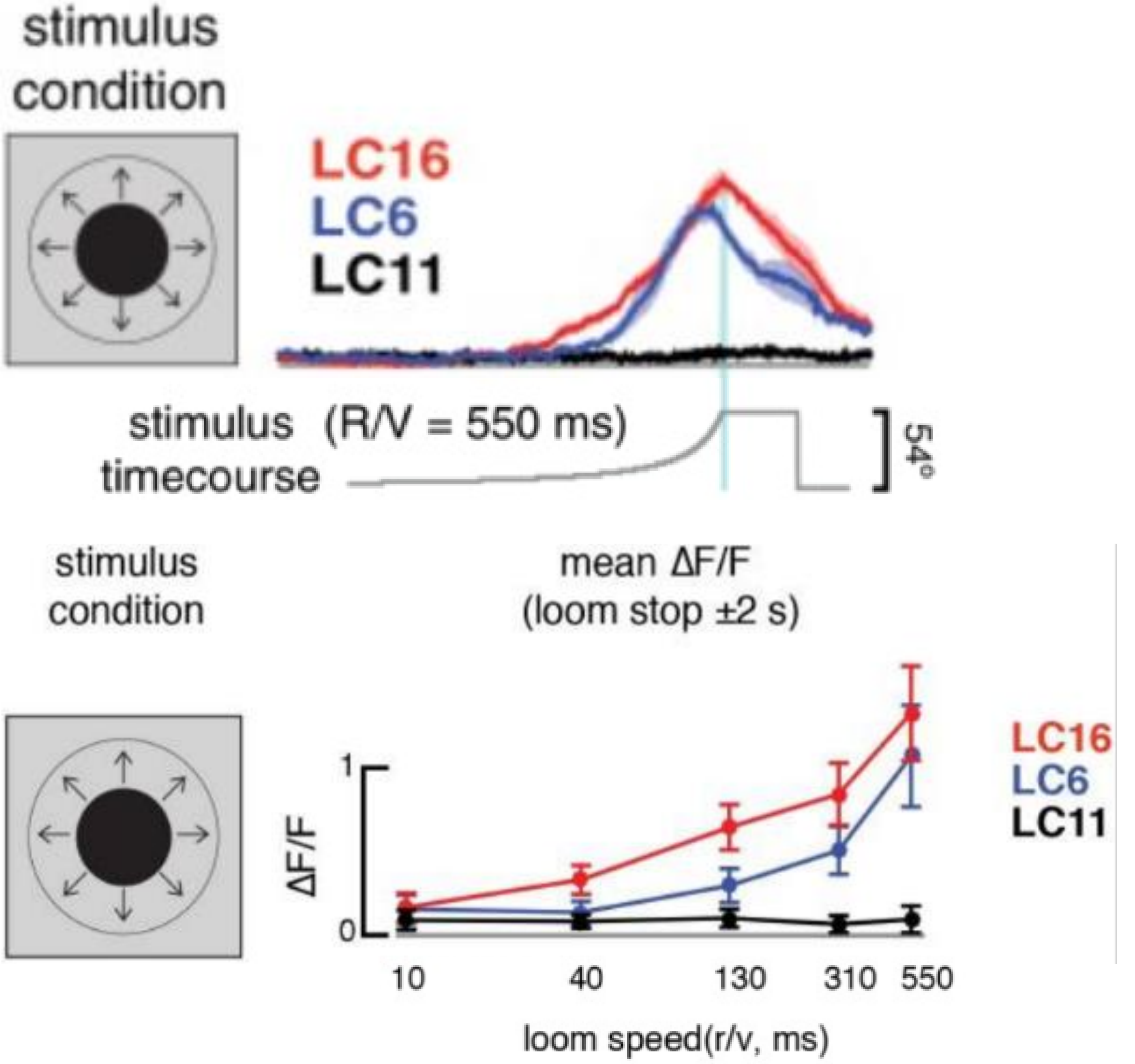


(Salil s. Bidaye, Barry J. Dickson, et al. Science, 2014)

LC16 is tuned to slower looming speeds



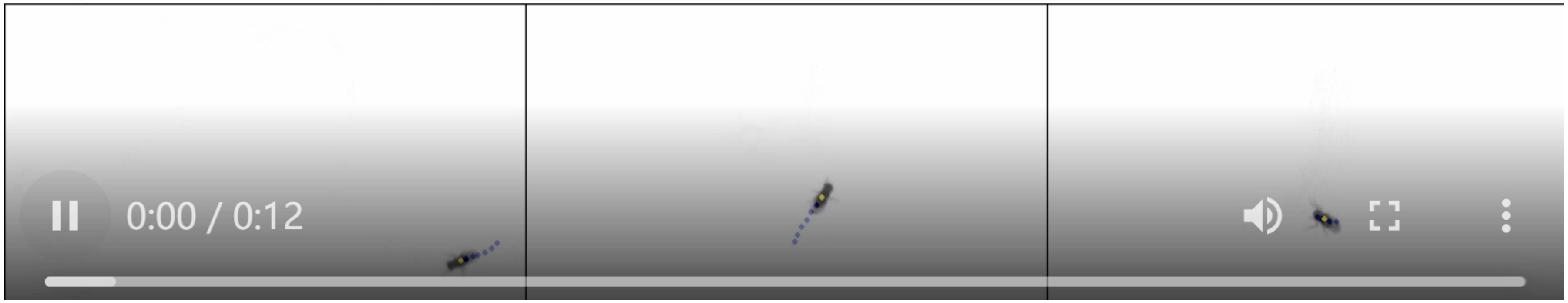


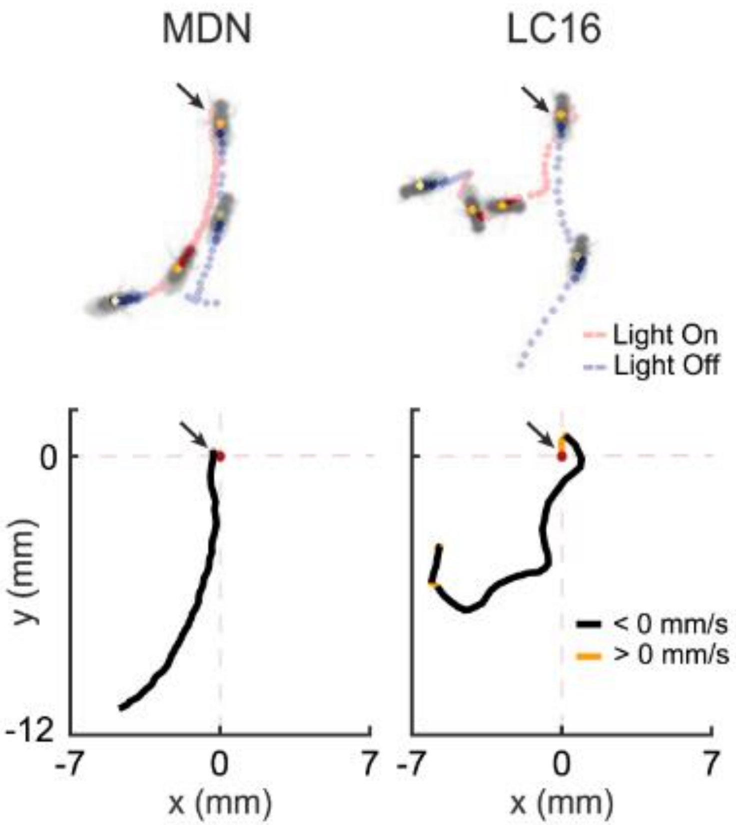


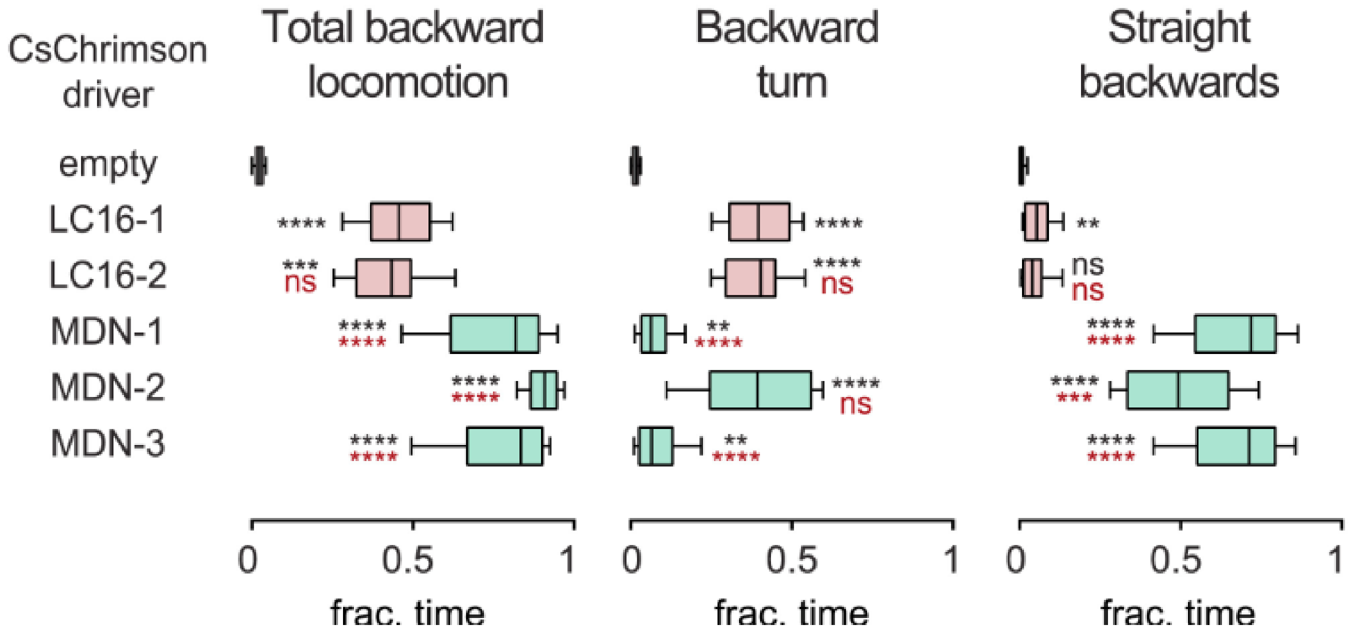
(Ming Wu, Gerald M Rubin, et al. eLife, 2016)

Lobula columnar 16 (LC16) and moonwalker descending neuron (MDN) cells trigger backward locomotion during looming

pBDPGAL4U > UAS-CsChrimson LC16-1 > UAS-CsChrimson MDN-2 > UAS-CsChrimson

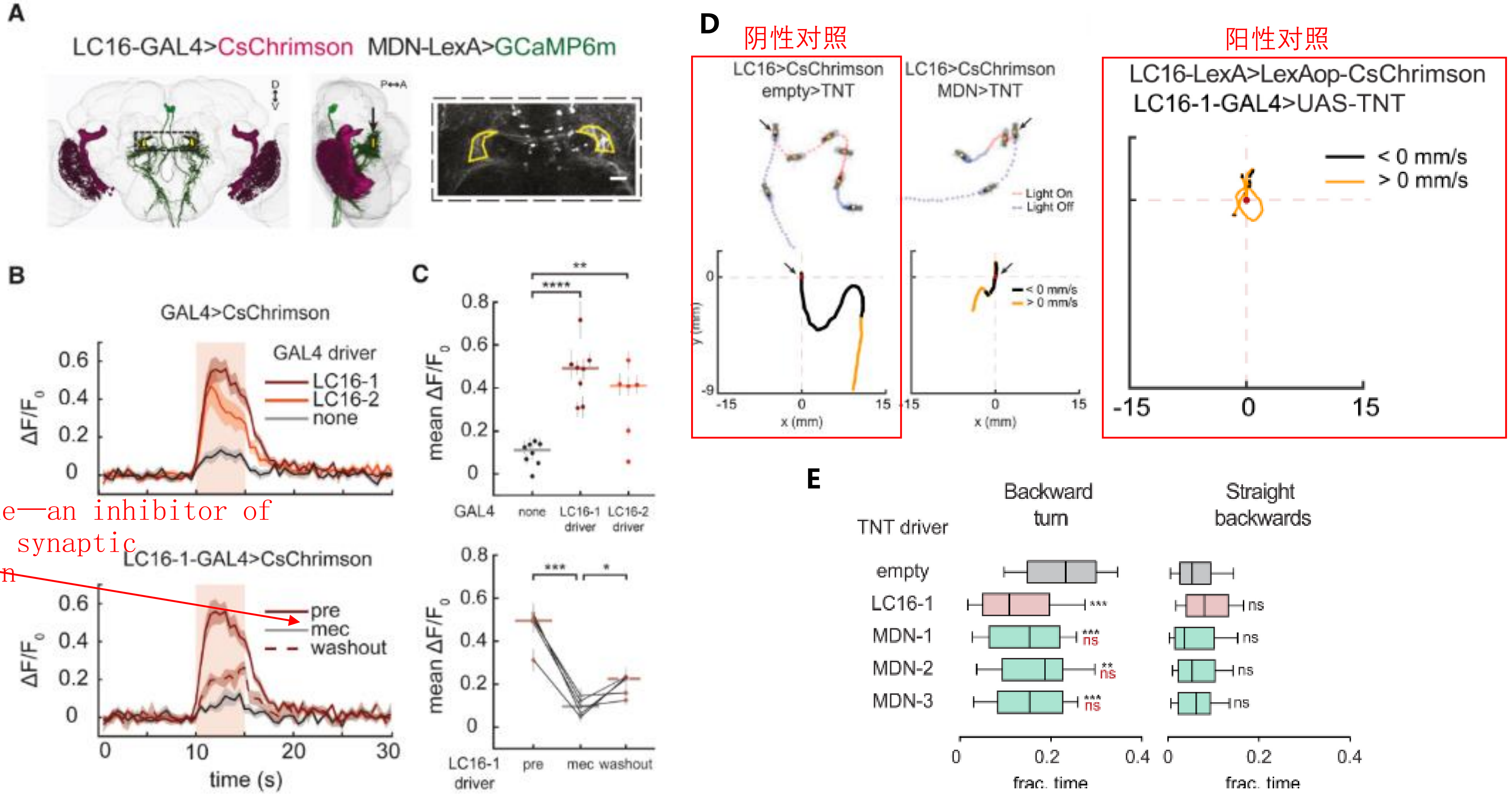






(Rajyashree Sen, Barry J. Dickson, et al. Current Biology, 2017)

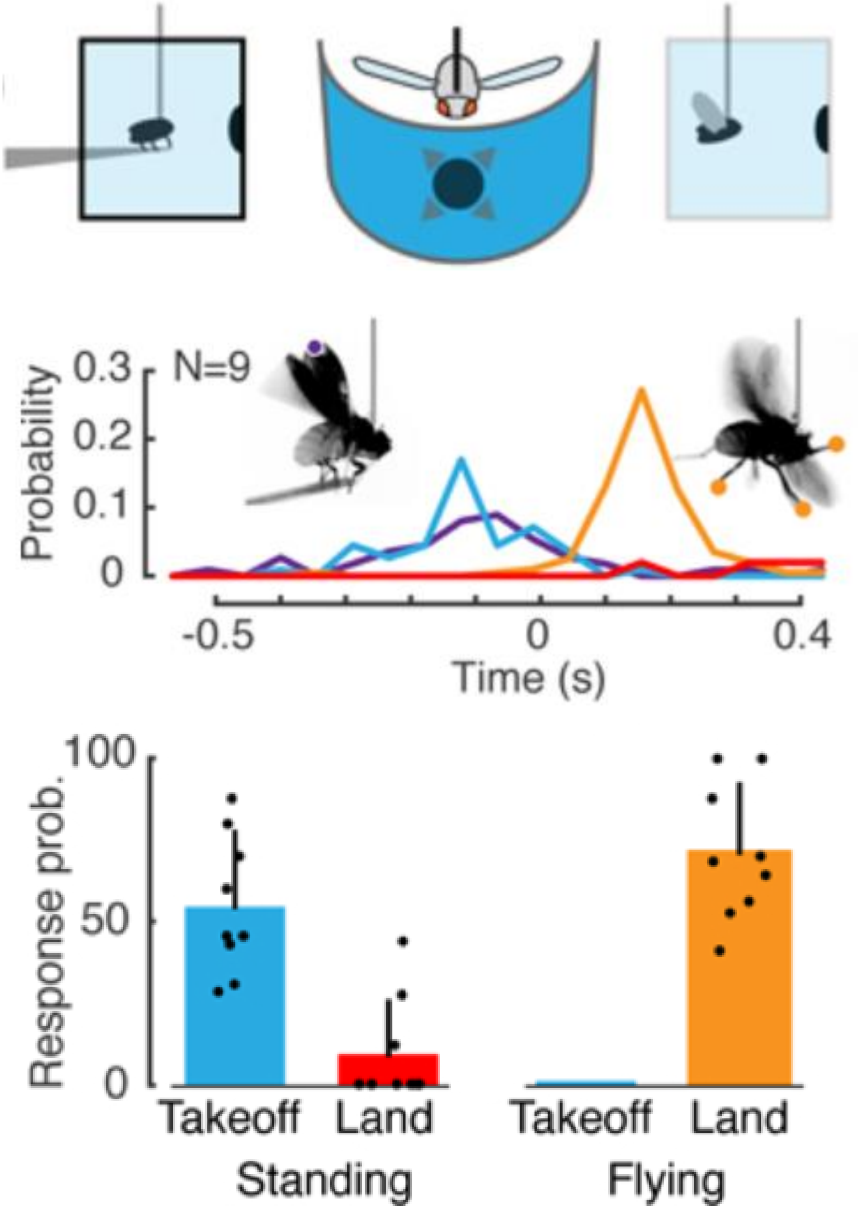
LC16 neurons activate MDN via excitatory cholinergic input to trigger backward movement

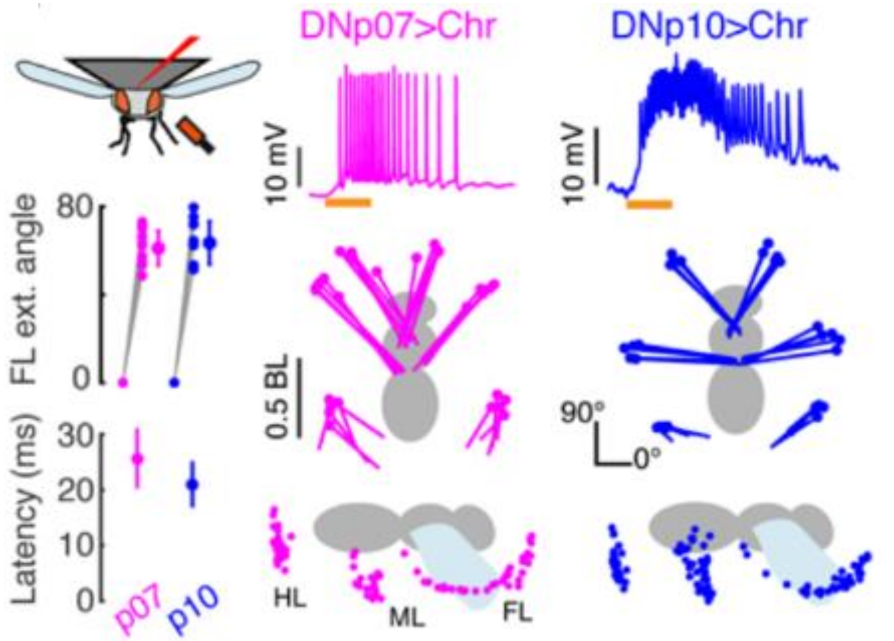


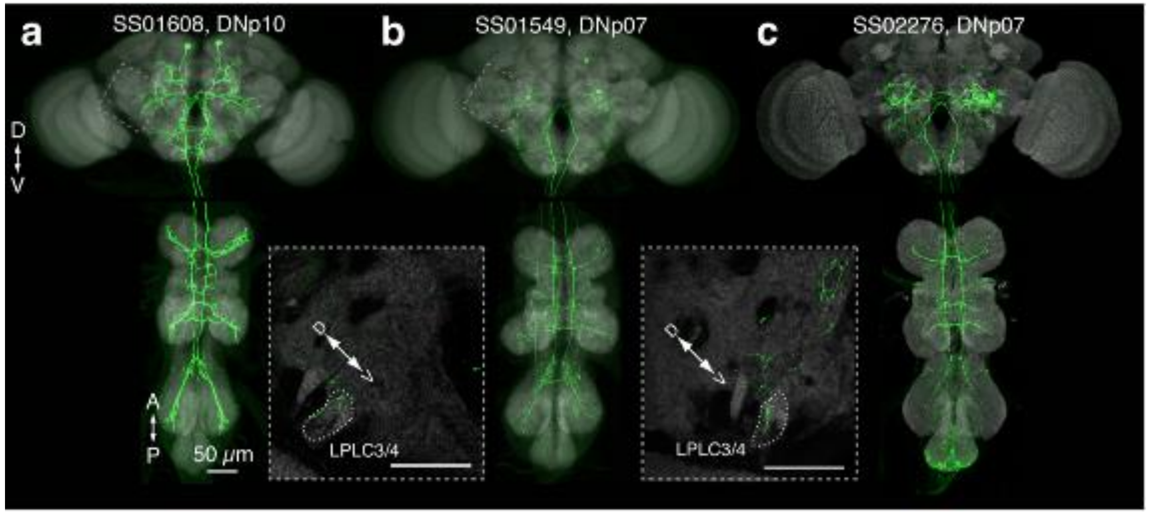
mecamylamine—an inhibitor of cholinergic synaptic transmission

(Rajyashree Sen, Barry J. Dickson, et al. Current Biology, 2017)

DNp07 and DNp10 contribute to landing responses





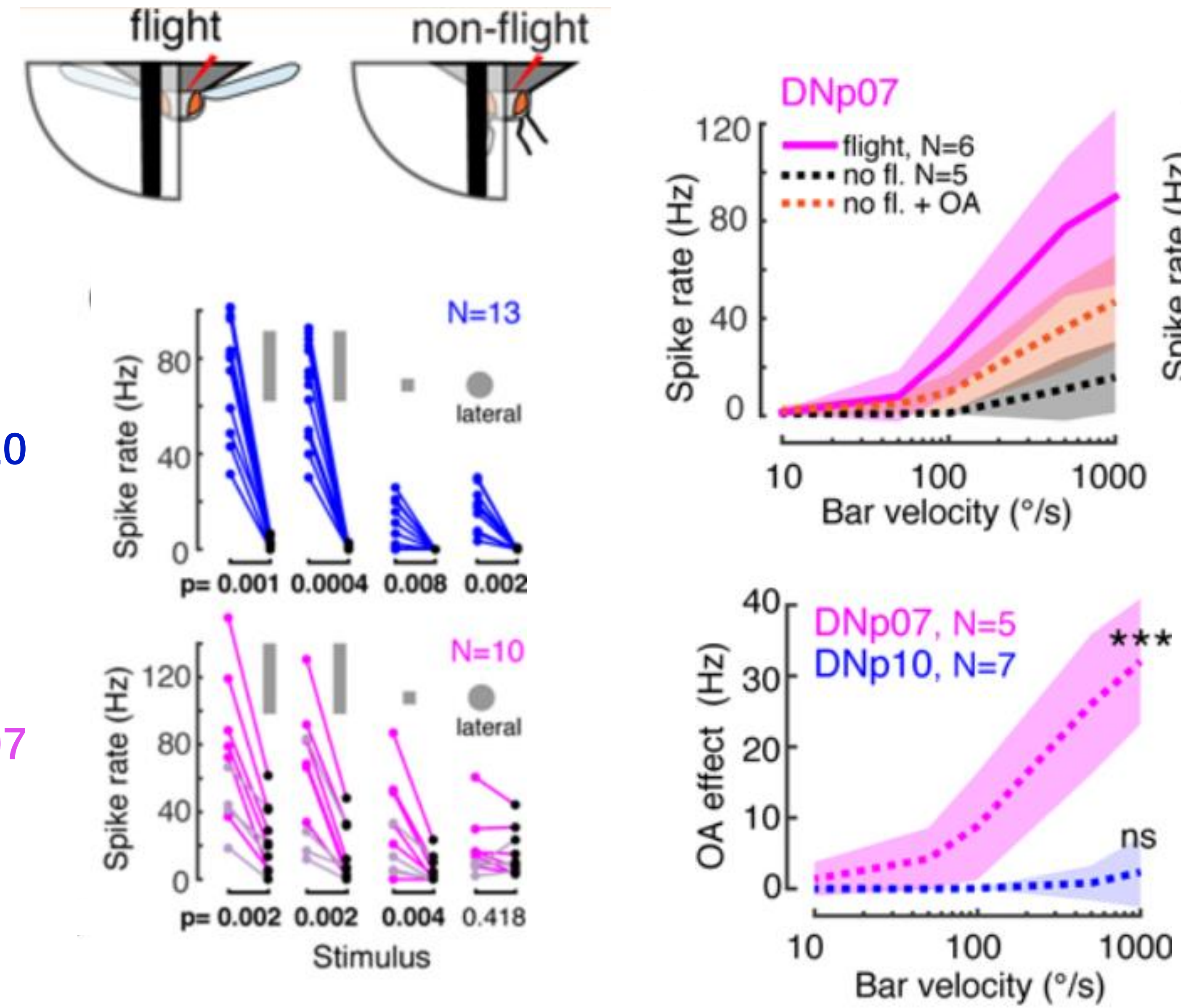


(Jan M. Ache, Gwyneth M. Card, et al. Nature Neuroscience, 2019)

Visual responses of landing DNs are gated by flight

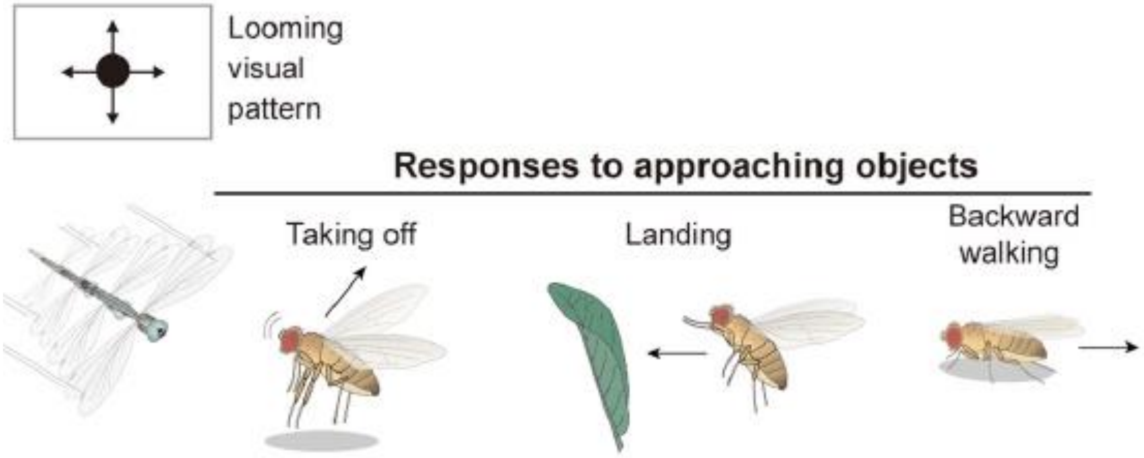
DNP10

DNP07



(Jan M. Ache, Gwyneth M. Card, et al. Nature Neuroscience, 2019)

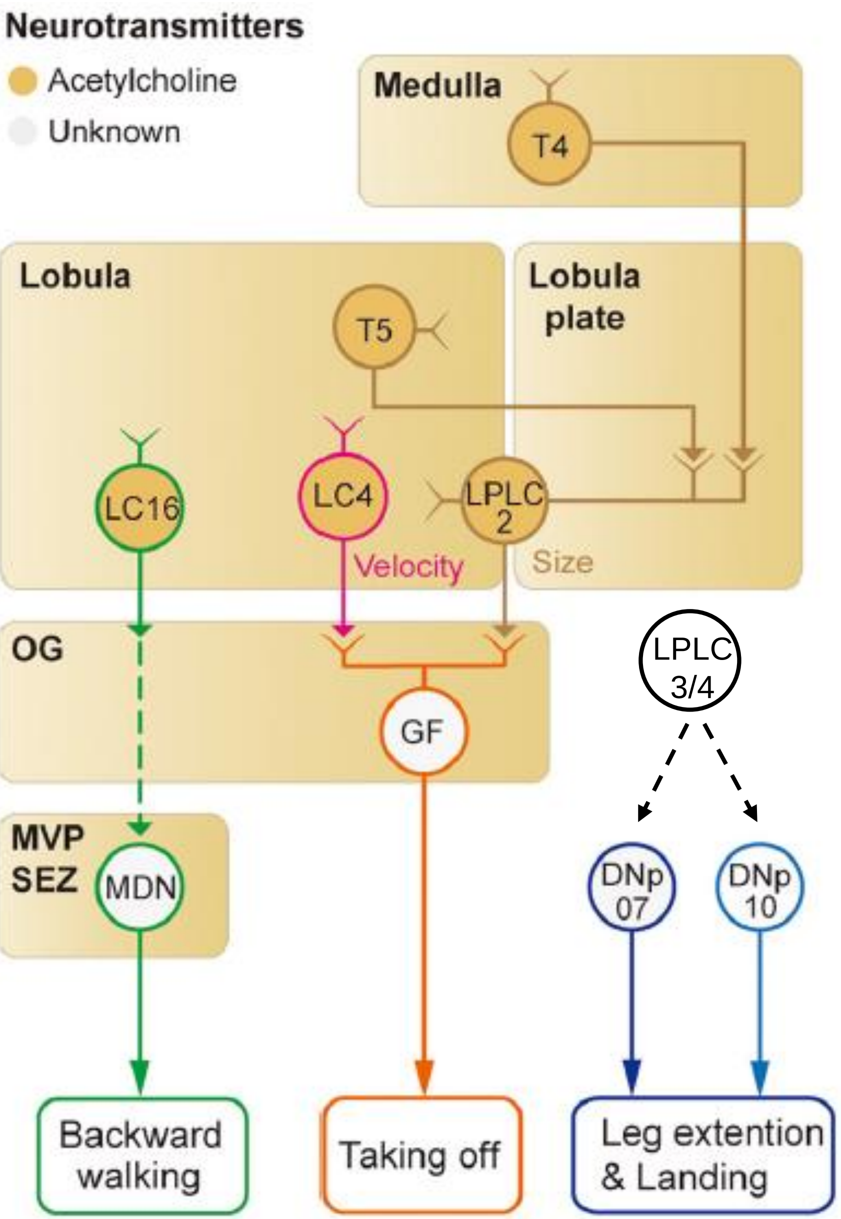
Summary



Flies in resting or walking：
a fast-approaching object☞Taking off
a slowly approaching object☞Backward walking

Flies in flight：
a looming visual pattern☞Landing

(Leesun Ryu, et al.
Front Neurosci, 2022)

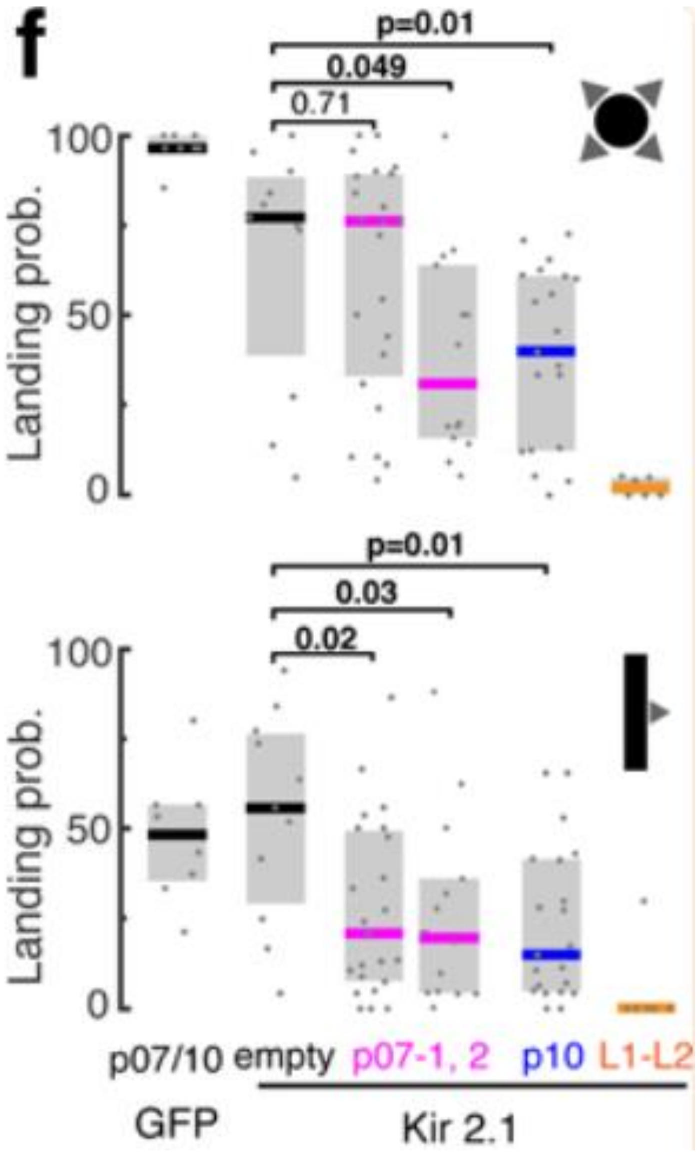


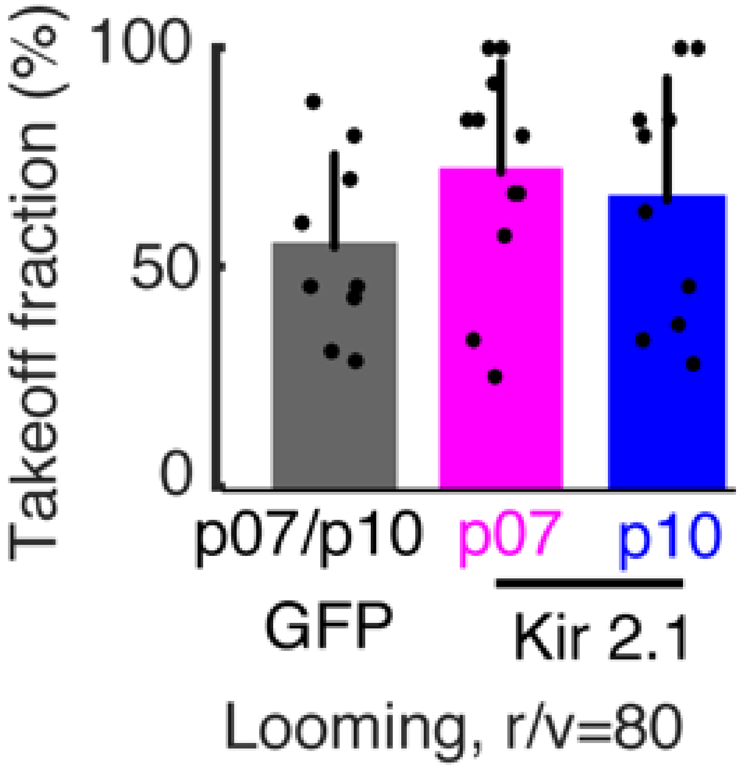
References

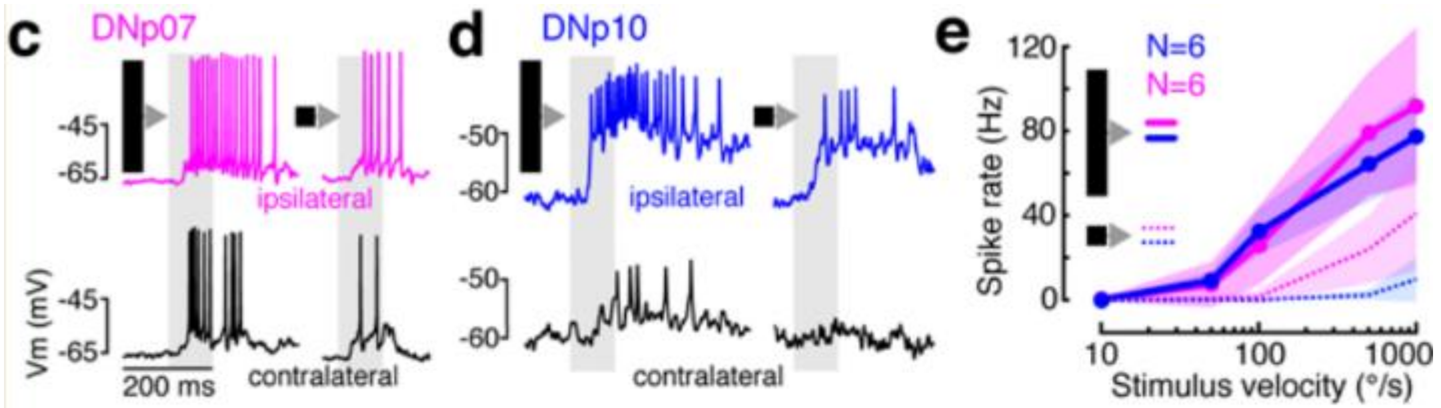
1. Ache, J.M., Namiki, S., Lee, A., Branson, K., and Card, G.M. (2019a). State-dependent decoupling of sensory and motor circuits underlies behavioral flexibility in Drosophila. Nature neuroscience *22*, 1132-1139.
2. Ache, J.M., Polsky, J., Alghailani, S., Parekh, R., Breads, P., Peek, M.Y., Bock, D.D., von Reyn, C.R., and Card, G.M. (2019b). Neural Basis for Looming Size and Velocity Encoding in the Drosophila Giant Fiber Escape Pathway. Curr Biol *29*, 1073-1081.e1074.
3. Bidaye, S.S., Machacek, C., Wu, Y., and Dickson, B.J. (2014). Neuronal control of Drosophila walking direction. Science *344*, 97-101.
4. Card, G., and Dickinson, M.H. (2008). Visually mediated motor planning in the escape response of Drosophila. Curr Biol *18*, 1300-1307.
5. Dombrovski, M., Peek, M.Y., Park, J.Y., Vaccari, A., Sumathipala, M., Morrow, C., Breads, P., Zhao, A., Kurmangaliyev, Y.Z., Sanfilippo, P.*, et al.* (2023). Synaptic gradients transform object location to action. Nature *613*, 534-542.
6. Graham, D., and Epstein, S. (1985). BEHAVIOR AND MOTOR OUTPUT FOR AN INSECT WALKING ON A SLIPPERY SURFACE .2. BACKWARD WALKING. Journal of Experimental Biology *118*, 287-296.
7. Klapoetke, N.C., Nern, A., Peek, M.Y., Rogers, E.M., Breads, P., Rubin, G.M., Reiser, M.B., and Card, G.M. (2017). Ultra-selective looming detection from radial motion opponency. Nature *551*, 237-241.
8. Ryu, L., Kim, S.Y., and Kim, A.J. (2022). From Photons to Behaviors: Neural Implementations of Visual Behaviors in Drosophila. Front Neurosci *16*, 883640.
9. Sen, R., Wu, M., Branson, K., Robie, A., Rubin, G.M., and Dickson, B.J. (2017). Moonwalker Descending Neurons Mediate Visually Evoked Retreat in Drosophila. Curr Biol *27*, 766-771.
10. von Reyn, C.R., Breads, P., Peek, M.Y., Zheng, G.Z., Williamson, W.R., Yee, A.L., Leonardo, A., and Card, G.M. (2014). A spike-timing mechanism for action selection. Nature neuroscience *17*, 962-970.
11. von Reyn, C.R., Nern, A., Williamson, W.R., Breads, P., Wu, M., Namiki, S., and Card, G.M. (2017). Feature Integration Drives Probabilistic Behavior in the Drosophila Escape Response. Neuron *94*, 1190-1204.e1196.
12. Wu, M., Nern, A., Williamson, W.R., Morimoto, M.M., Reiser, M.B., Card, G.M., and Rubin, G.M. (2016). Visual projection neurons in the Drosophila lobula link feature detection to distinct behavioral programs. Elife *5*.

Thanks！

Supplementary Data







Supplementary Data