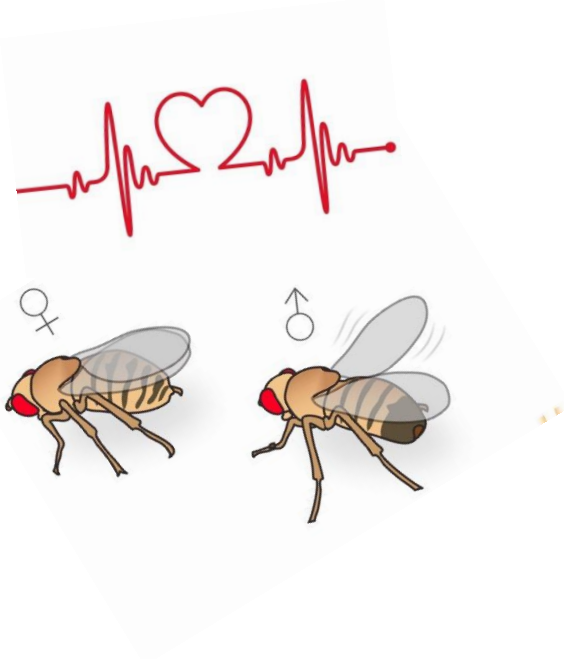
Journal Club

苏祥彬　韩彩红　陈江涛

2022.03.31

Courtship song in *Drosophila*

- The function and overview of courtship song—Su Xiangbin
- Generation of courtship song—Chen Jiangtao
- Female response to courtship song—Han Caihong



The function and overview of courtship song

苏祥彬

2022.03.31

Animal ardour

图源： https://cn.bing.com

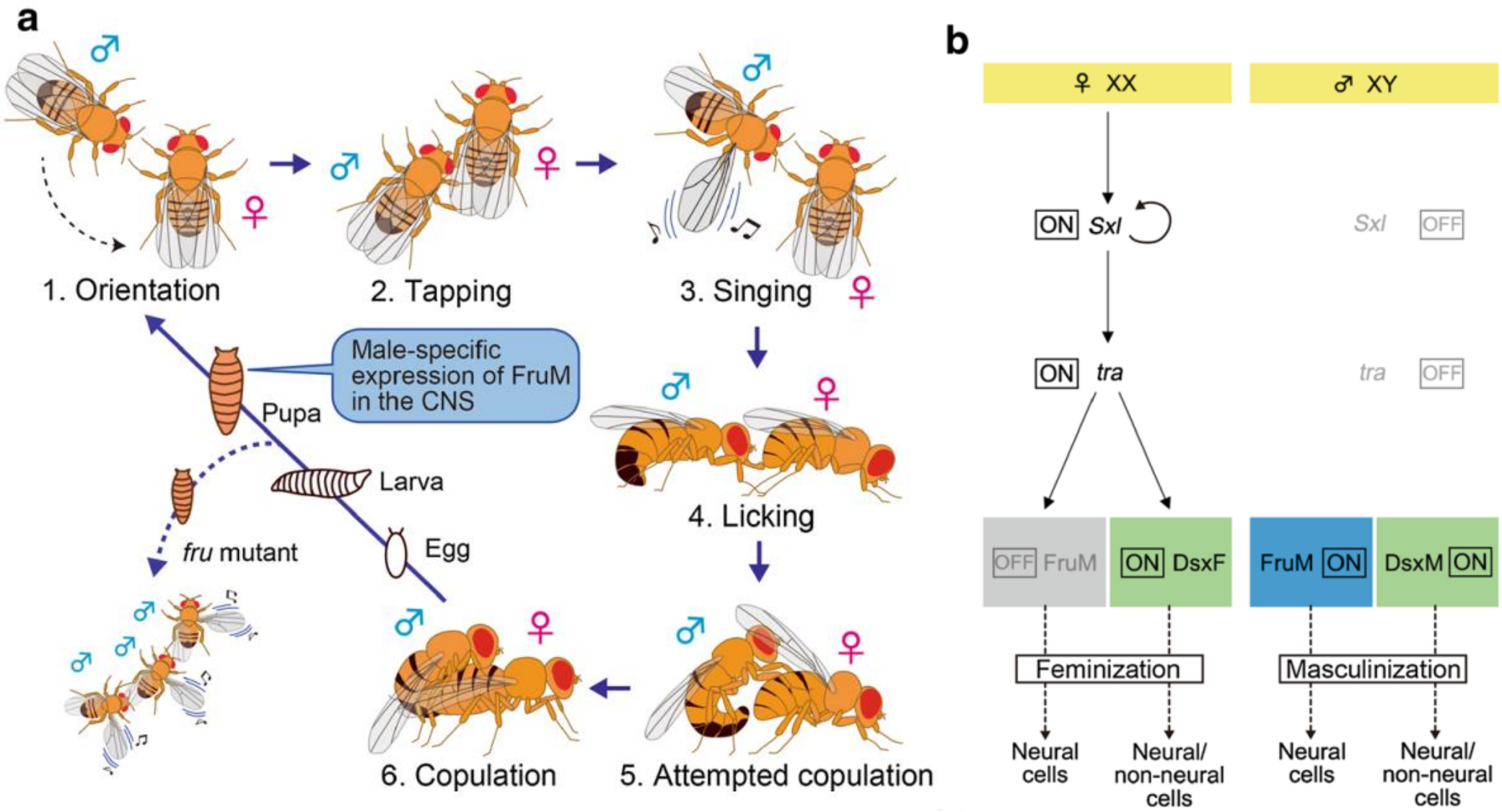
Signaling, Differentiation and Selection

Reproduction

图源：https://cn.bing.com

To succeed, show more...

Courtship ritual and neural sex determination in *Drosophila*



Daisuke Yamamoto and Kosei Sato and Masayuki Koganezawa. (2014)

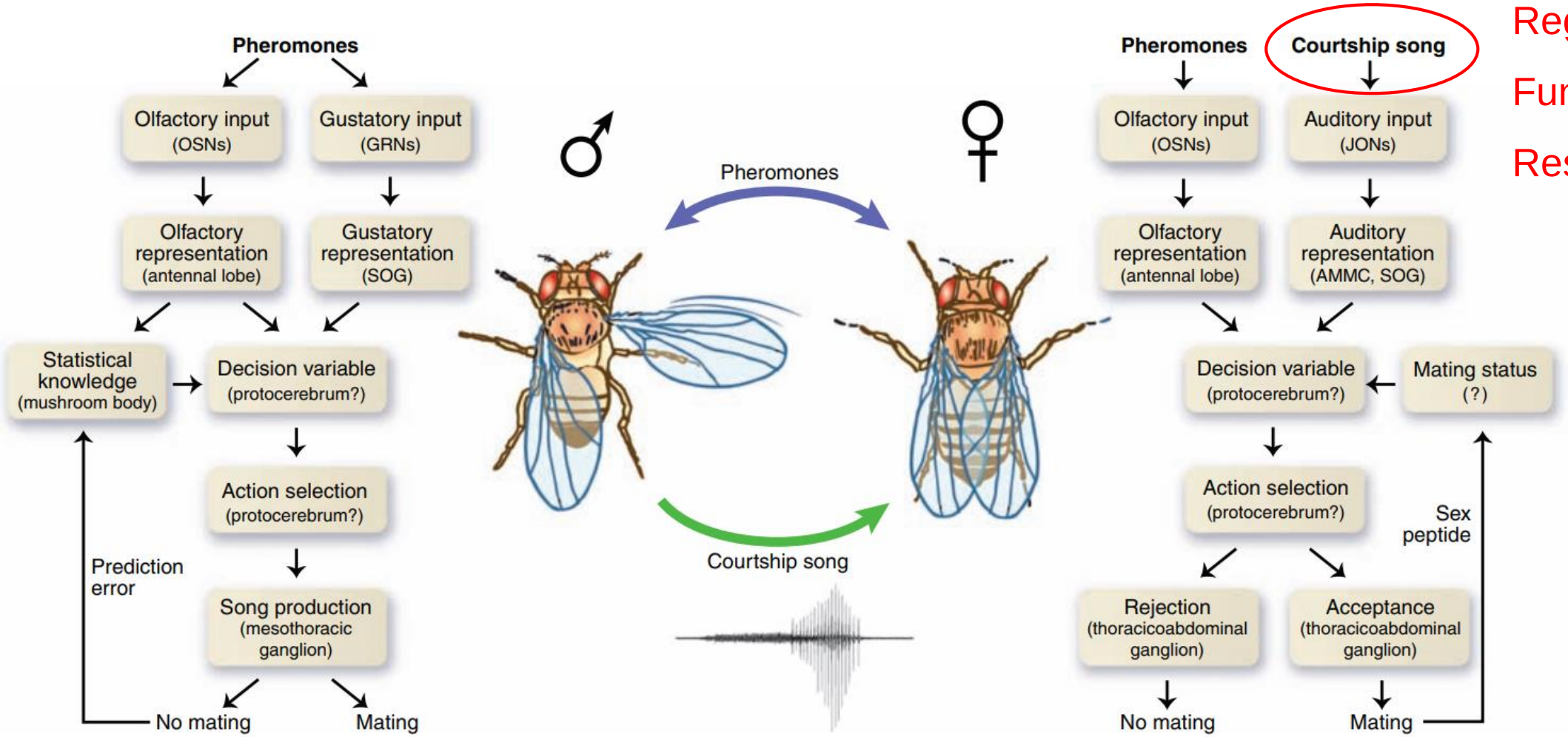
Elements of *Drosophila* male (left) and female (right) mating decisions

Generation

Regulation

Function

Response



Barry J. Dickson. (2008)

The discovery of courtship songs

Science. 1962 Aug 31;137(3531):677-8. doi: 10.1126/science.137.3531.677.

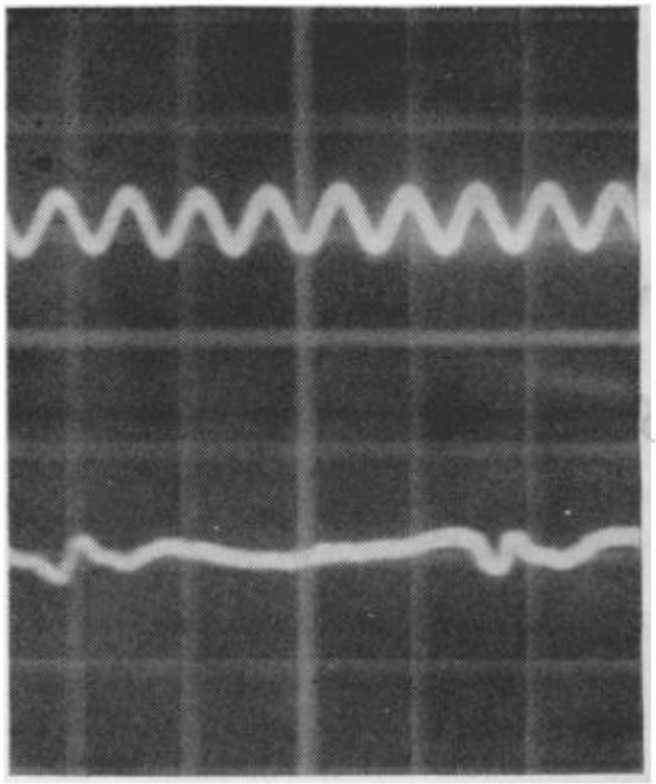
Nature of the Sound Produced by Drosophila melanogaster during Courtship

H H Shorey

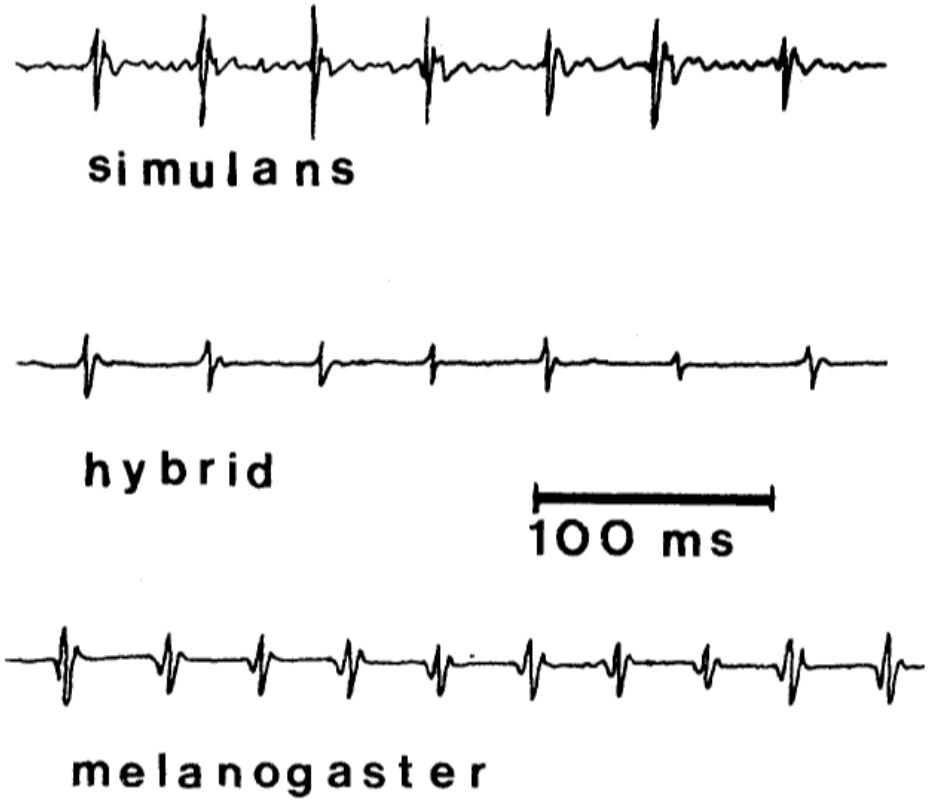
PMID: 17770950 DOI: 10.1126/science.137.3531.677

Abstract

The wing vibrations of courting male Drosophila melanogaster Meigen produced pulsations of sound, with each pulse apparently caused by 1 to 2 cycles of wing movement. The average repetition rate at 25 degrees C was 29.8 pulses per second. The rate was dependent on temperature, increasing at 1.4 pulses per additional degree Celsius.



Oscilloscope records of the songs of males of *D. simulans*, *D. melanogaster*, and their hybrid

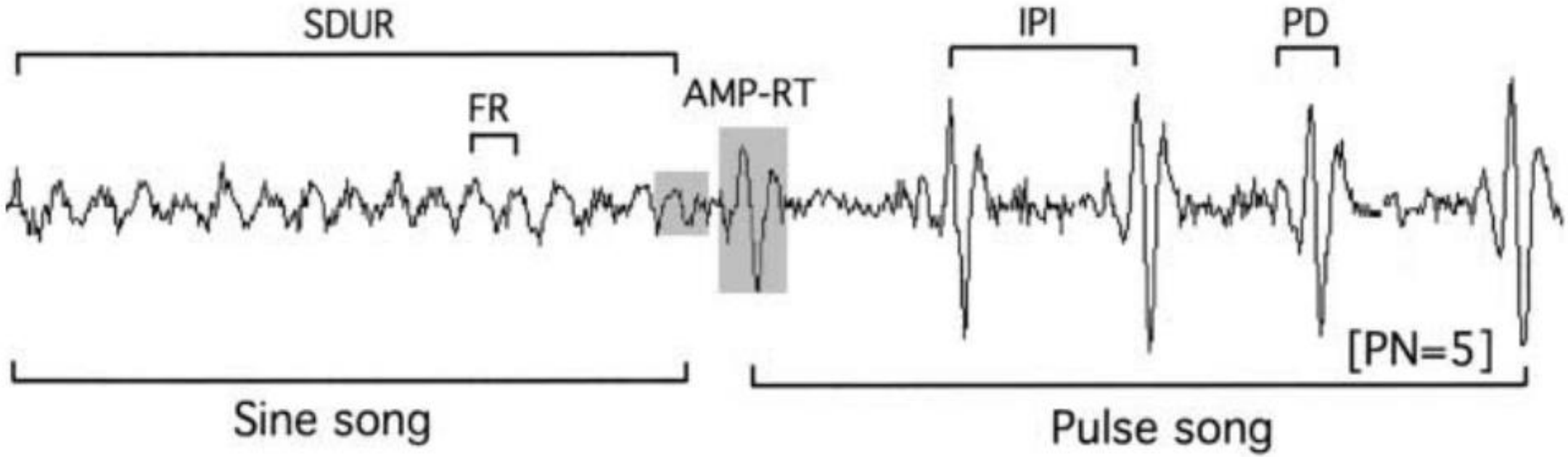


Florian von Schilcher and Aubrey Manning, (1975)

Table III. "Interpulse Intervals" in Courtship Song and Wingbeat Frequency in Flight of the Males of the Two Species and Their Hybrid

	Ipi ± SE	Wingbeat frequency ± SE (cycles/sec)
D. melanogaster	34.6 ± 0.4	218.3 ± 2.4
D. simulans	48.7 ± 1.2	252.7 ± 2.9
Hybrid	47.7 ± 1.2	240.6 ± 2.6

Courtship Song components of Males



Eran Tauberá and Daniel F. Eberl, (2001)

SDUR/sine duration FR/carrier frequency of the sine song

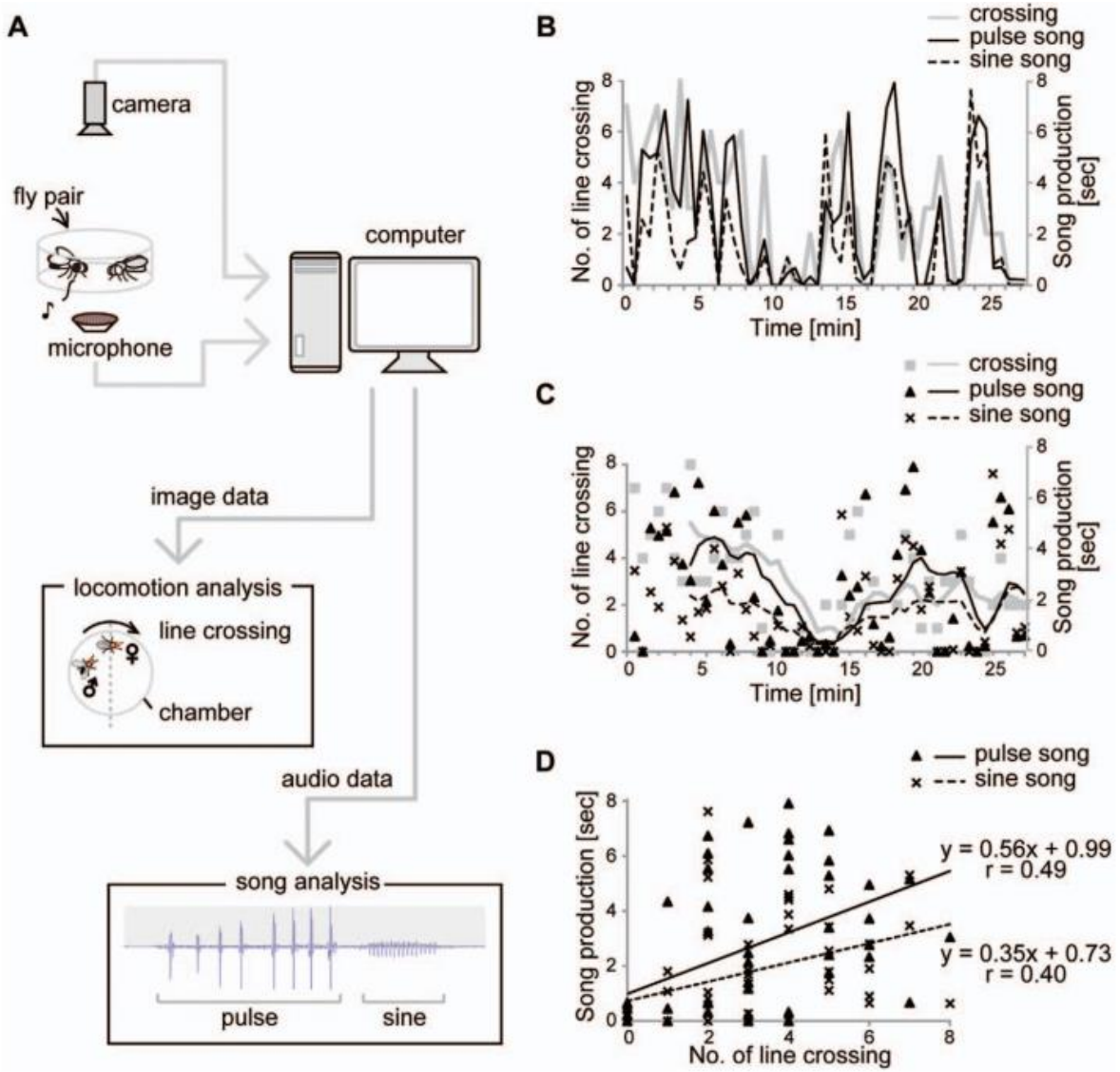
AMP-RT/amplitude ratio between sine and pulse song

IPI/inter-pulse interval PD/pulse duration

PN/number of pulses in a train

Regulation of courtship song

— Female movement



Alexander R. Trott, et al., (2012)

How courtship song are regulated by female cues?

Generation of courtship song—Chen Jiangtao

Why did we study courtship songs?

Courtship song in *Drosophila melanogaster*: a differential effect on male and female

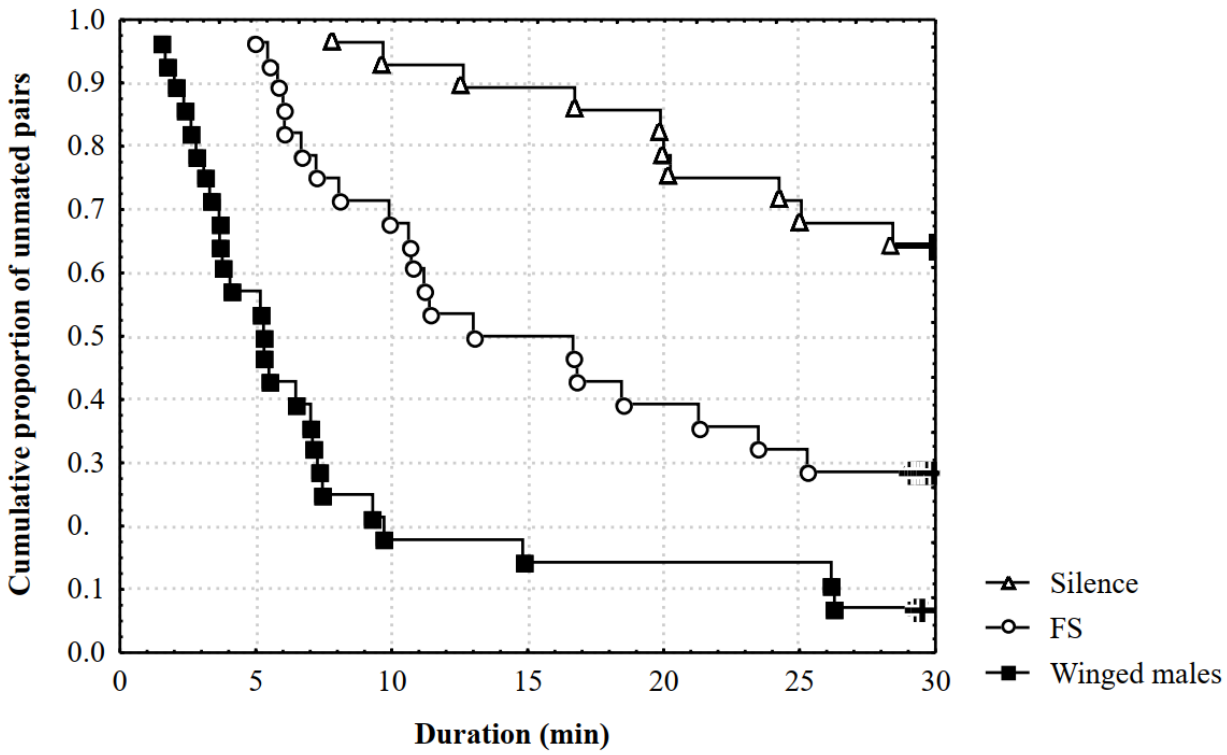
The role of courtship song for female

— Copulation

Table I. Thirty-Minute Copulation Percentages of *rsd* Flies and Controls[a]

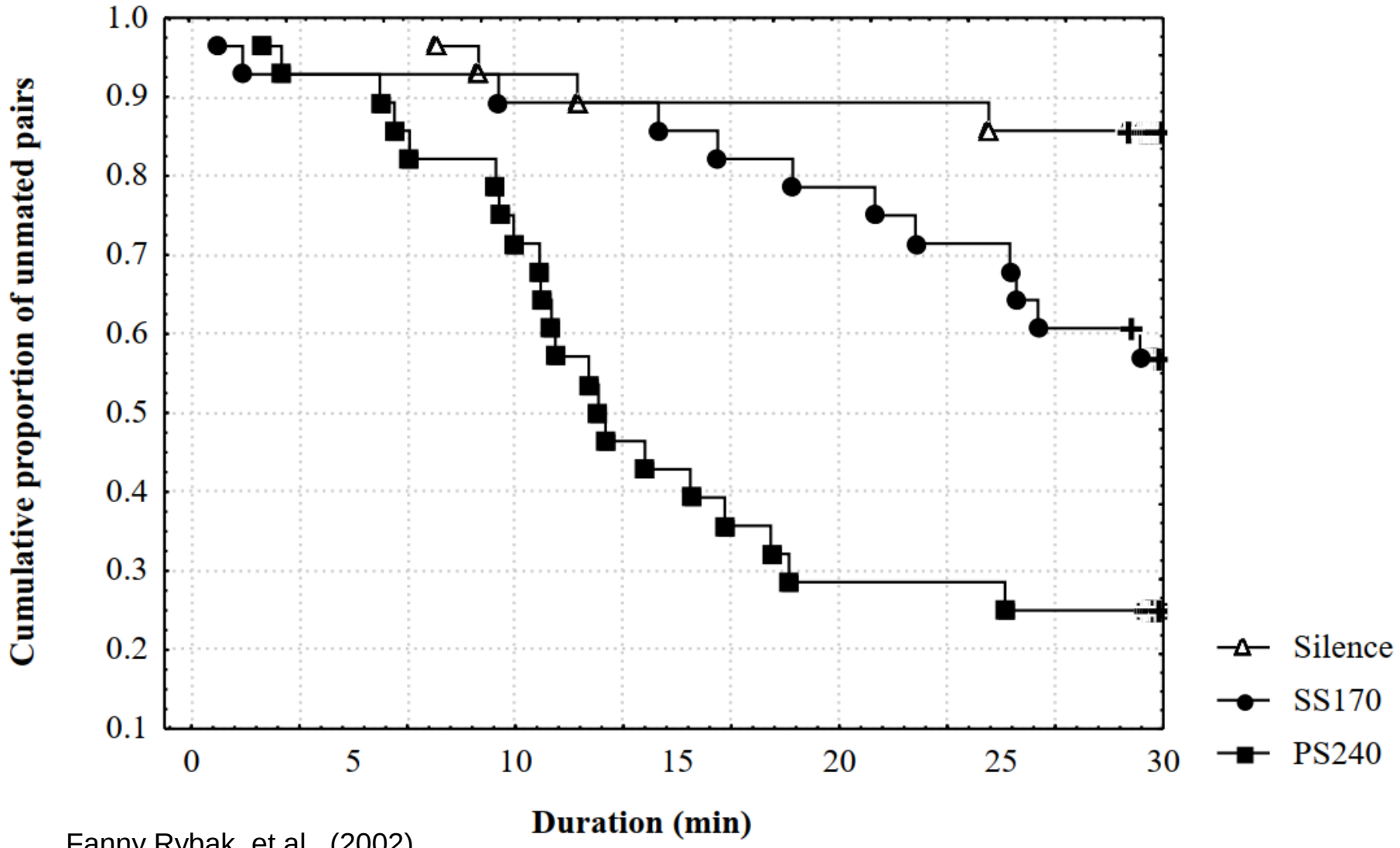
Male	Female	Fraction copulating	Percentage copulating*
CS	CS	53/75	71[a,b]
rsd	CS	2/75	3[c]
CS (wingless)	CS	4/50	8
rsd (wingless)	CS	1/50	2
CS	*rsd*	69/75	92[a,d]
CS	*rsd* (BG)	67/75	89[b]
rsd	*rsd*	13/75	17[c]
CS (wingless)	*rsd*	10/50	20[d]
rsd (wingless)	*rsd*	9/50	18

Scott P. McRobert, Fred B. Sehnee and Laurie Tompkins, (1995)



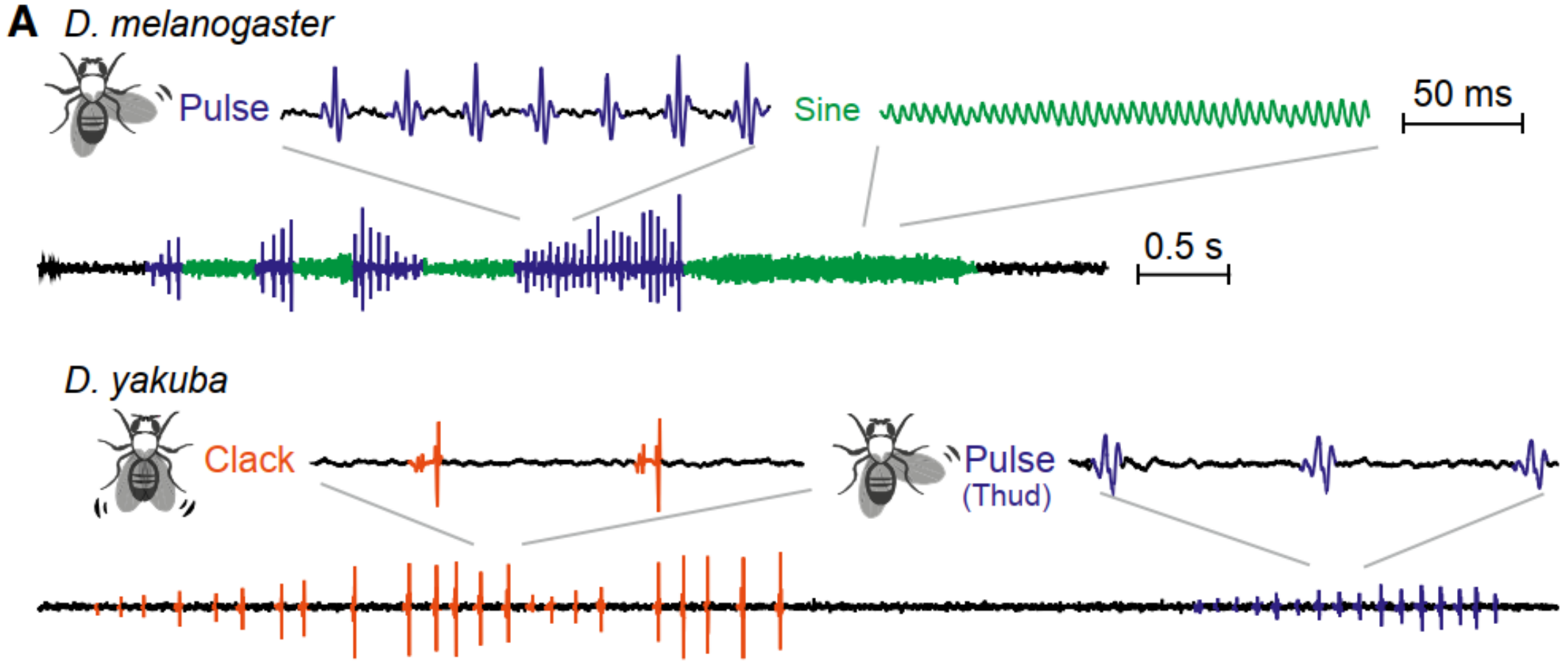
Fanny Rybak, et al., (2002)

The respective importance of pulse and sine song



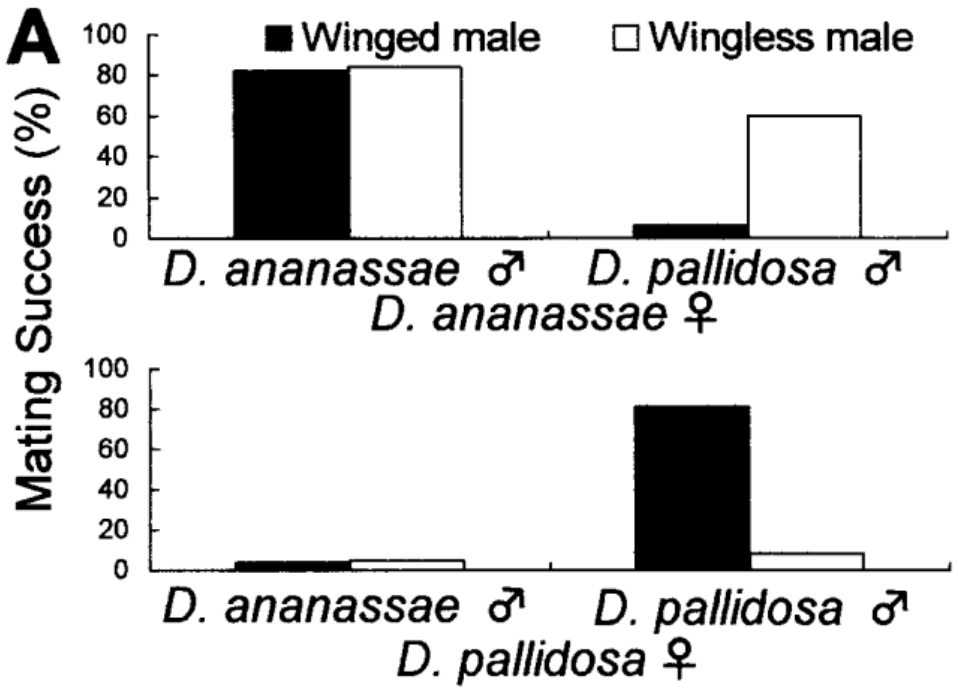
Fanny Rybak, et al., (2002)

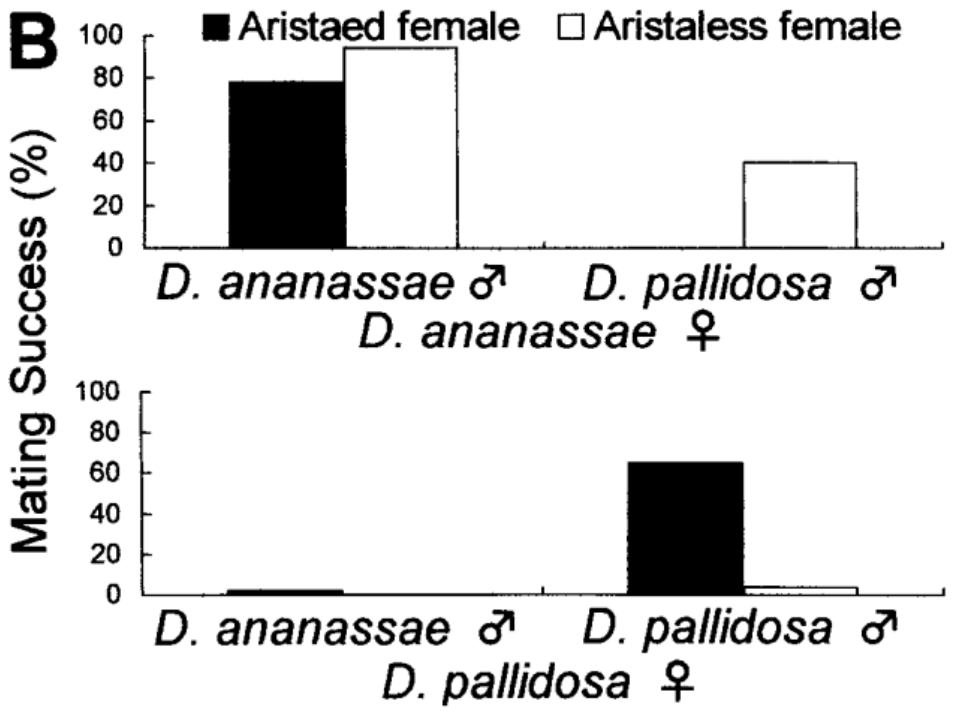
Comparison of the love song components of mature males



Ding Y, et al., (2019)

Female discrimination between *D. ananassae* and *D. pallidosa*





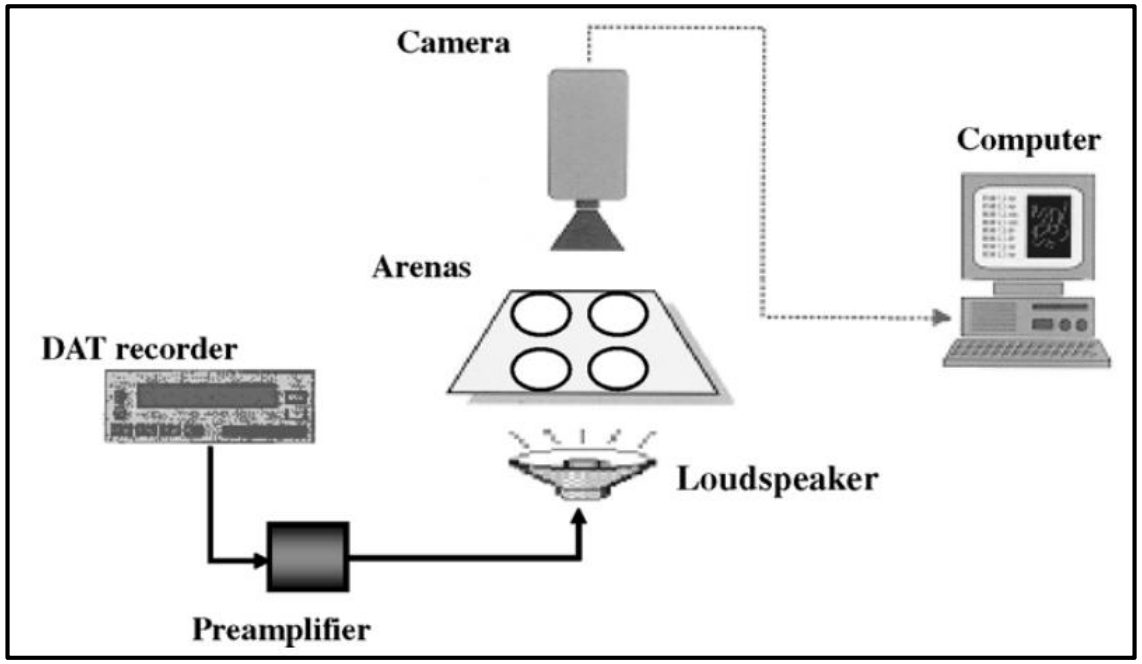
Motomichi Doi, et al., (2001)

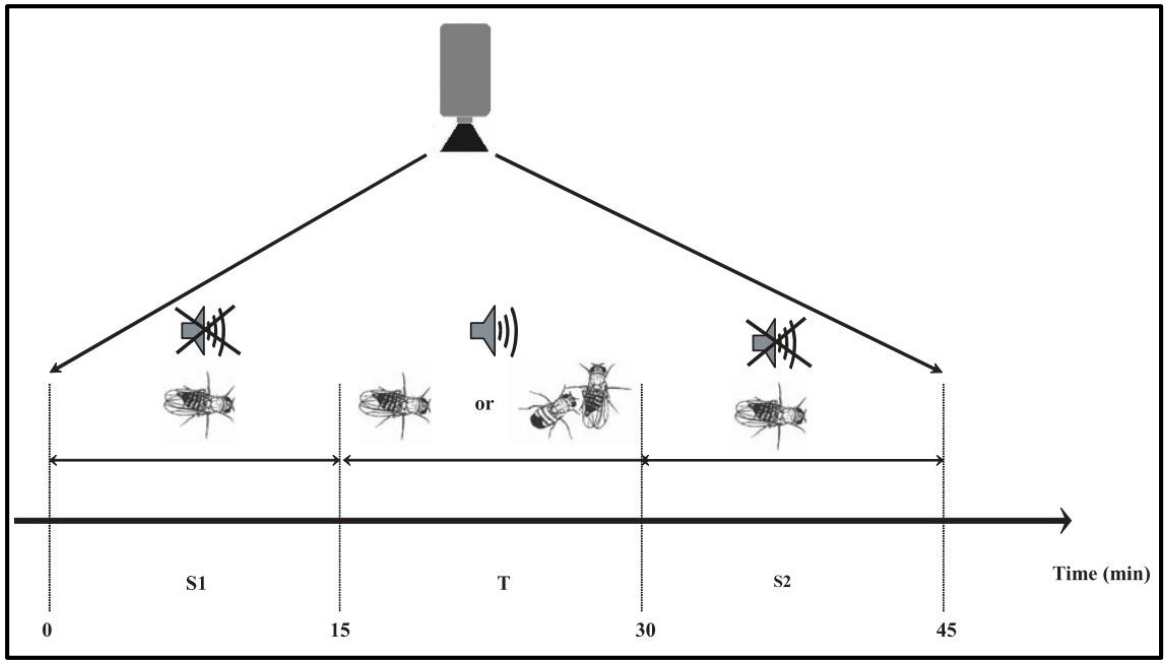
How species-specific songs are detected and recognized, a goal that has yet to be achieved in any species.

The role of courtship song for female

— Locomotion

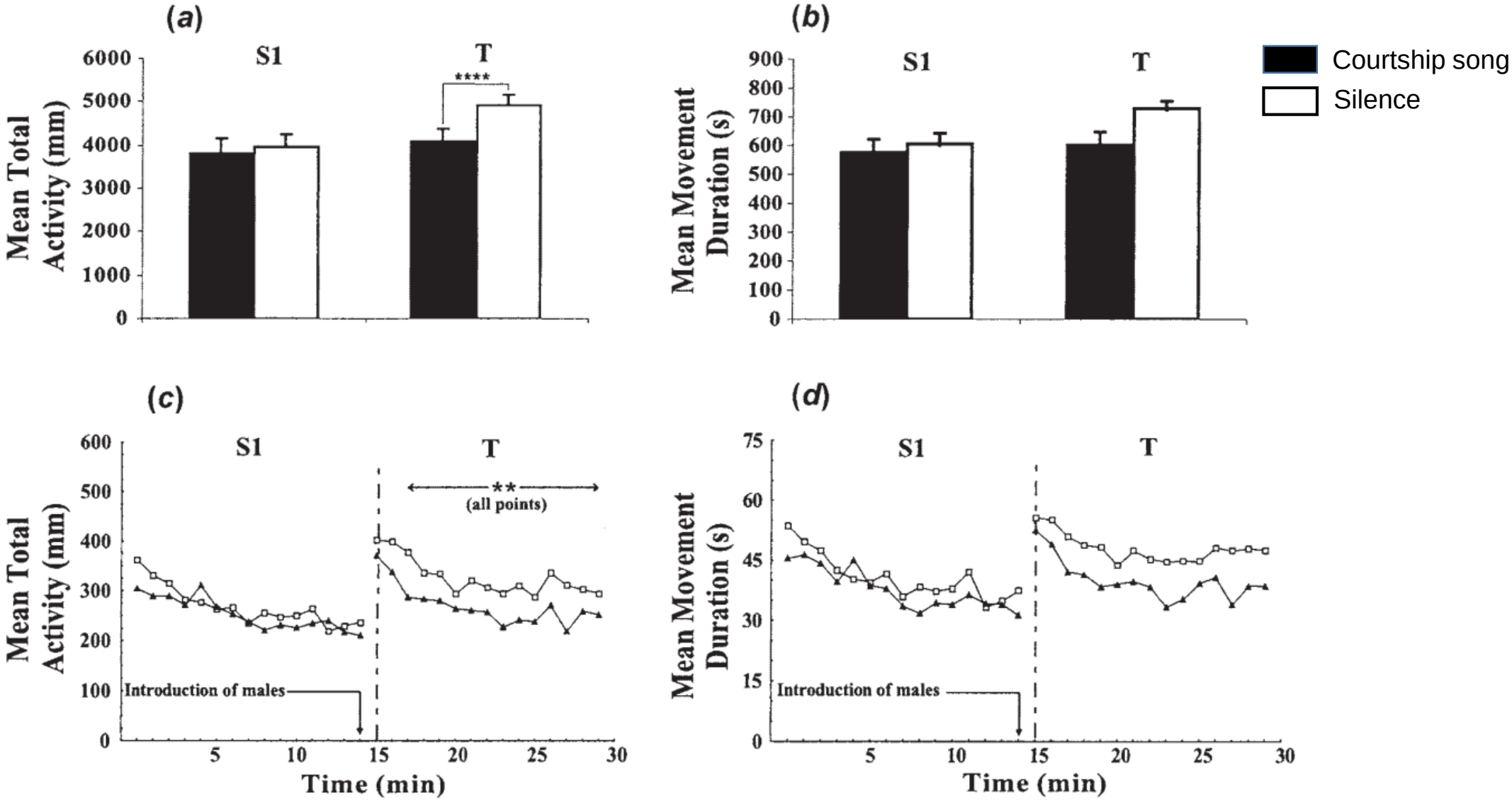
Experimental apparatus designed to study courtship song of *Drosophila melanogaster*





Solange Kowalski, Thierry Aubin, and Jean-René Martin., (2004)

MTA and MMD of *D. melanogaster* females for the two recording periods(with male)

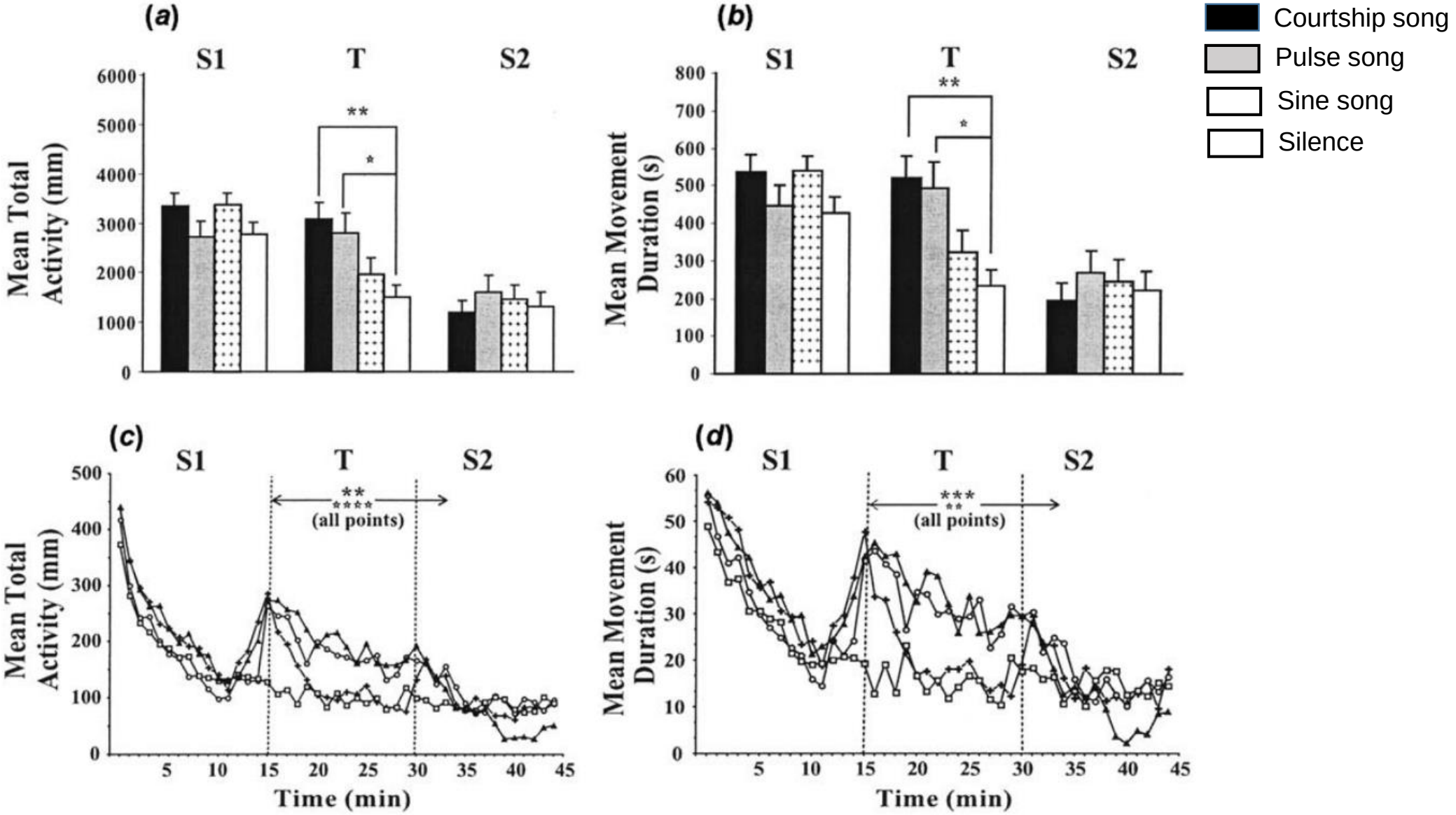


How do courtship song affect female receptivity?

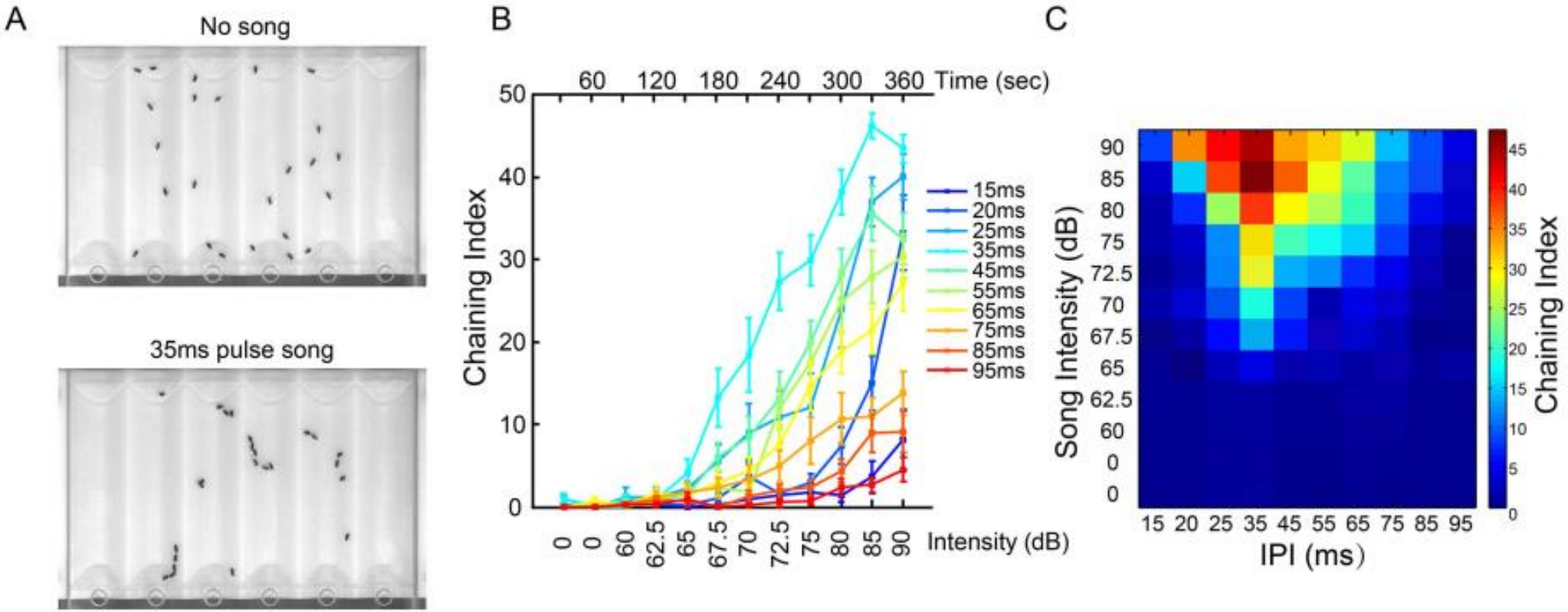
Female response to courtship song—Han Caihong

The role of courtship song for male(alone)

— Locomotion

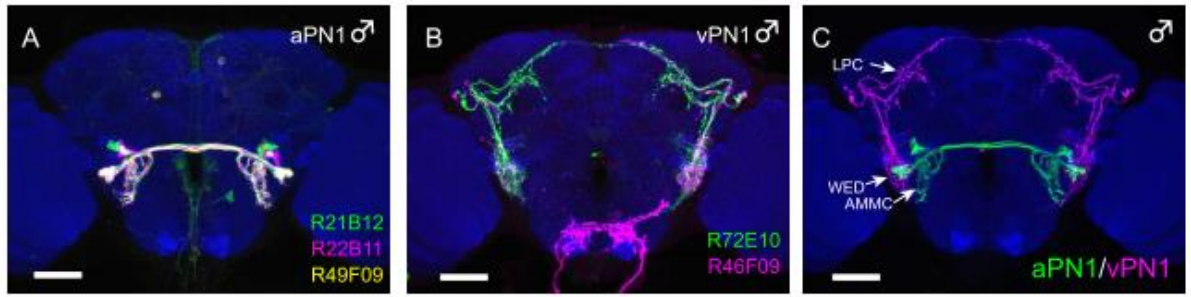


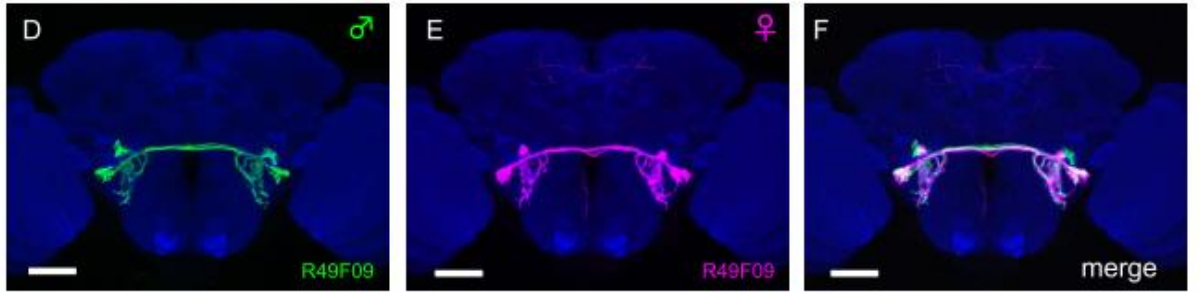
The role of courtship song for male
— Chaining behavior

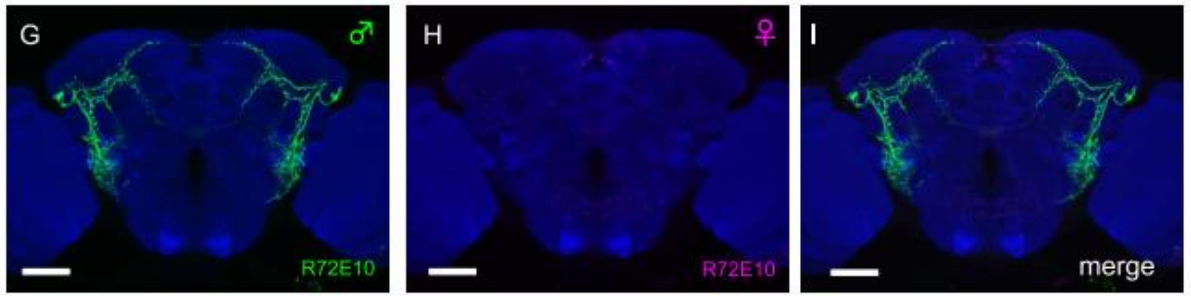


Zhou C, et al., (2015)

Intersectional labeling of auditory neurons







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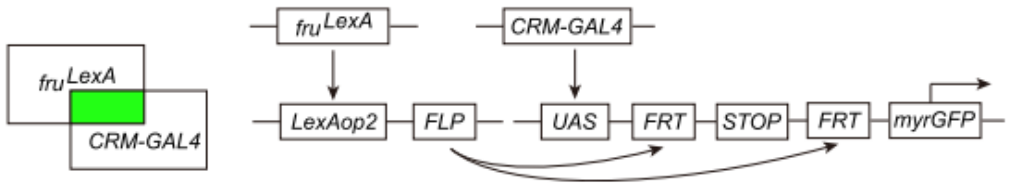
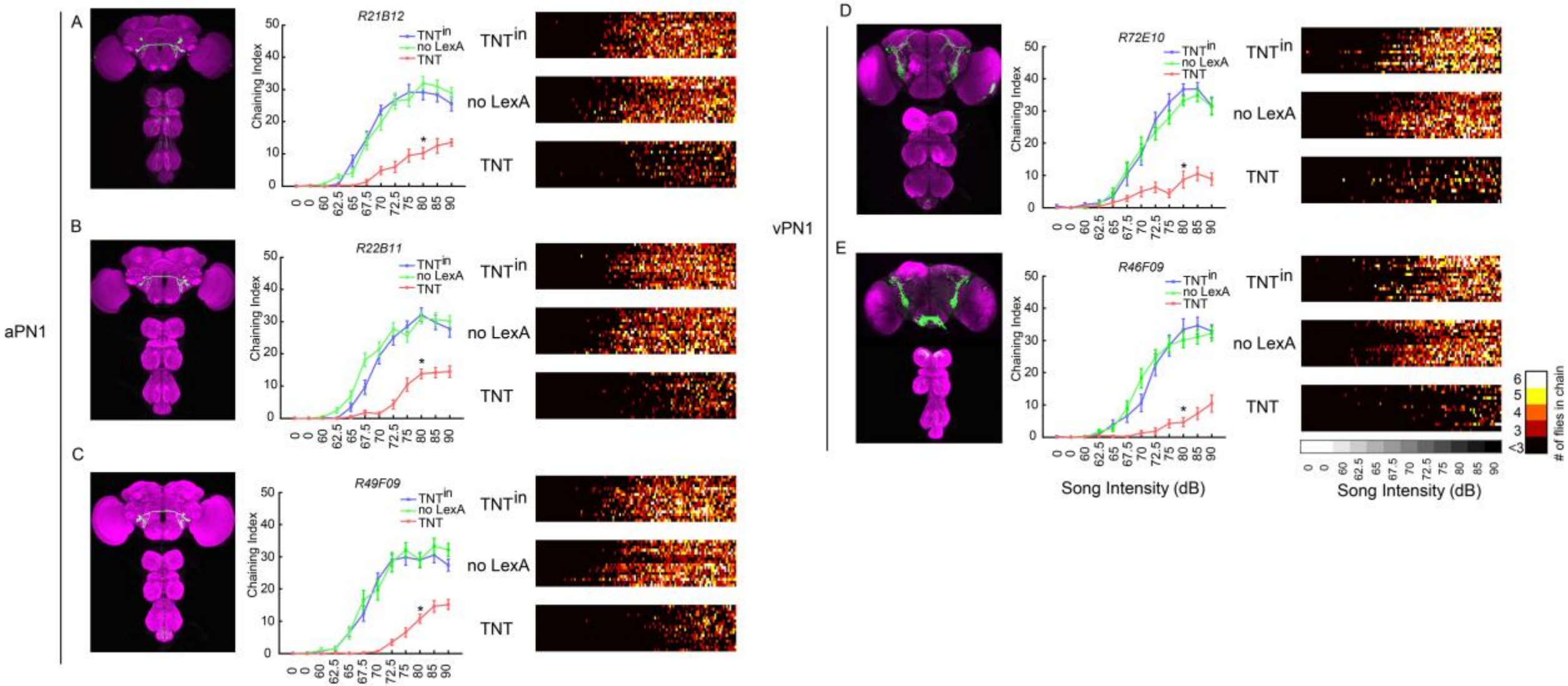
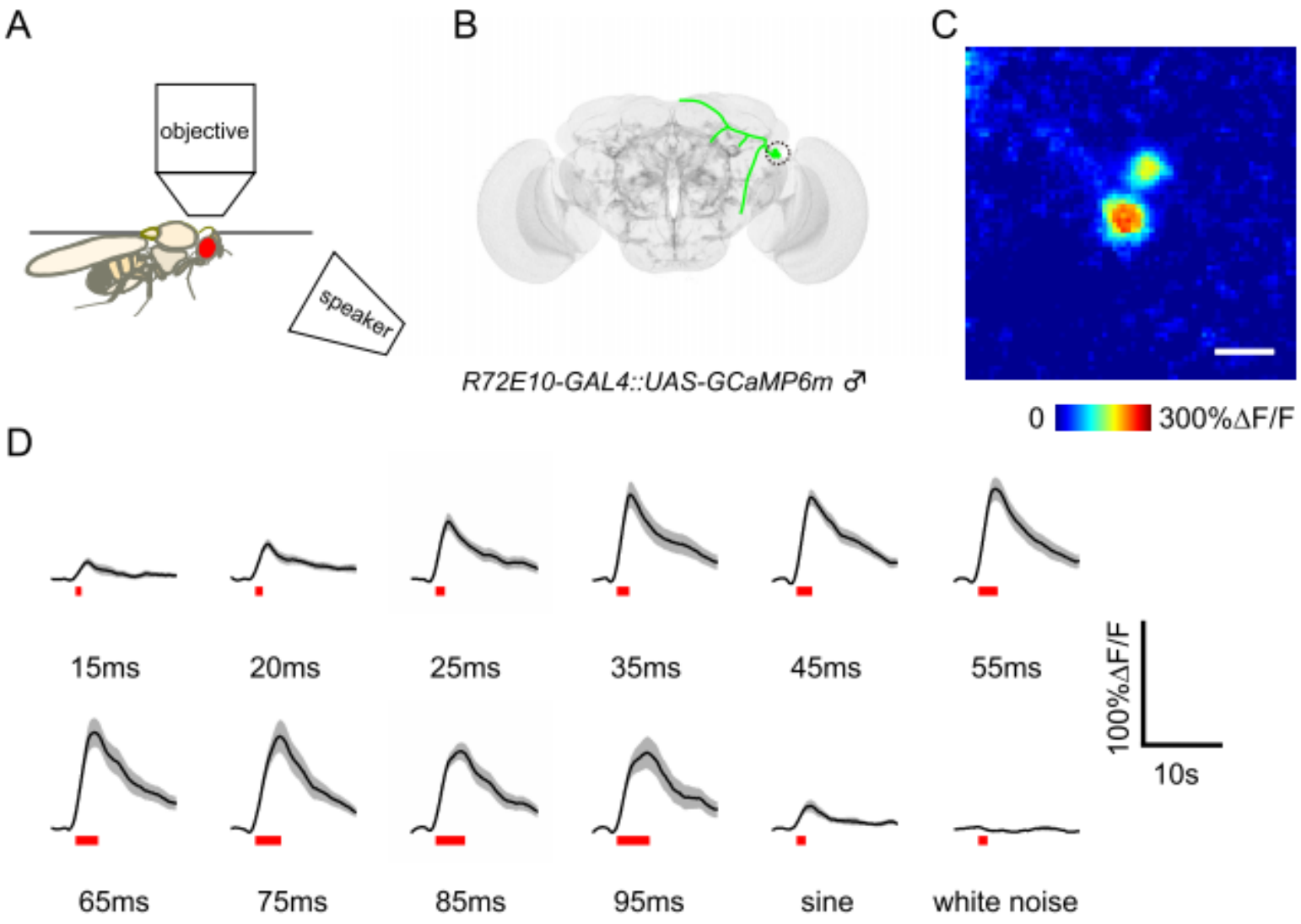


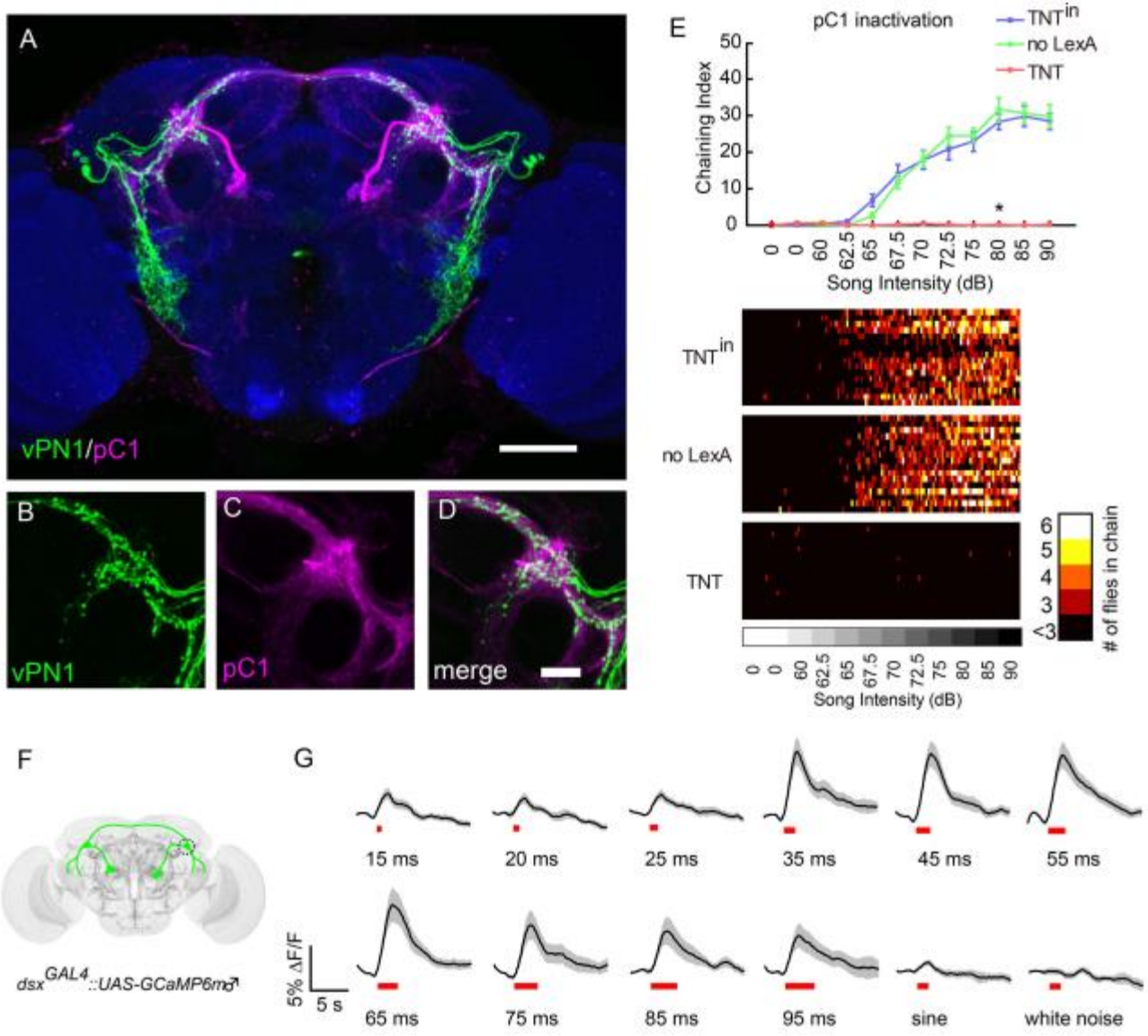
Inactivation of second- and third-order auditory neurons reduced chaining responses to pulse song



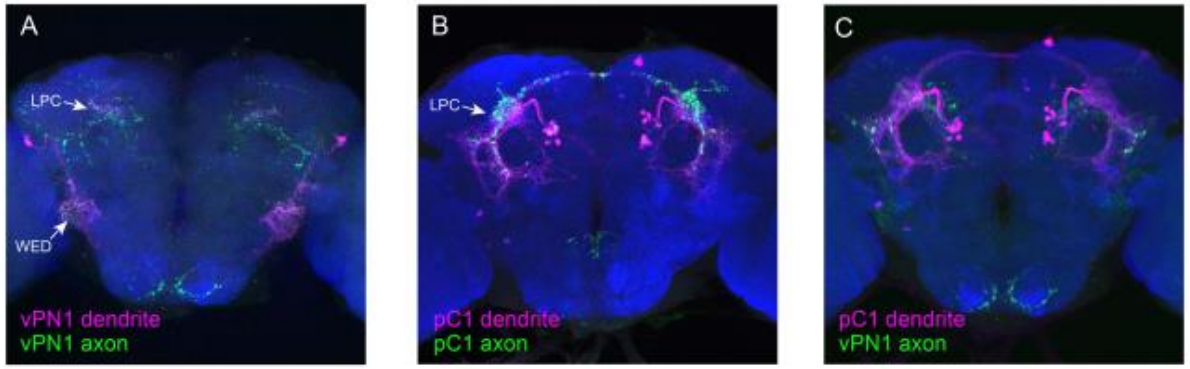
Calcium responses of vPN1 neurons to courtship song

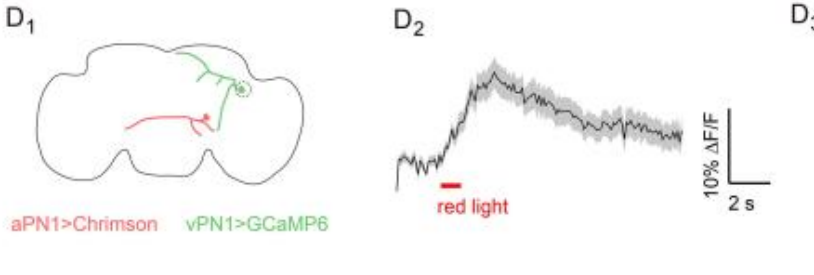


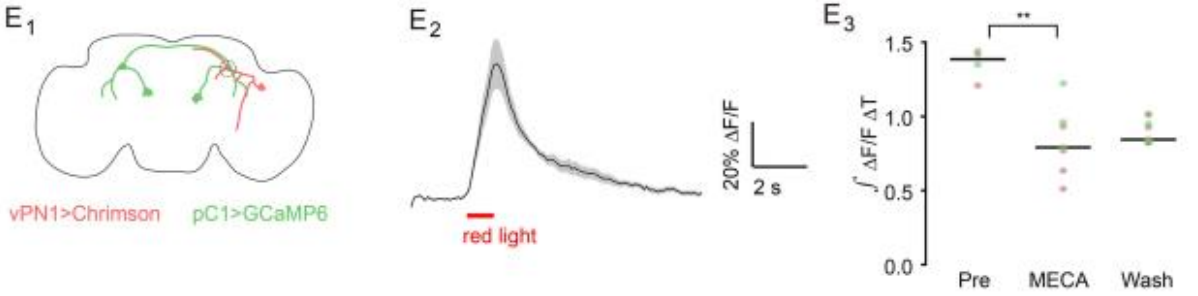
The role of pC1 dsx neurons in song perception

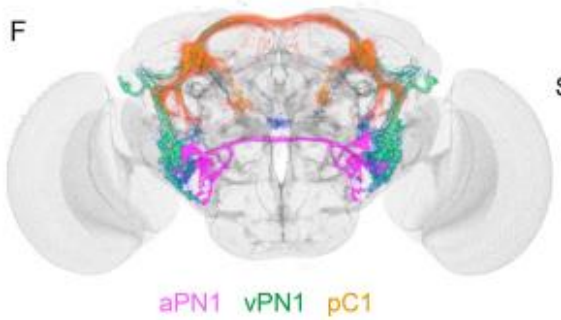


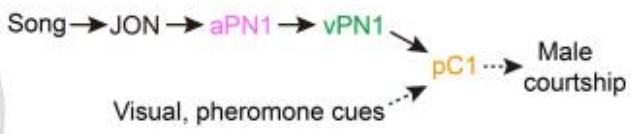
The aPN1-vPN1-pC1 pathway is functionally interconnected



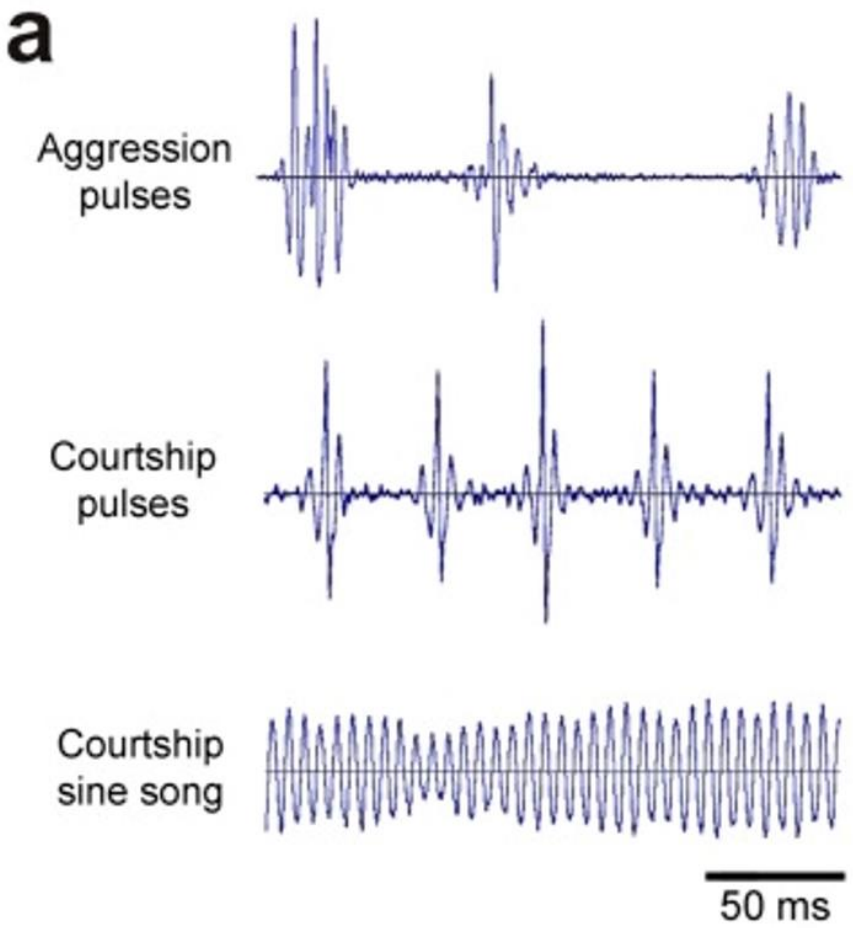


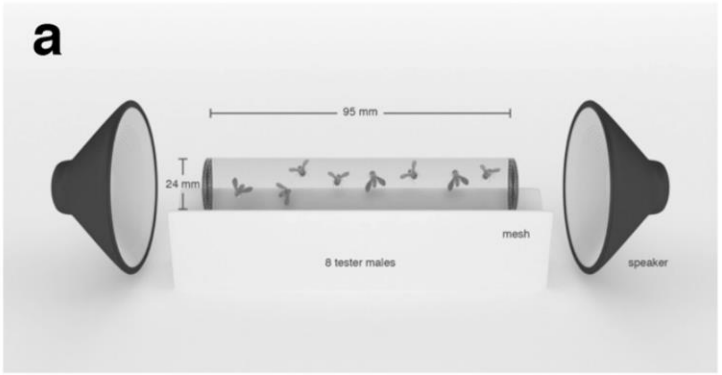


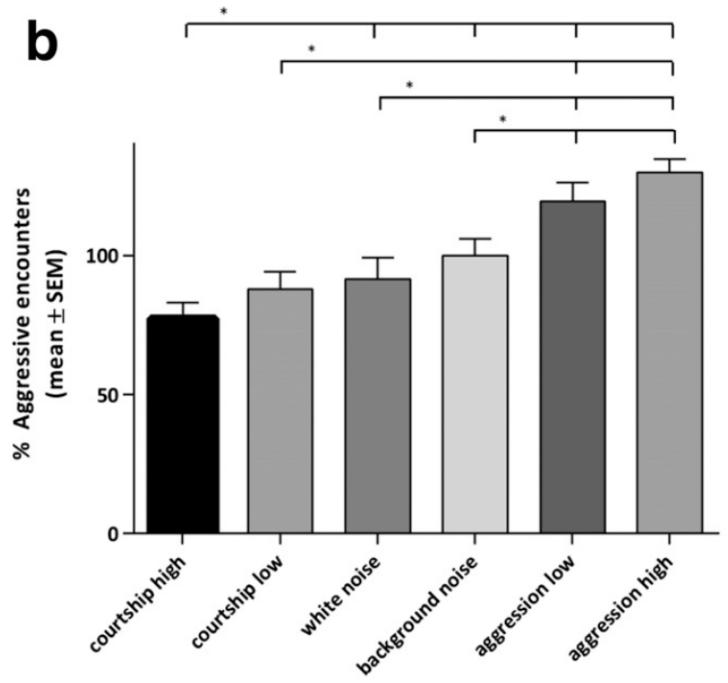




The role of courtship song for male
— Aggression

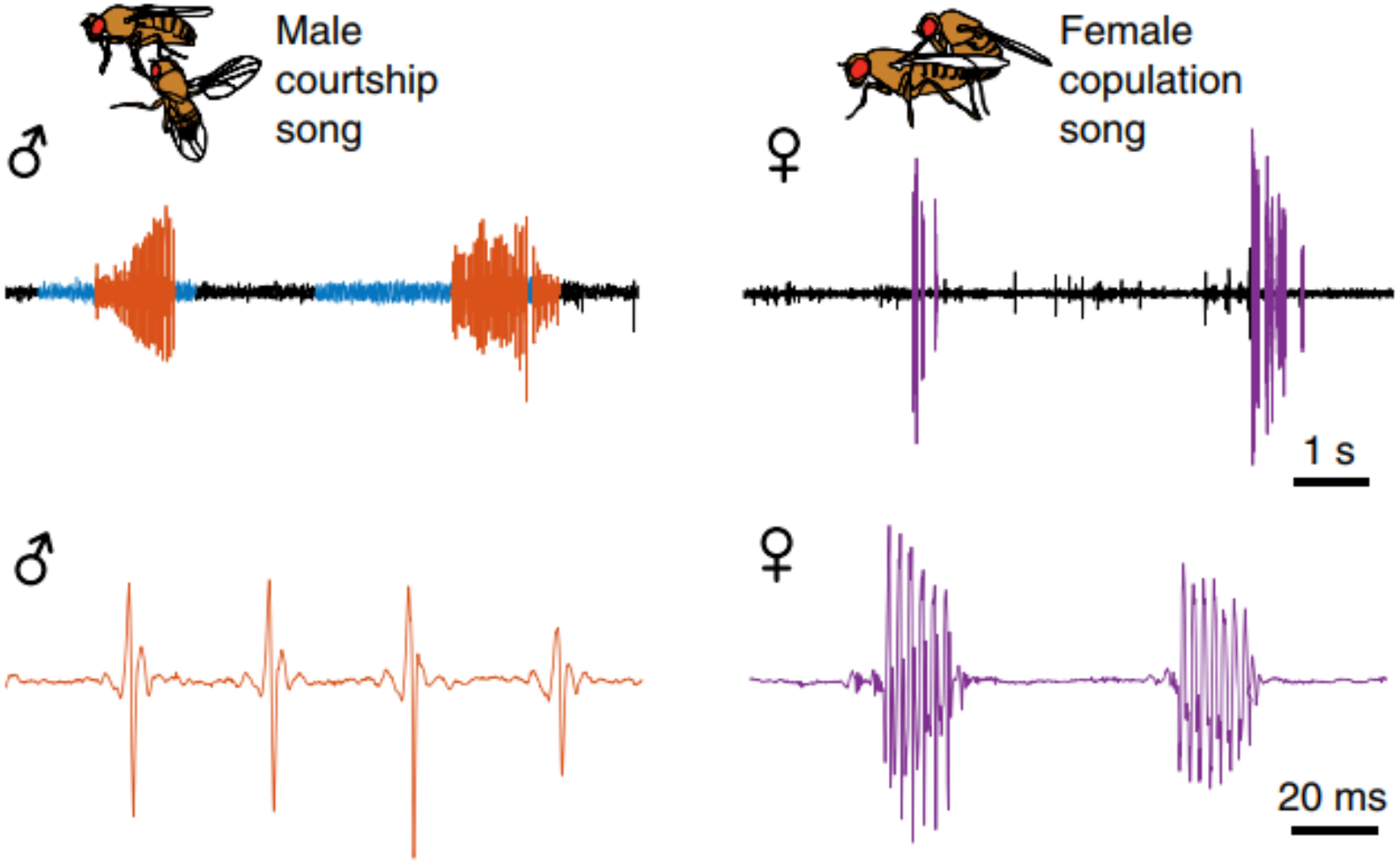






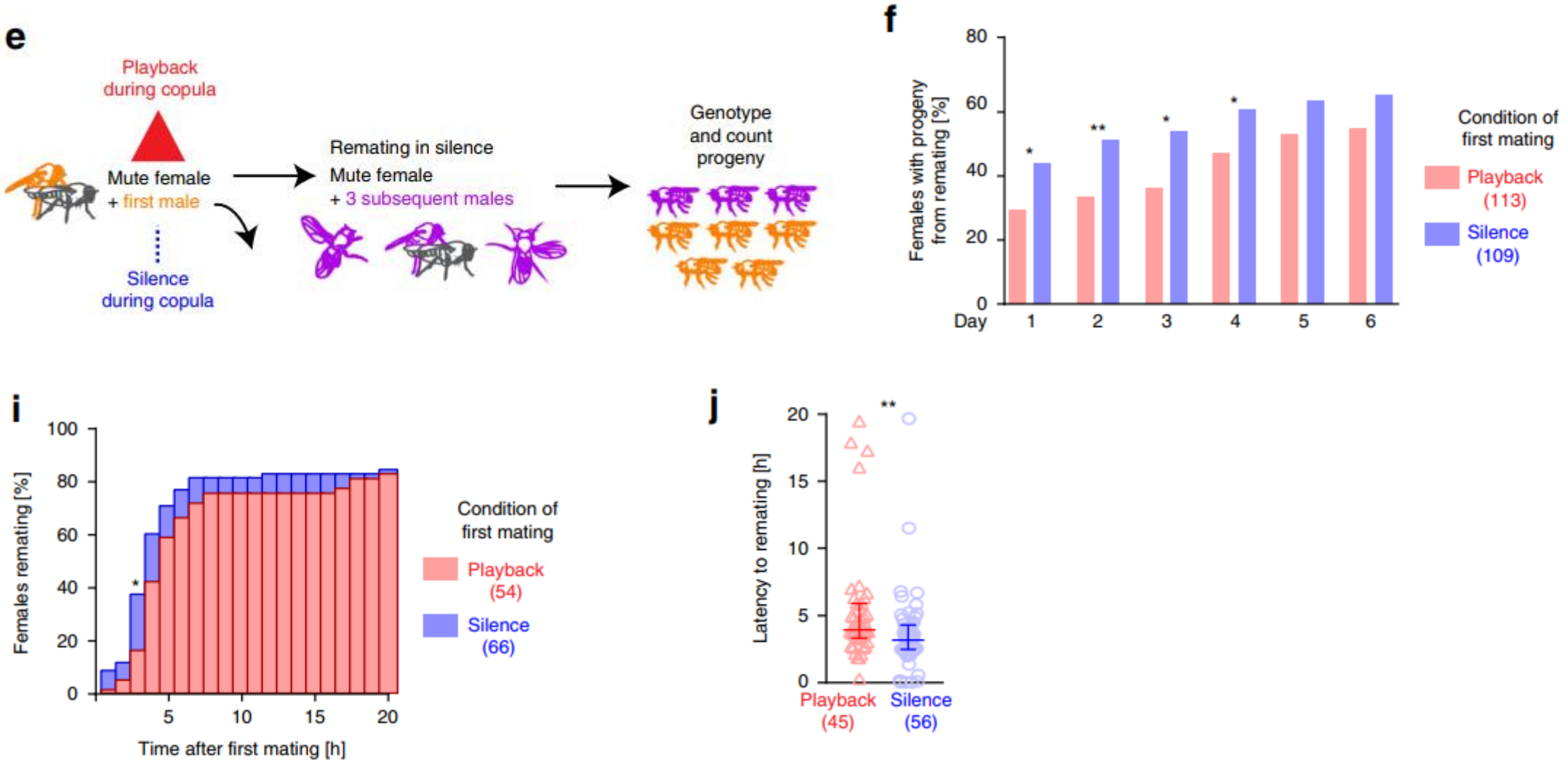
Marijke Versteven, et al., (2017)

Female *Drosophila* sing a sex specific song during copulation



Peter Kerwin, et al., (2020)

Female copulation song decreases remating



Summary

- Courtship songs were mainly composed of pulse song and sine song, and its function is dominated by pulse song
- Courtship songs are involved in regulating a variety of behaviors, such as sexual behavior, aggression and locomotion
- Female *Drosophila* sing a copulation song to reduce remating

Generation of courtship song—Chen Jiangtao

Generation of *Drosophila* courtship song

Chen Jiangtao

2022/03/31

Content

1. **How to initiate a courtship song?**

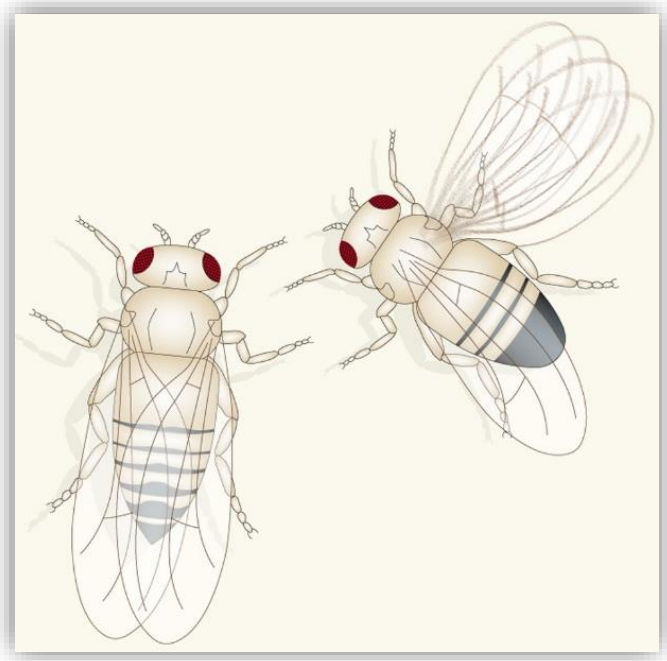
   Female stimulation; Motion feedback

2. **How to decide a courtship song?**

   Neuronal control

3. **How to perform a courtship song?**

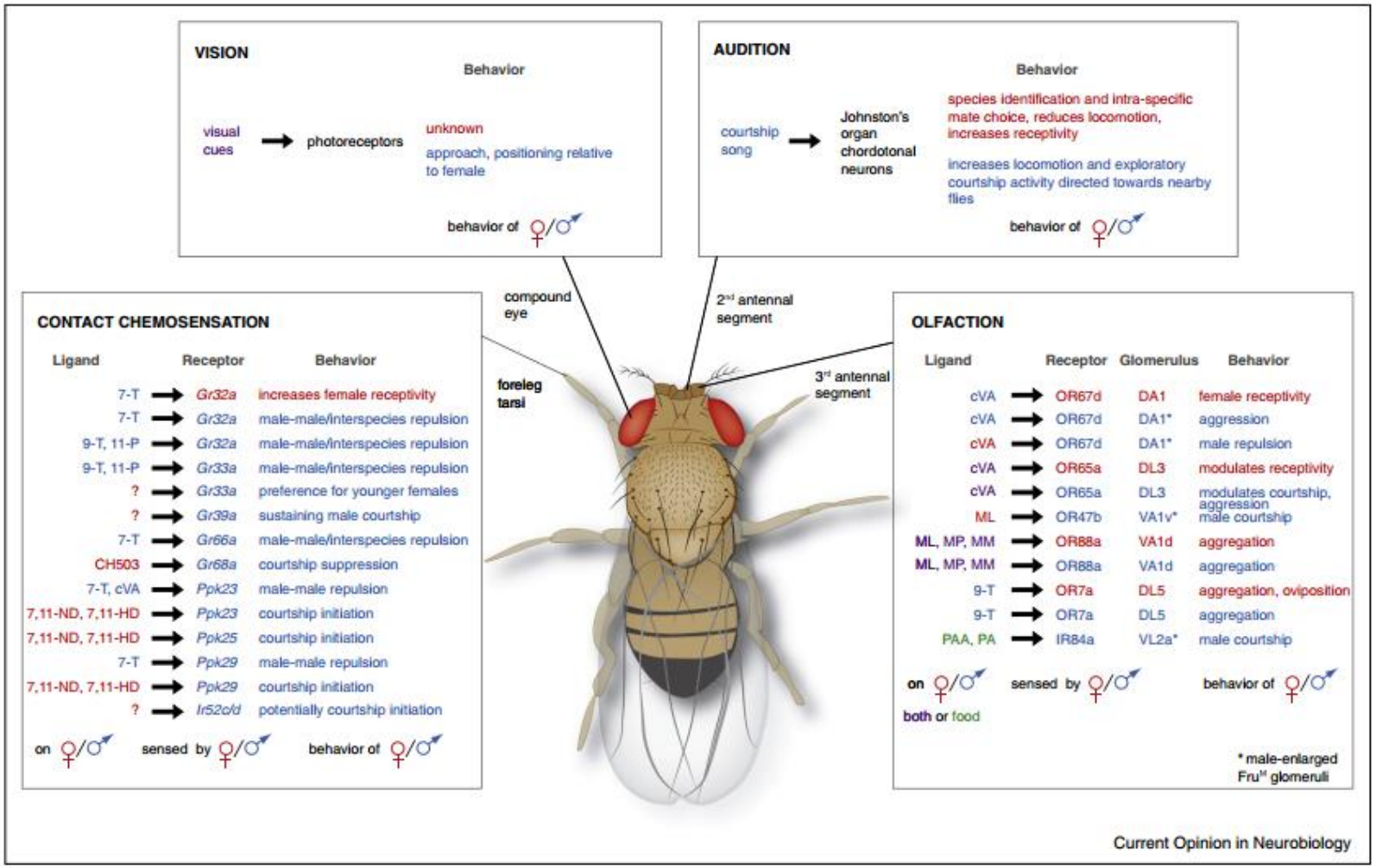
   Motor control

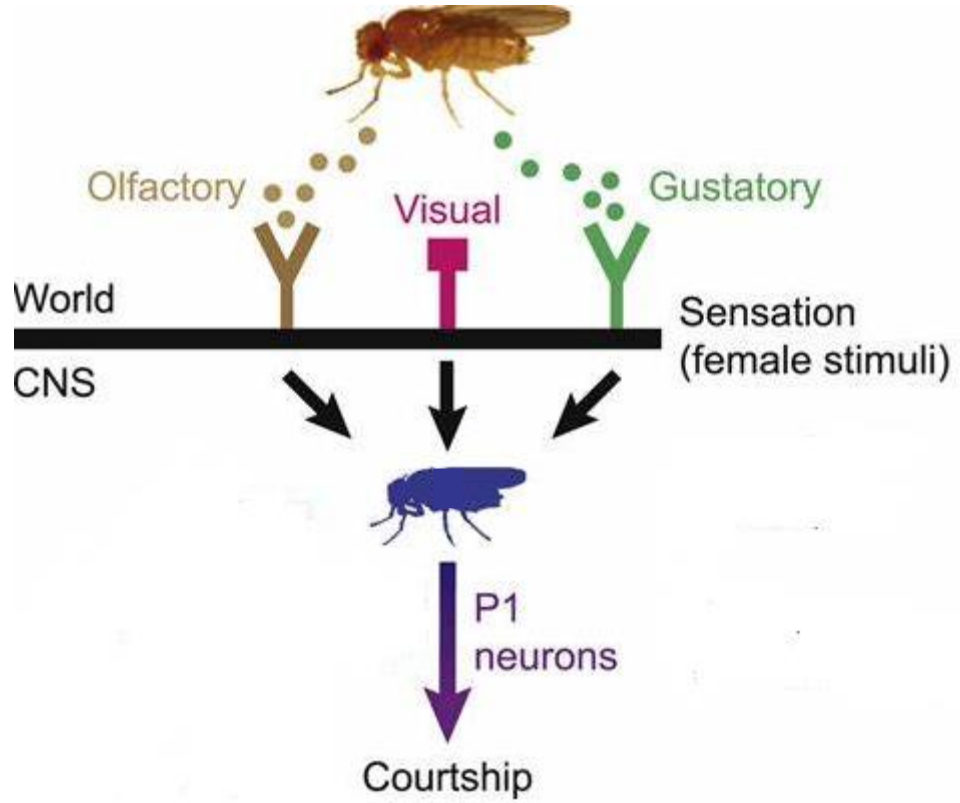


1. How to initiate a courtship song?

Female stimulation; Motion feedback

Multiple sensory modalities control the initiation of courtship song

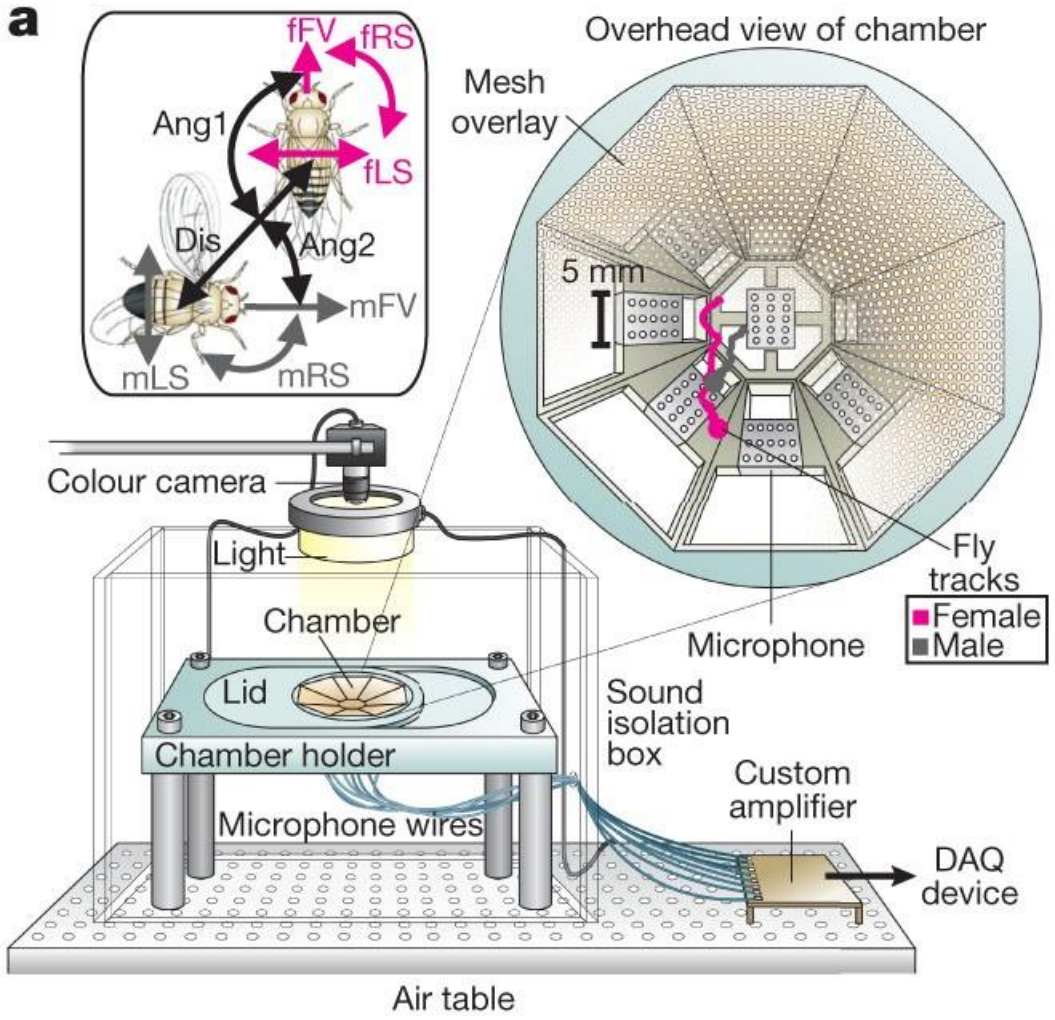




Sensory control of *D. melanogaster* sexual behaviors

Thomas O Auer et al. *Curr Opin Neurobiol*. 2016 Jun

Dynamic sensory cues shape song structure in *Drosophila*



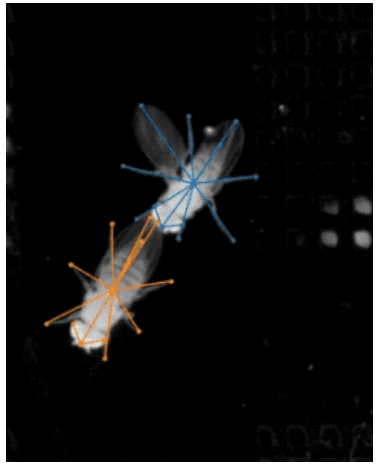
将果蝇的运动分为：

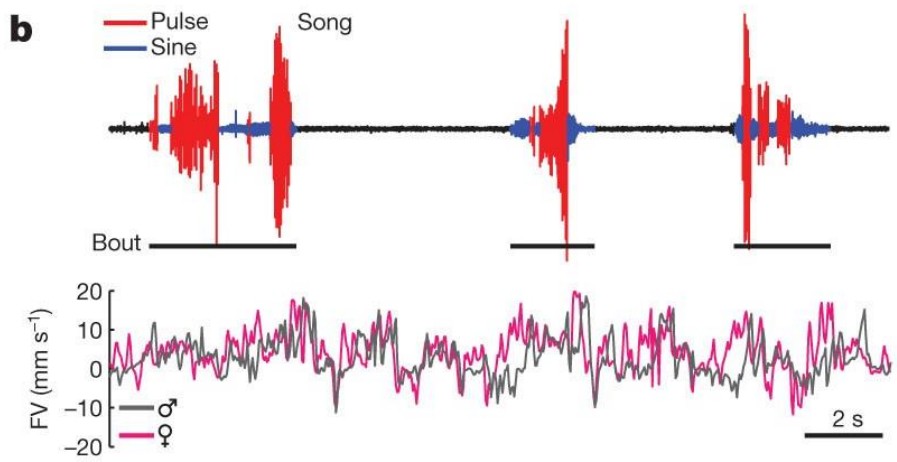
Dis--果蝇中心之间的距离

mFV/fFV--雄性/雌性前进速度

mLS/fLS和mRS/fRS--雄性/雌性横向速度和旋转速度

Ang1/Ang2--雌性/雄性航向与雄性/雌性中心之间的绝对角度

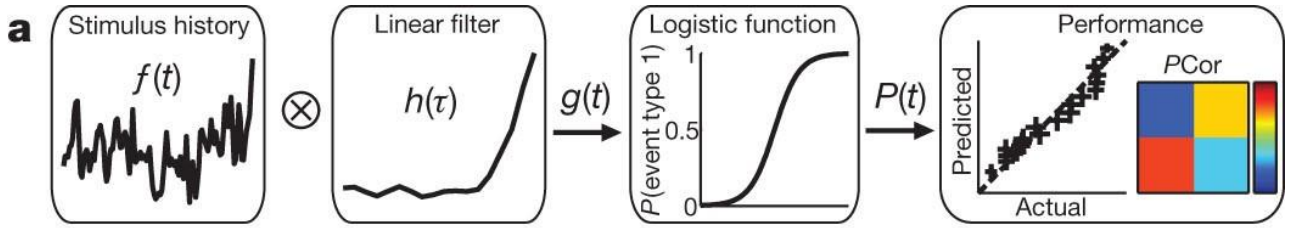




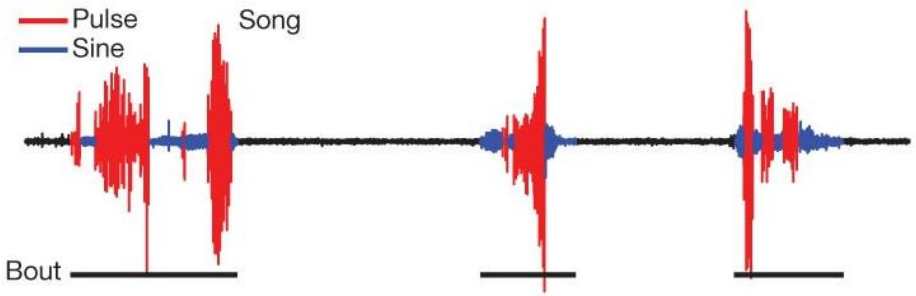
A novel assay to study *Drosophila* song behaviour

Philip Coen et al. *Nature* . 2014 Mar 13

Dynamic sensory cues shape song structure in *Drosophila*

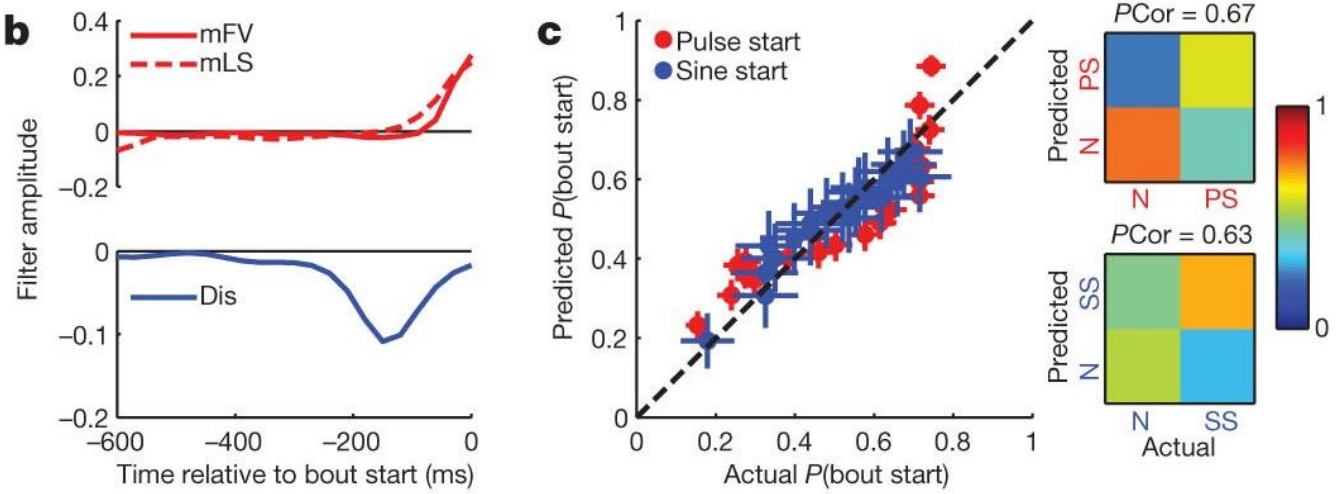


Courtship song行为数据 → GLM广义线性模型分析 → 对courtship song有贡献的相关参数



频繁的模式转换（pulse/sine）

可变的模式持续时间



雄蝇前进速度和横向速度 → pulse song starts (PS)

male lateral speed (mLS)

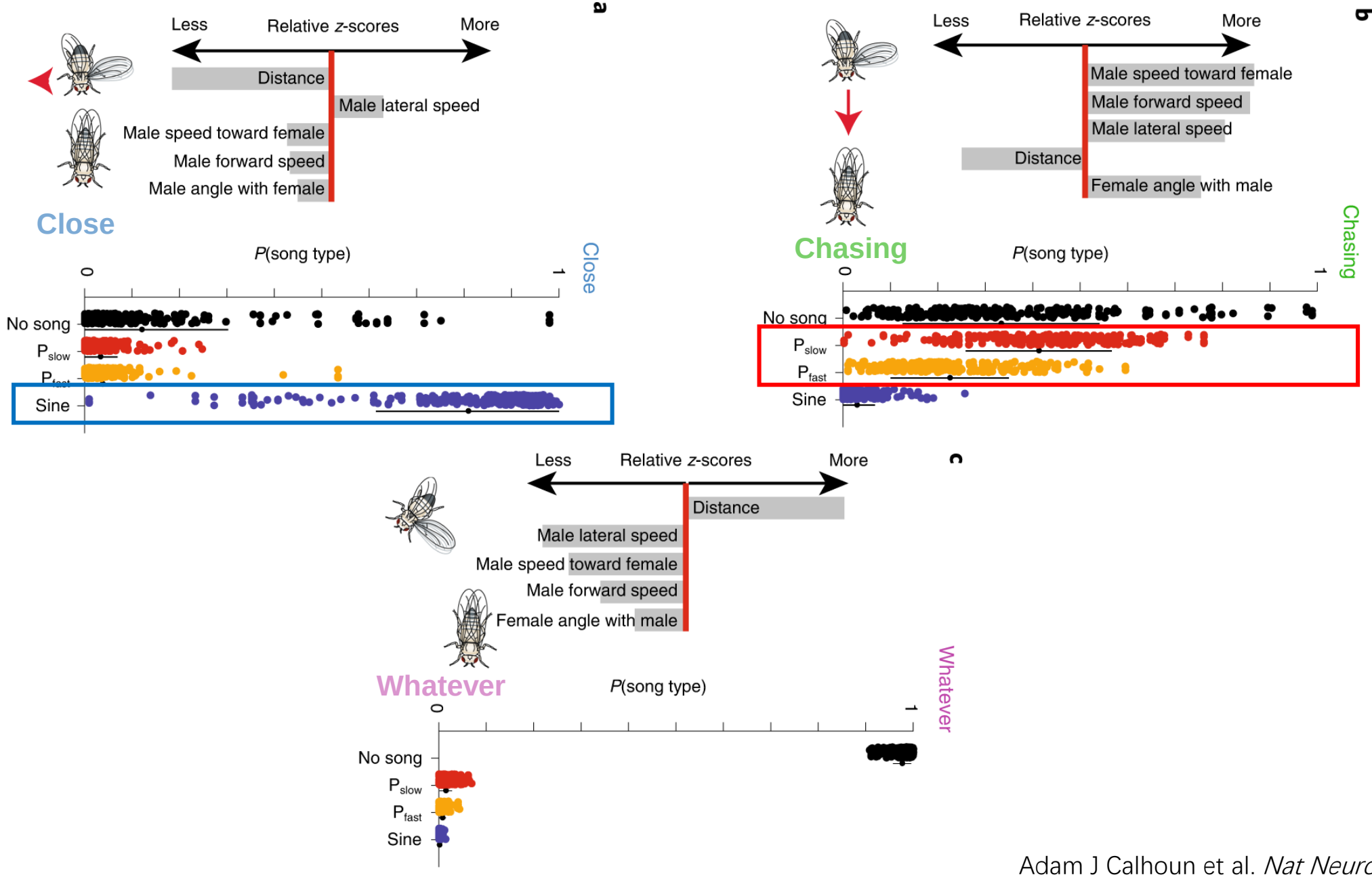
male forward velocity (mFV)

果蝇中心之间的距离 → sine song starts (SS)

Distance between fly centres(Dis)

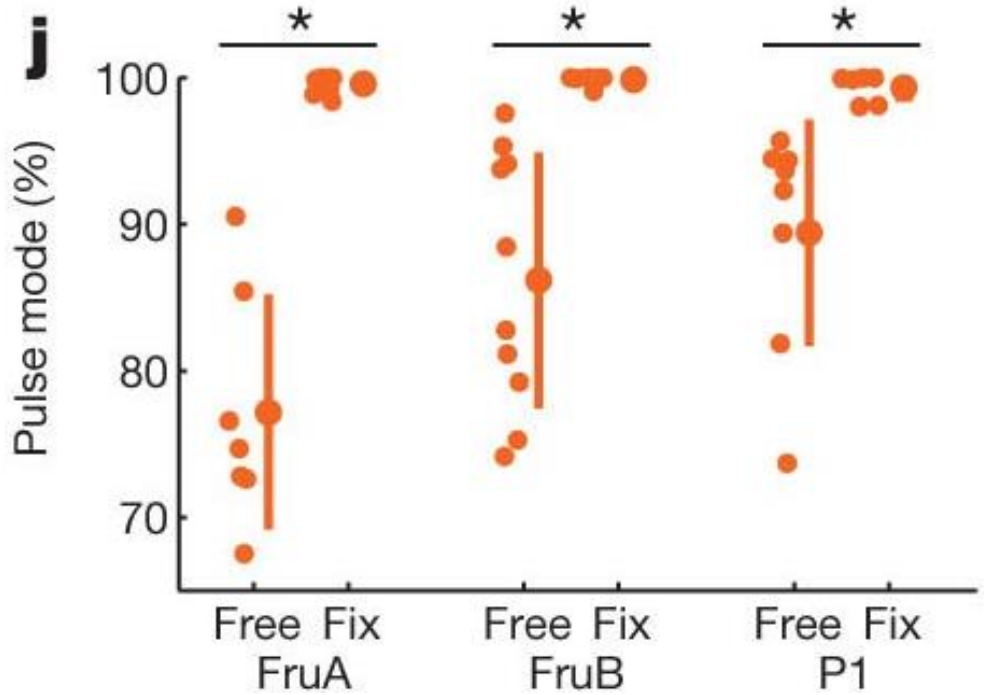
Philip Coen et al. *Nature* . 2014 Mar 13

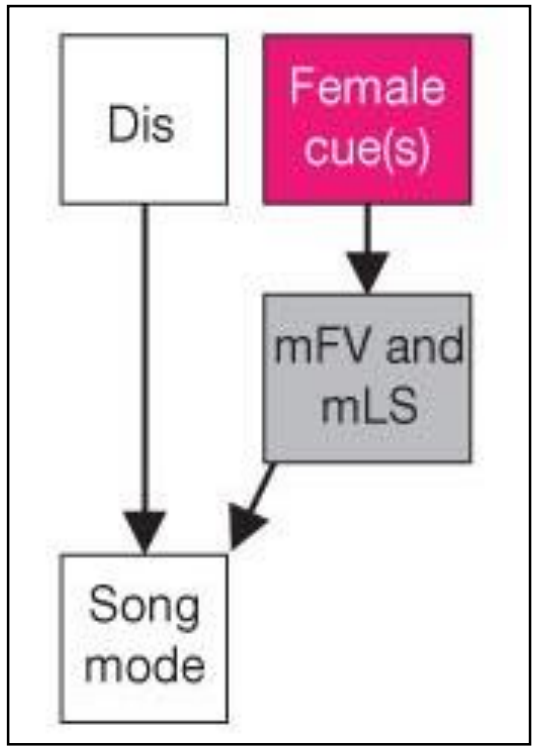
Dynamic sensory cues shape song structure in *Drosophila*



Adam J Calhoun et al. *Nat Neurosci* . 2019 Dec

Dynamic sensory cues shape song structure in *Drosophila*





Male motion modulate song patterning circuits

(via either a copy of the motor commands or proprioceptive feedback from the legs)

Philip Coen et al. *Nature* . 2014 Mar 13

Summary

1. **How to initiate a courtship song?**

   Female stimulation：雄蝇通过雌蝇带来的视觉、嗅觉等感官线索开启求偶歌;
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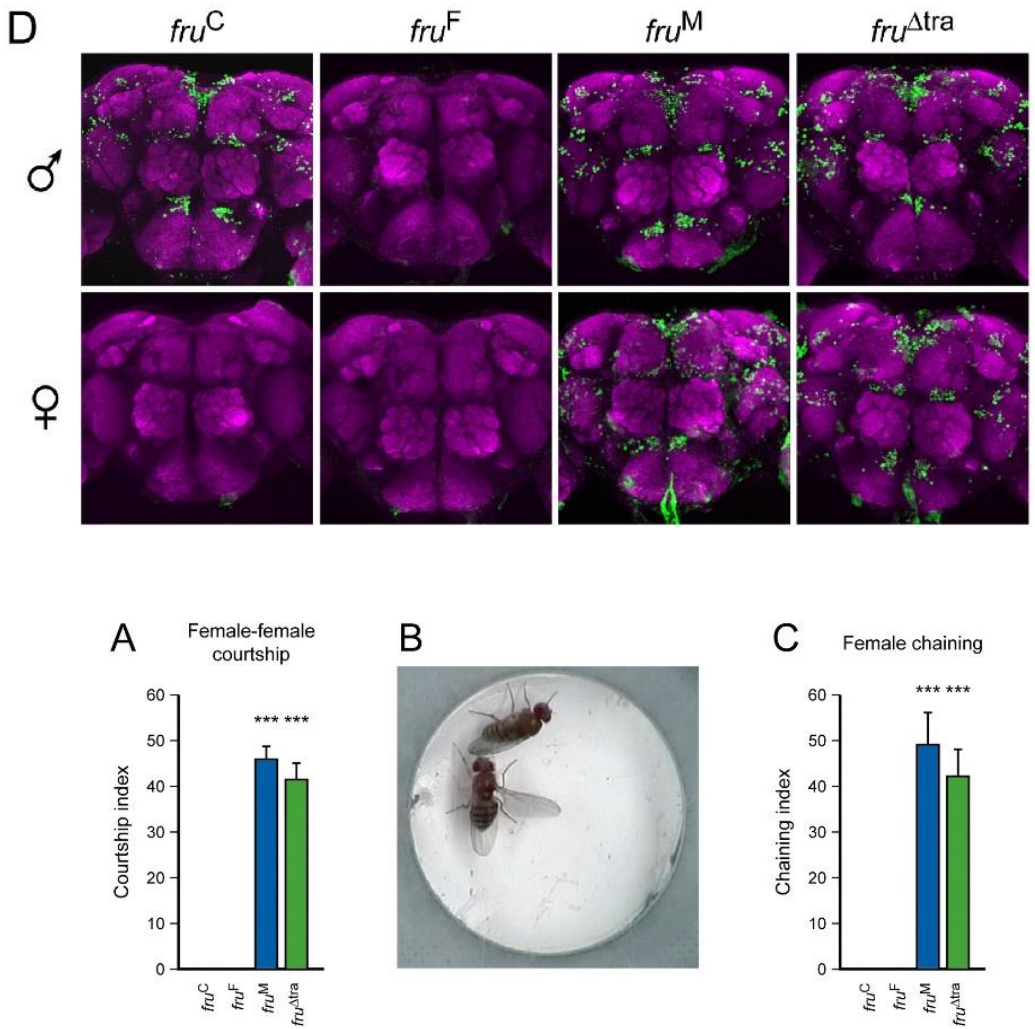
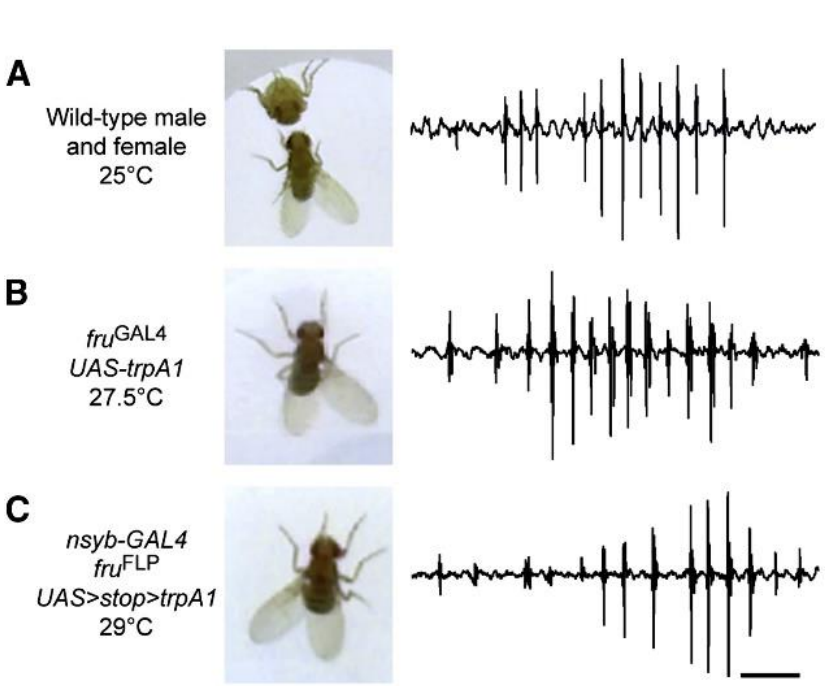
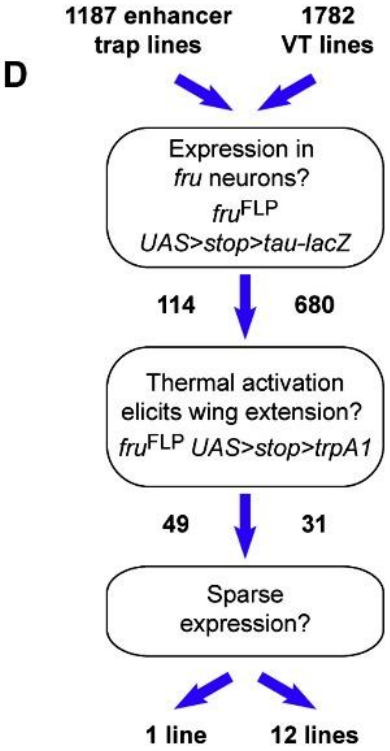
2. How to decide a courtship song?

Neuronal control

Neuronal Control of Drosophila Courtship Song







Thermogenetics defines 5 classes of neuron with distinct functions in courtship song

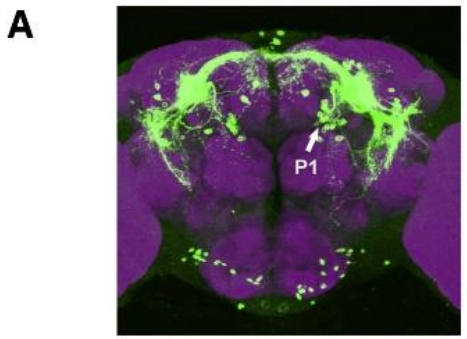
P1 pIP10 dPR1 vPR6 vMS11

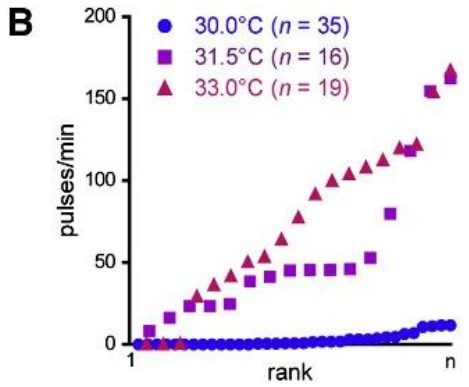
Ebru Demir et al. *Cell* . 2005 Jun

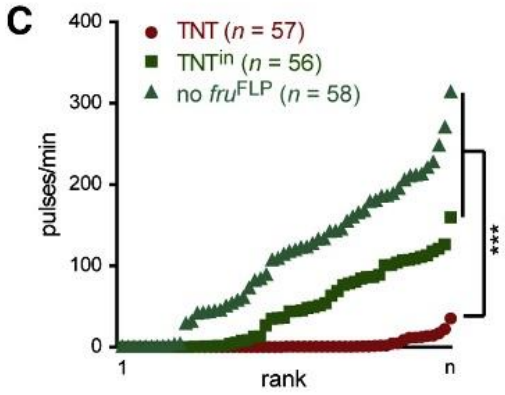
Anne C von Philipsborn et al. *Neuron* . 2011 Feb

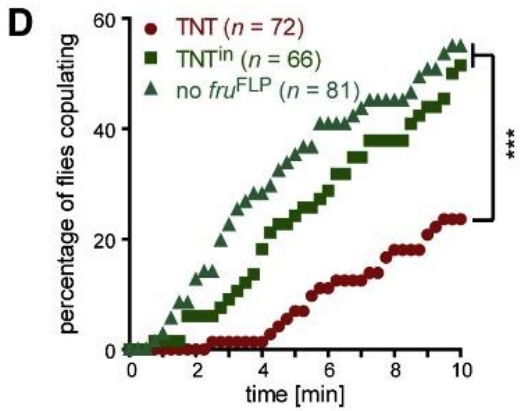
Neuronal Control of Drosophila Courtship Song

P1

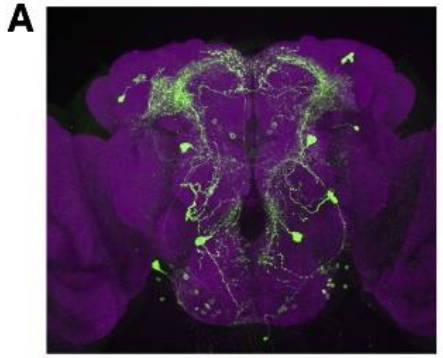


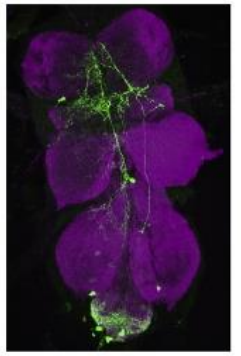


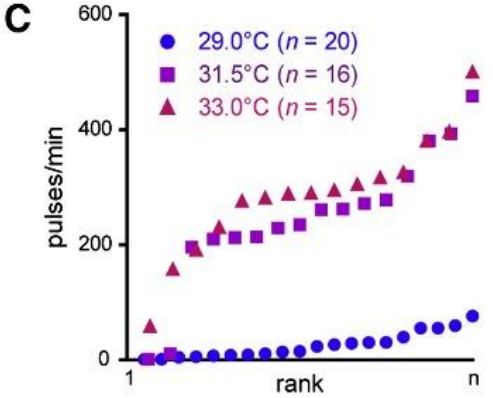


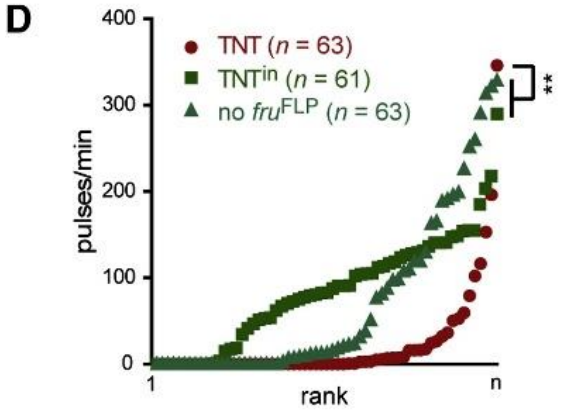


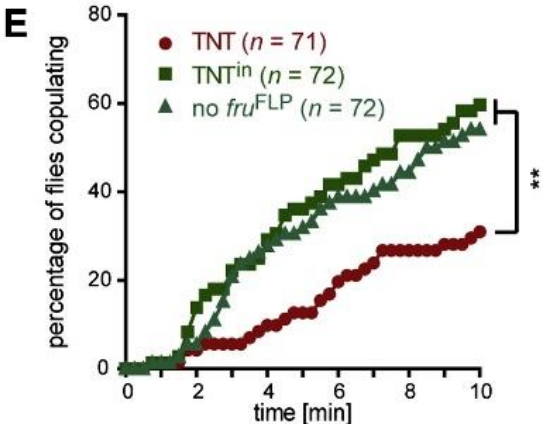
pIP10









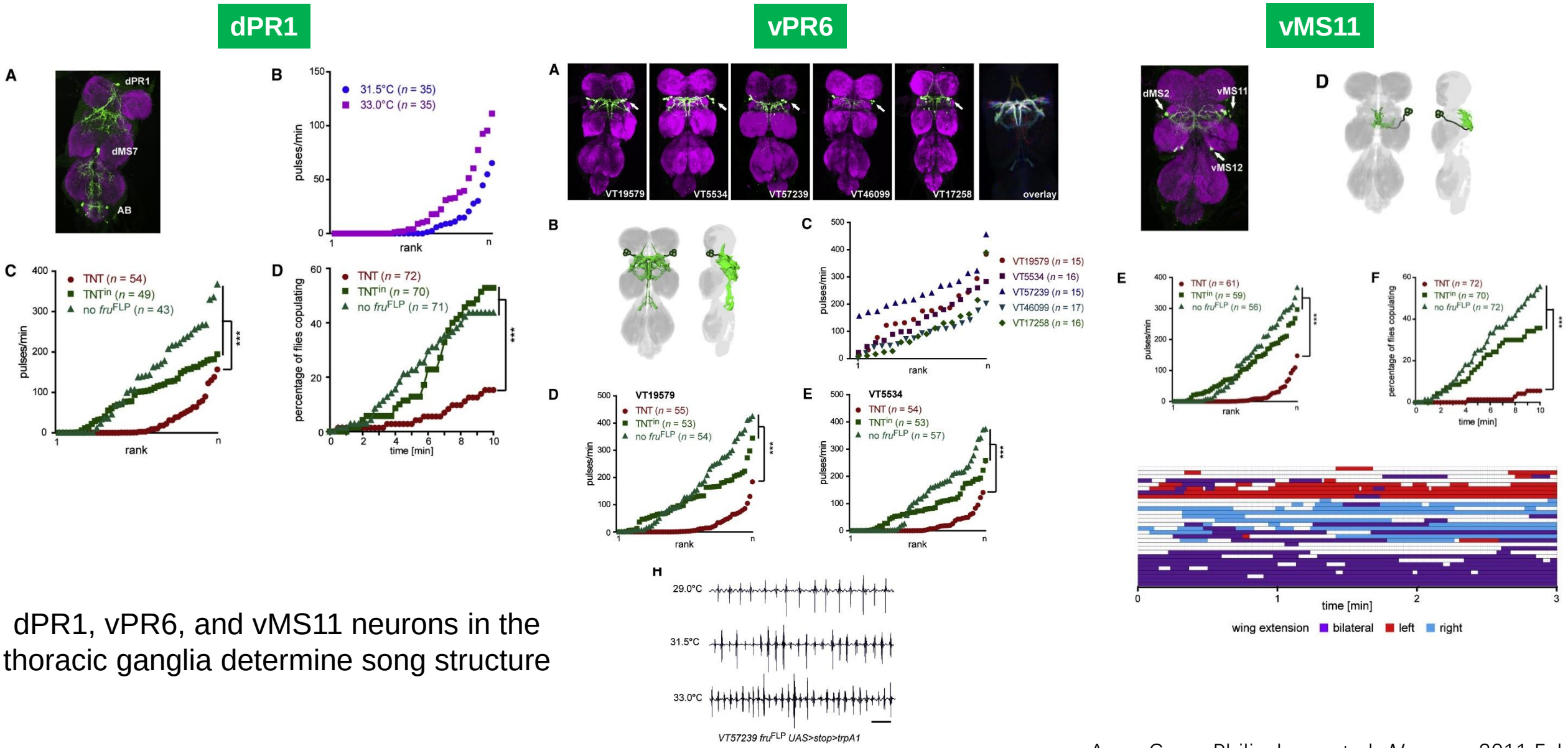


P1 and pIP10 neurons in the brain trigger song production

Anne C von Philipsborn et al. *Neuron* . 2011 Feb

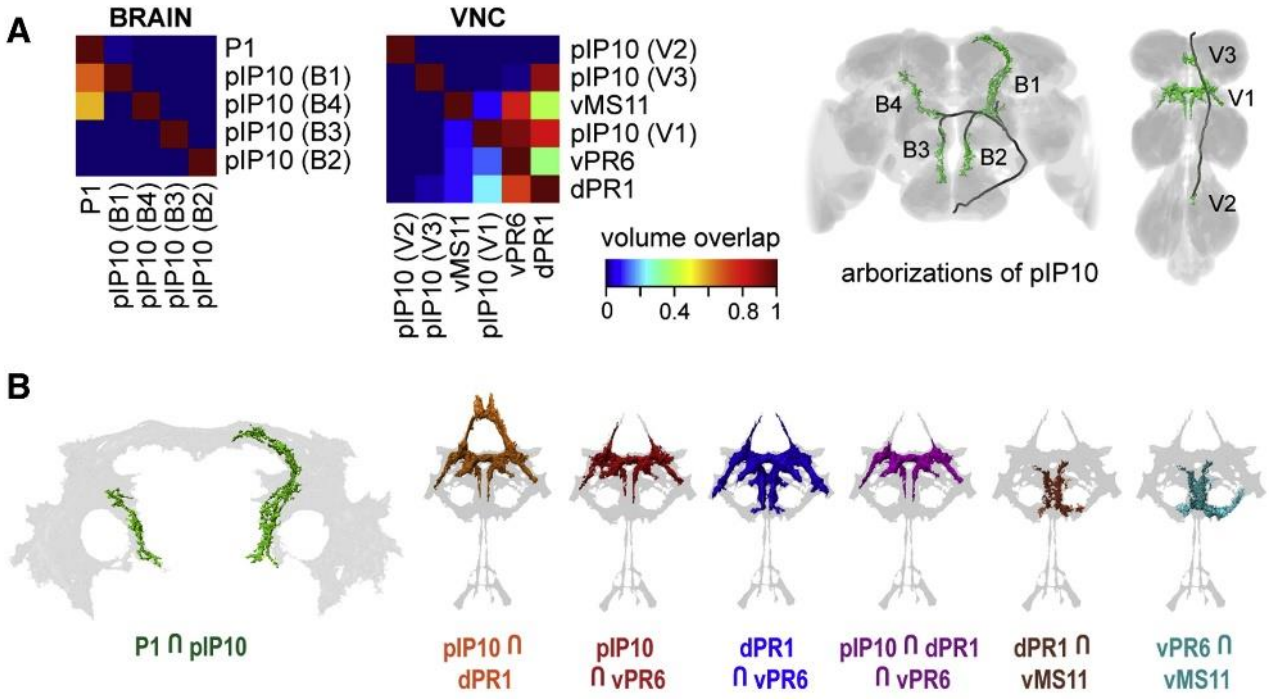
Neuronal Control of Drosophila Courtship Song

dPR1, vPR6, and vMS11 neurons in the thoracic ganglia determine song structure

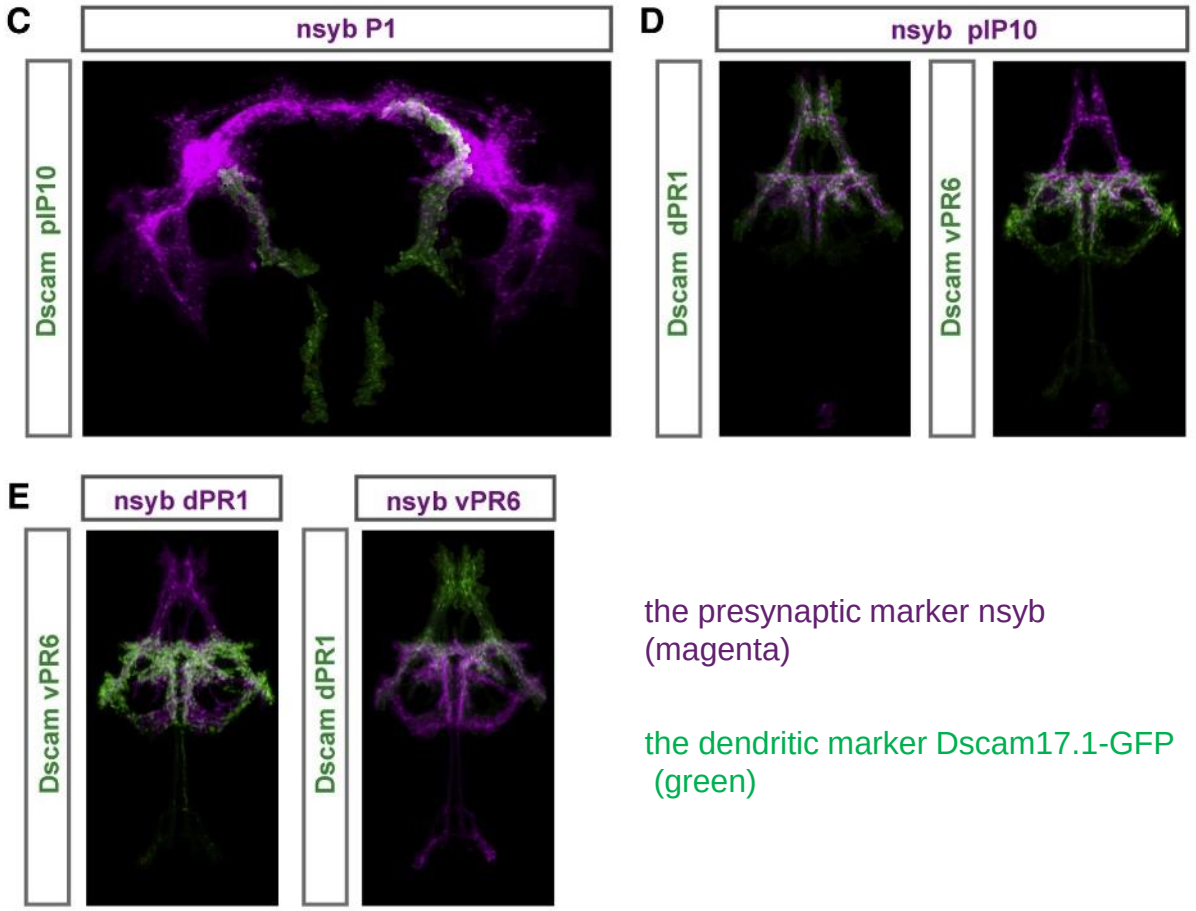


Anne C von Philipsborn et al. *Neuron* . 2011 Feb

Neuronal Control of Drosophila Courtship Song



Calculated overlap



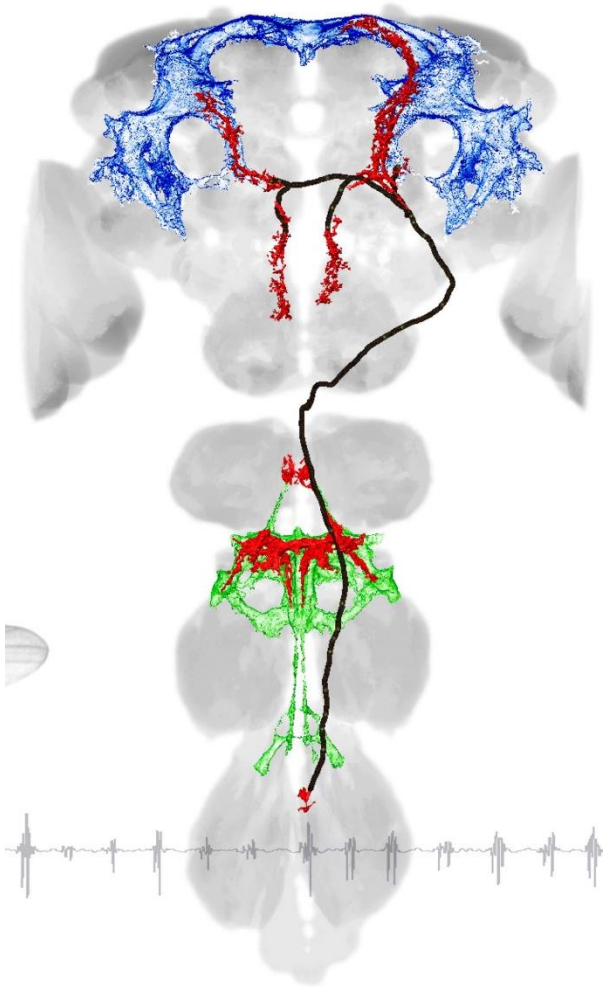
the presynaptic marker nsyb (magenta)

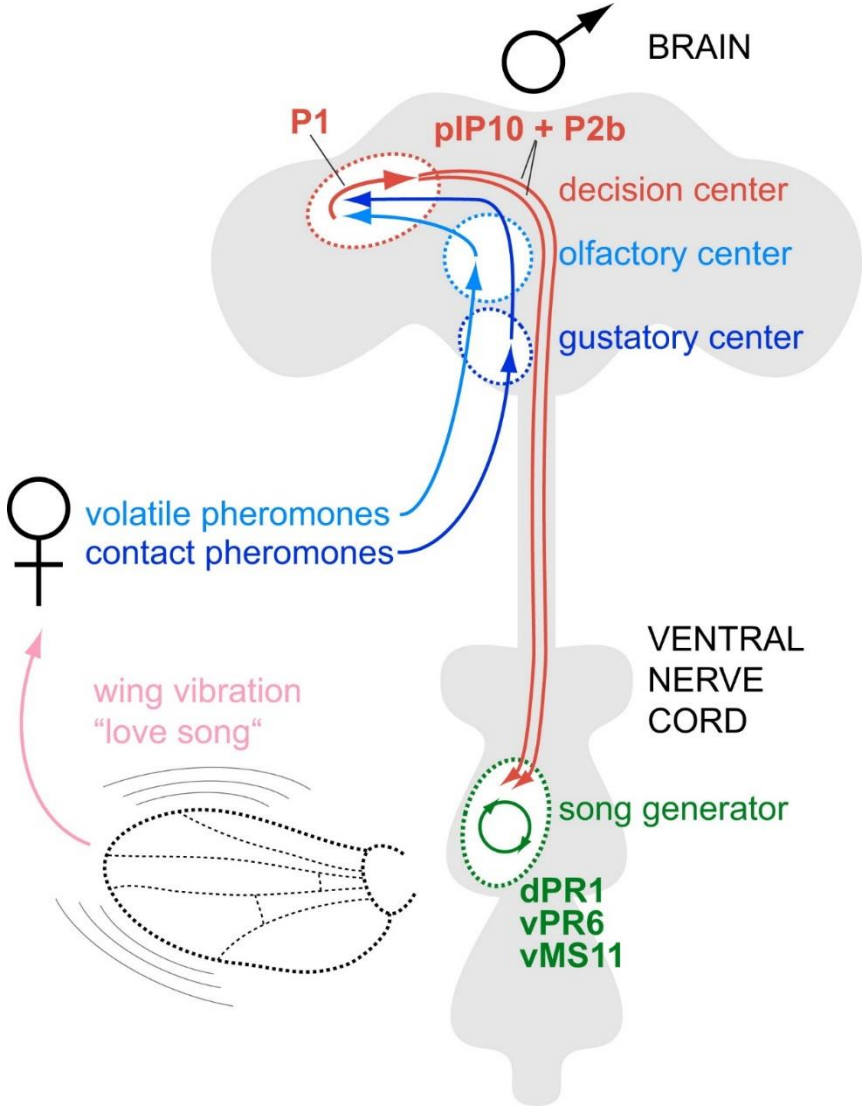
the dendritic marker Dscam17.1-GFP (green)

Descending pIP10 neurons may link the two song centers in a male-specific circuit

Anne C von Philipsborn et al. *Neuron* . 2011 Feb

Neuronal Control of Drosophila Courtship Song





A Schematic Circuit Underlying Male Love Song Production

Richard Benton. *Neuron* . 2011 Feb

Summary

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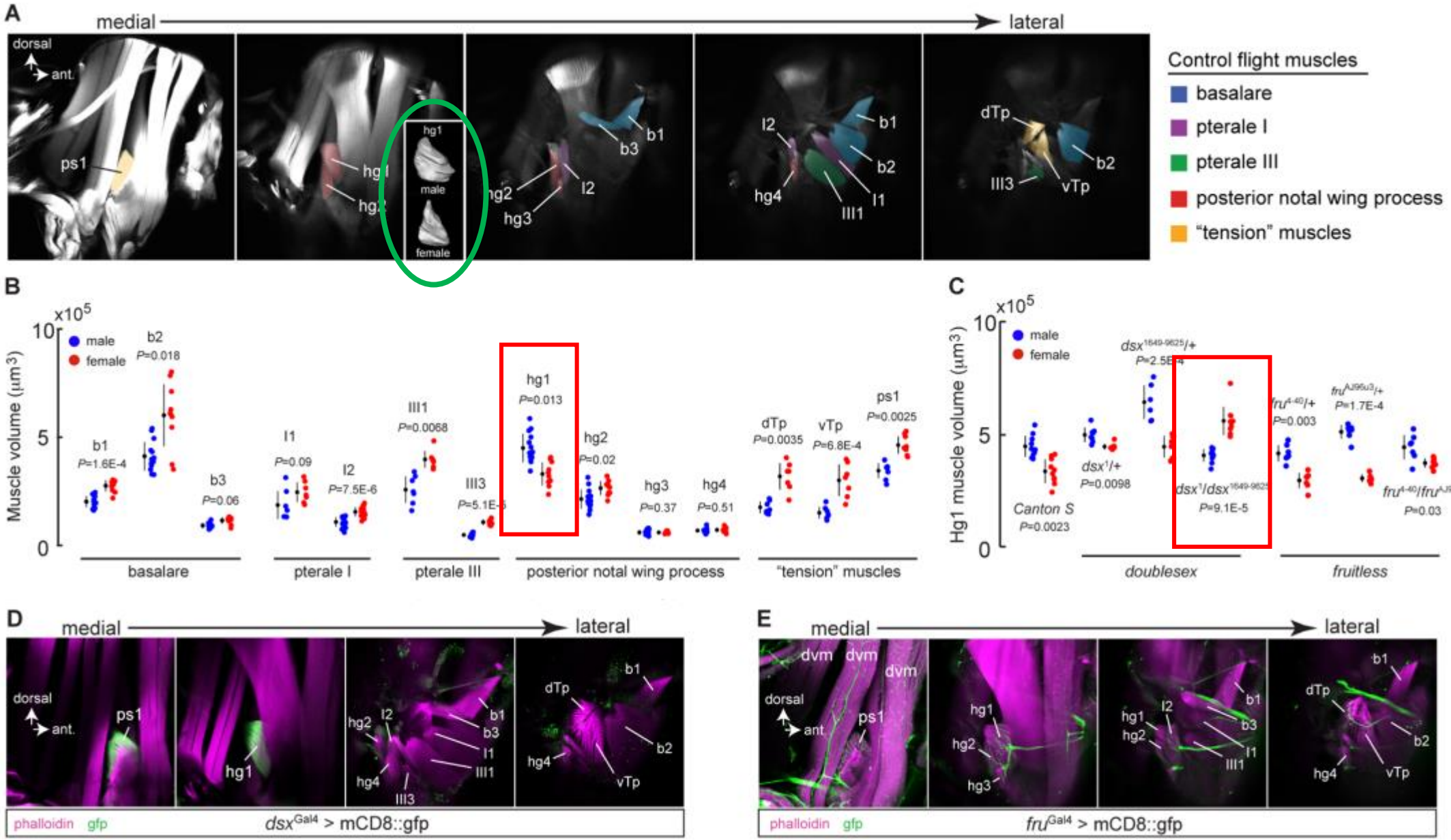
3. How to perform a courtship song?

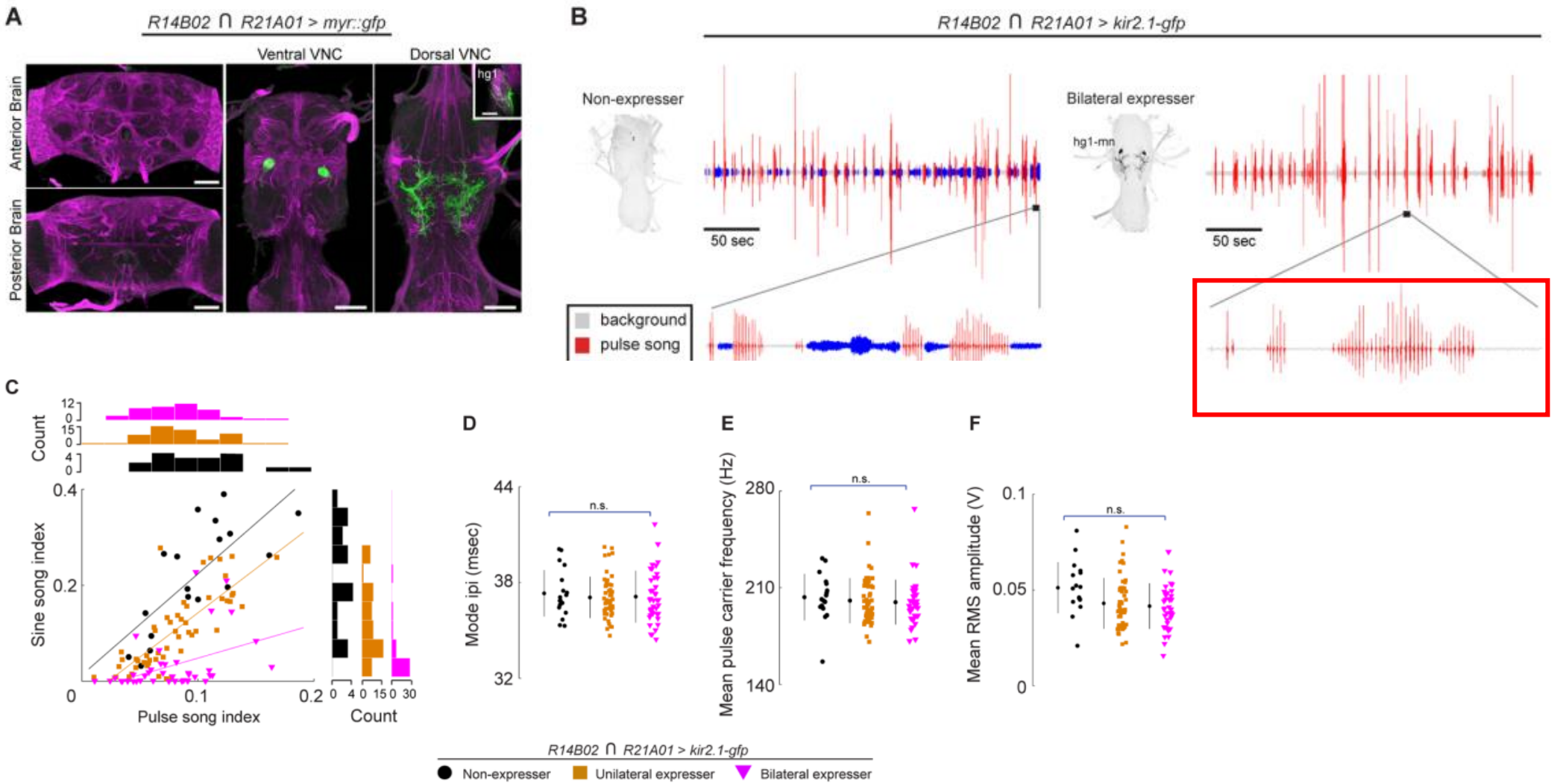
Motor control

Motor Control of Drosophila Courtship Song



Troy R Shirangi et al. *Cell Rep* . 2013 Nov

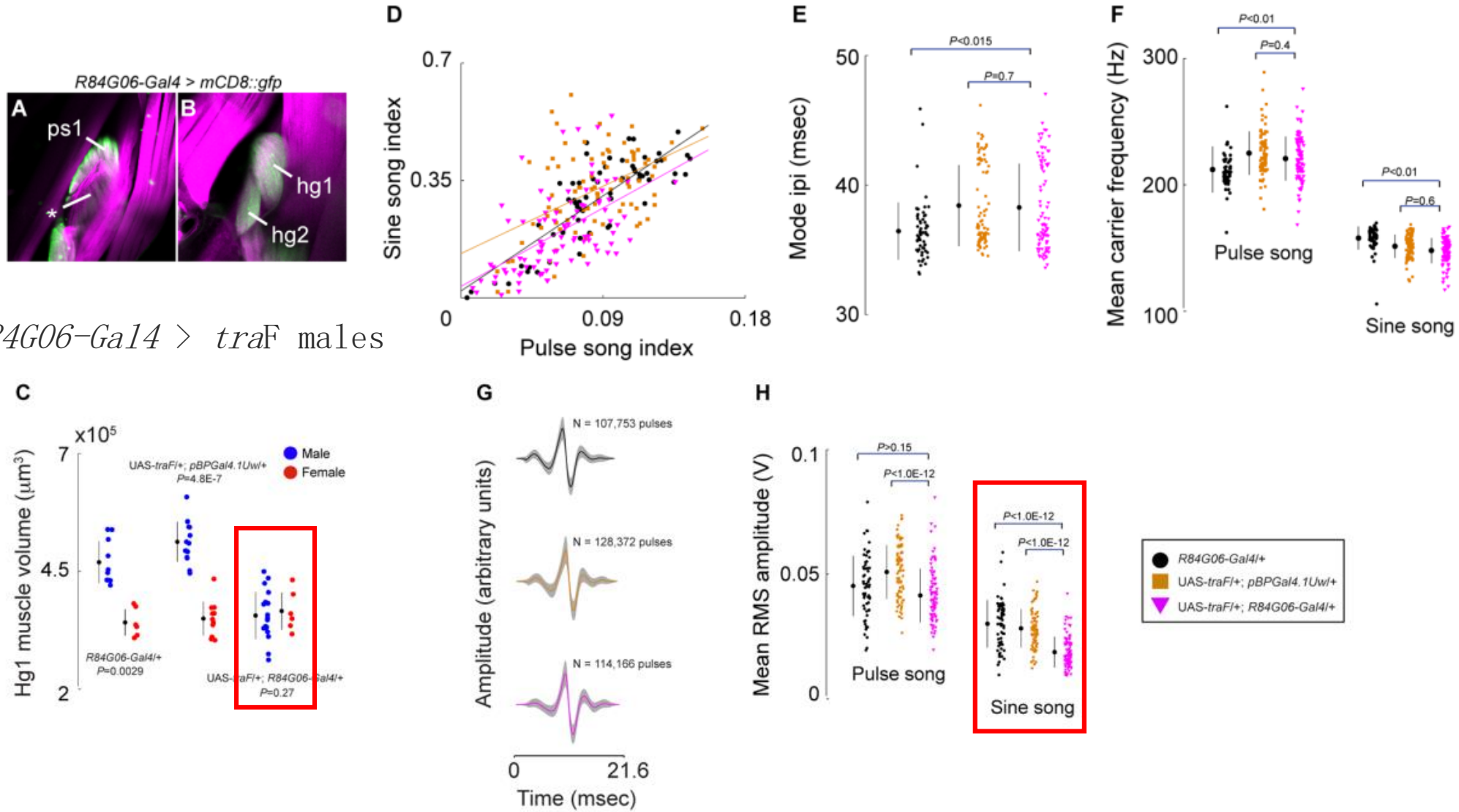
Motor Control of Drosophila Courtship Song



Silencing the hg1 Motoneuron in Males Specifically Impairs Their Ability to Generate Sine Song

Troy R Shirangi et al. *Cell Rep* . 2013 Nov

Motor Control of Drosophila Courtship Song

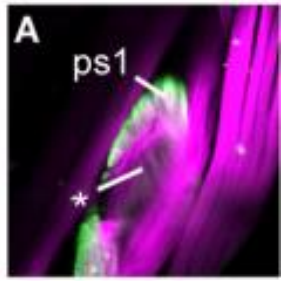


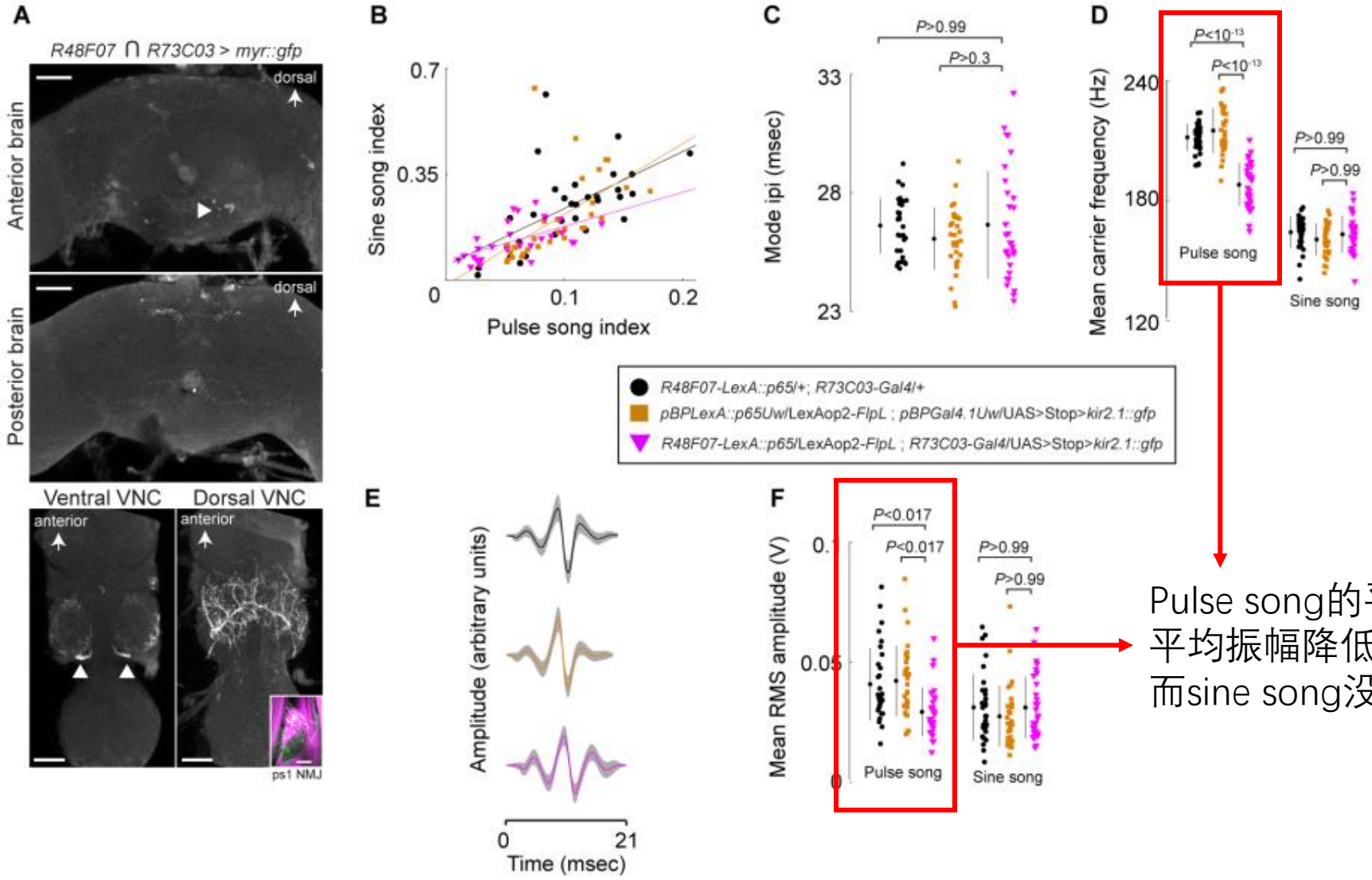
R84G06-Gal4 > traF males

Sexually Dimorphic Development of hg1 Is Required for Maximal Sine Song Amplitude

Troy R Shirangi et al. *Cell Rep* . 2013 Nov

Motor Control of Drosophila Courtship Song





Pulse song的平均脉冲频率和平均振幅降低，
而sine song没有影响

Inhibition of the ps1 Motoneuron Specifically Reduces Pulse Carrier Frequency and Amplitude

Troy R Shirangi et al. *Cell Rep* . 2013 Nov

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3. **How to perform a courtship song?**

   Motor control：hg1运动神经元和hg1肌肉的性别二态性发育是雄蝇求偶歌正弦成分表达所必需的；ps1肌肉，其运动神经元对于脉冲求偶歌的特征很重要。

4. **How to finish a courtship song?**

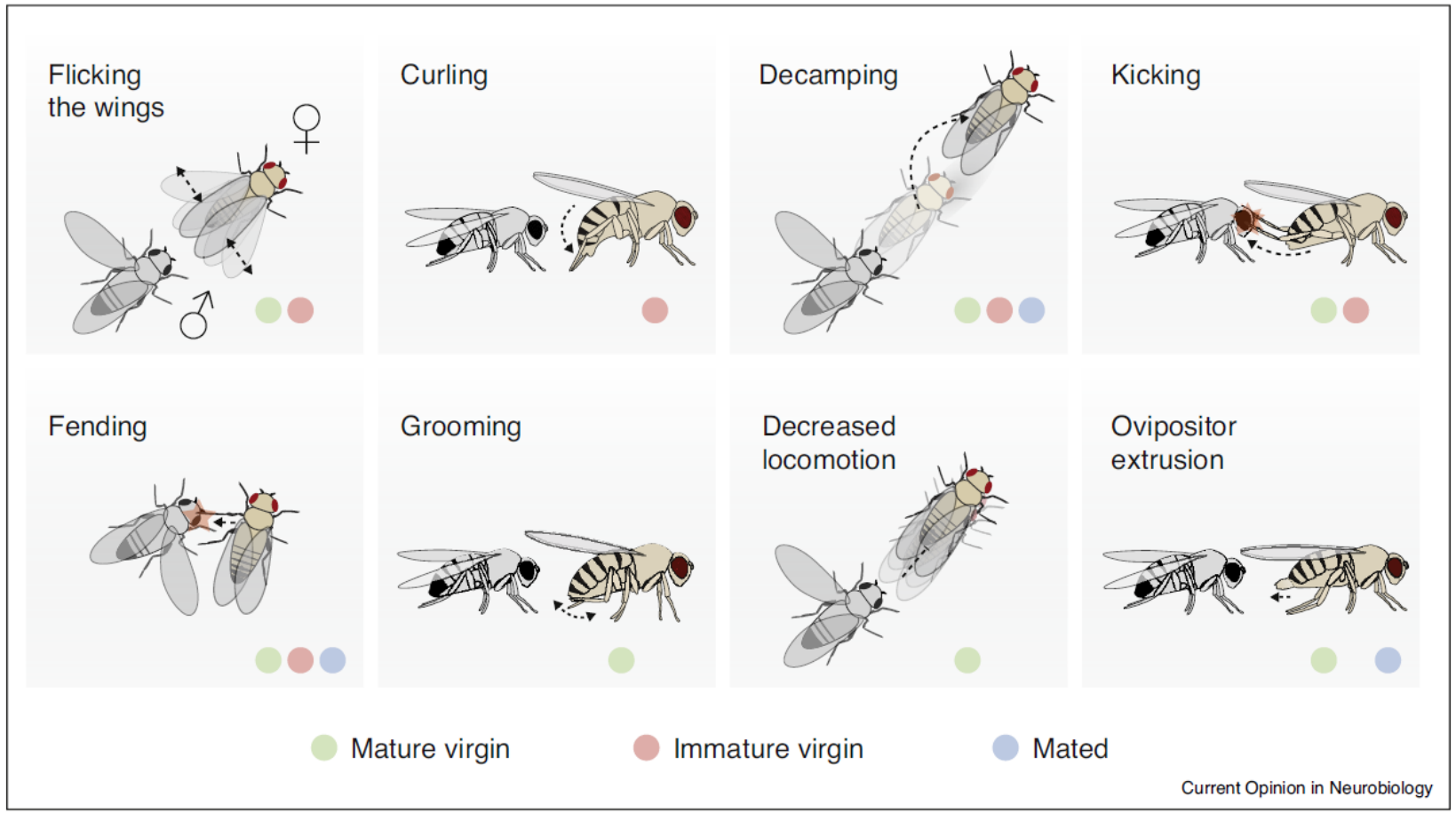
THANKS!

Female responses to courtship songs

Caihong Han

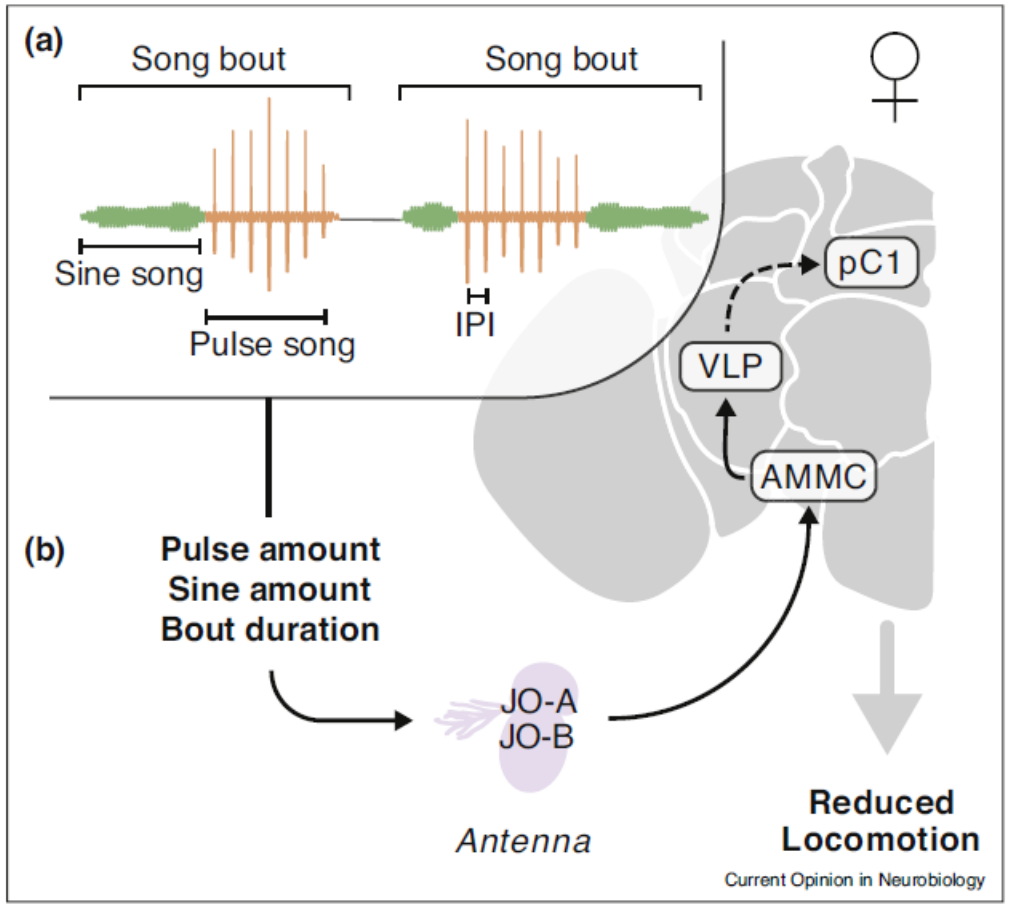
2022-03-31

Behavioral components of courtship in the female fly at different receptivity states

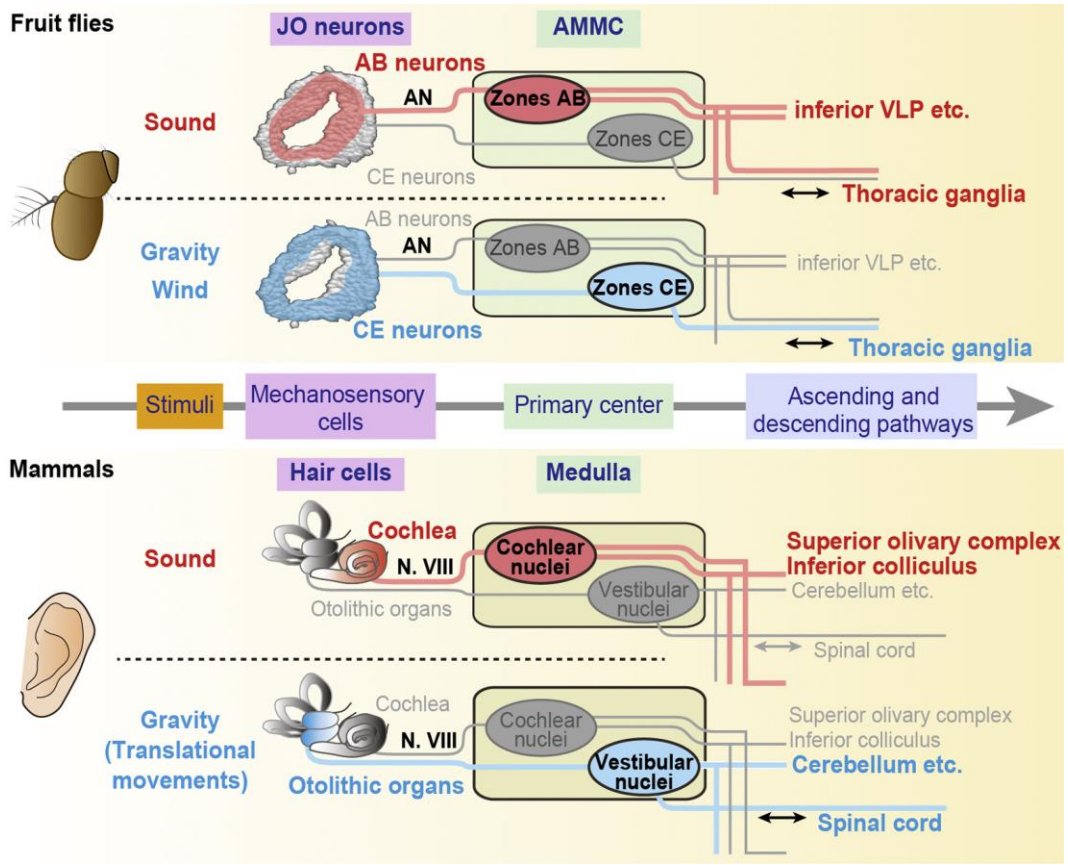


Aranha, M.M. and M.L. Vasconcelos, *Curr Opin Neurobiol*, 2018.

Courtship song response in female and comparison of the sound pathways in flies and mammals.

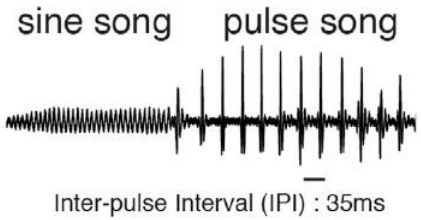


Aranha, M.M. and M.L. Vasconcelos, *Curr Opin Neurobiol*, 2018.



Kamikouchi, A. *Neurosci Res.* 2013

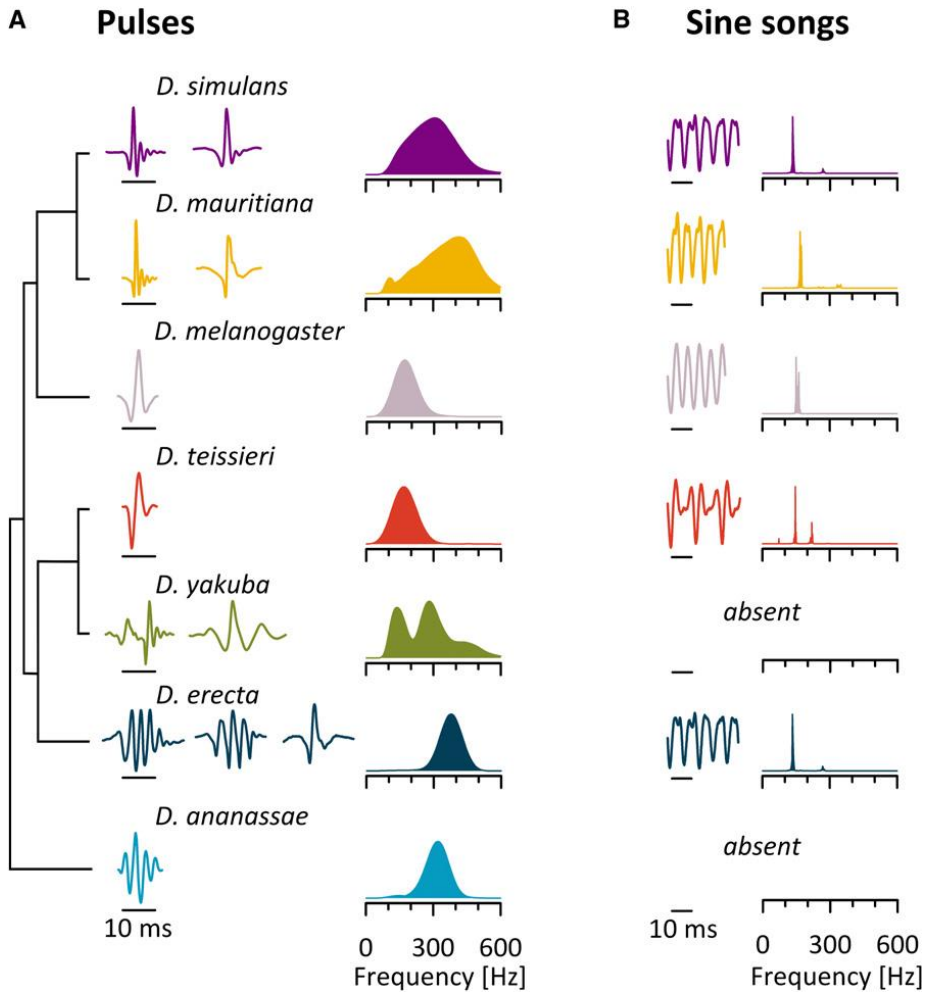
Phylogenetic relationships of *Drosophila* courtship songs across species



Sine song:
a humming sound around 160 Hz

Pulse song:
a species-specific 35ms
inter-pulse interval (IPI)

IPI contributes to species recognition, and thus also has a significant impact on sexual selection.

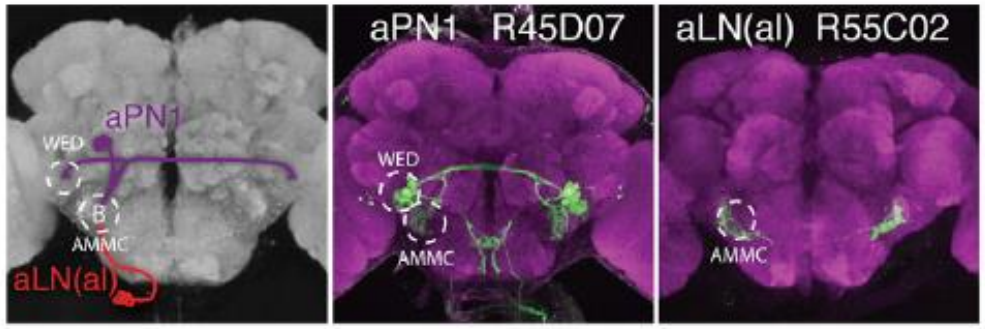


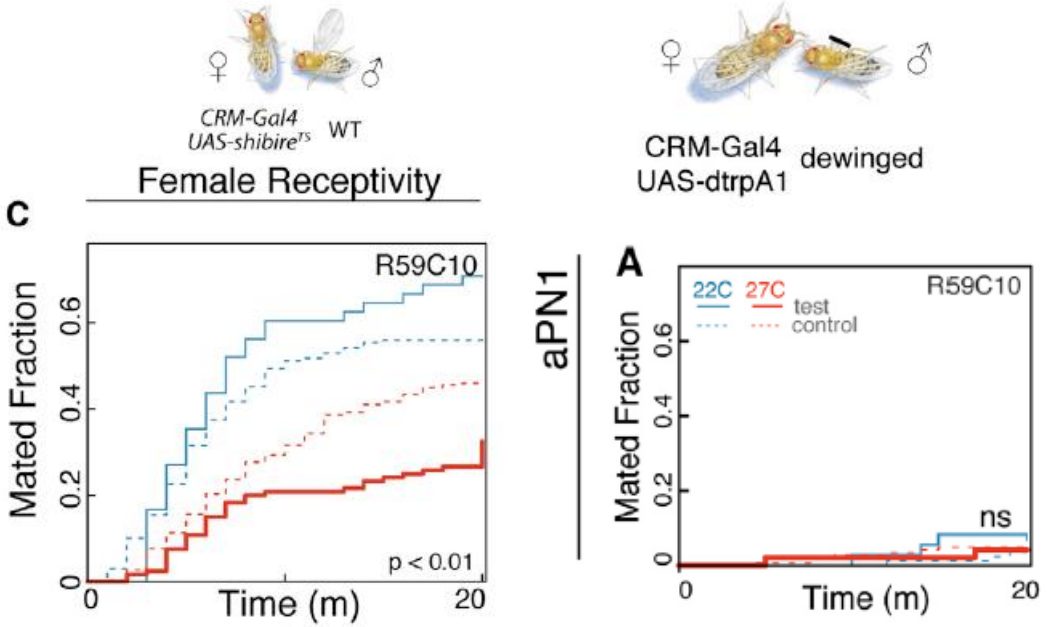
Riabinina, O., et al. *Curr Biol*, 2011

aLN(al) and aPN1 mediate the detection of conspecific song in *D. melanogaster*

~6000 GAL4 →

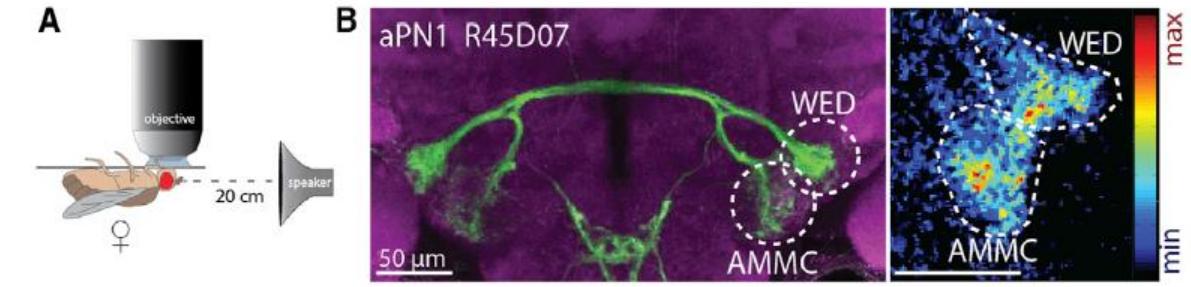
7 auditory projection neurons(aPNs)	aPN1
5 auditory local neurons(aLNs)	aLN(al)

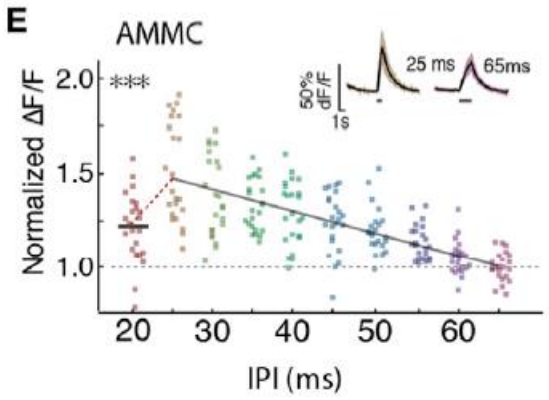


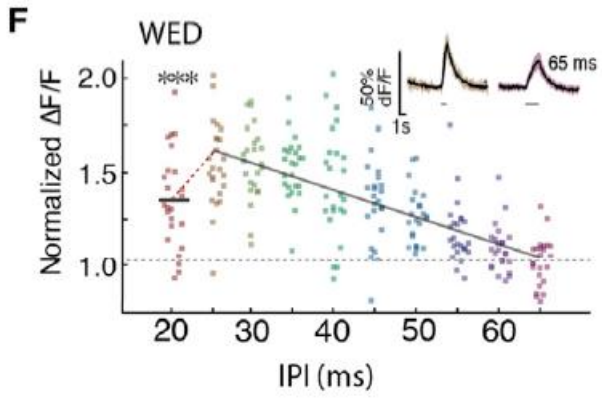


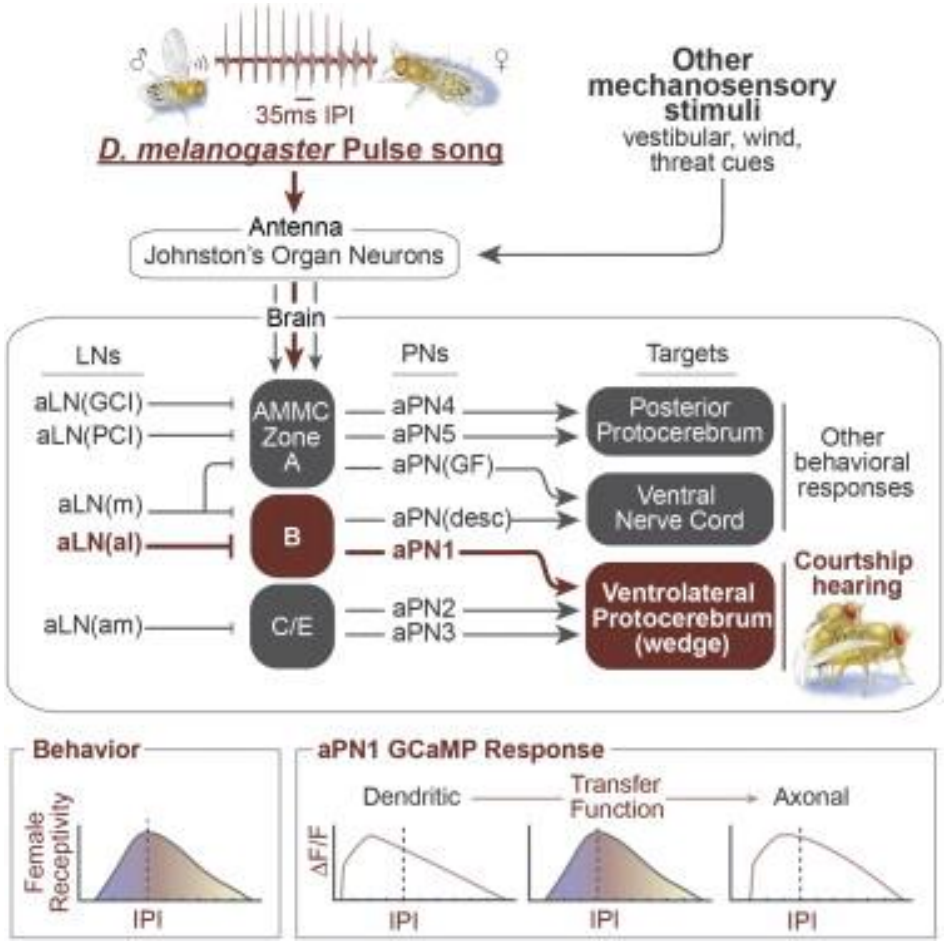
Vaughan, Alexander G., et al., *Curr Biol*, 2014

aPN1 response to pulse song in AMMC



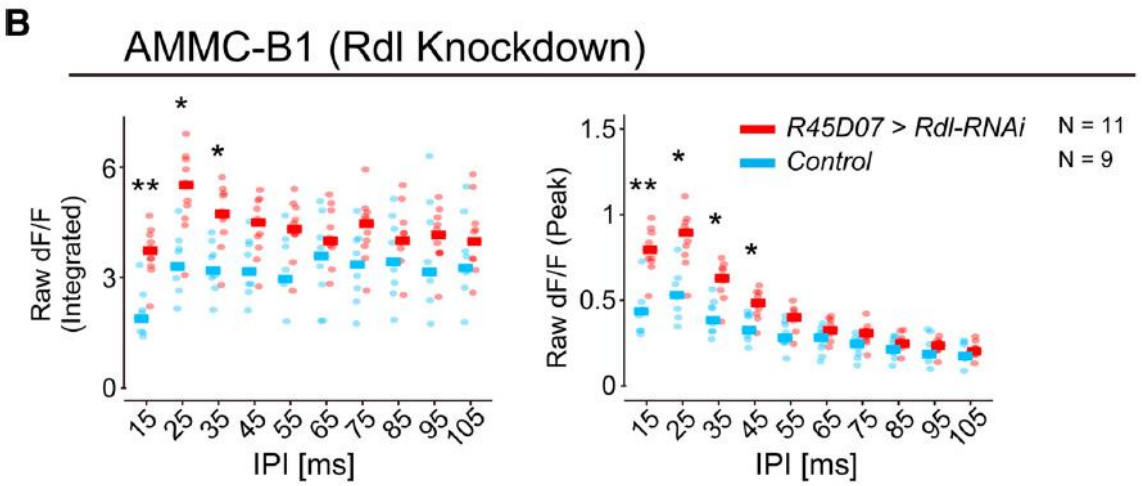


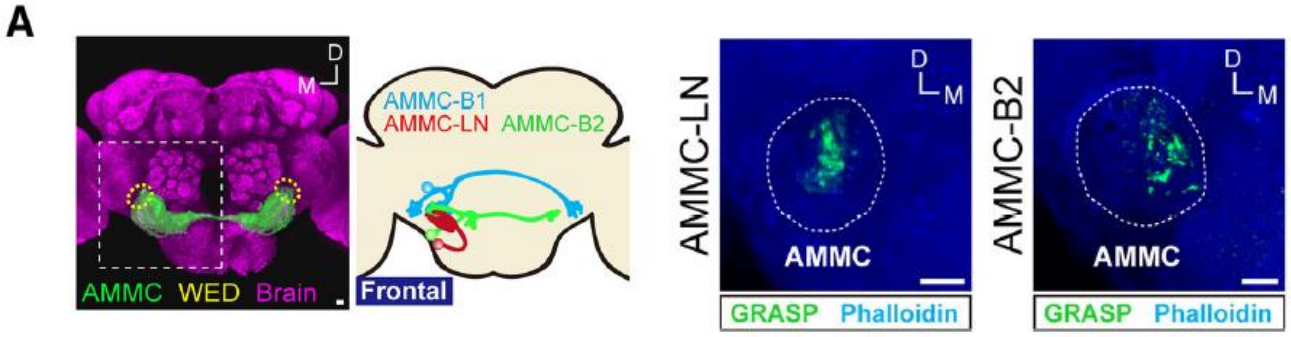


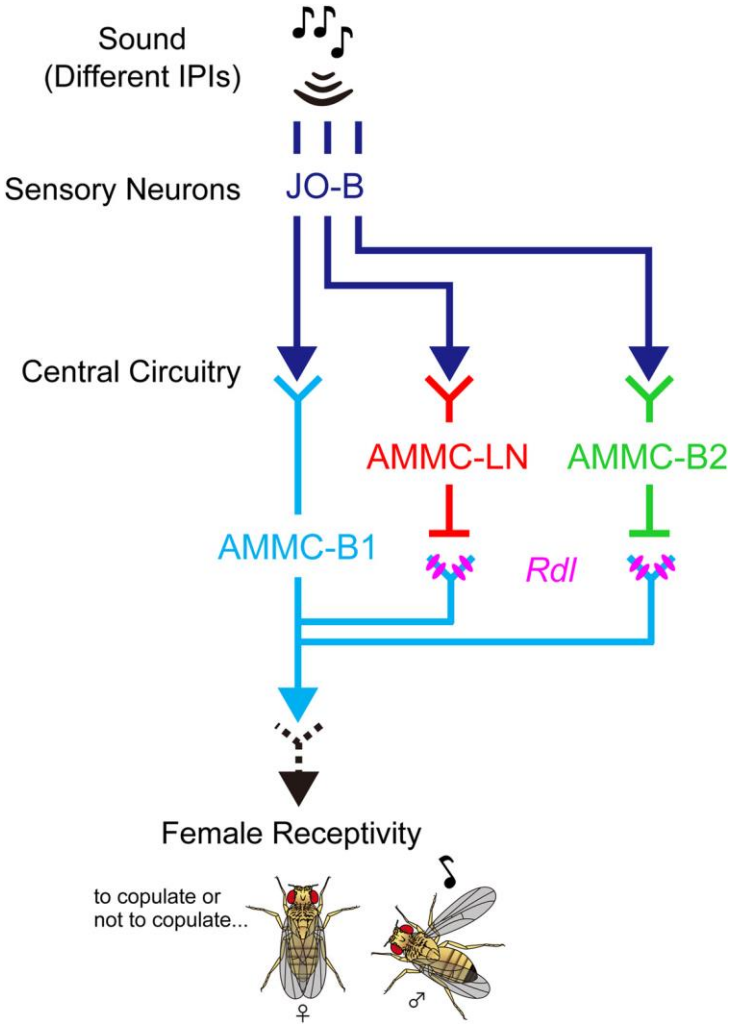


Vaughan, Alexander G., et al., *Curr Biol*, 2014

GABAergic local interneurons suppress the song response of AMMC neurons





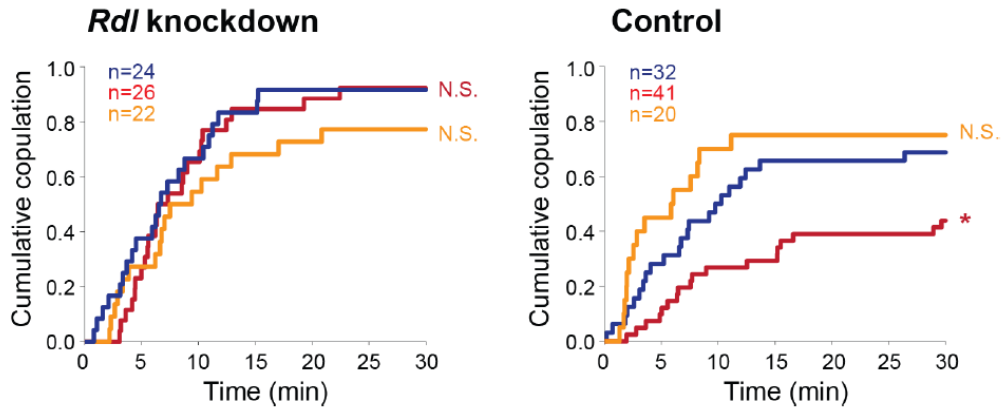


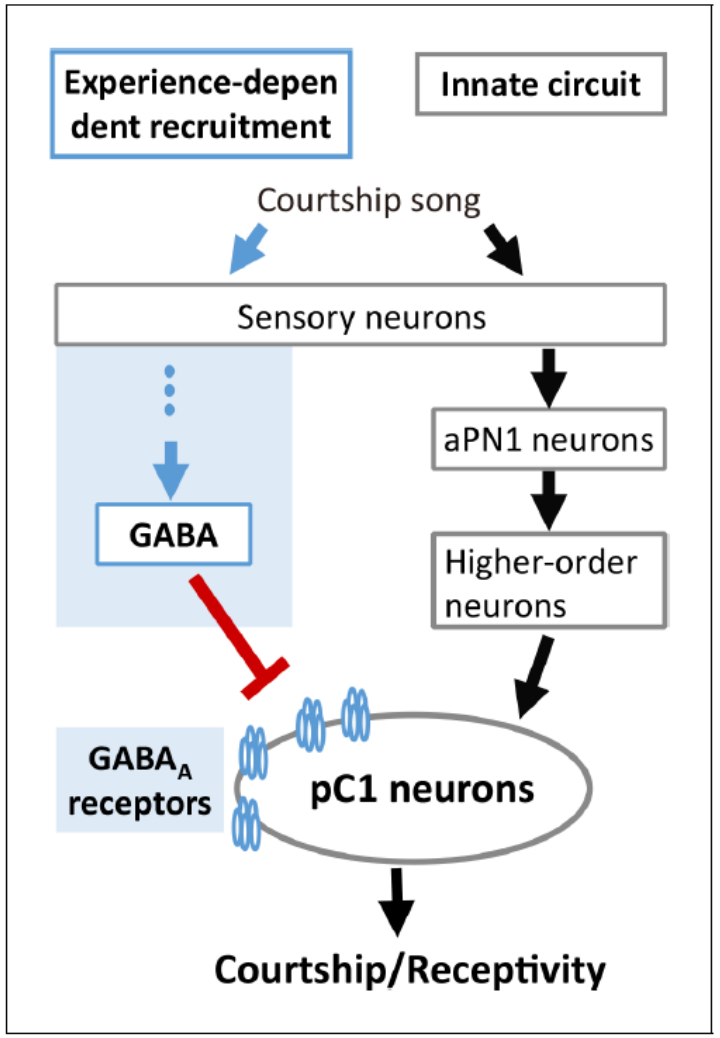
Yamada, D., et al. *J Neurosci*, 2018.

Rdl receptors in pC1 neurons modulate the experience-dependent song preference in females.

B

	Training	Test
N	No sound	Heterospecific
E	Conspecific	Heterospecific
E	Heterospecific	Heterospecific

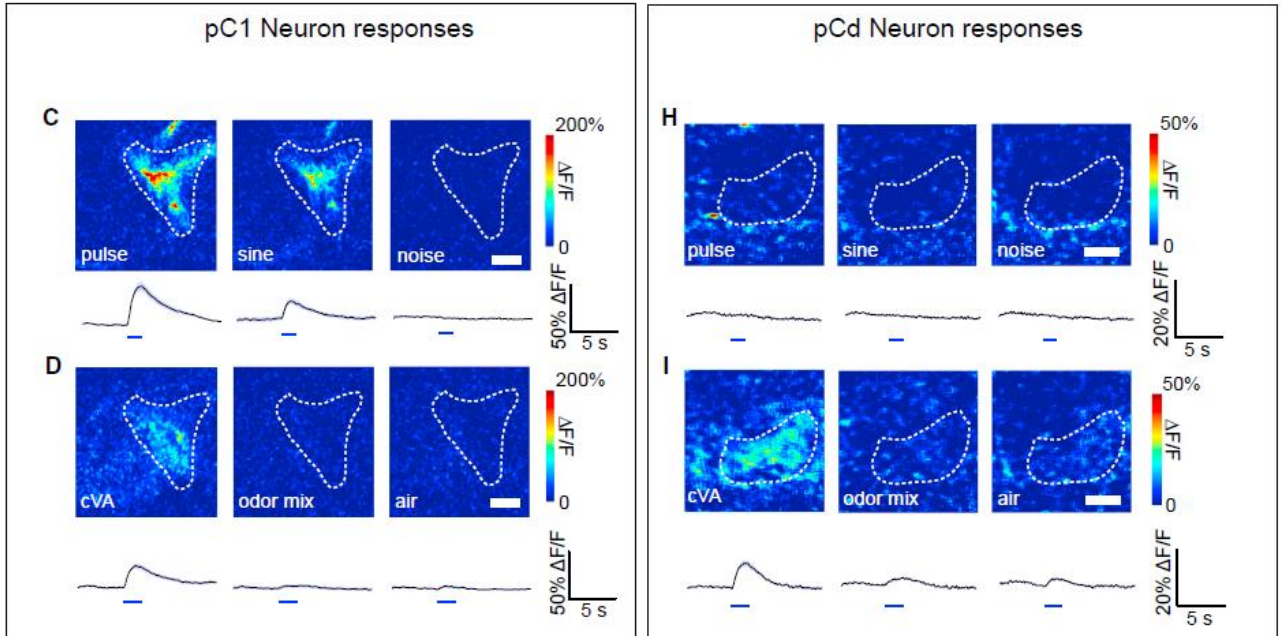


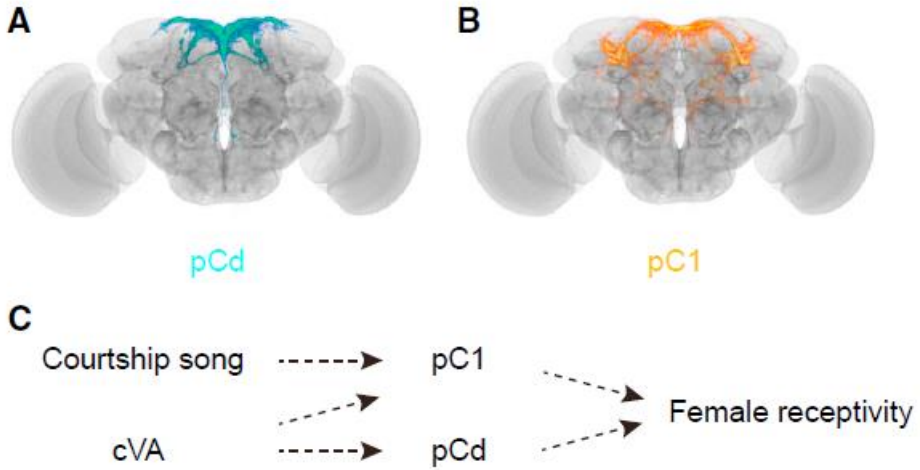


Li, X. *Elife*, 2018

How does the courtship song signals female acceptance?

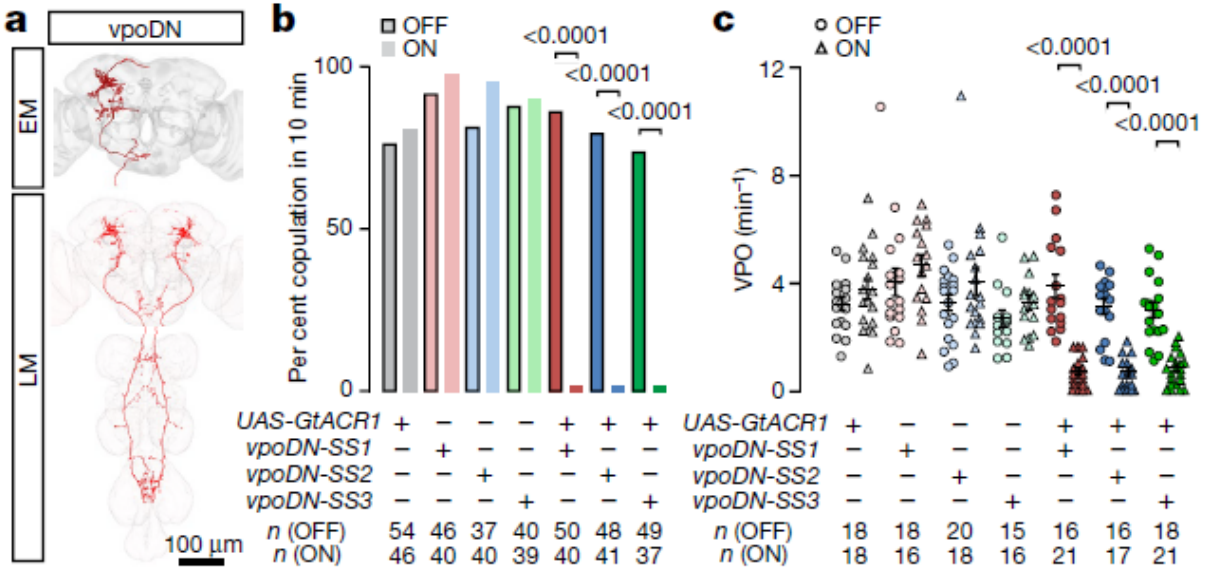
cVA sensitizes the responses of pC1 neurons to courtship song

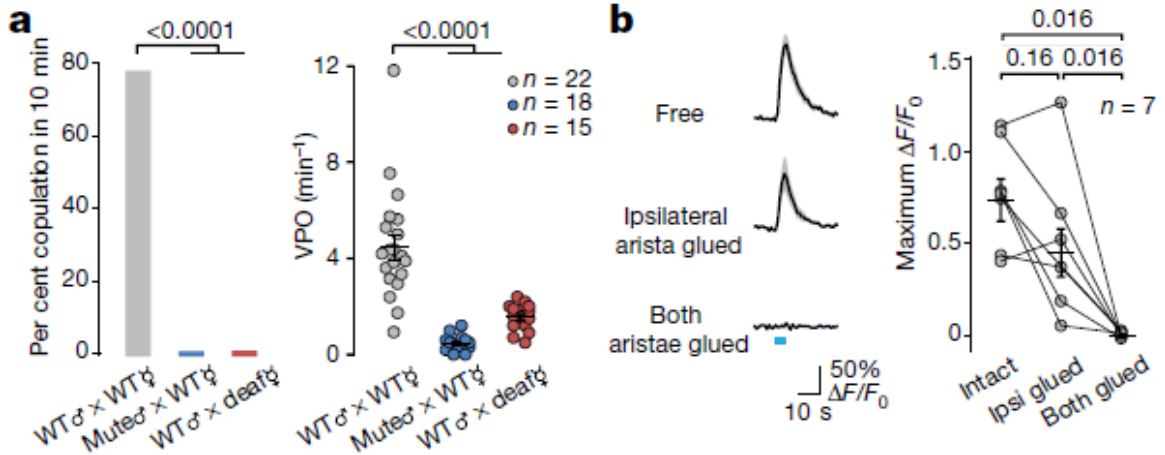




Zhou, C., et al. *Neuron*, 2014.

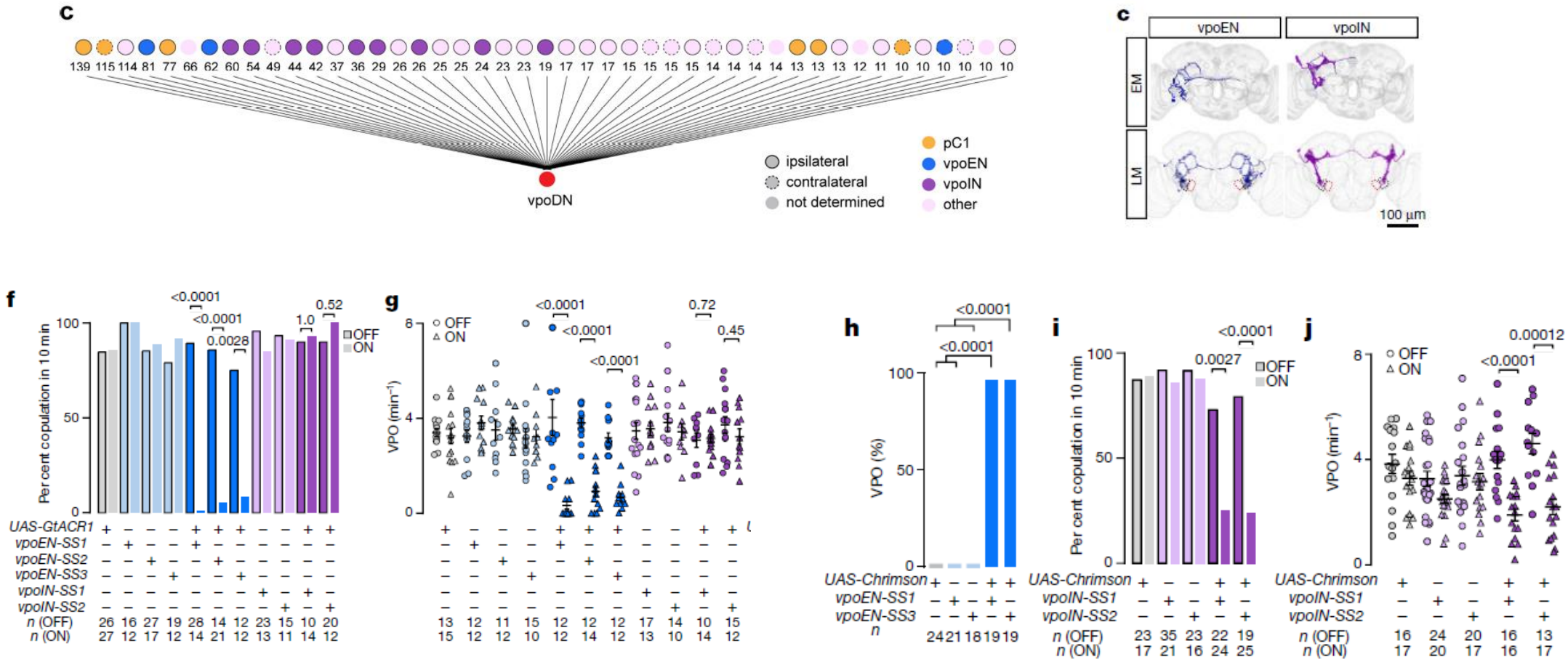
Auditory inputs to female-specific vpoDNs controlling vaginal plate opening (VPO)





Wang et al., 2020, *Nature*.

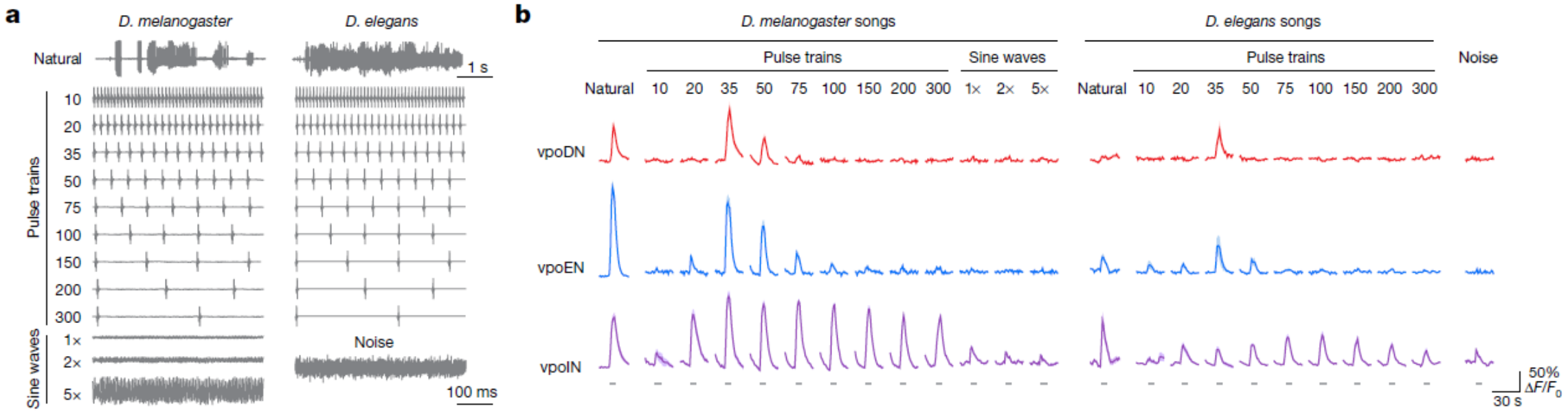
Auditory input to vpoDN to control VPO and receptivity



vpoENs and vpoINs promote and suppress, respectively, both VPO and receptivity.

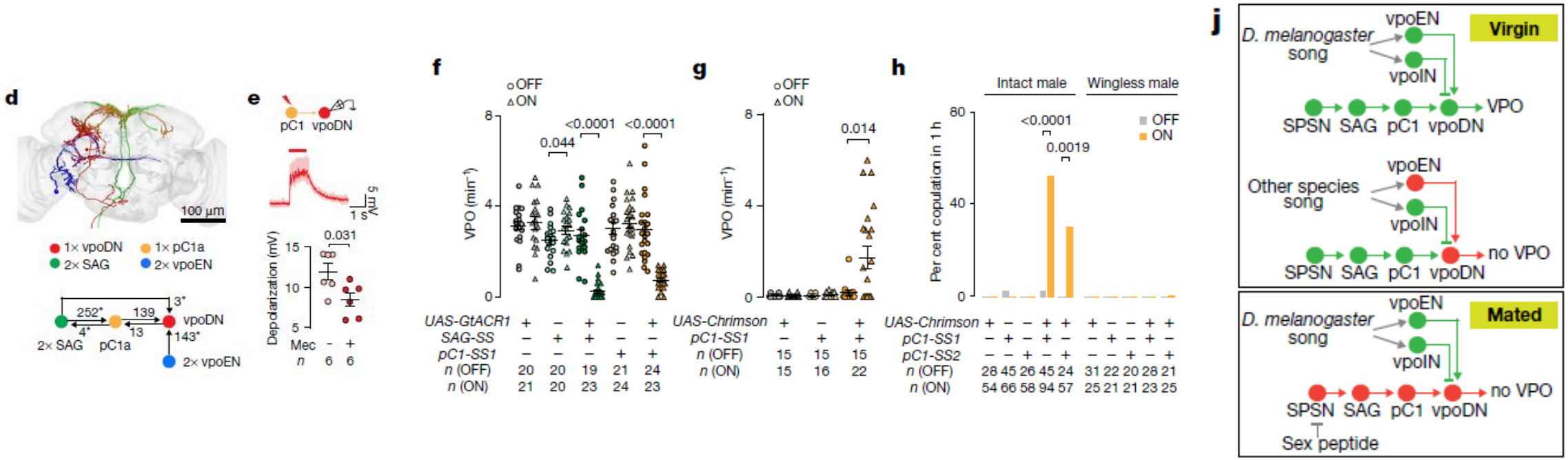
Wang et al., 2020, *Nature*.

vpoENs and vpoDNs are tuned to conspecific courtship song



Wang et al., 2020, *Nature*.

vpoDNs integrate mating status and song



The female fly to mate or not to mate is largely determined by how the vpoDNs integrate signals from two direct synaptic inputs:

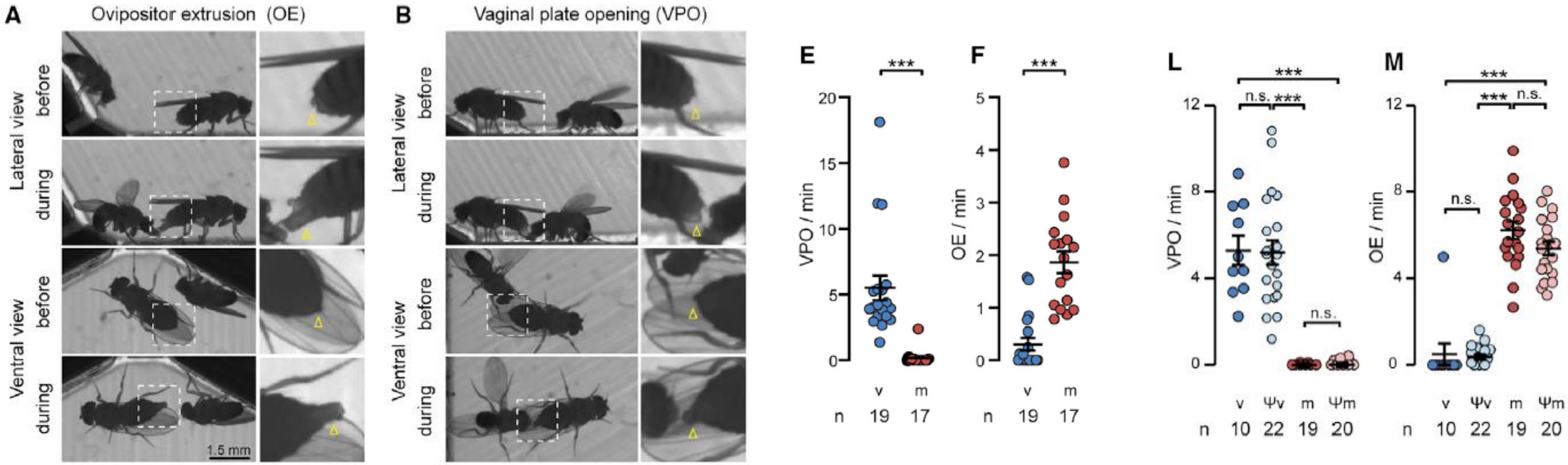
1、the vpoENs, which are selectively tuned to the conspecific male courtship song,

2、the pC1 cells, which encode the mating status of the female.

Wang et al., 2020, *Nature*.

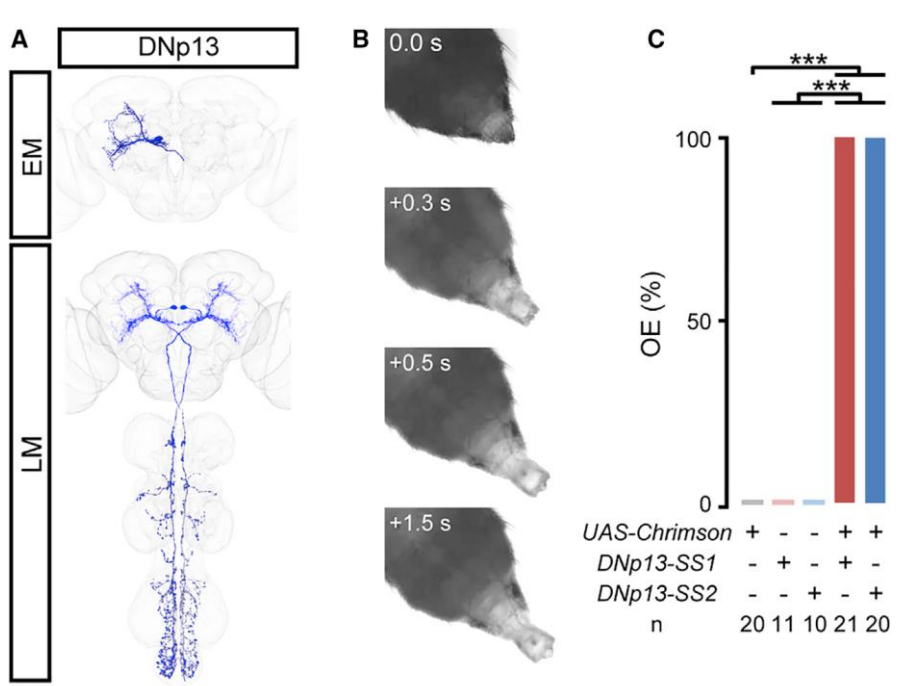
How does the brain processes courtship song for rejection responses in females?

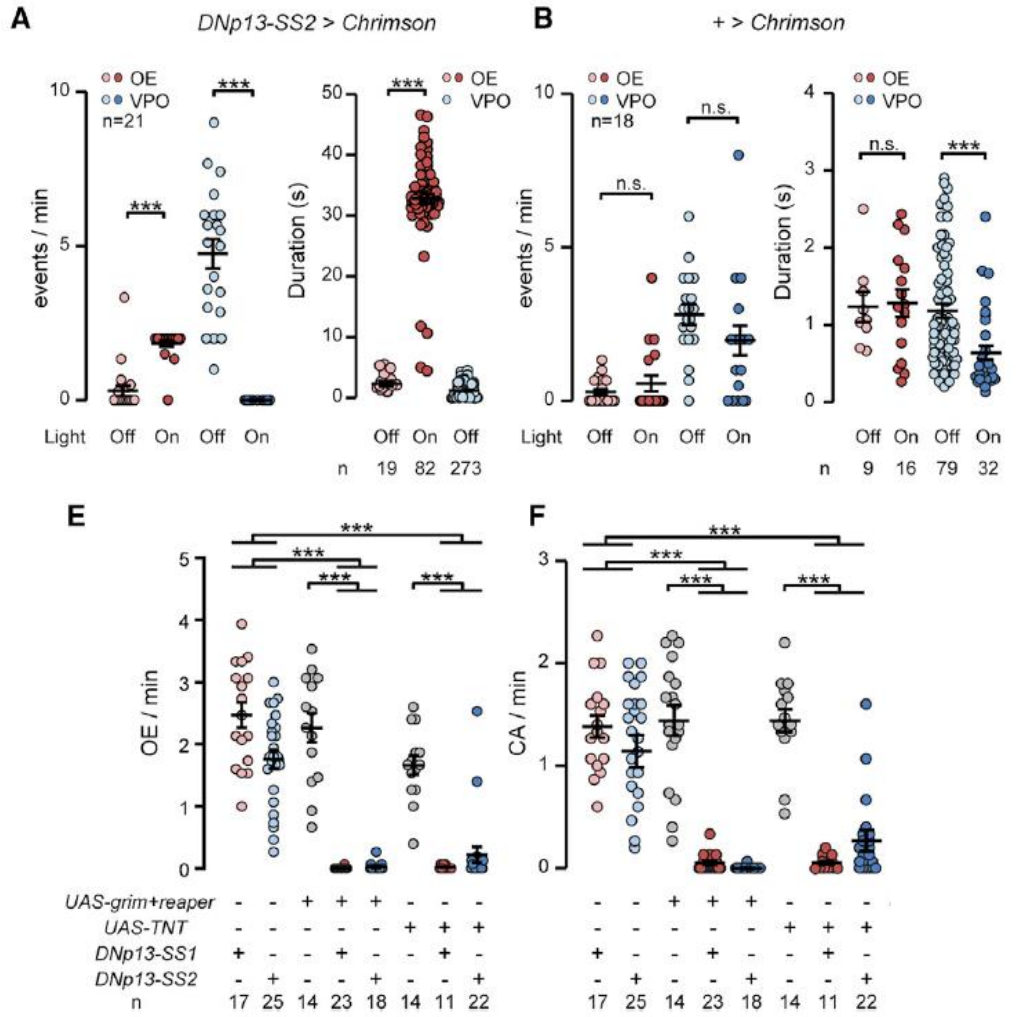
Ovipositor extrusion mediates rejection when performed by a mated female



Wang et al., 2020, *Current Biology*

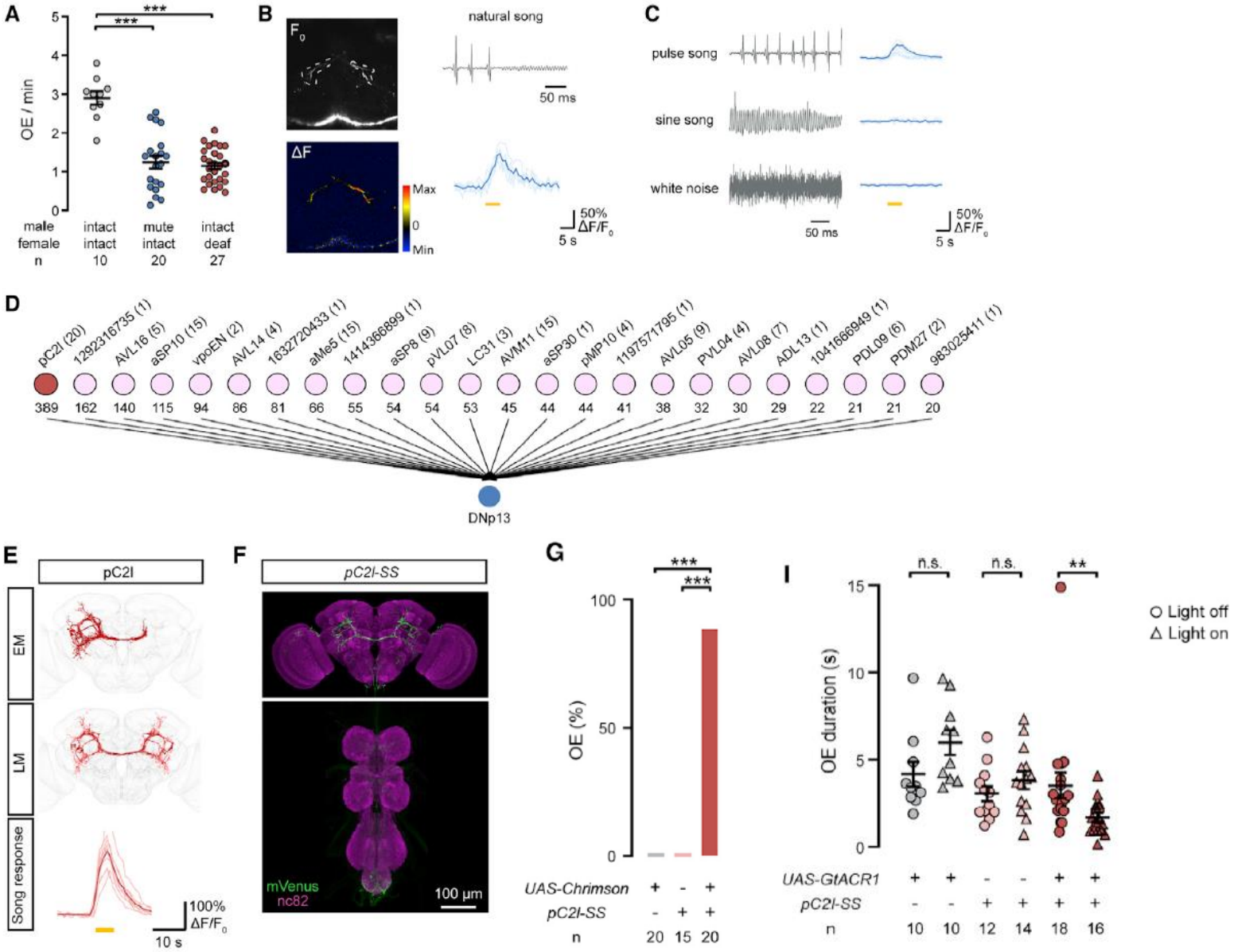
Photoactivation of DNp13 neurons mediate ovipositor extrusion





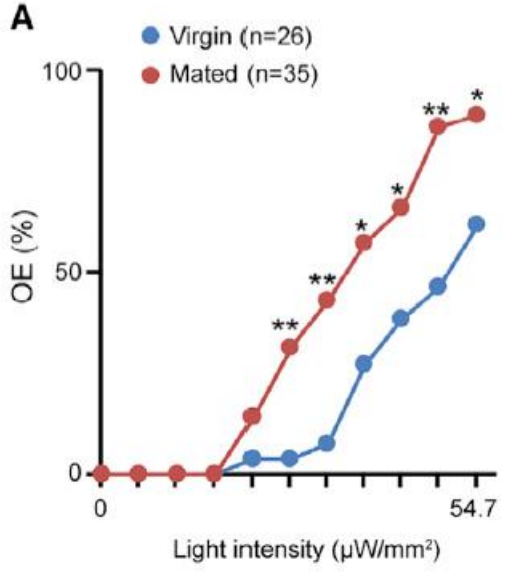
Wang et al., 2020, *Current Biology*

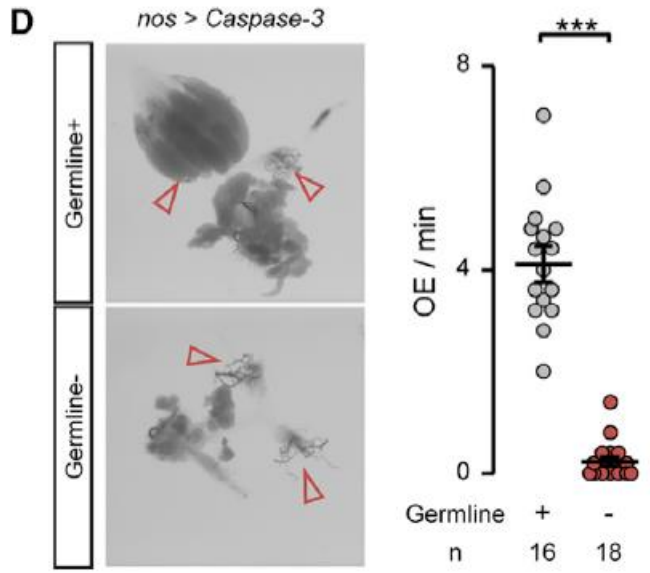
DNp13 neurons receive auditory input from pC2l cells

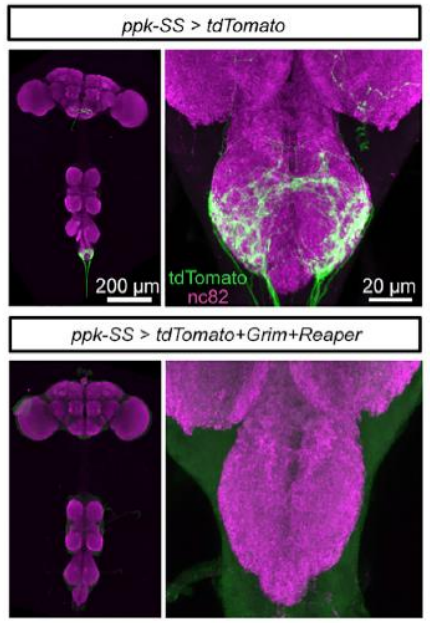


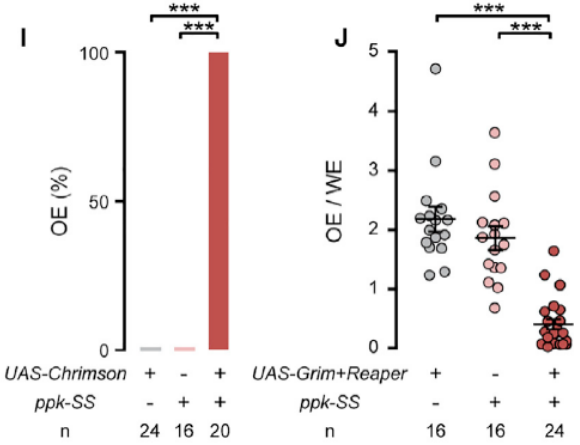
Wang et al., 2020, *Current Biology*

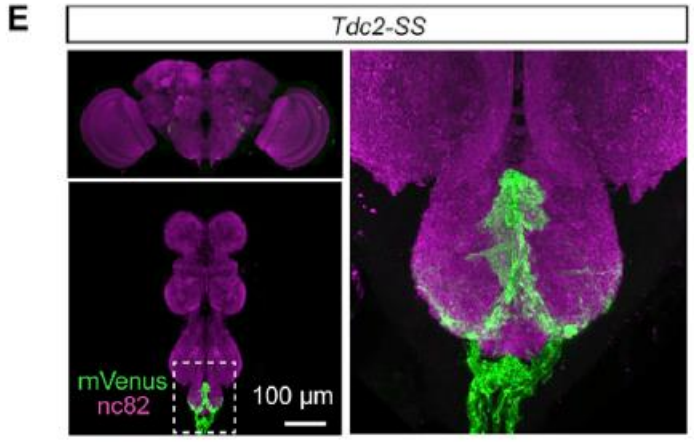
Ovulation facilitates the ability of DNp13 neurons to trigger ovipositor extrusion

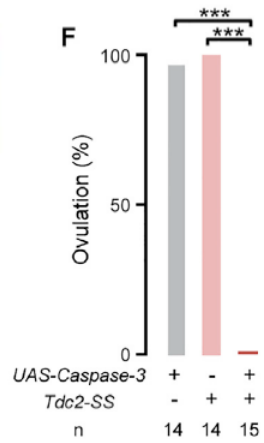


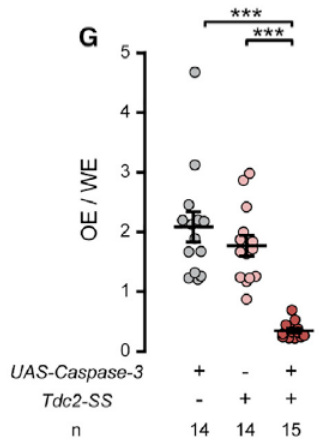








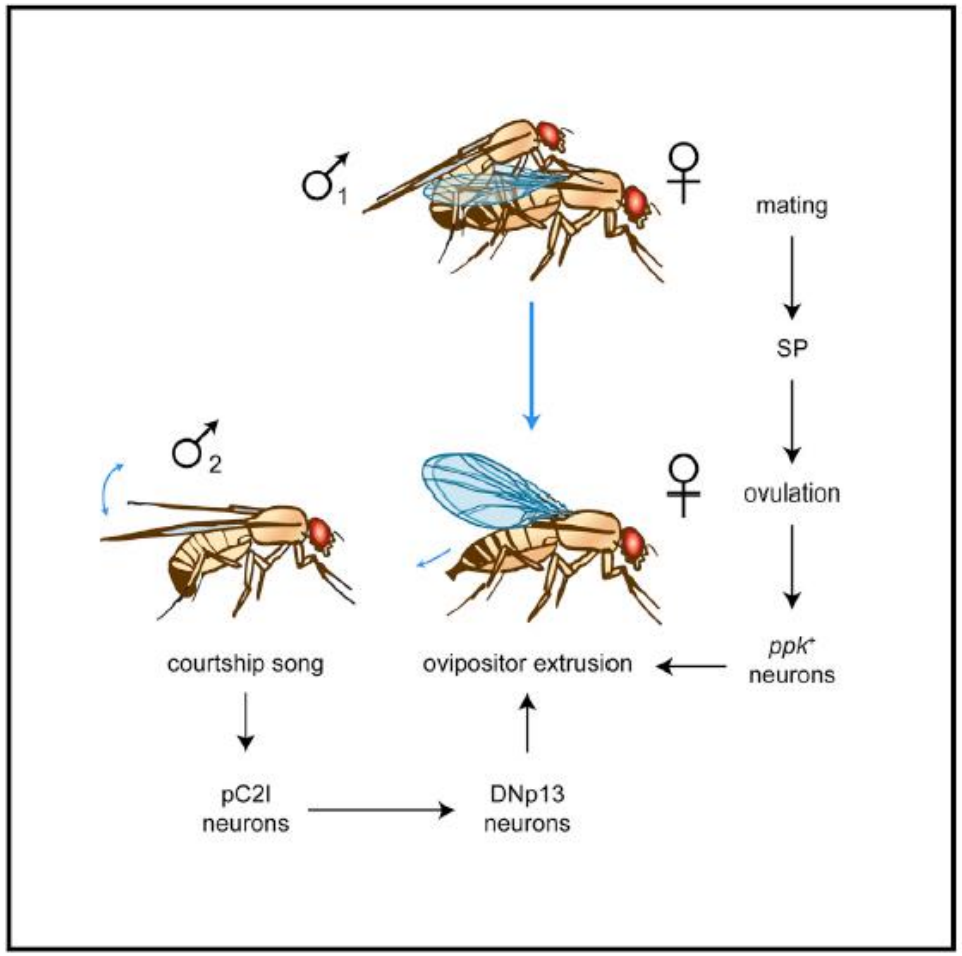




Article

Current Biology

Circuit and Behavioral Mechanisms of Sexual Rejection by *Drosophila* Females



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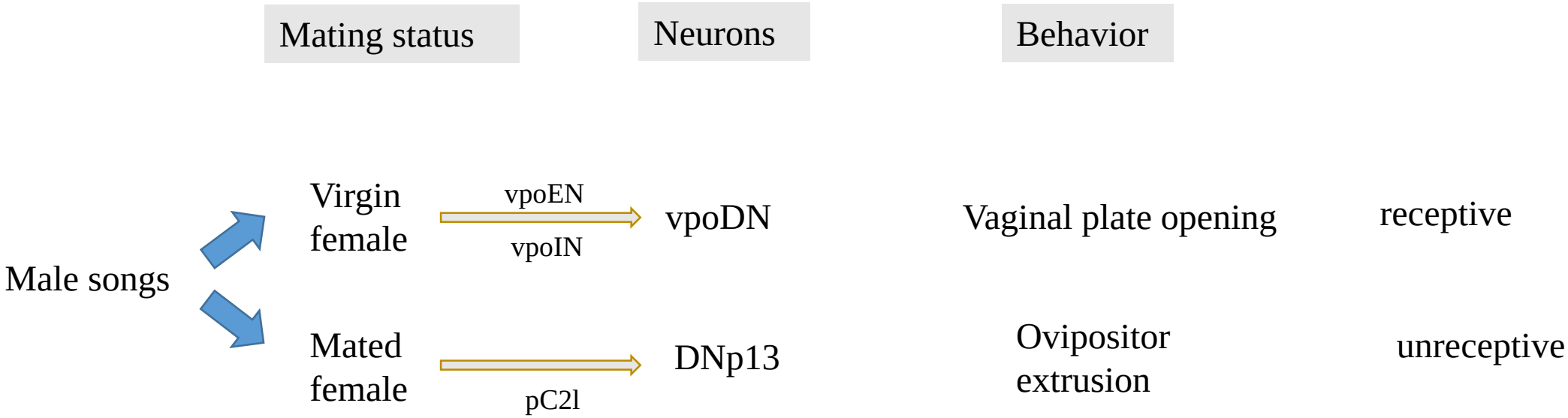
Highlights

- Mated *Drosophila* females extrude their ovipositors to reject courting males
- The DNp13 descending neurons are command neurons for ovipositor extrusion
- DNp13 neurons respond to male courtship song via pC2l auditory neurons
- Ovulation, triggered by a prior mating, enhances DNp13 motor output


Mating status
Neurons
Behavior
Male songs
Virgin female
vpoEN
vpoIN
vpoDN
Vaginal plate opening
receptive
Mated female
pC2l
DNp13
Ovipositor extrusion
unreceptive

Current Biology

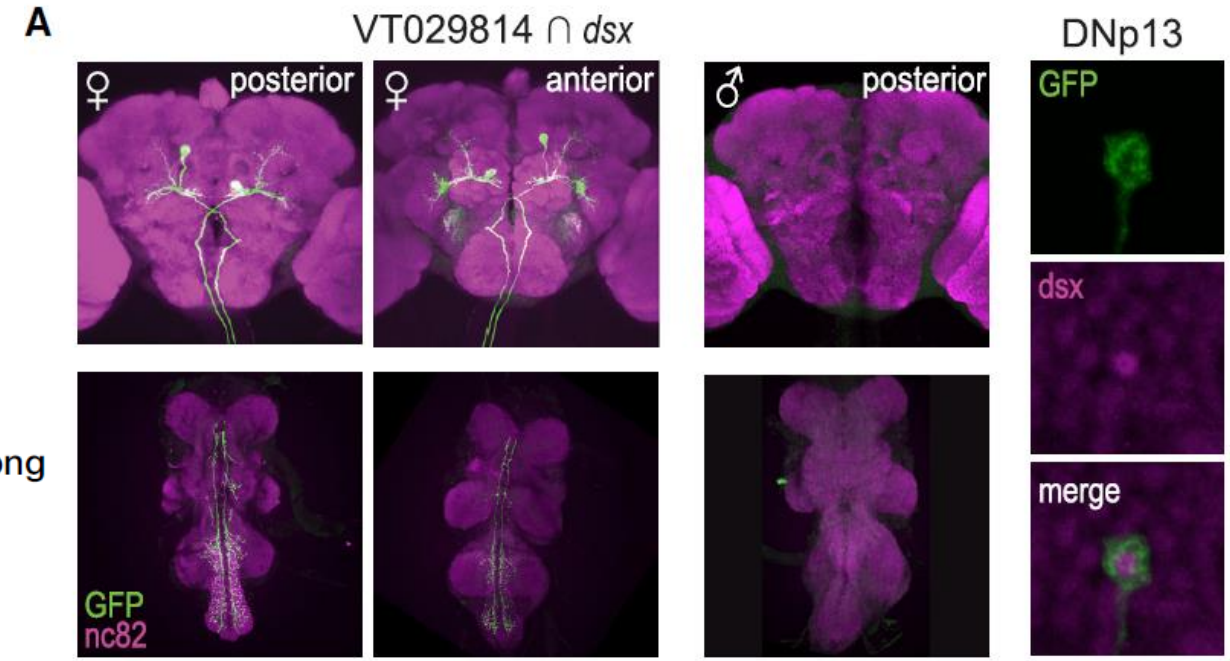
Ovipositor Extrusion Promotes the Transition from Courtship to Copulation and Signals Female Acceptance in *Drosophila melanogaster*

Authors

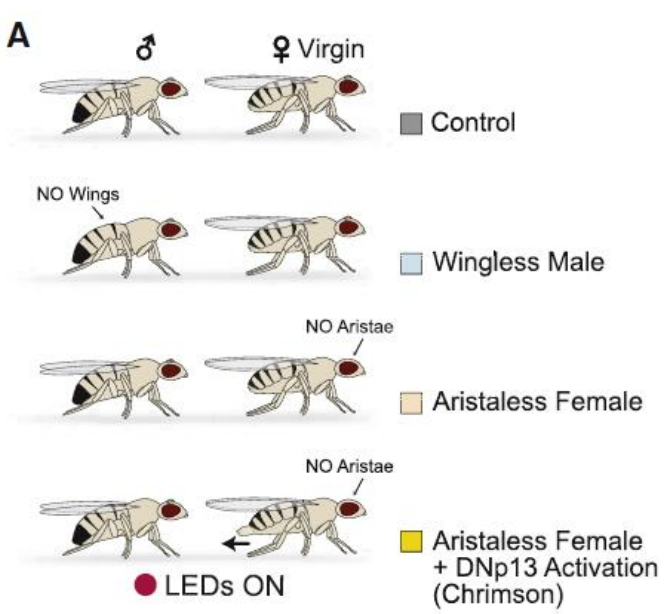
Cecilia Mezzera, Margarida Brotas, Miguel Gaspar, Hania J. Pavlou, Stephen F. Goodwin, Maria Luísa Vasconcelos

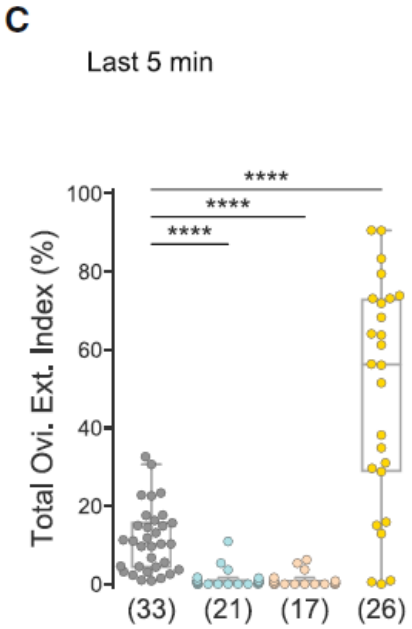
Highlights

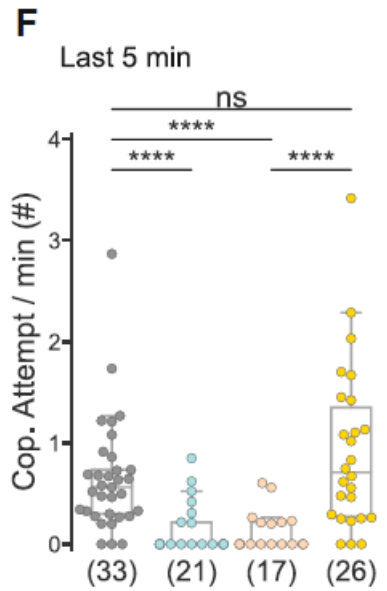
- DNp13 activity induces full ovipositor extrusion
- Ovipositor extrusion is a response to the male courtship song
- Male licking an extruded ovipositor prompts copulation attempt
- Upon copulation attempt, receptive females retract the ovipositor to allow copulation

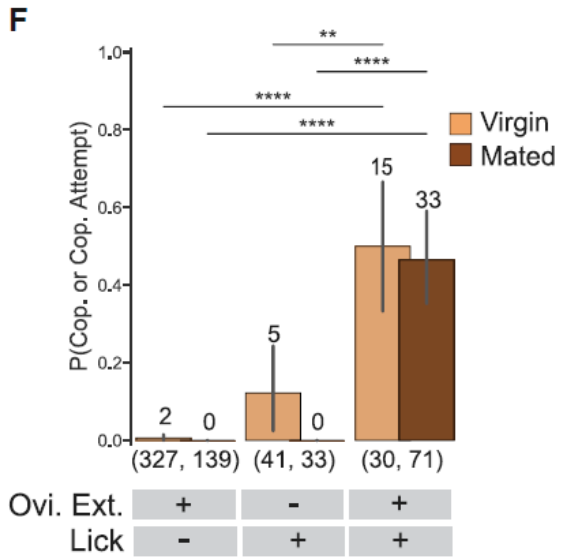


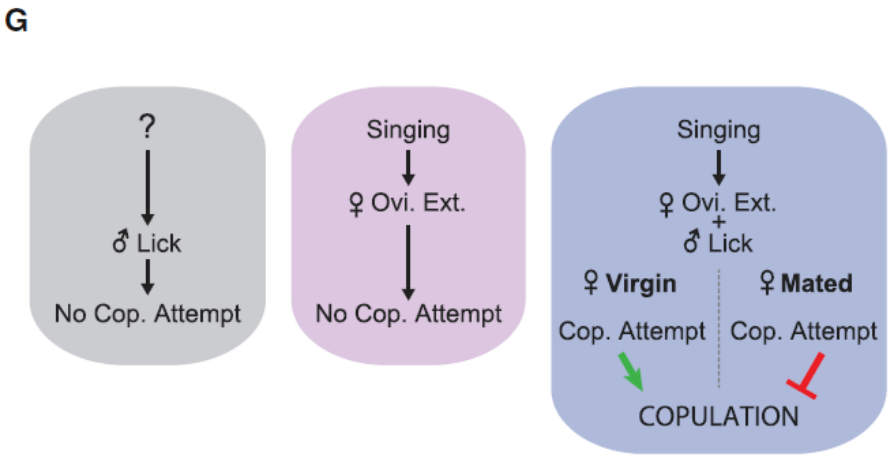
Licking and ovipositor extrusion together prompt male copulation attempt





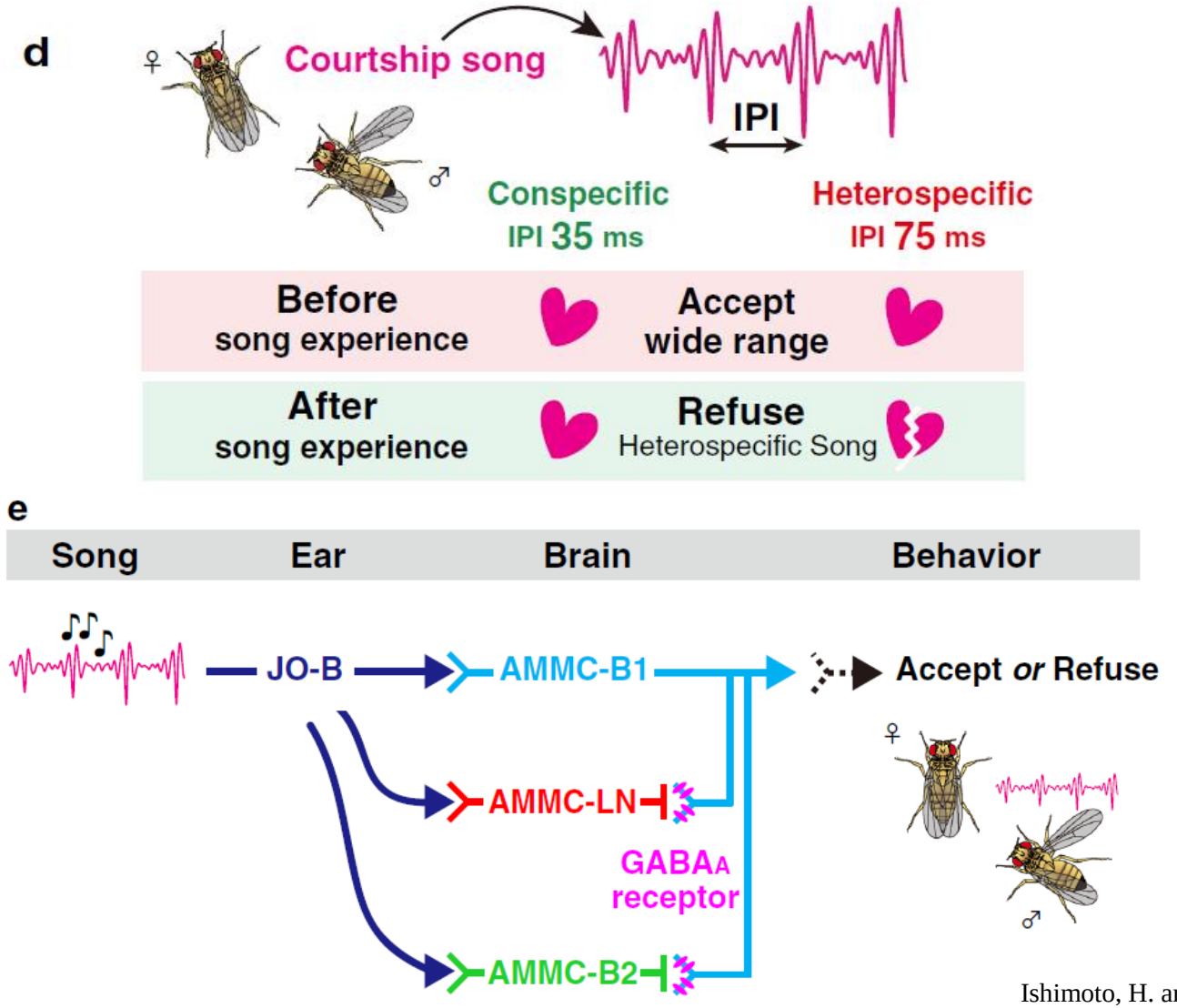






Mezzera, C., et al., *Curr Biol*, 2020

A model of the auditory pathways involved in relay of song signals to modulate female receptivity.



Ishimoto, H. and A. Kamikouchi, *Cell Mol Life Sci*, 2021.

summary

- aPN1 mediate the detection of conspecific song in *D. melanogaster.*
- Female-specific vpoDNs neurons act as command-type neurons for vaginal plate opening to allow copulation.
- The DNp13 neurons respond to male song via direct synaptic input from the pC2l auditory neurons for ovipositor extrusion to reject the male.
- Licking and ovipositor extrusion together prompt male copulation attempt.
- GABAergic local interneurons suppress the song response of AMMC neurons

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