Sleep on Drosophila

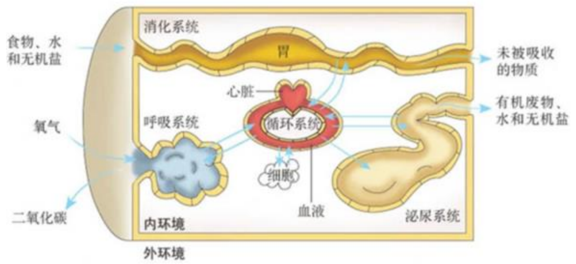
李小龙 王林 朱寰

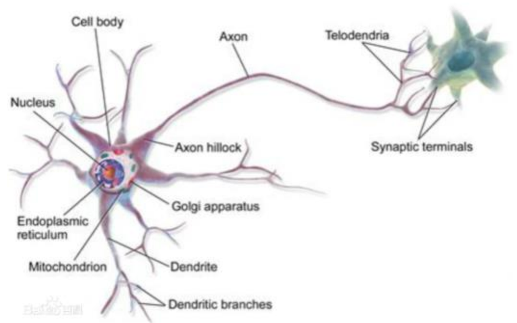
2021/10/14

Most living things need sleep

Function of Sleep

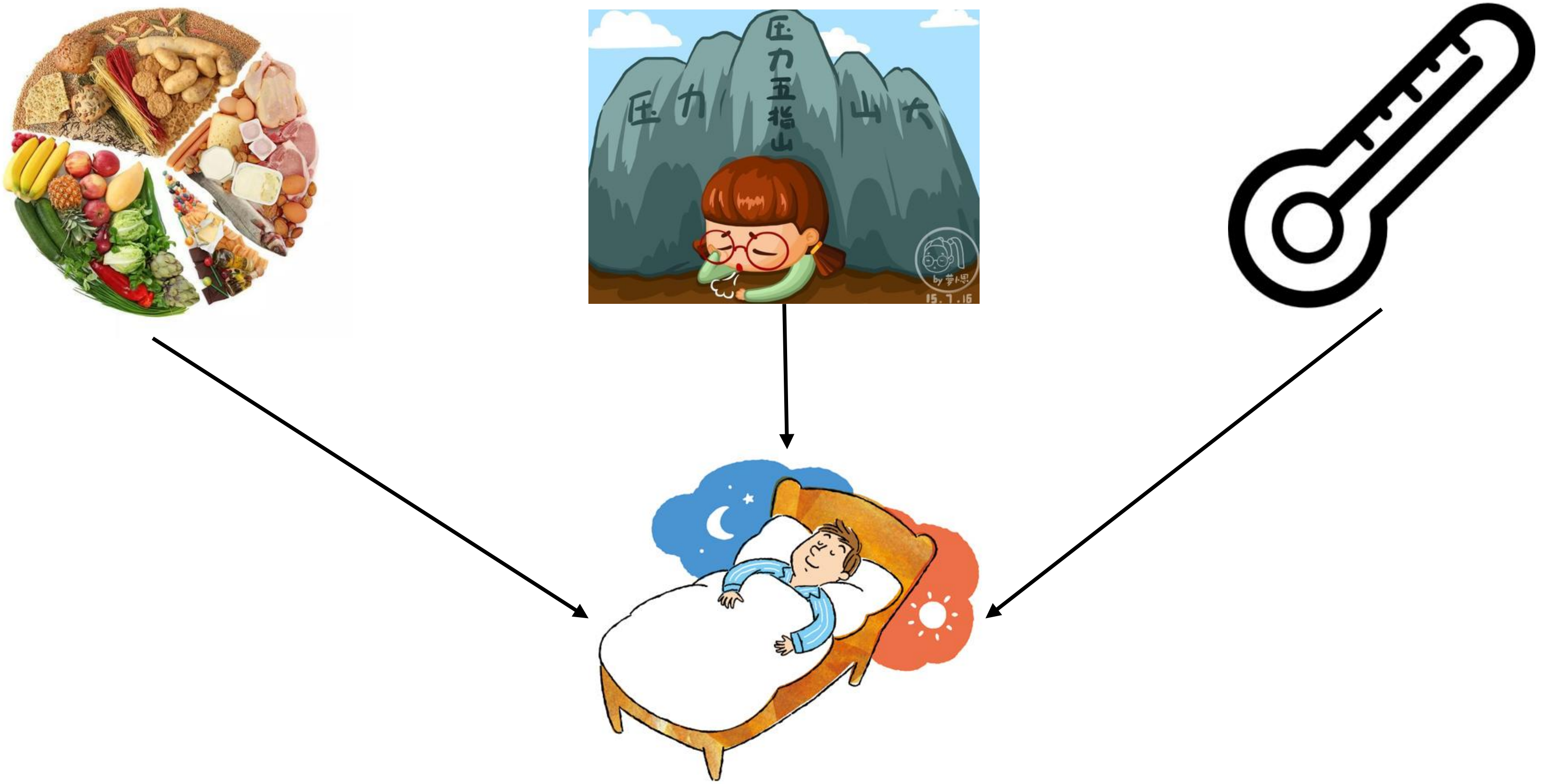
- Physiological homeostasis
- Neural homeostasis
- Consolidate memory
- Boost Immune function



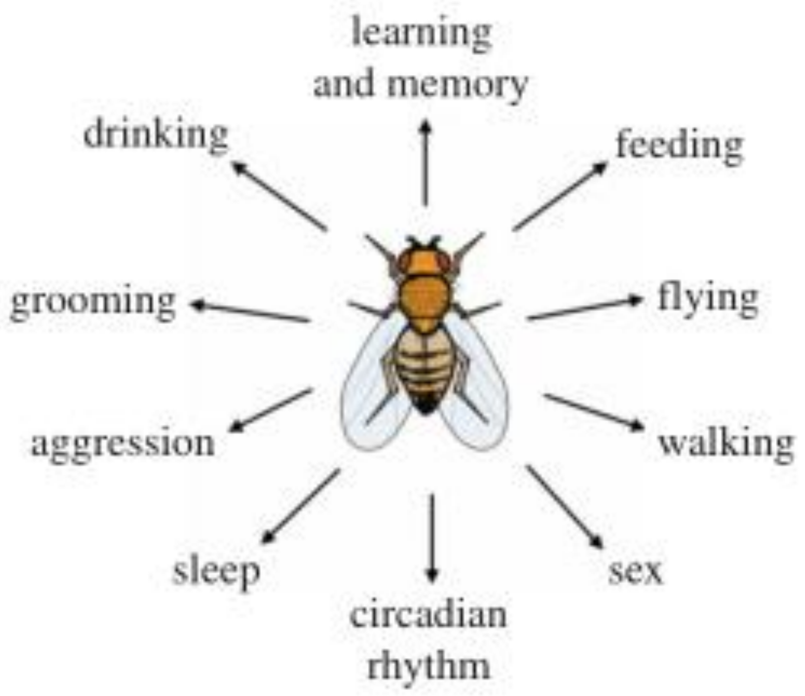


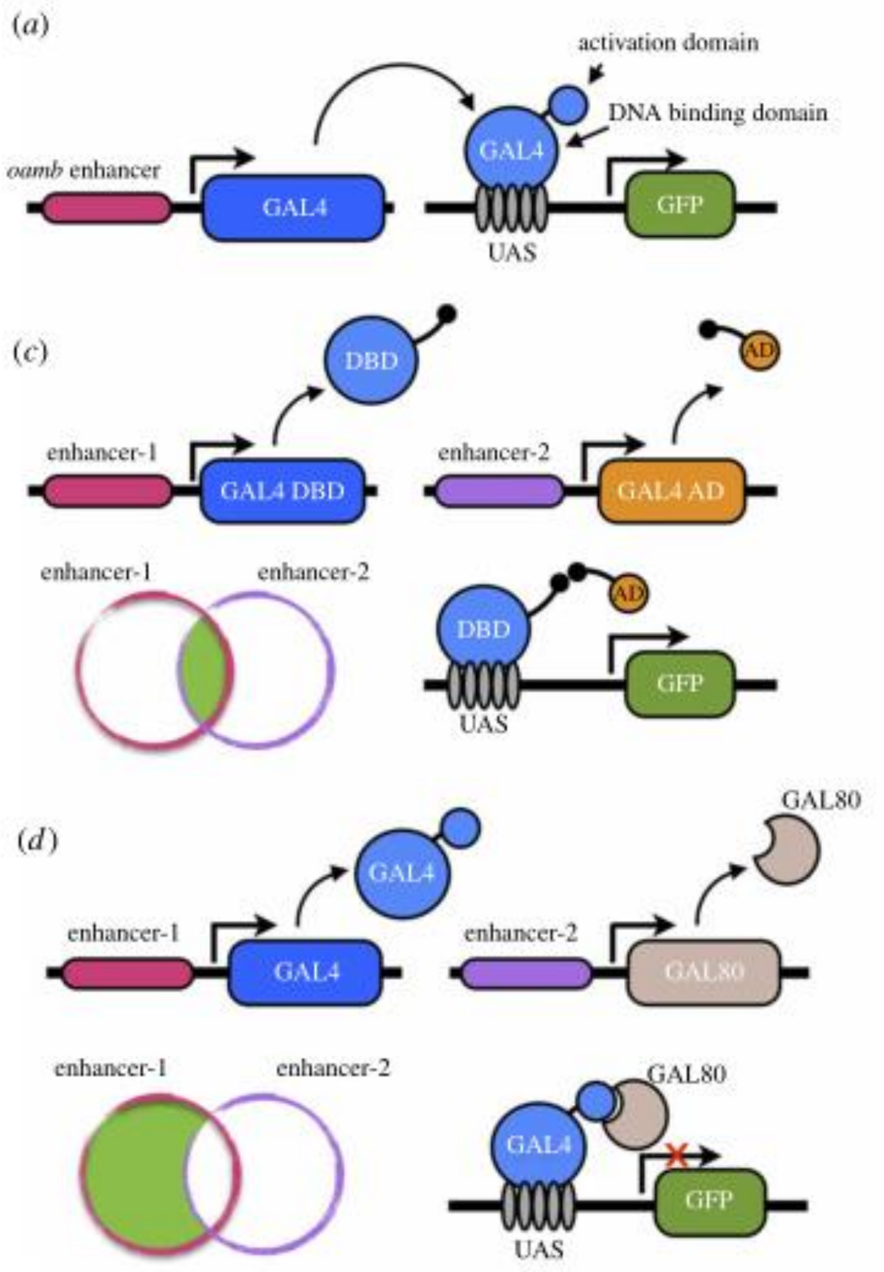
Context-Dependent Modulation of Sleep

Environmental factors （food, stress, temperature,etc）



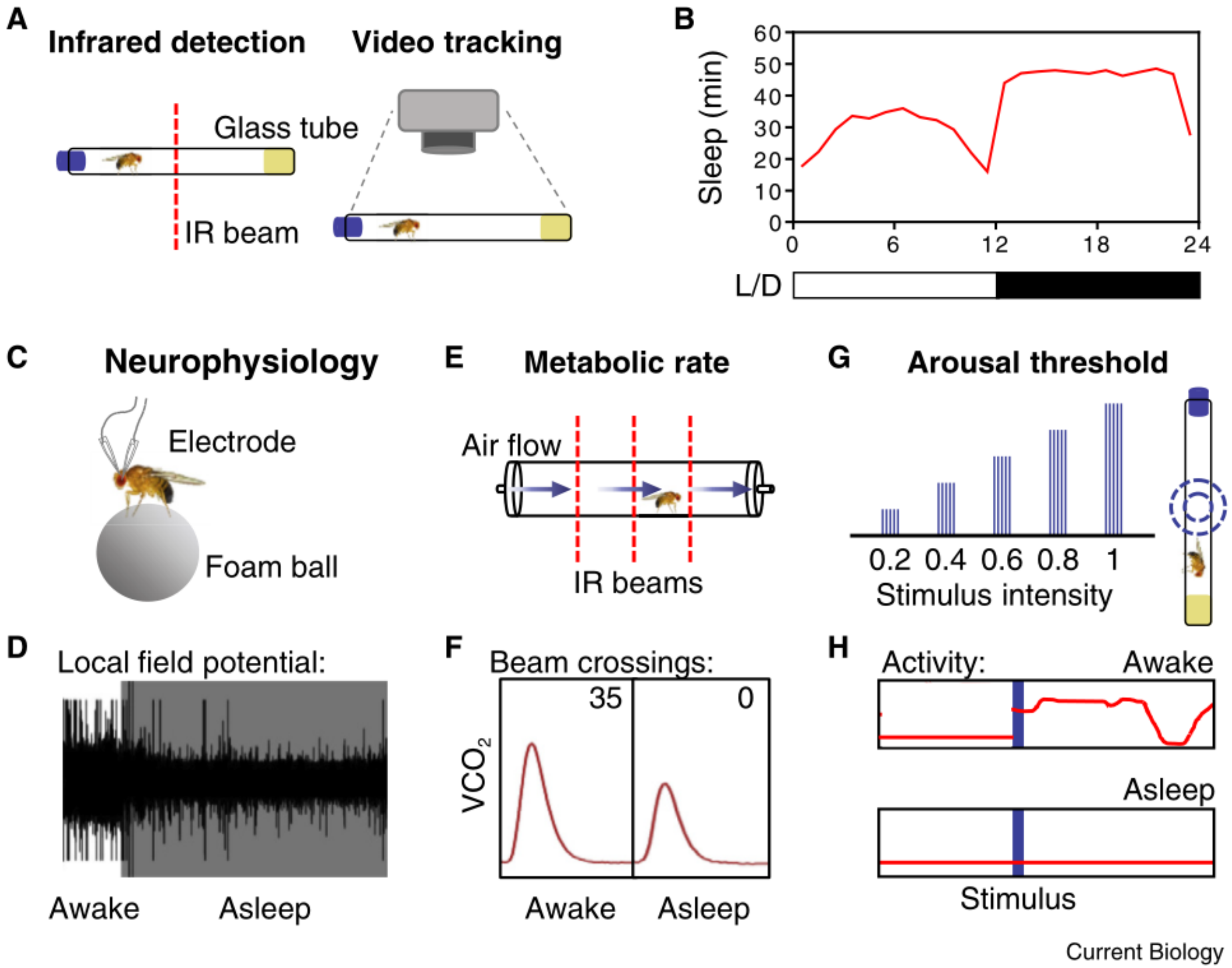
Advantages of *Drosophila* as a model animal





David Owald,et al. ,Phil. Trans. R. Soc. B.2015

Drosophila sleep was defined as prolonged immobility, reduced responsiveness to sensory stimuli, species-specific postures, restorative sleep after deprivation, and rapid reversibility



Orie T. Shafer,et al. ,2020,Current biology

Content

- Relationship between Sleep and Feeding By LXL
- Relationship between Sleep and Temperature By WL
- Relationship between Sleep and Memory By ZH

Relationship between Sleep and Feeding

LXL

2021/10/14

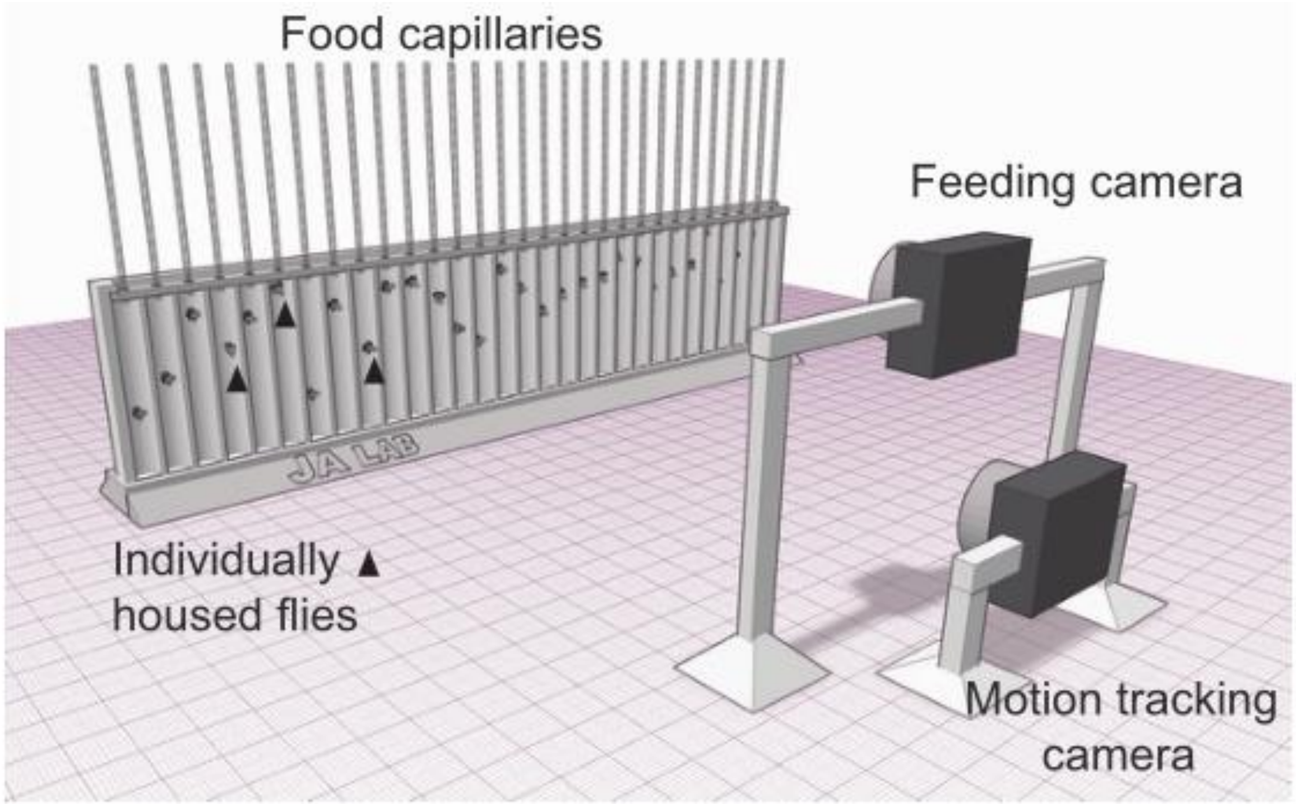
1. Does feeding affect sleep?
2. How does starvation affect sleep ?
3. What ingredients in feeding can affect sleep?

Does feeding affect sleep?

eLIFE
elifesciences.org
RESEARCH ARTICLE

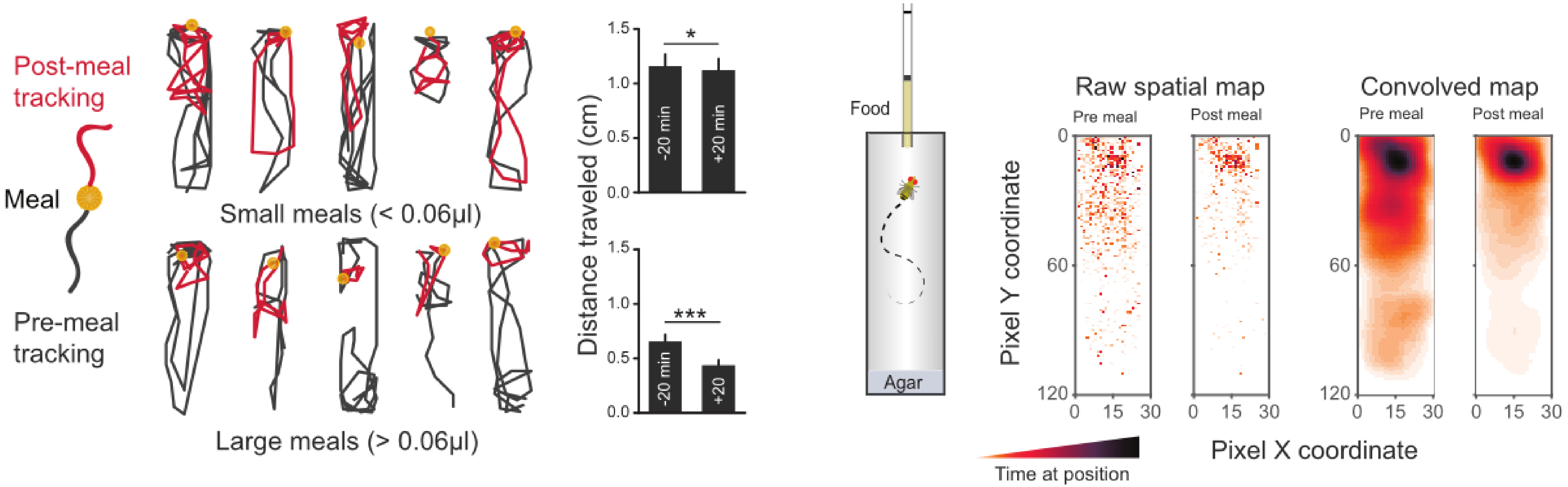
Postprandial sleep mechanics in *Drosophila*

Keith R Murphy[1,2,3], Sonali A Deshpande[1], Maria E Yurgel[2], James P Quinn[1], Jennifer L Weissbach[1], Alex C Keene[2], Ken Dawson-Scully[2], Robert Huber[4,5], Seth M Tomchik[3], William W Ja[1,3]*

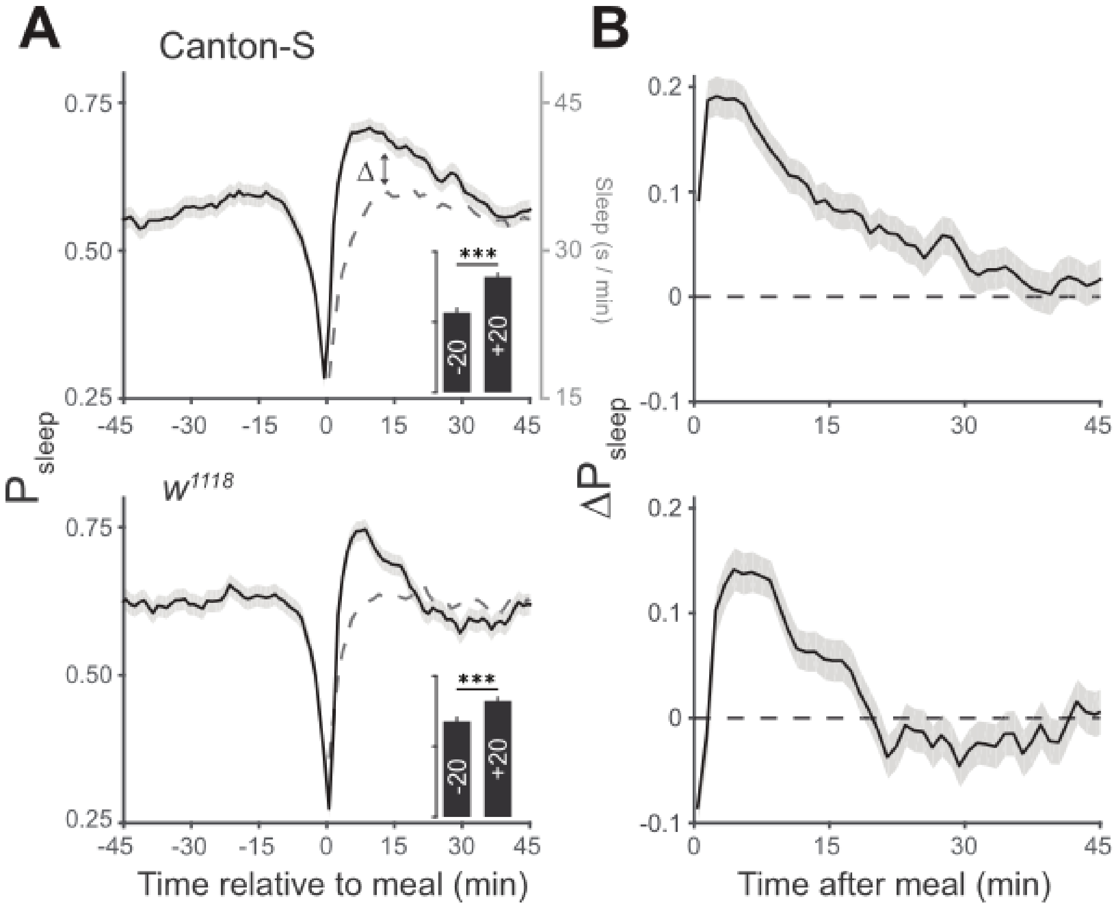


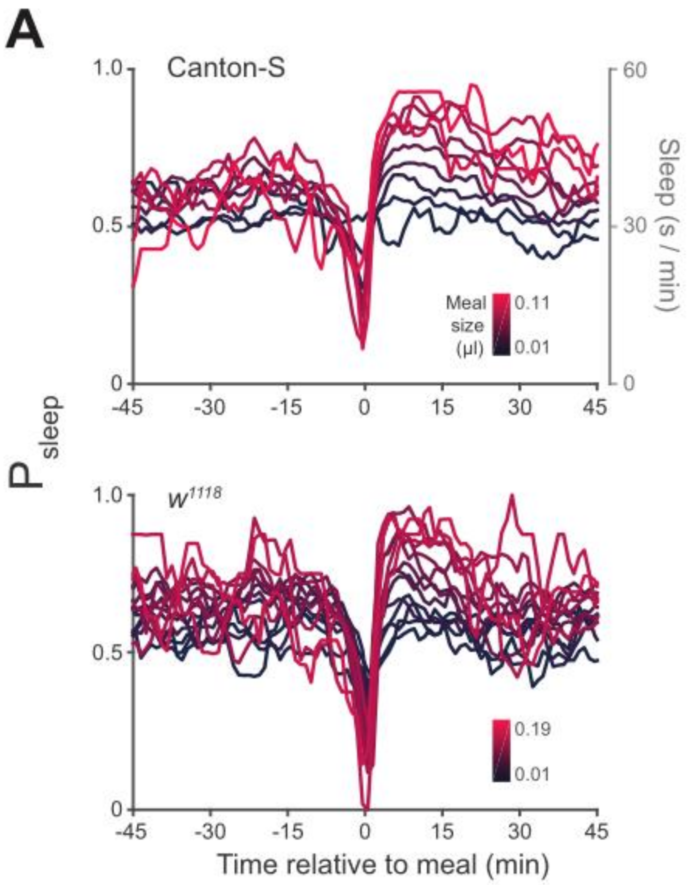
Murphy KR,et al.,Elife. 2016

Drosophila sleep more and move closer to the food after meals

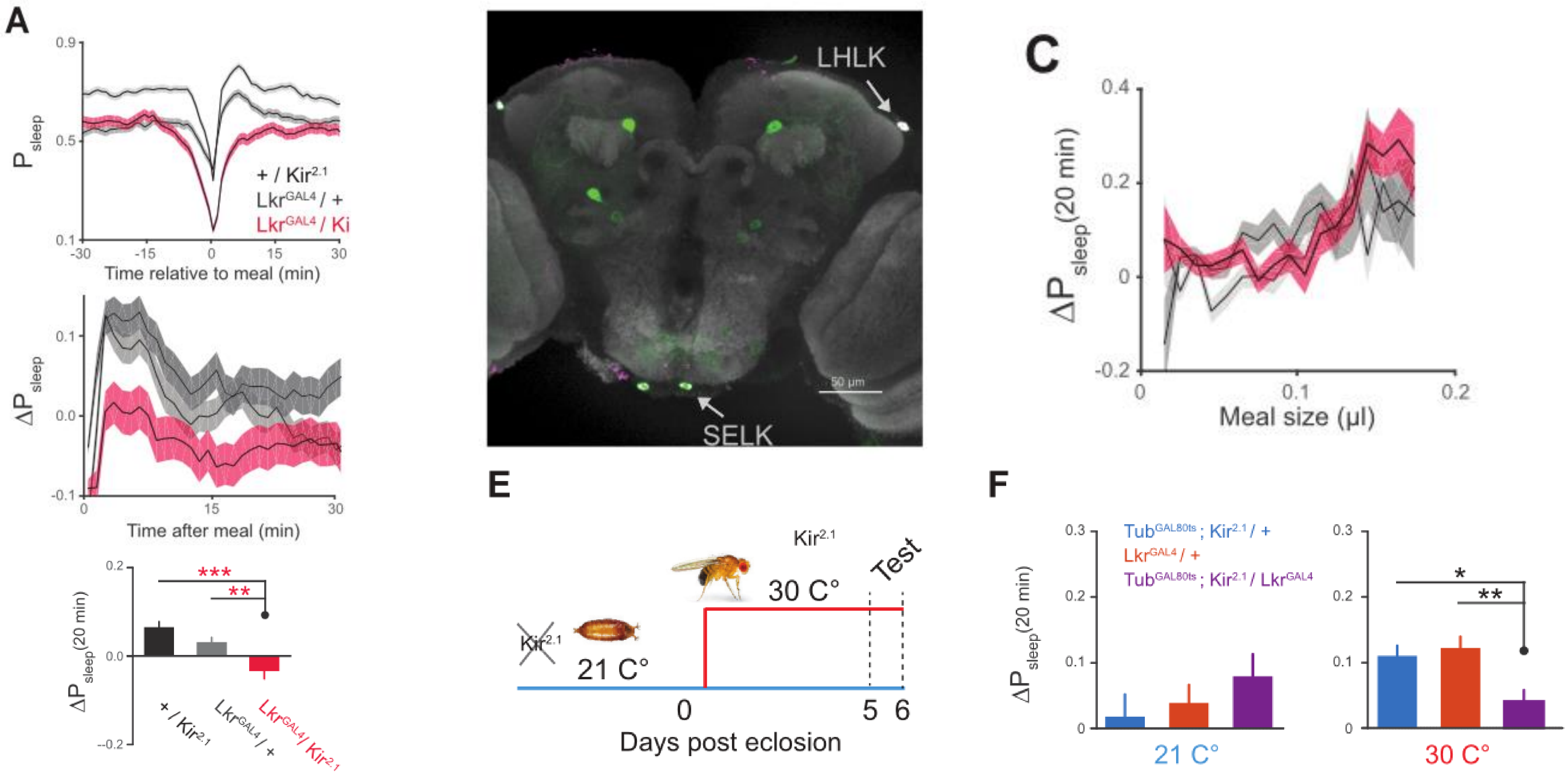


The amount of sleep increases with the amount of food





LK signaling regulates postprandial sleep



Summary

- *Drosophila* sleep more after meals
- The amount of sleep increases with the amount of food
- LK signaling regulates postprandial sleep

How does starvation affect sleep？

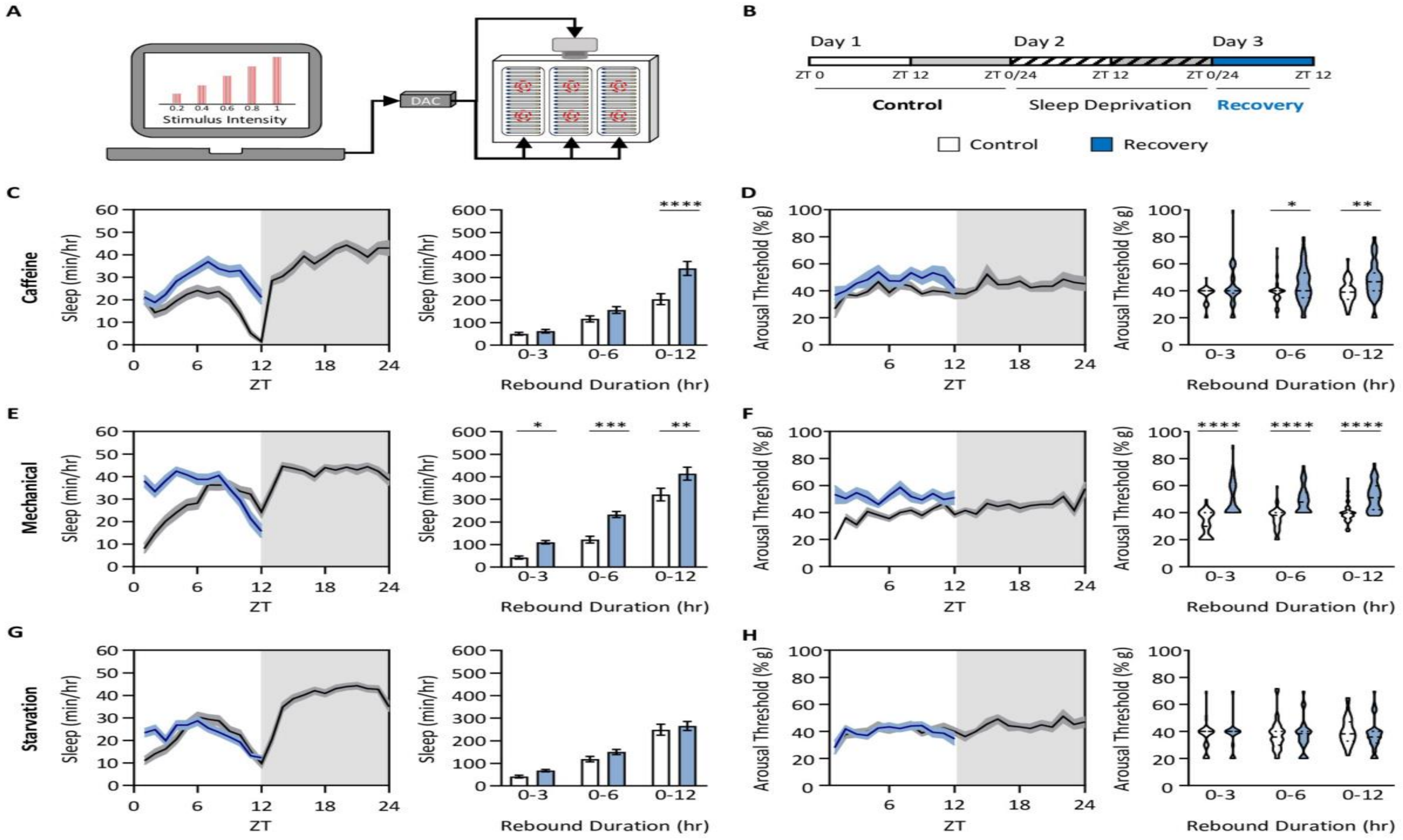
PLOS GENETICS

RESEARCH ARTICLE

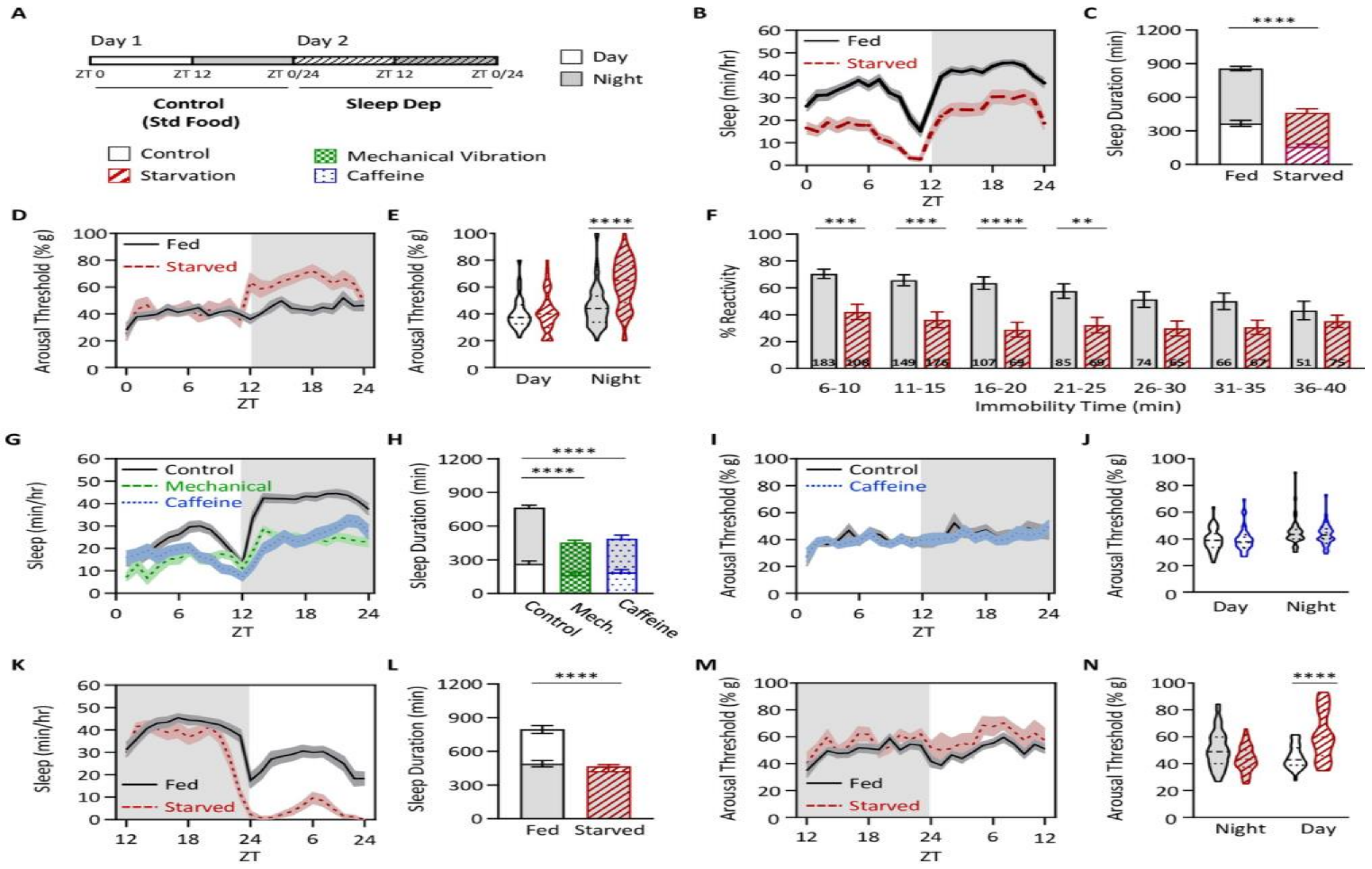
Drosophila insulin-like peptide 2 mediates dietary regulation of sleep intensity

Elizabeth B. Brown,et al.,Plos Genetics. 2019

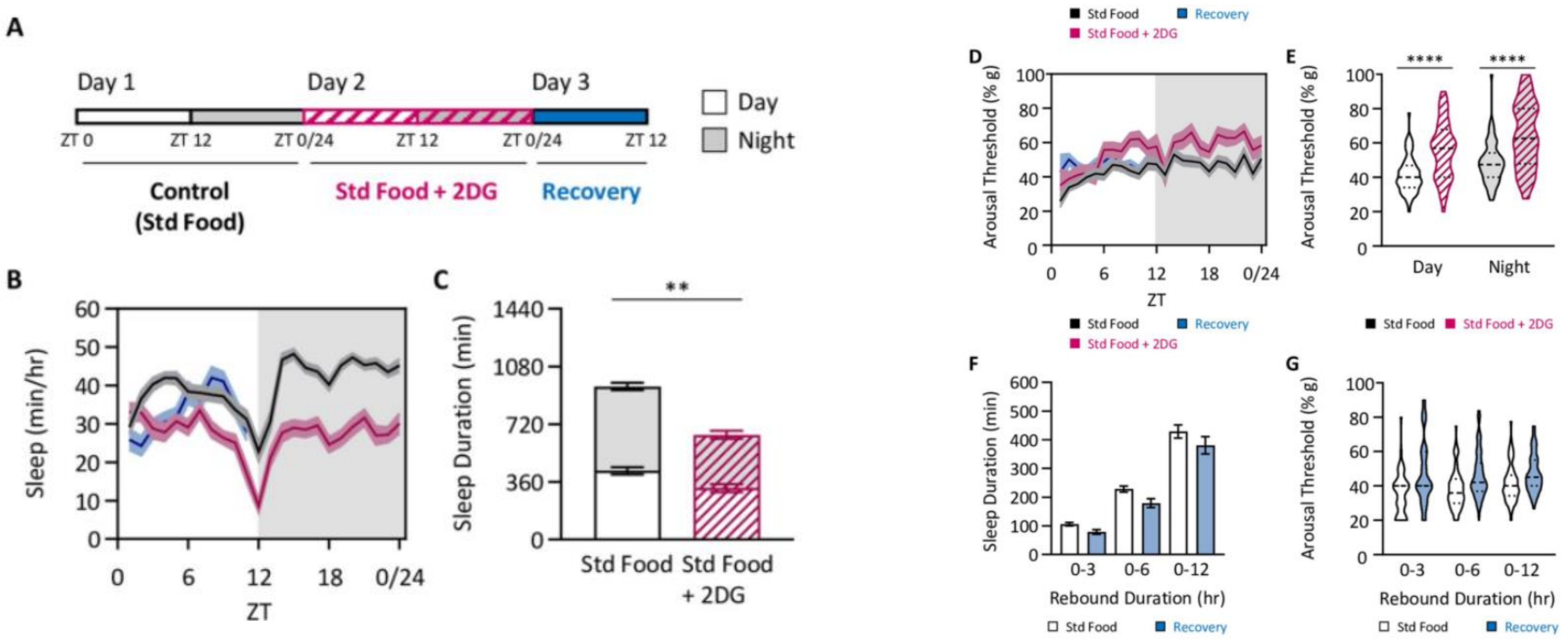
Starvation-induced sleep deprivation does not rebound



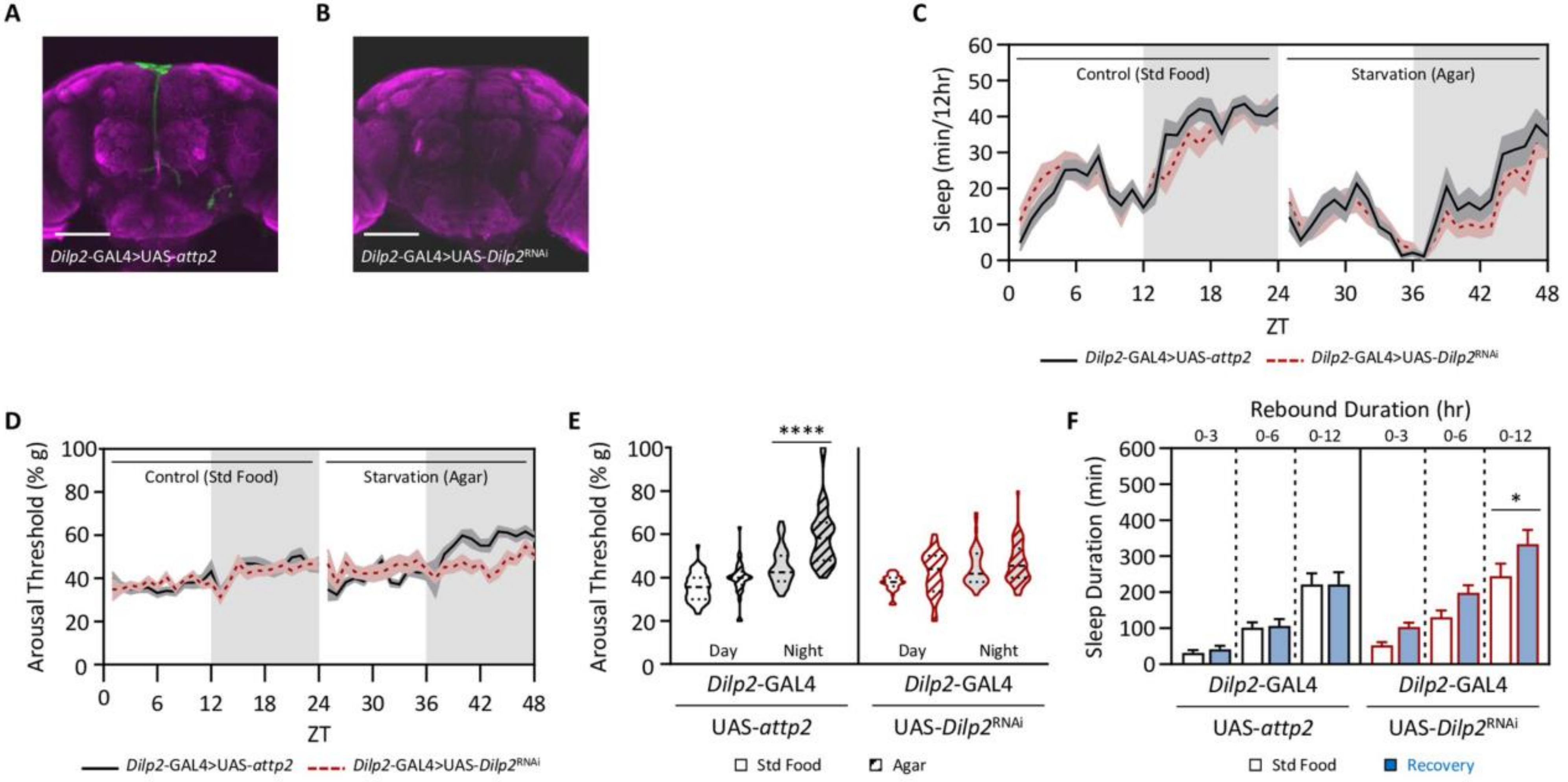
Starvation-induced sleep deprivation does not rebound



Starvation-induced sleep deprivation results from inhibition of glycolysis



Dilp2 increases sleep depth during starvation and prevents sleep rebound

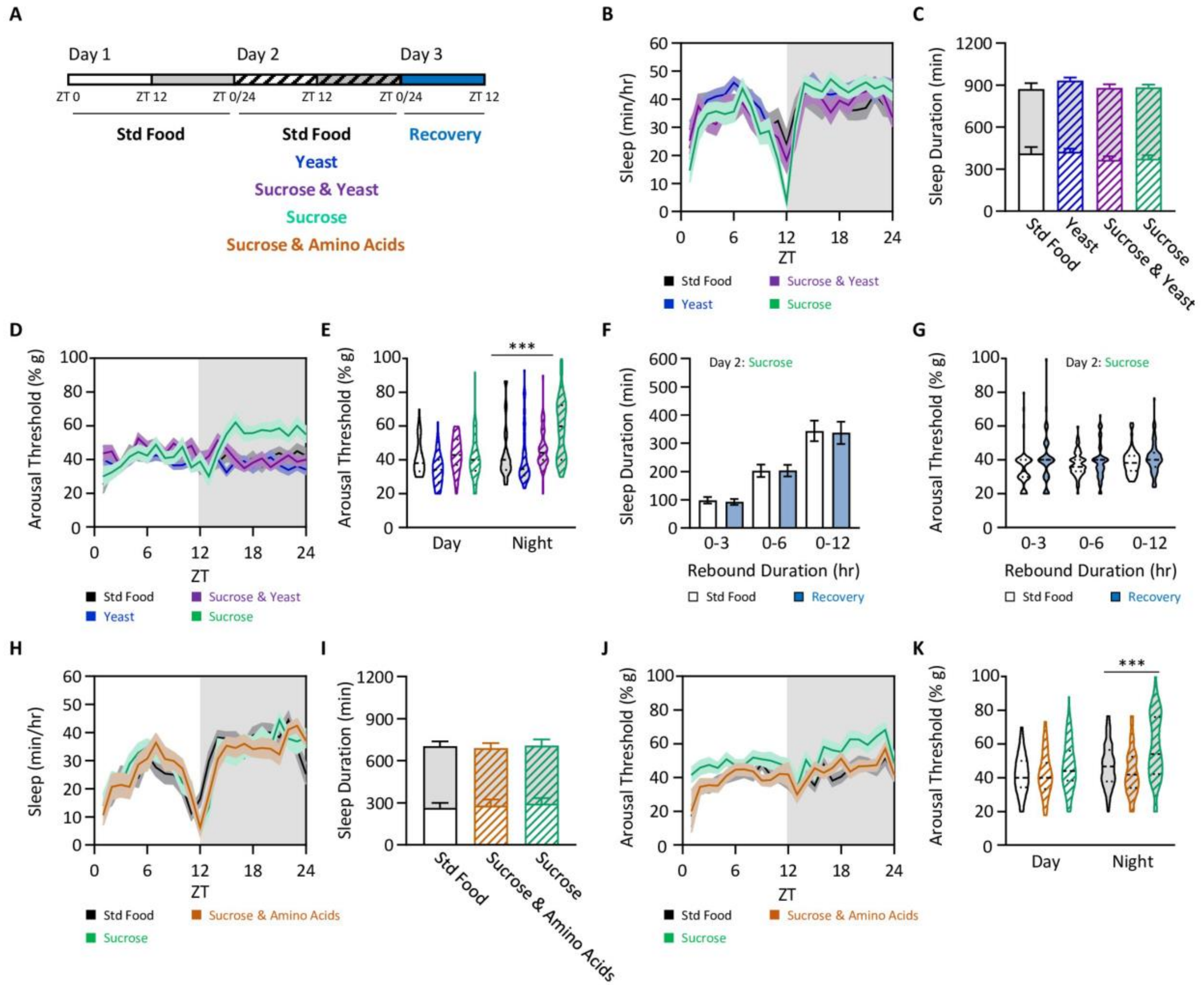


Summary

- Starvation-induced sleep deprivation does not rebound
- Starvation-induced sleep deprivation results from inhibition of glycolysis
- Dilp2 increases sleep depth during starvation and prevents sleep rebound

What ingredients in feeding can affect sleep?

There are many ingredients can affect sleep

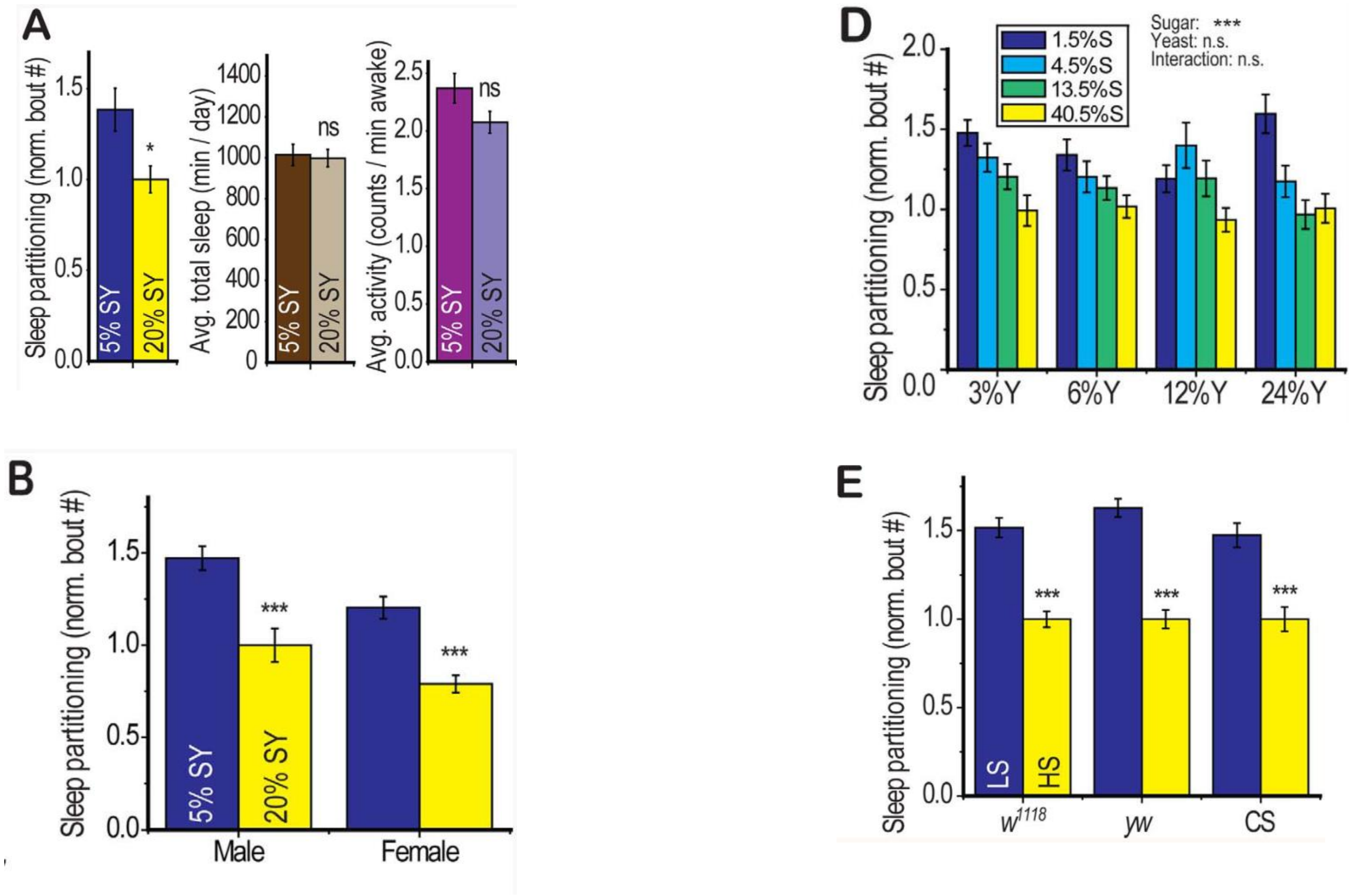


OPEN ACCESS Freely available online PLoS GENETICS

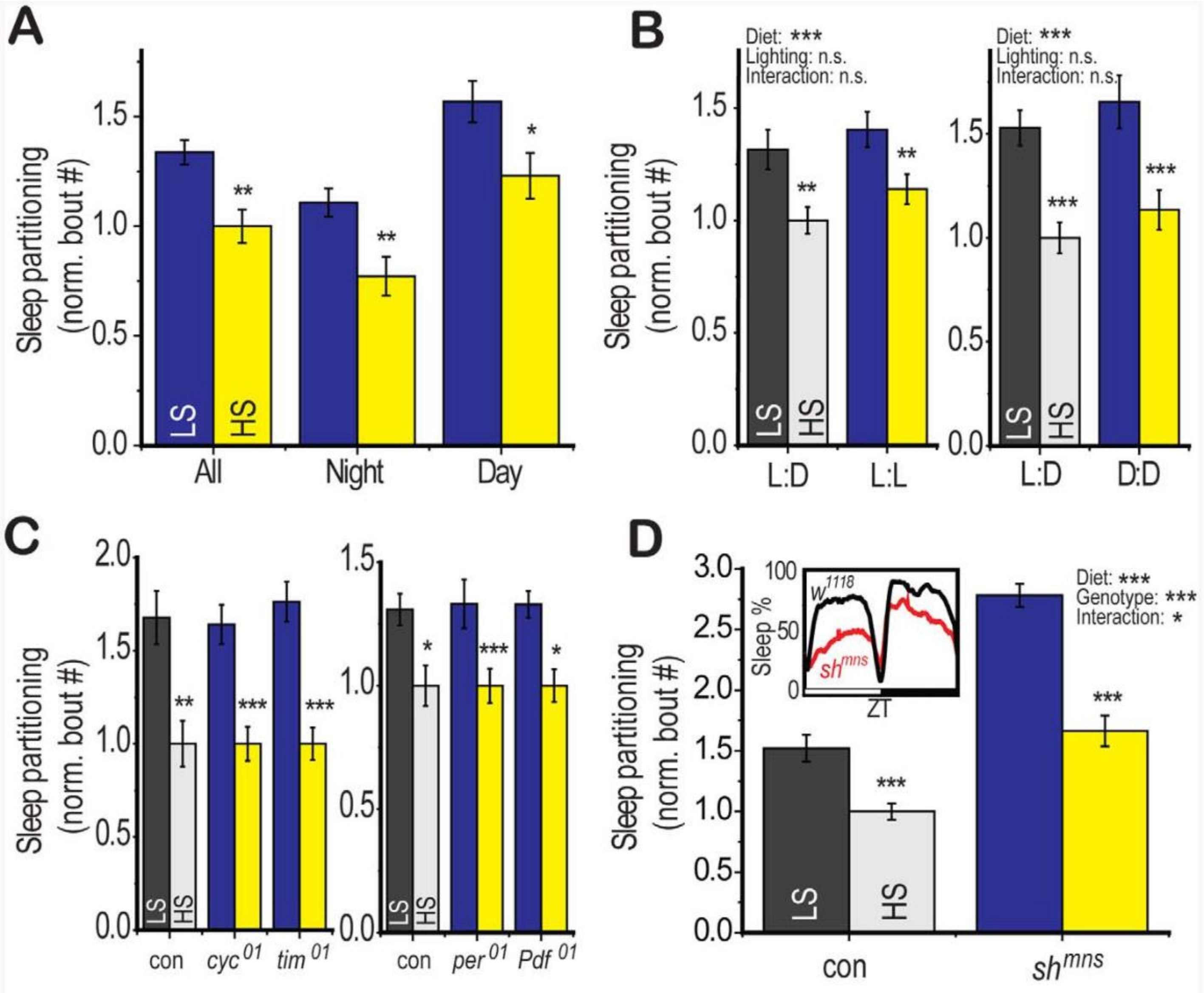
Re-Patterning Sleep Architecture in *Drosophila* through Gustatory Perception and Nutritional Quality

Nancy J. Linford[1]*, Tammy P. Chan[1,2], Scott D. Pletcher[1,2]

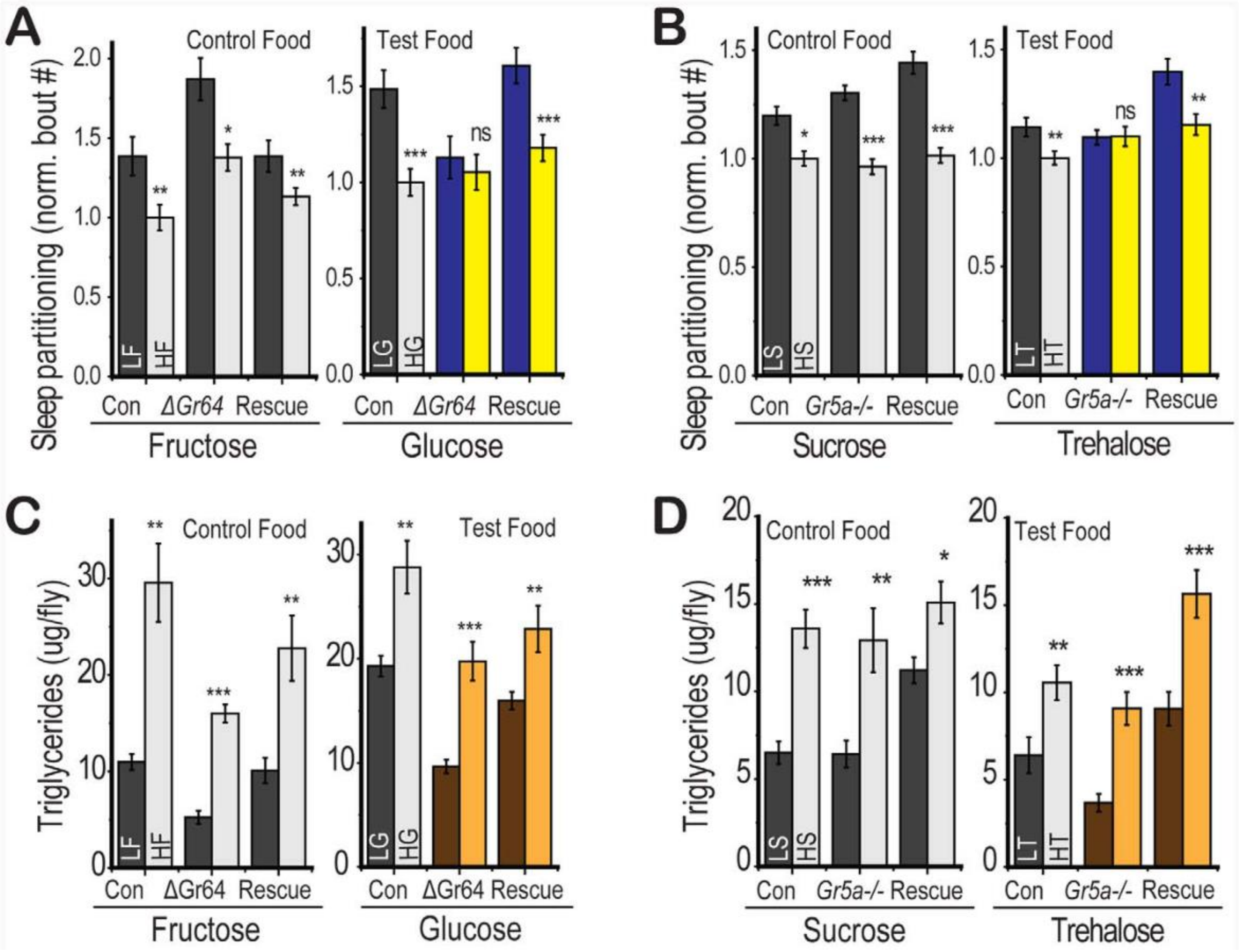
Dietary sugar modulates sleep architecture



Sugar-induced sleep partitioning does not depend on circadian rhythm



Gustatory inputs mediate sleep partitioning in response to dietary sugar

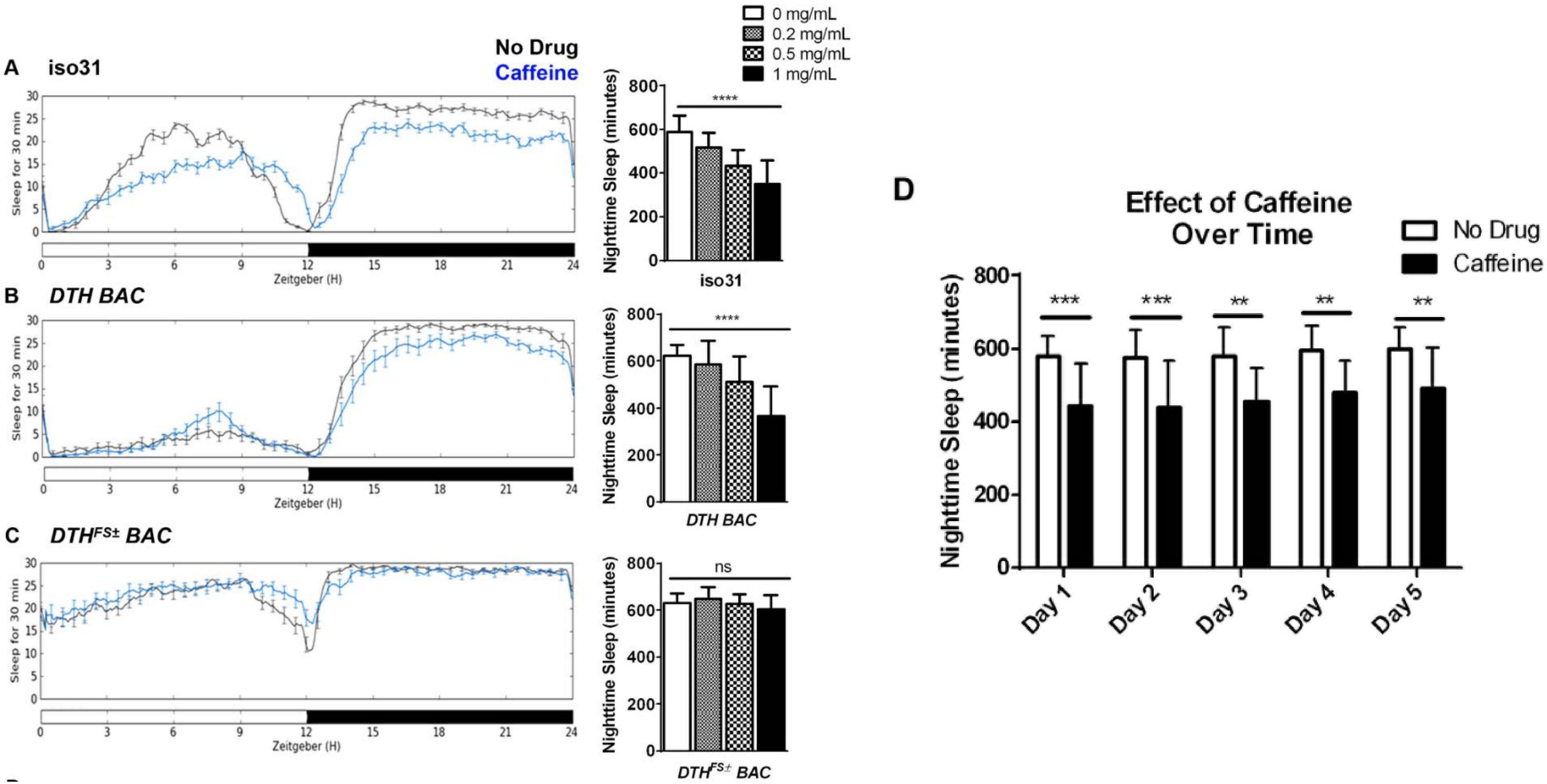


SCIENTIFIC REPORTS

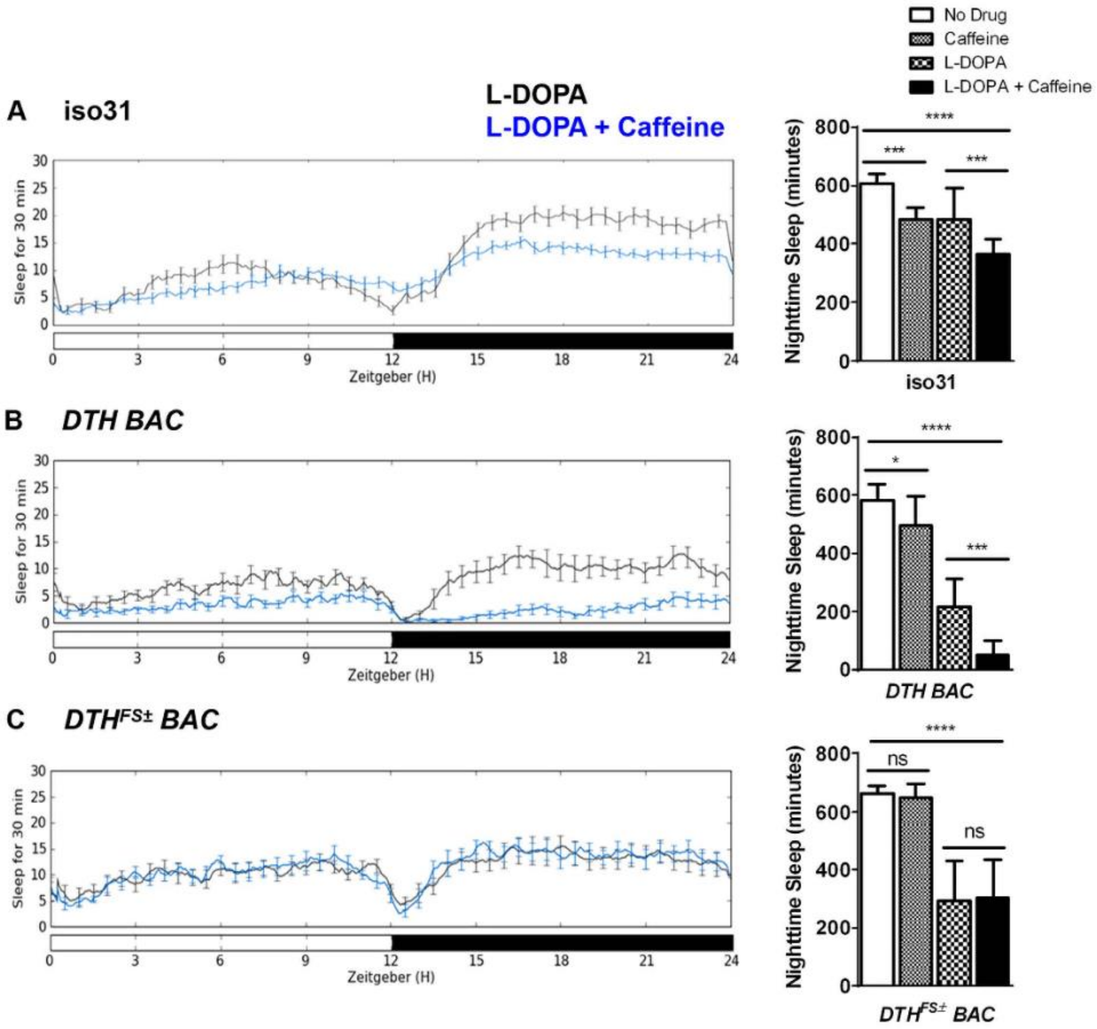
OPEN

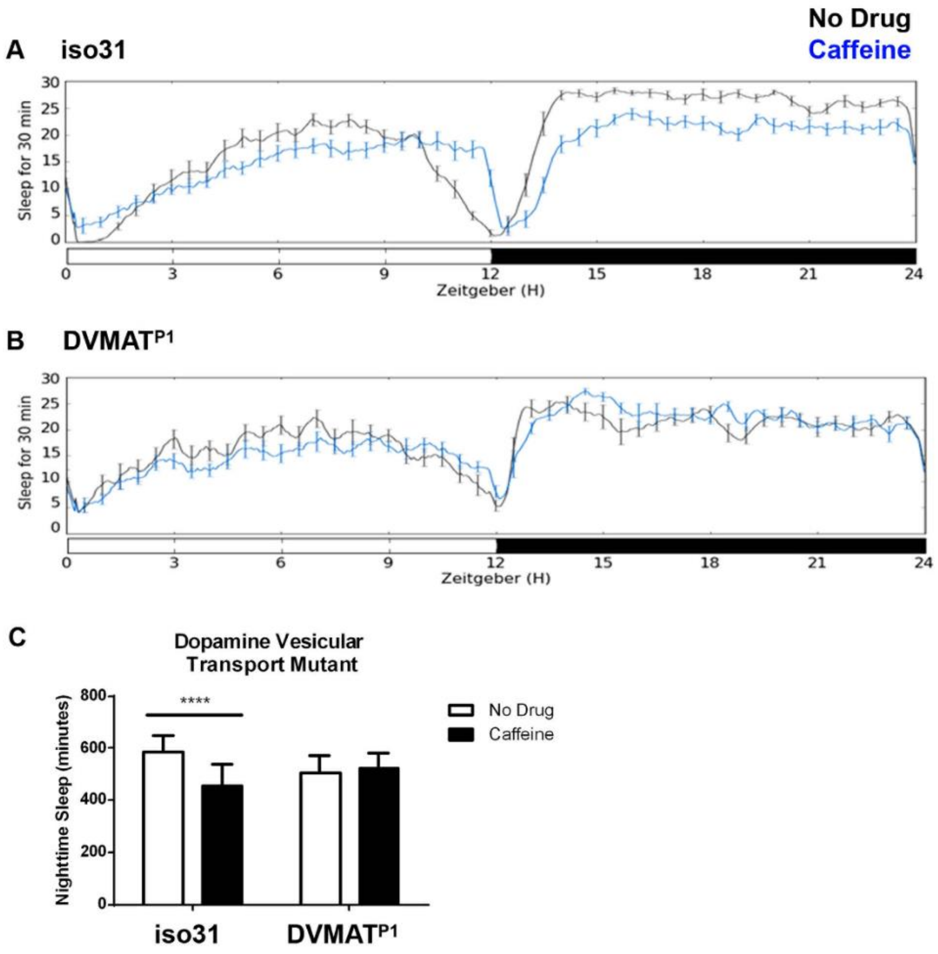
Caffeine promotes wakefulness via dopamine signaling in *Drosophila*

The decrease of sleep requires dopamine synthesis by caffeine

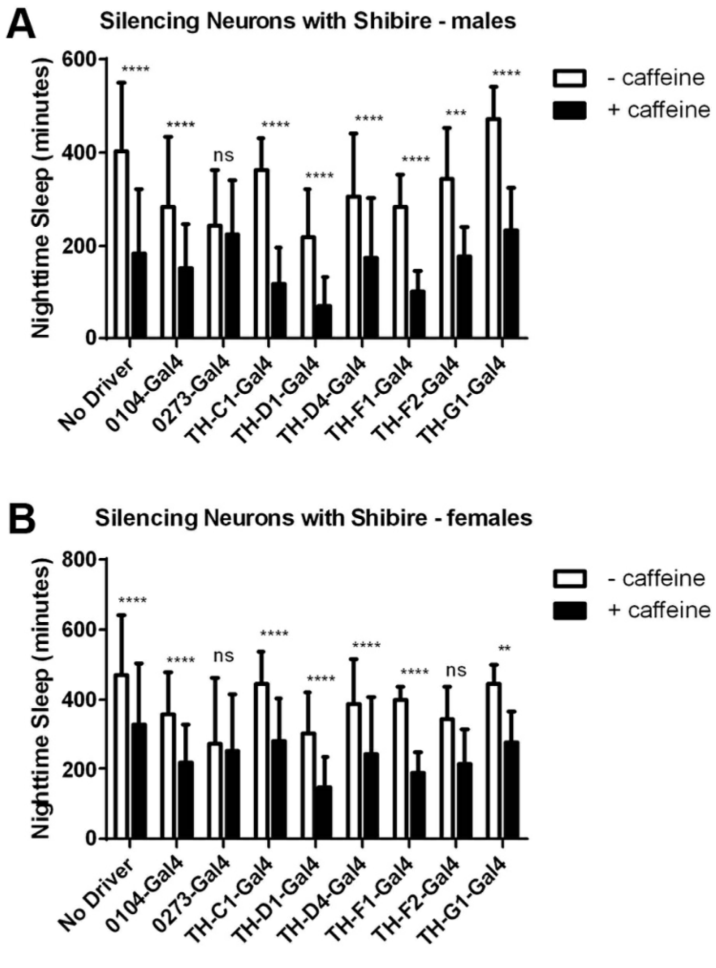


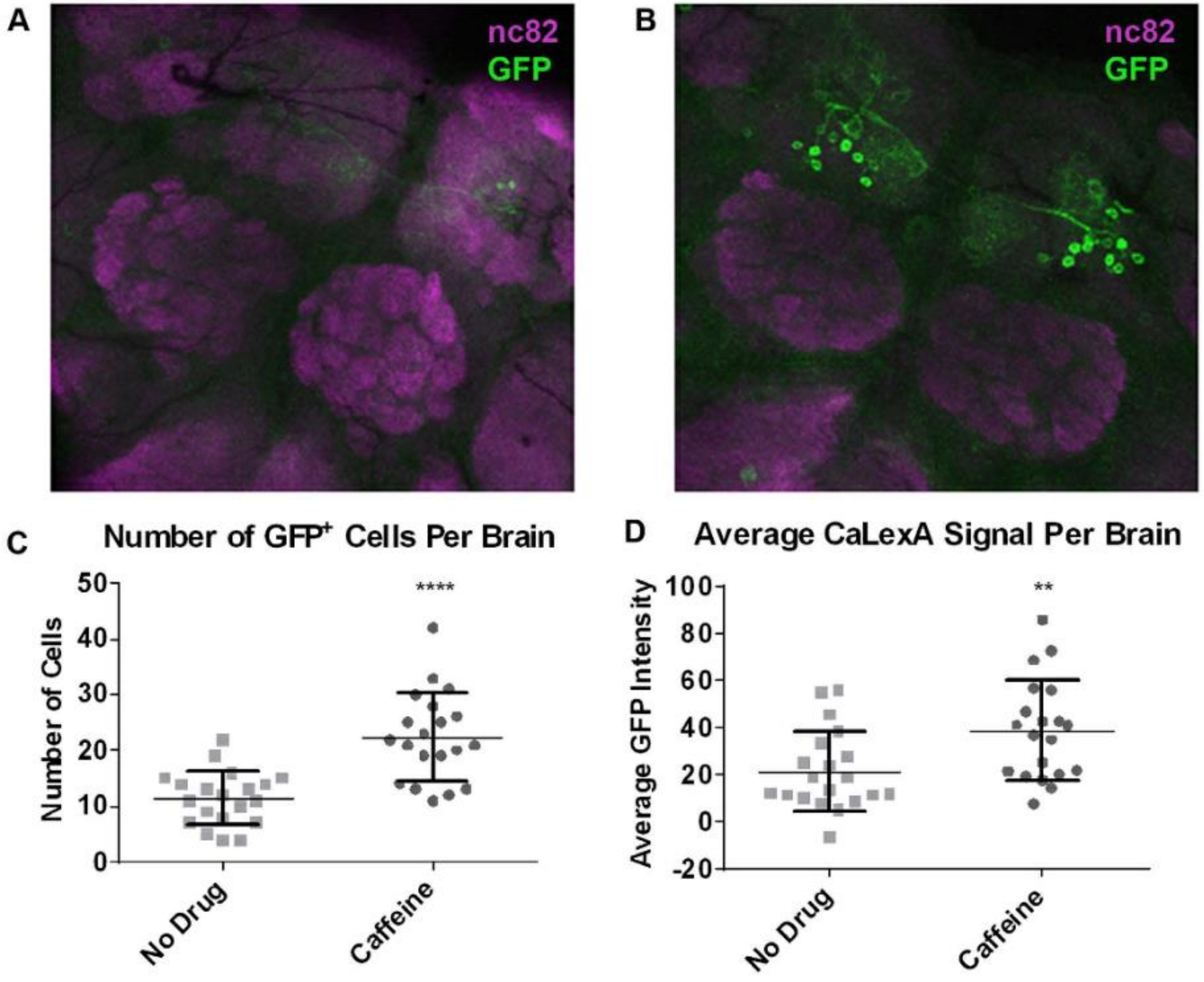
Caffeine may affect dopaminergic signaling upstream of DTH





Caffeine increases activity of PAM cluster neurons





Summary

- Dietary sugar modulates sleep architecture by gustatory inputs
- Caffeine decreases sleep by dopaminergic signaling

References:

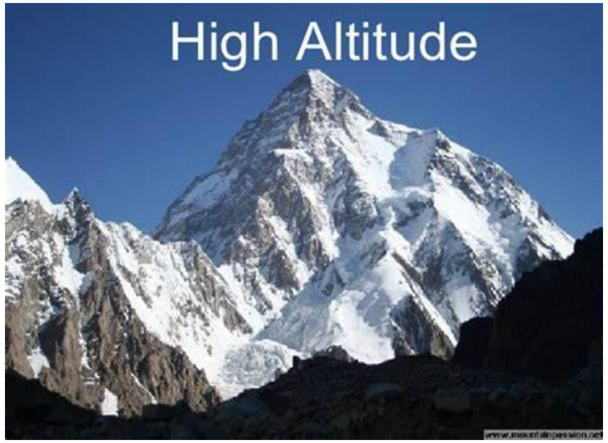
1. Murphy KR, Deshpande SA, Yurgel ME, Quinn JP, Weissbach JL, Keene AC, Dawson-Scully K, Huber R, Tomchik SM, Ja WW. Postprandial sleep mechanics in *Drosophila*. Elife. 2016
2. Linford NJ, Chan TP, Pletcher SD. Re-patterning sleep architecture in Drosophila through gustatory perception and nutritional quality. PLoS Genet. 2012;8(5):e1002668.
3. Brown EB, Shah KD, Faville R, Kottler B, Keene AC. Drosophila insulin-like peptide 2 mediates dietary regulation of sleep intensity. PLoS Genet. 2020
4. Nall AH, Shakhmantsir I, Cichewicz K, Birman S, Hirsh J, Sehgal A. Caffeine promotes wakefulness via dopamine signaling in Drosophila. Sci Rep. 2016
5. Shafer OT, Keene AC. The Regulation of Drosophila Sleep. Curr Biol. 2021 Jan 11;31(1):R38-R49. doi: 10.1016/j.cub.2020.10.082. PMID: 33434488.
6. Owald D, Lin S, Waddell S. Light, heat, action: neural control of fruit fly behaviour. Philos Trans R Soc Lond B Biol Sci. 2015 Sep 19;370(1677):20140211. doi: 10.1098/rstb.2014.0211. PMID: 26240426; PMCID: PMC4528823.
7. Al-Anzi B, Armand E, Nagamei P, Olszewski M, Sapin V, Waters C, Zinn K, Wyman RJ, Benzer S. The leucokinin pathway and its neurons regulate meal size in Drosophila. Curr Biol. 2010 Jun 8;20(11):969-78. doi: 10.1016/j.cub.2010.04.039. Epub 2010 May 20. PMID: 20493701; PMCID: PMC2896026.

Thanks!

PARTII:
Sleep And Temperature

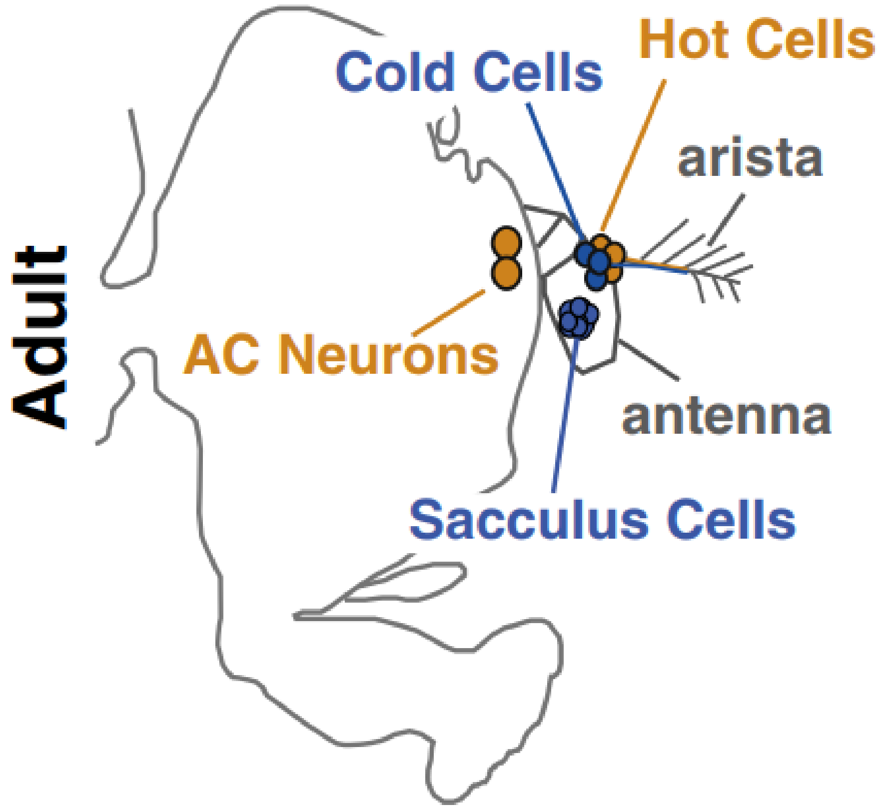
Wang Lin
2021.10.14

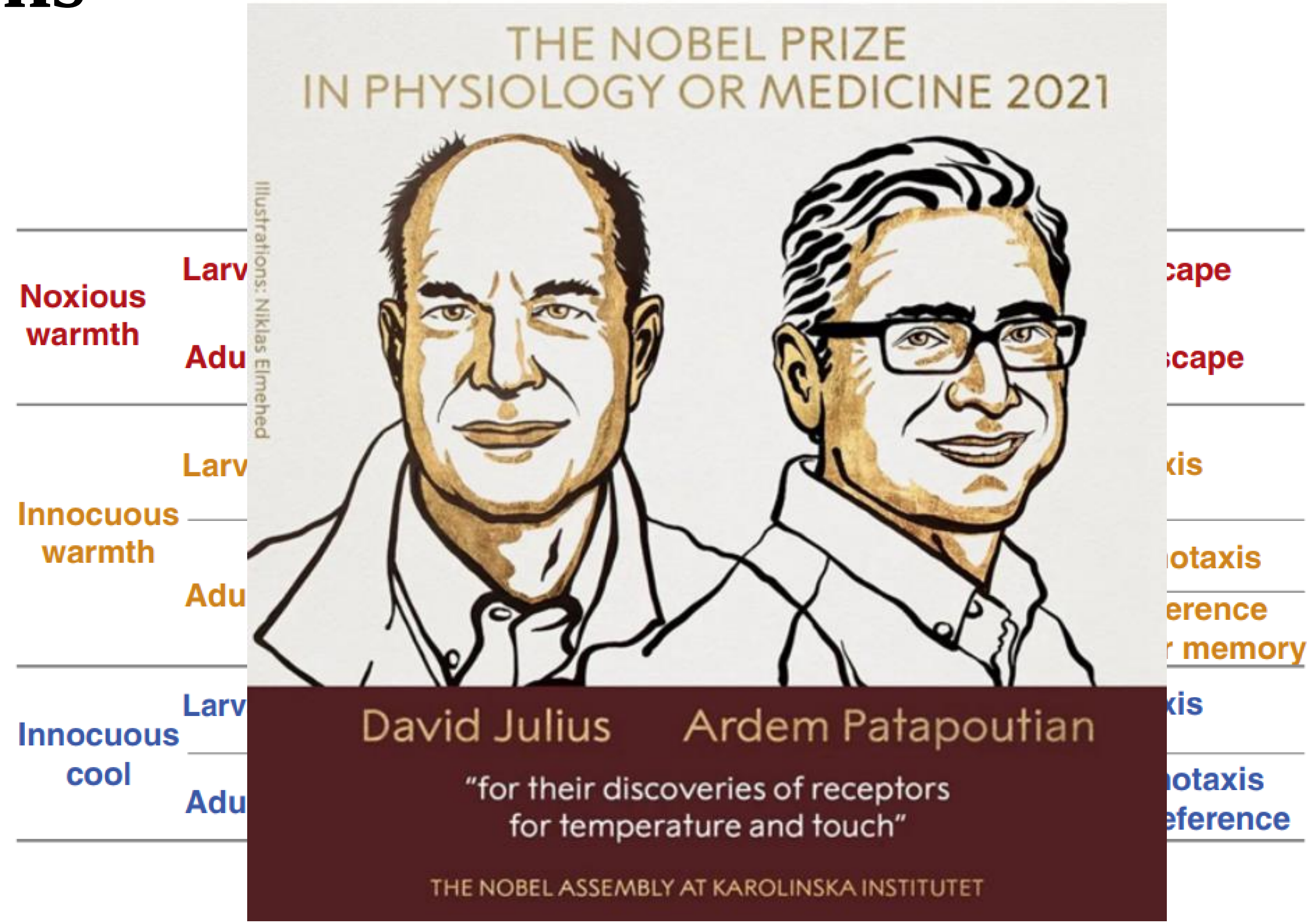

CLIMATE CHANGE


High Altitude

How do *Drosophila* process thermal stimuli?

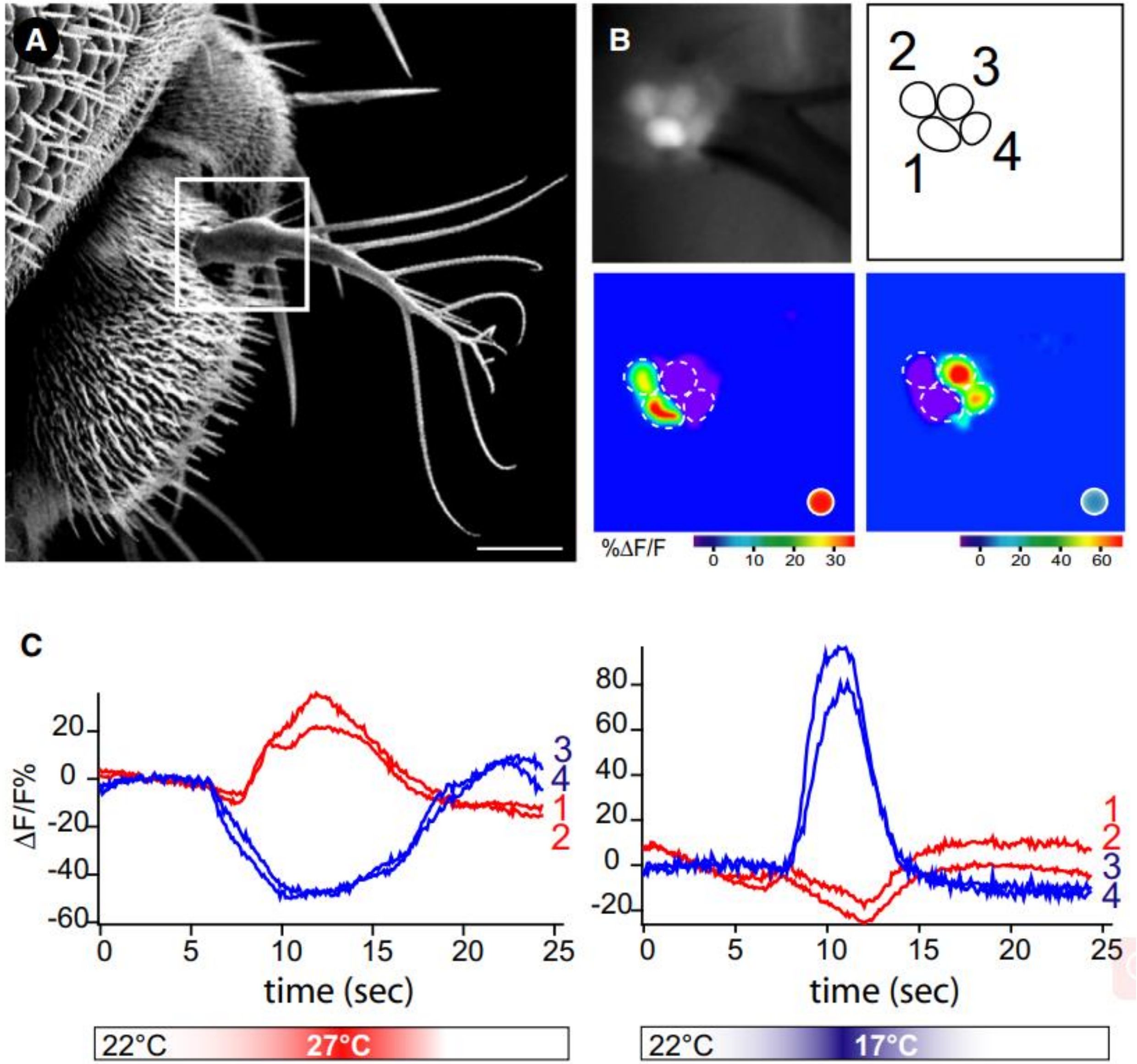
Thermosensory Neurons

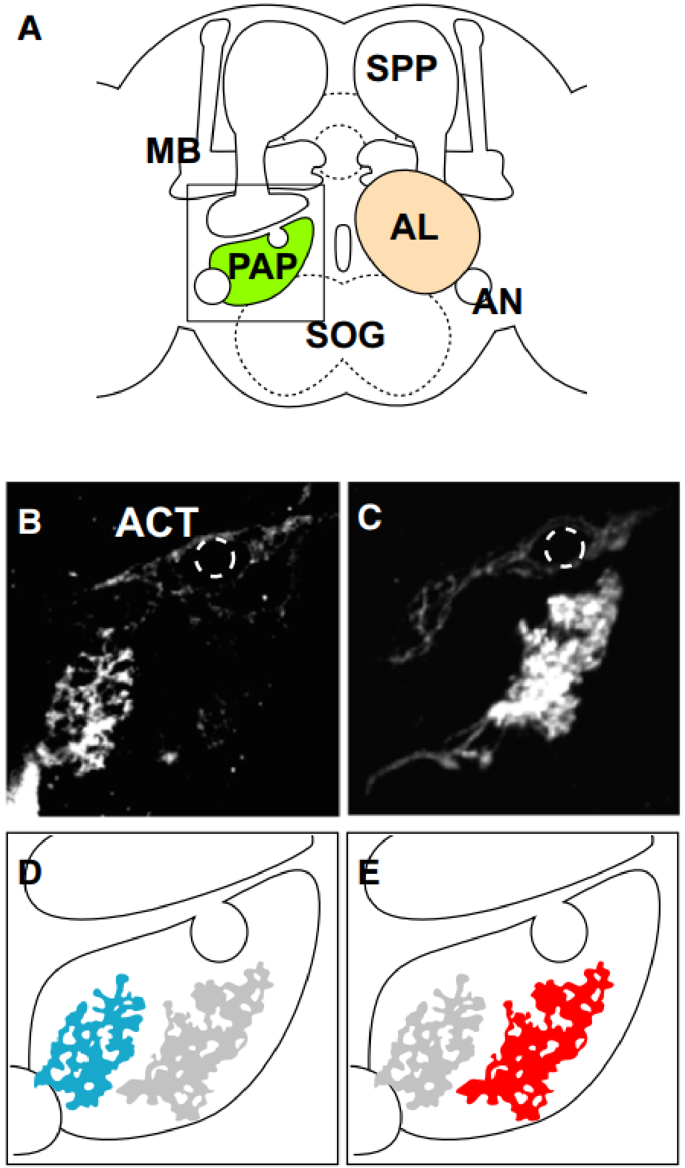




Barbagallo B, Garrity PA. *Curr Opin Neurobiol*,2015

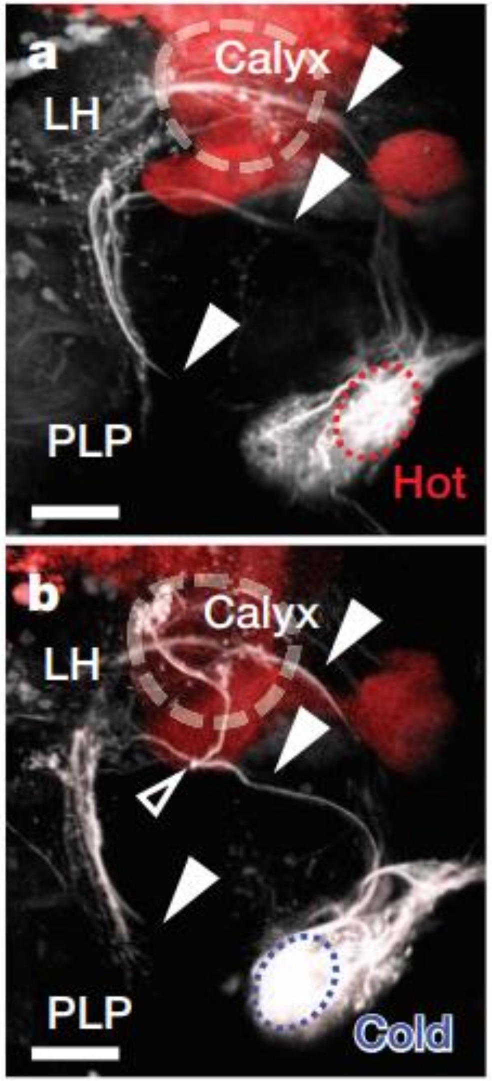
Hot and cold fibers define two distinct glomeruli



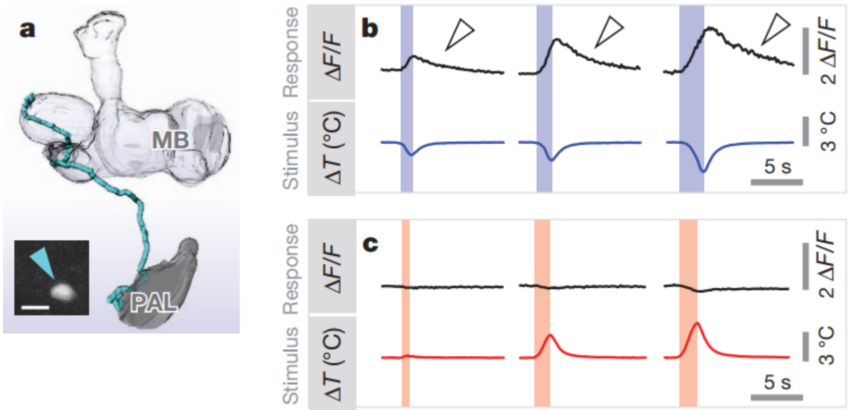


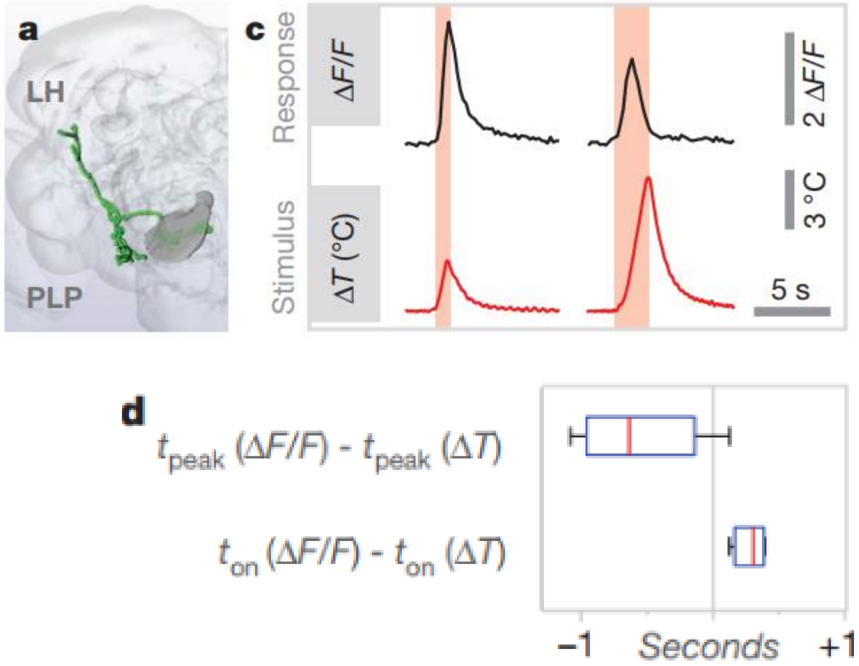
Gallio M,et al.,*Cell*,2011

Second-order thermosensory



Pathway	Driver	Dendrites (Denmark)	Terminals (syt:GFP)	GRASP	Narrowly Tuned
mALT	R22c06	PAL	MB, LH, PLP	Hot and Cold	●● (blue)
	VT40053	PAL	MB, LH, PLP	Hot and Cold	● (blue)
	VT26020	PAL	MB, LH	Cold	●●● (blue)
lALT					
Posterior	R95c02	PAL	LH, PLP	Hot and Cold	●●●● (blue) ●● (red)
	VT19428	PAL	LH, PLP	Cold	●●●●● (blue)
Anterior	VT46265	PAL	LH, PLP	Hot	● (red)
	VT60737	PAL	LH, PLP	N.D.	● (red)
t3ALT	R84e08	PAL	LH, PLP	Hot and Cold	● (blue) ● (red)
t5ALT	R60h12	PAL	MB	Cold	● (blue)
	R30b06	N.D.	MB	N.D.	● (blue)



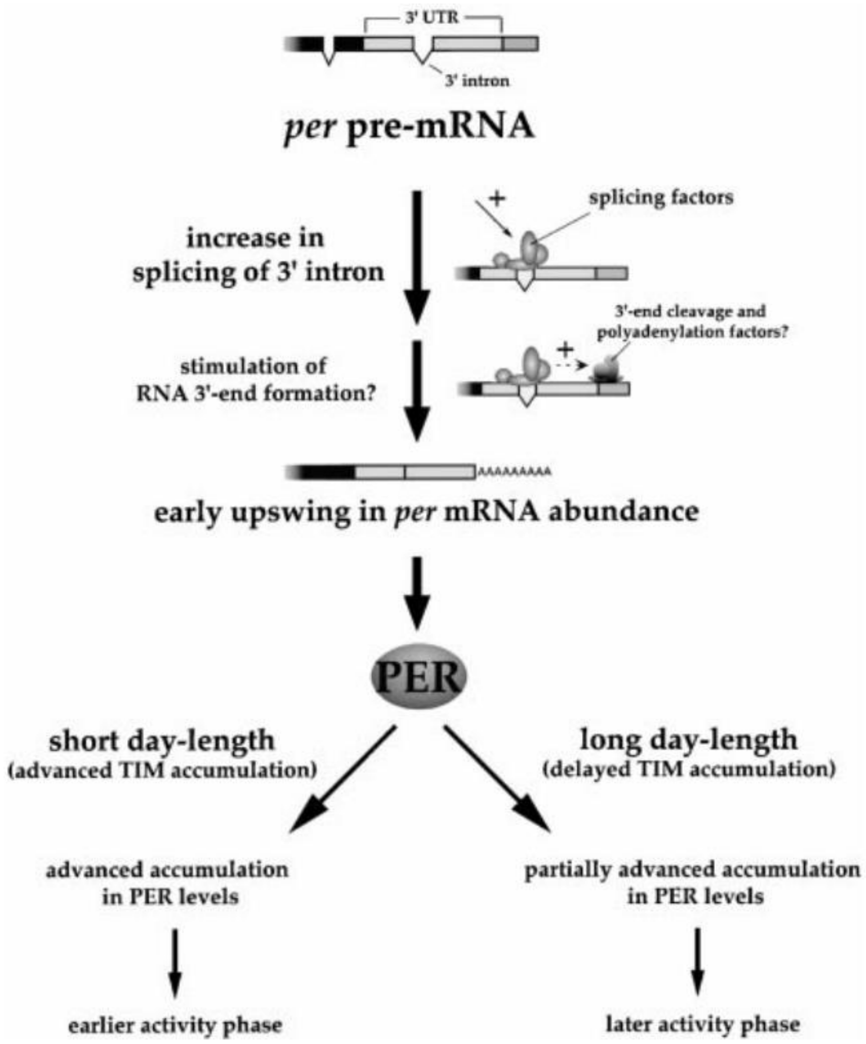


Photoactivatable GFP

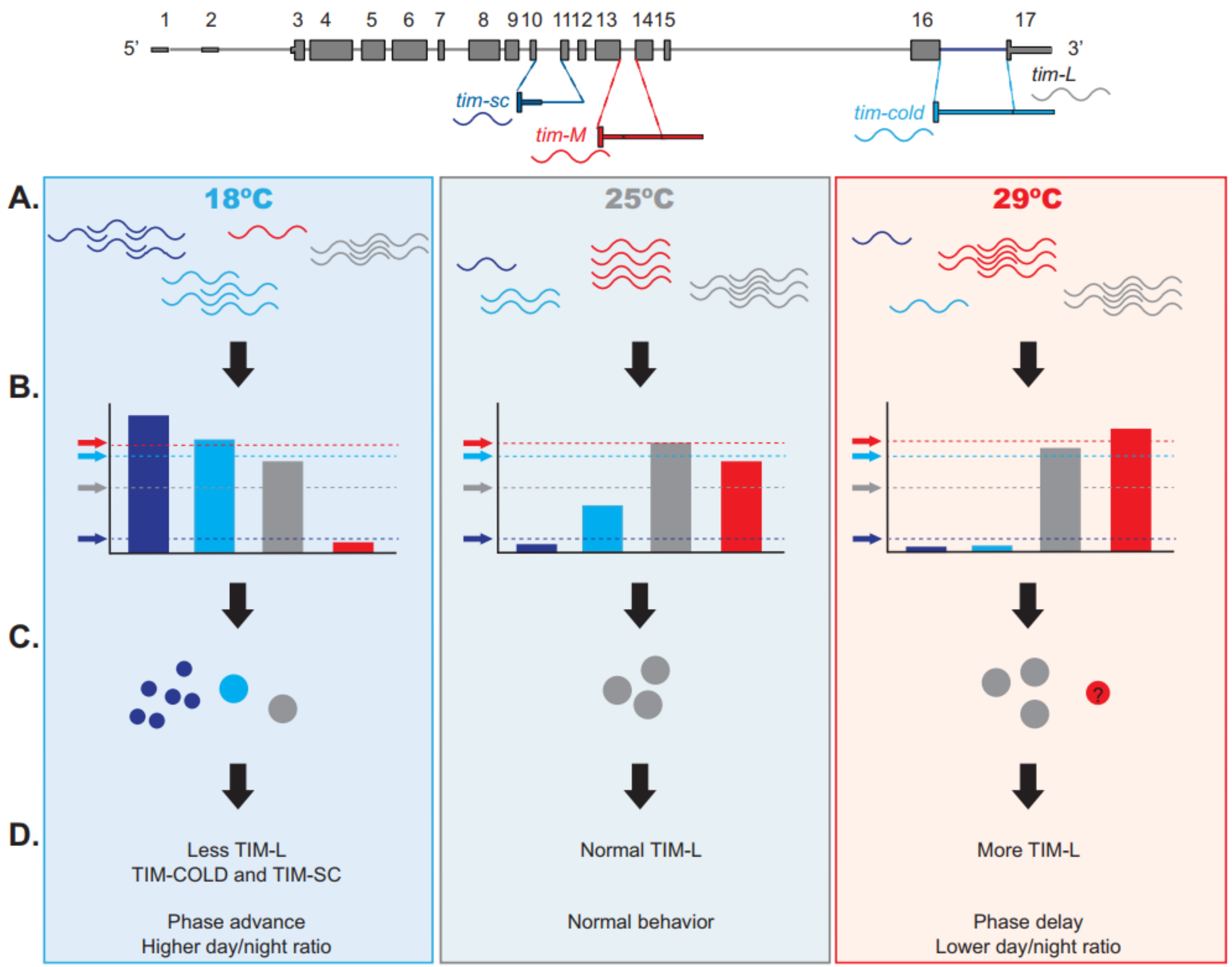
Frank DD,et al.,*Nature*,2015

How dose the environmental temperature influences on the circadian rhythm?

Temperature dramatically changes the splicing of clock genes



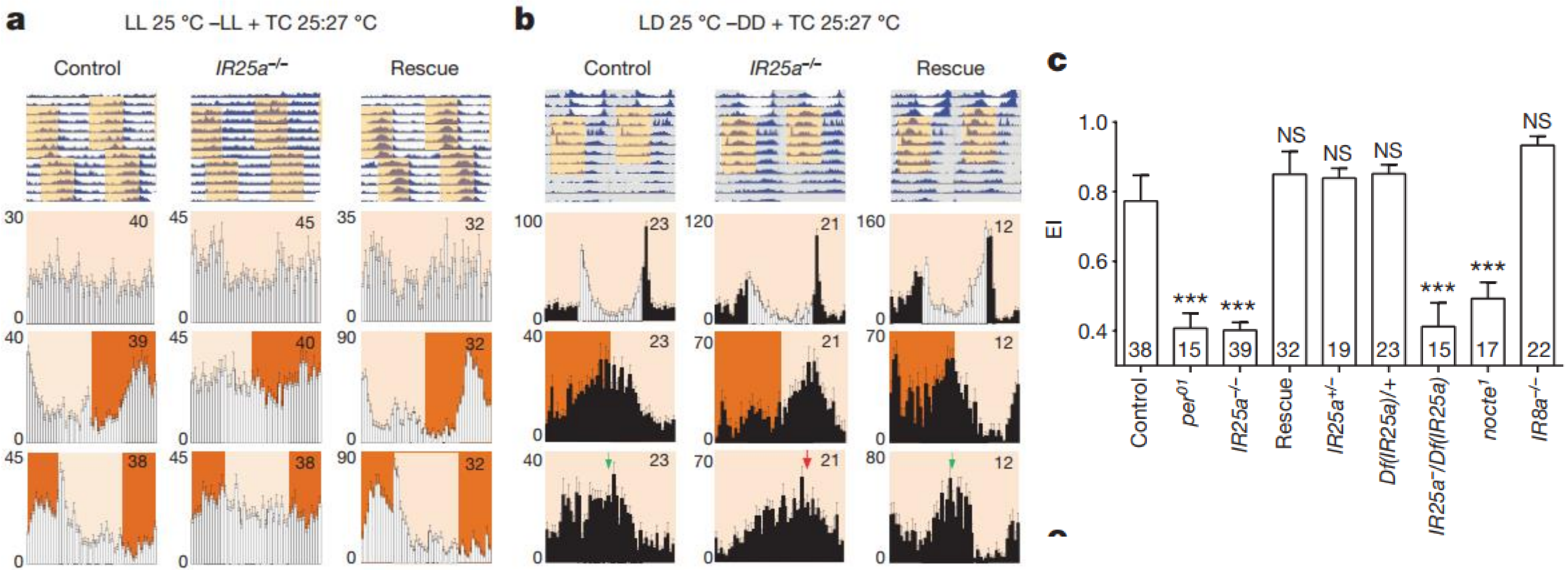
Majercak J,et al.,*Neuron*,1999



Martin Anduaga A,et al.,*Elife*,2019

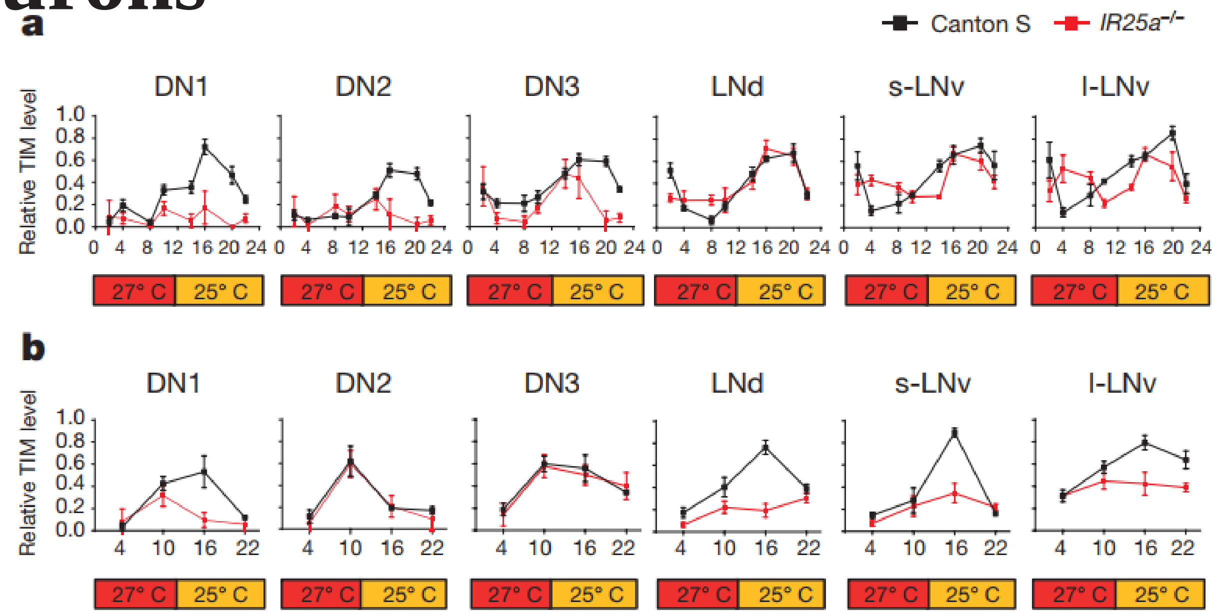
How the circadian clock neuron network of *Drosophila* processes changes in environmental temperature?

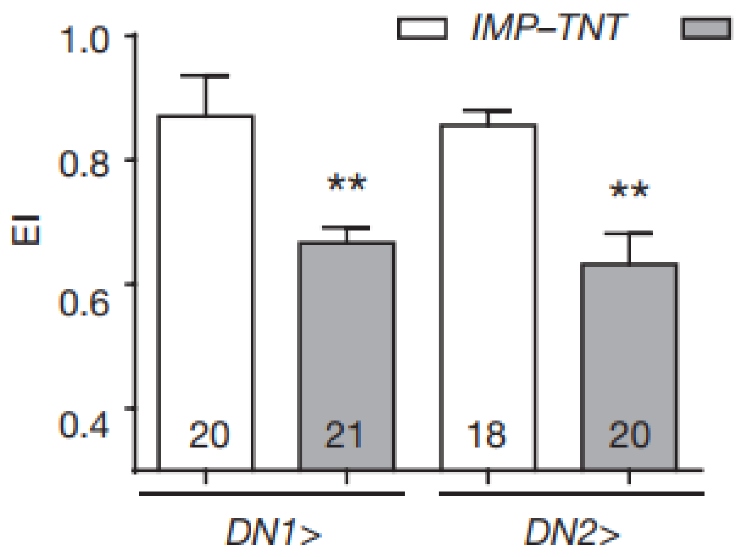
IR25a is required for behavioural synchronization to temperature cycles.

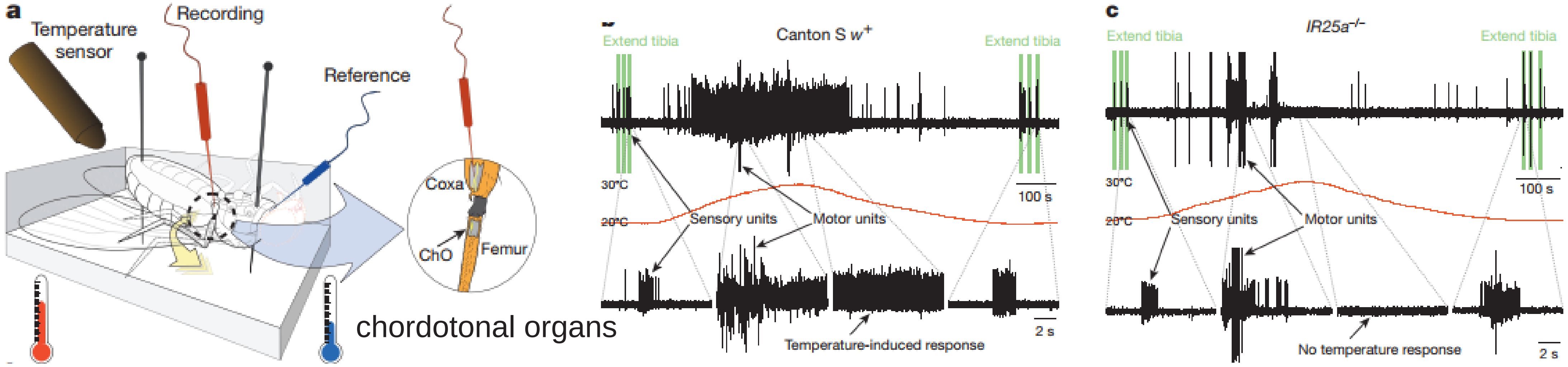


Chen C,et al.,*Nature*,2015

IR25a is required for clock protein oscillations in central clock neurons







Chen C,et al.,*Nature*,2015

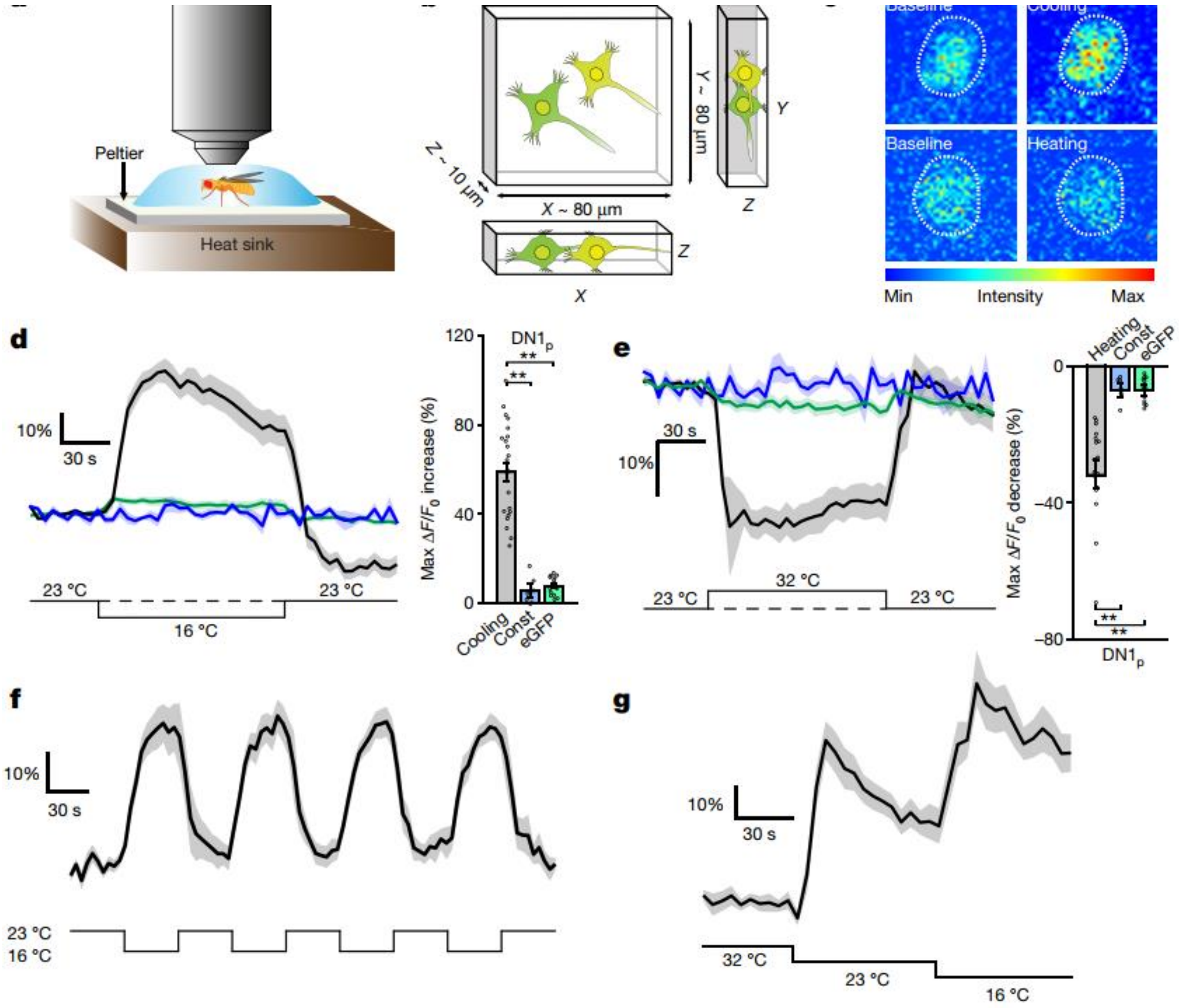
LETTER

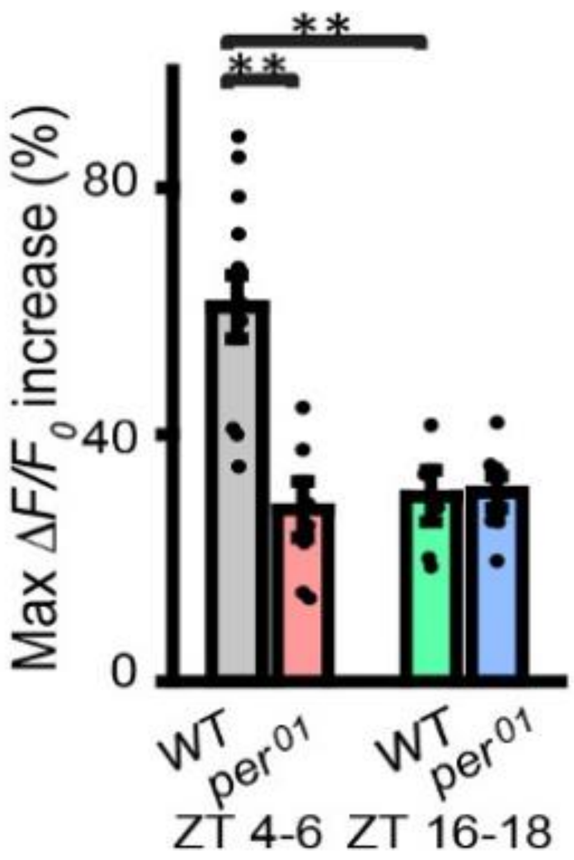
doi:10.1038/nature25740

Circadian clock neurons constantly monitor environmental temperature to set sleep timing

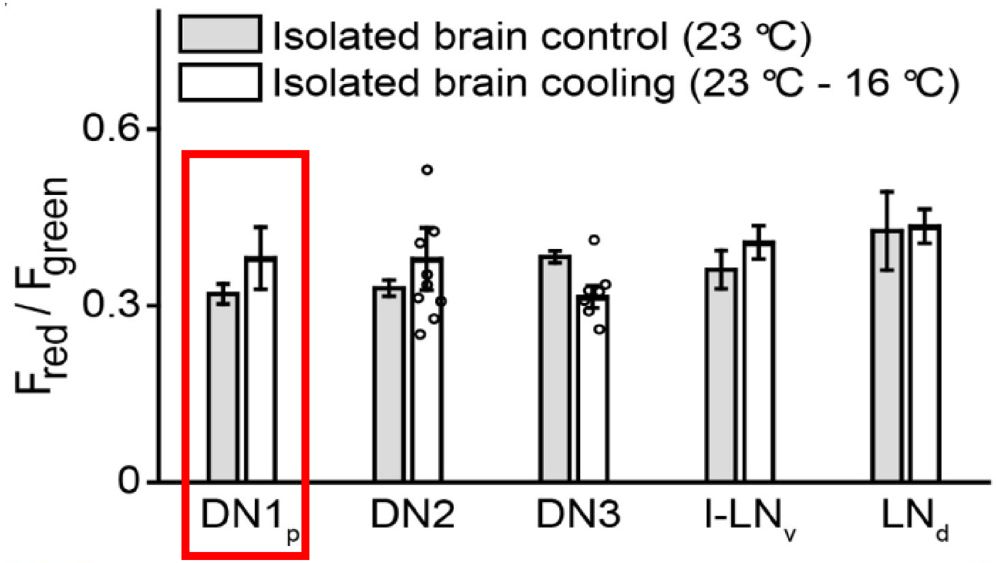
Swathi Yadlapalli[1]*, Chang Jiang[2]*, Andrew Bahle[1]†, Pramod Reddy[2], Edgar Meyhofer[2] & Orie T. Shafer[1]

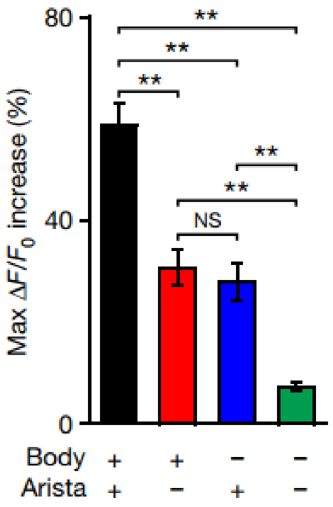
DN1ps are acutely excited by cooling and inhibited by heating.

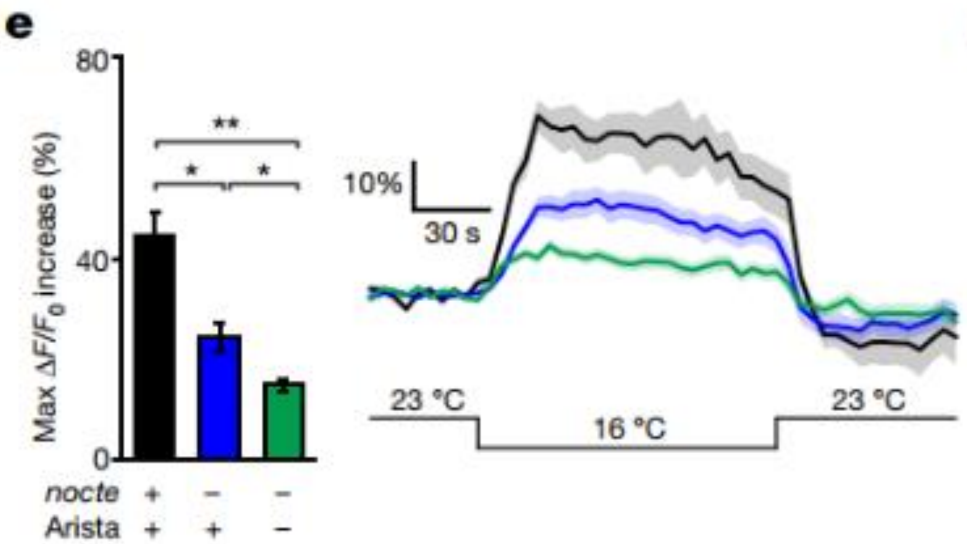


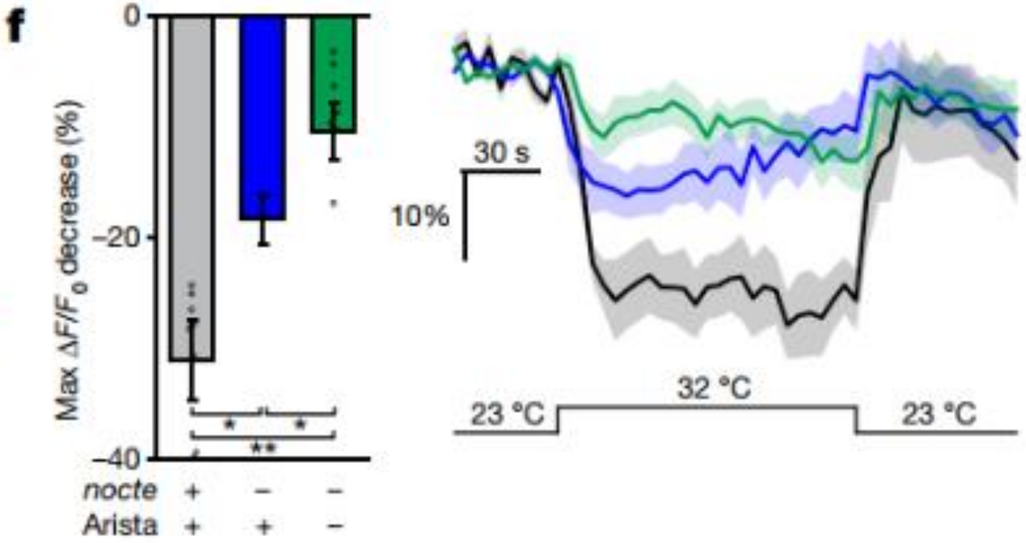


Thermoreceptors in the aristae and the chordotonal organs are required for the responses of DN1ps to temperature changes.



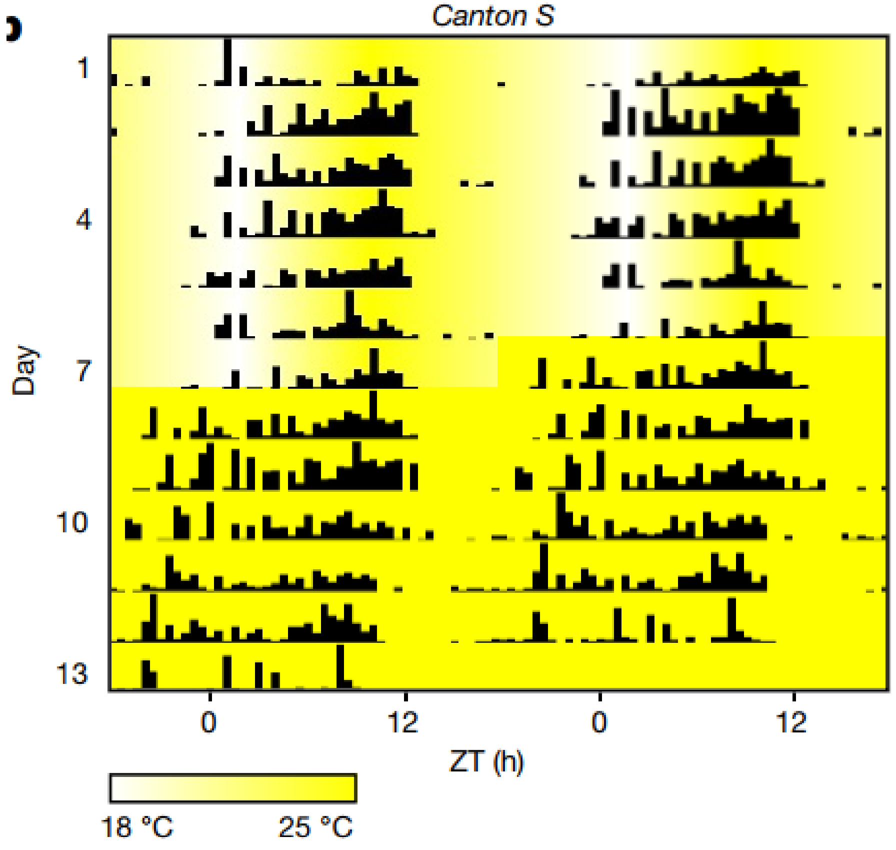


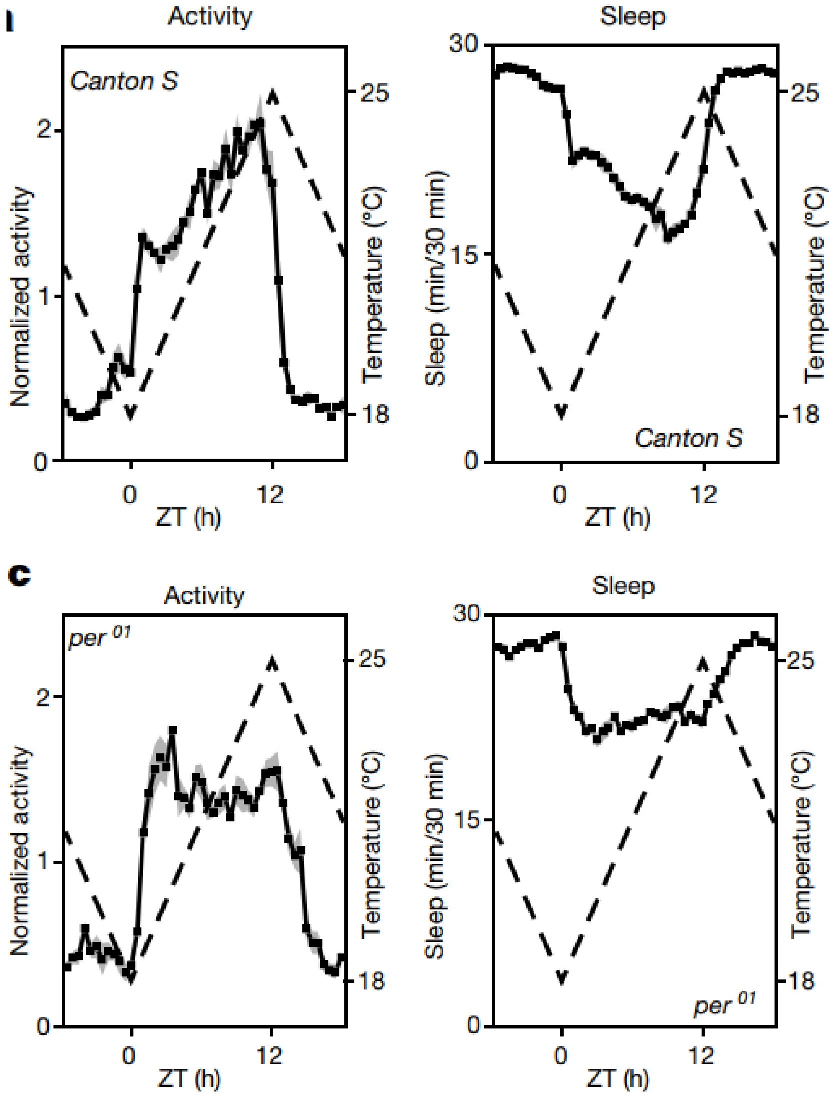




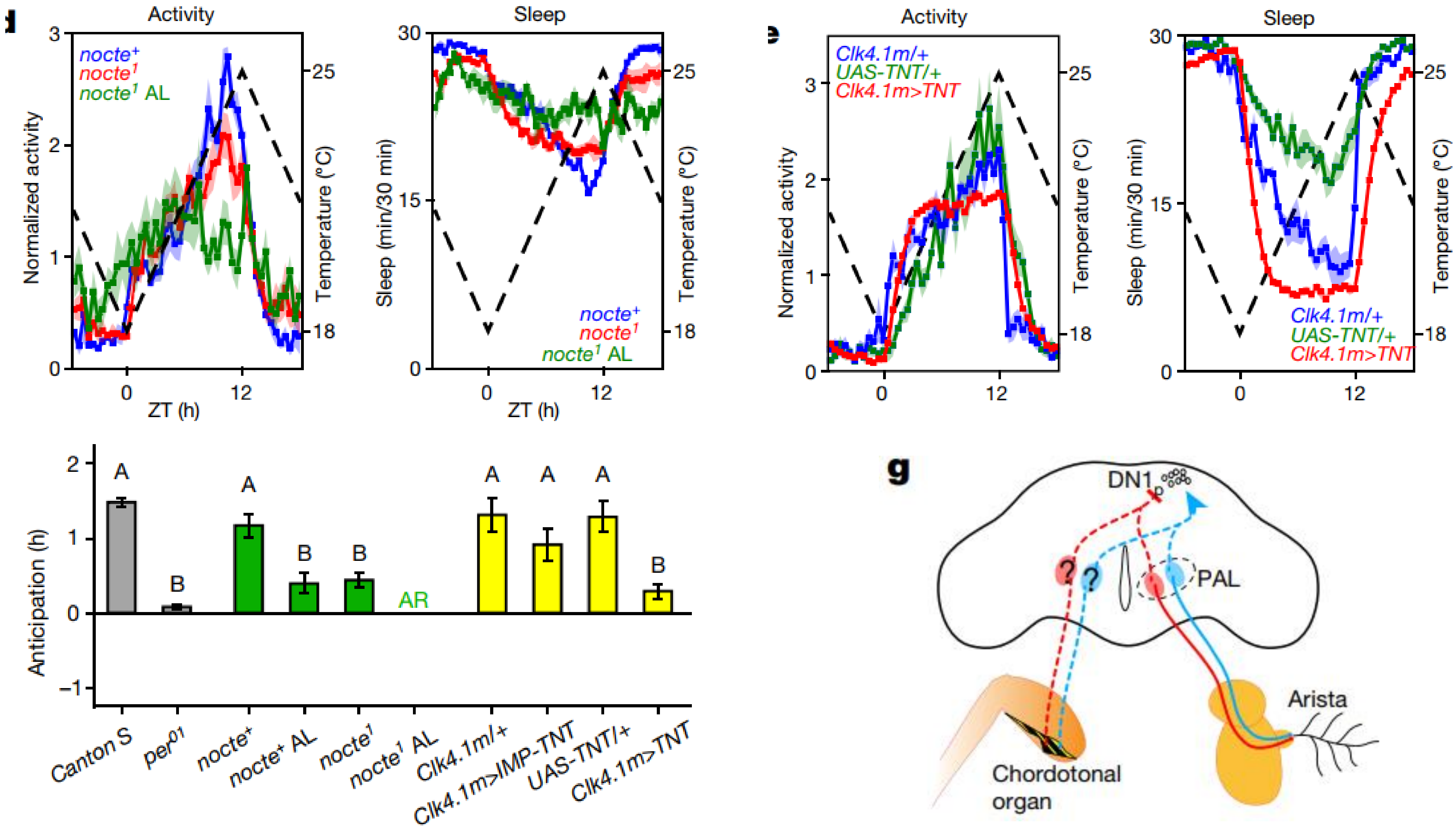
nocte[1] :defects in chordotonal organ and temperature entrainment

per01 mutant are sensitive to the heating and cooling transitions of ramping temperature cycles





DN1ps are required for the synchronization of behavior to ramping temperature cycles.



How dose the environmental temperature influences on the sleep time?

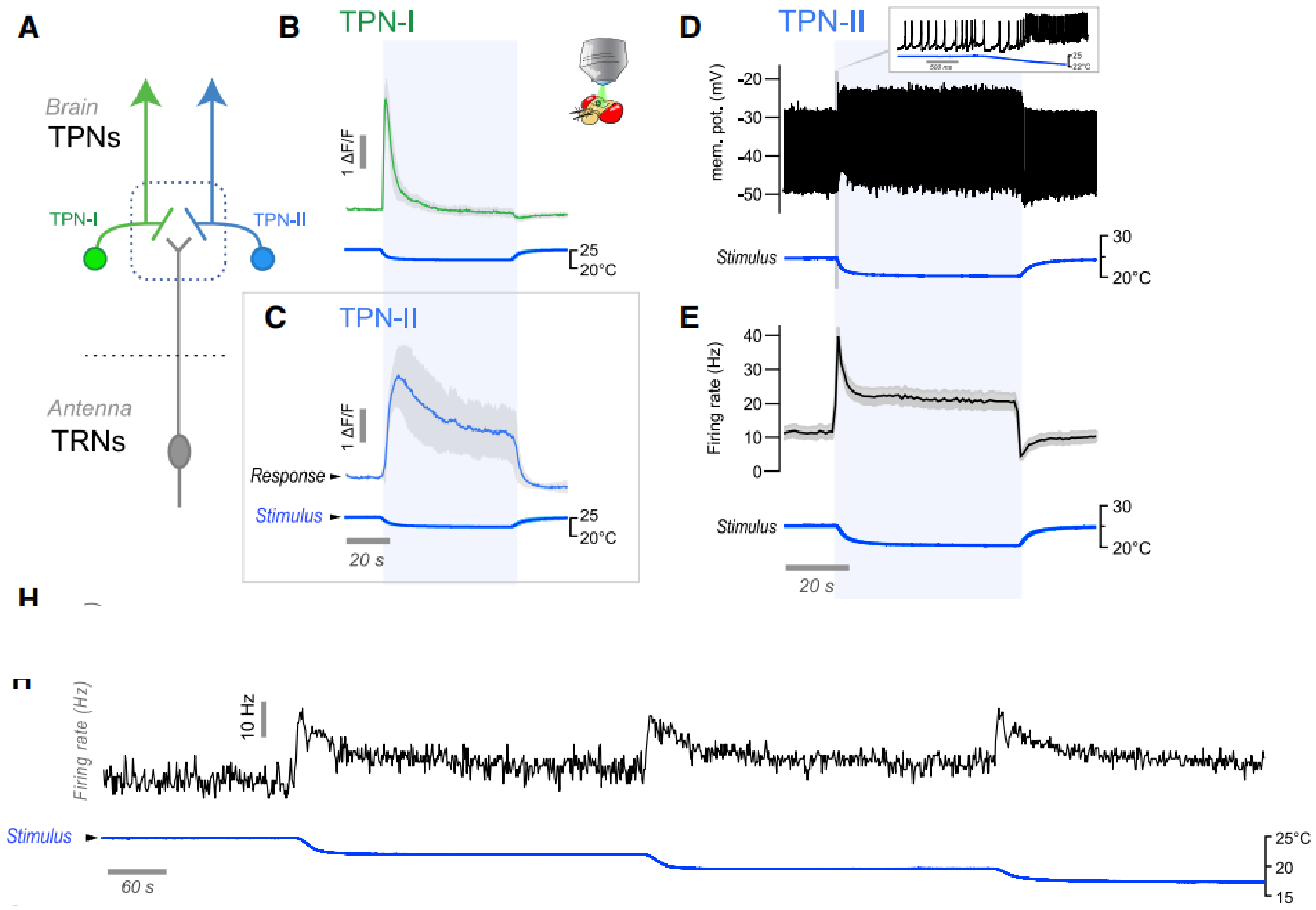
Current Biology

Article

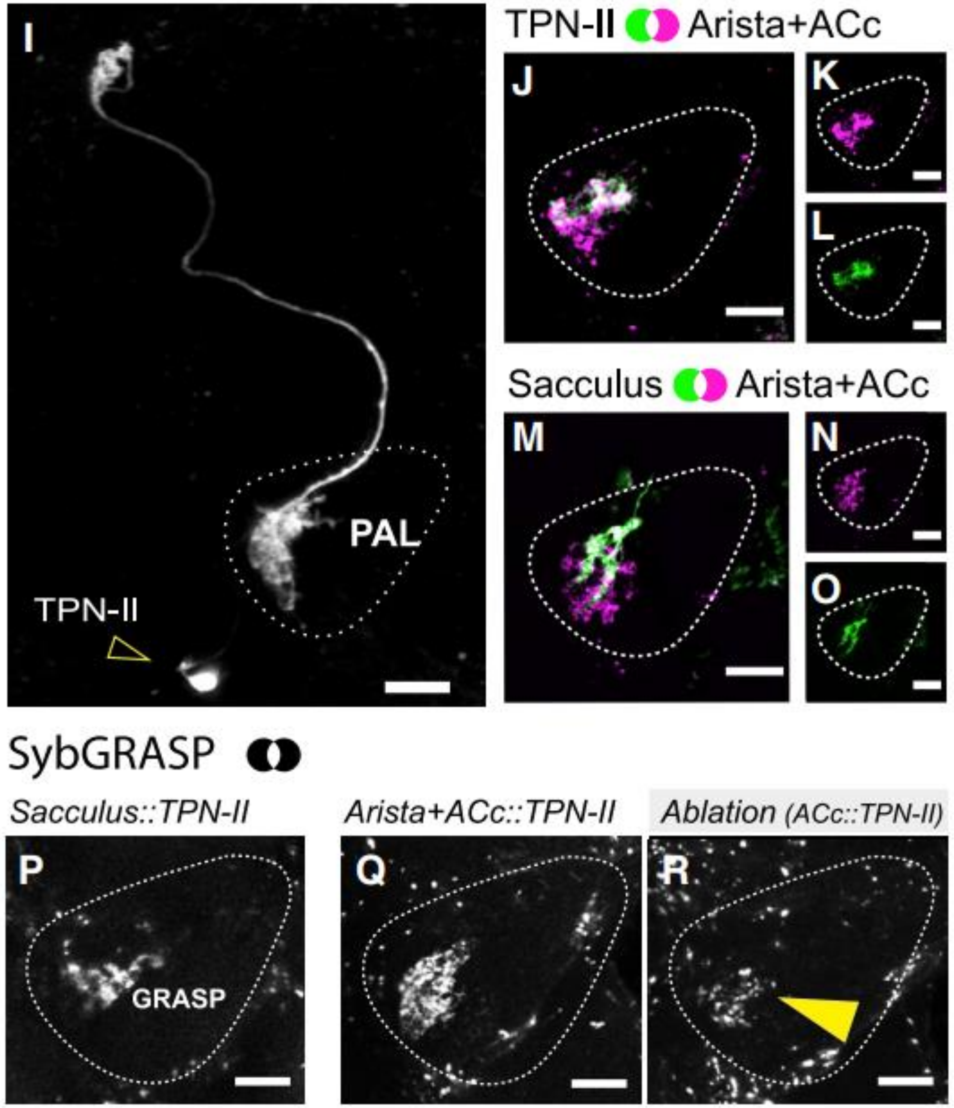
A Circuit Encoding Absolute Cold Temperature in *Drosophila*

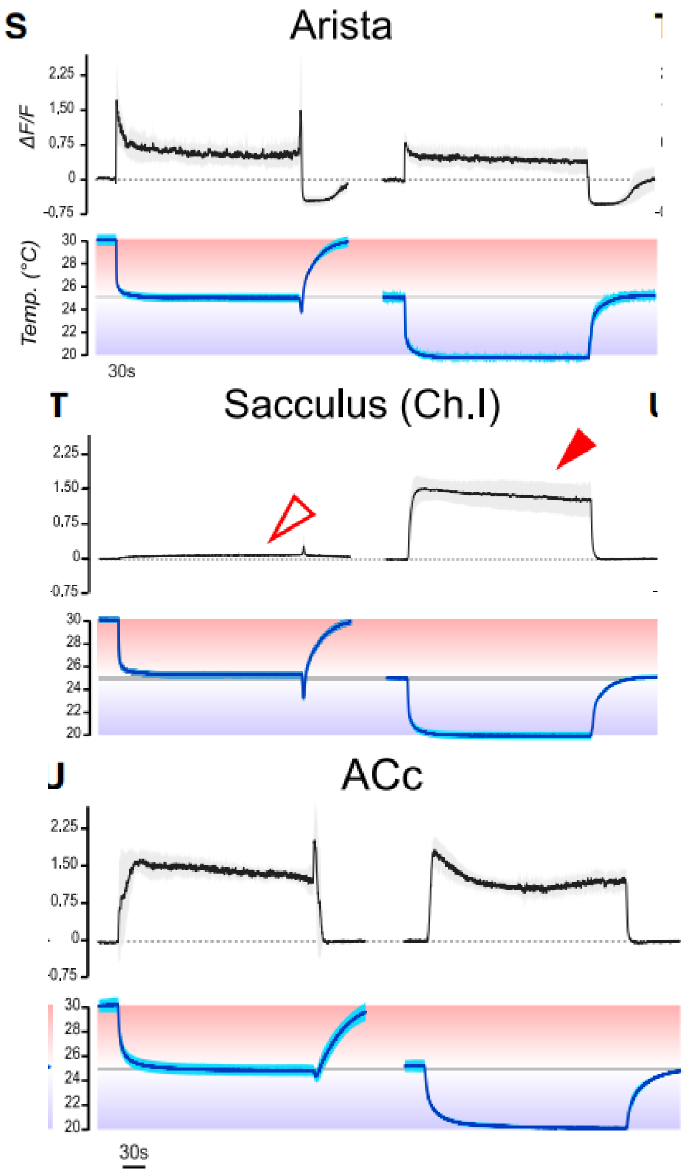
Michael H. Alpert,[1,2] Dominic D. Frank,[1,2] Evan Kaspi,[1] Matthieu Flourakis,[1] Emanuela E. Zaharieva,[1] Ravi Allada,[1] Alessia Para,[1] and Marco Gallio[1,3,*]
[1]Department of Neurobiology, Northwestern University, Evanston, IL 60208, USA
[2]These authors contributed equally
[3]Lead Contact
*Correspondence: marco.gallio@northwestern.edu
https://doi.org/10.1016/j.cub.2020.04.038

A thermosensory PN displays persistent activity in response to extended cold steps

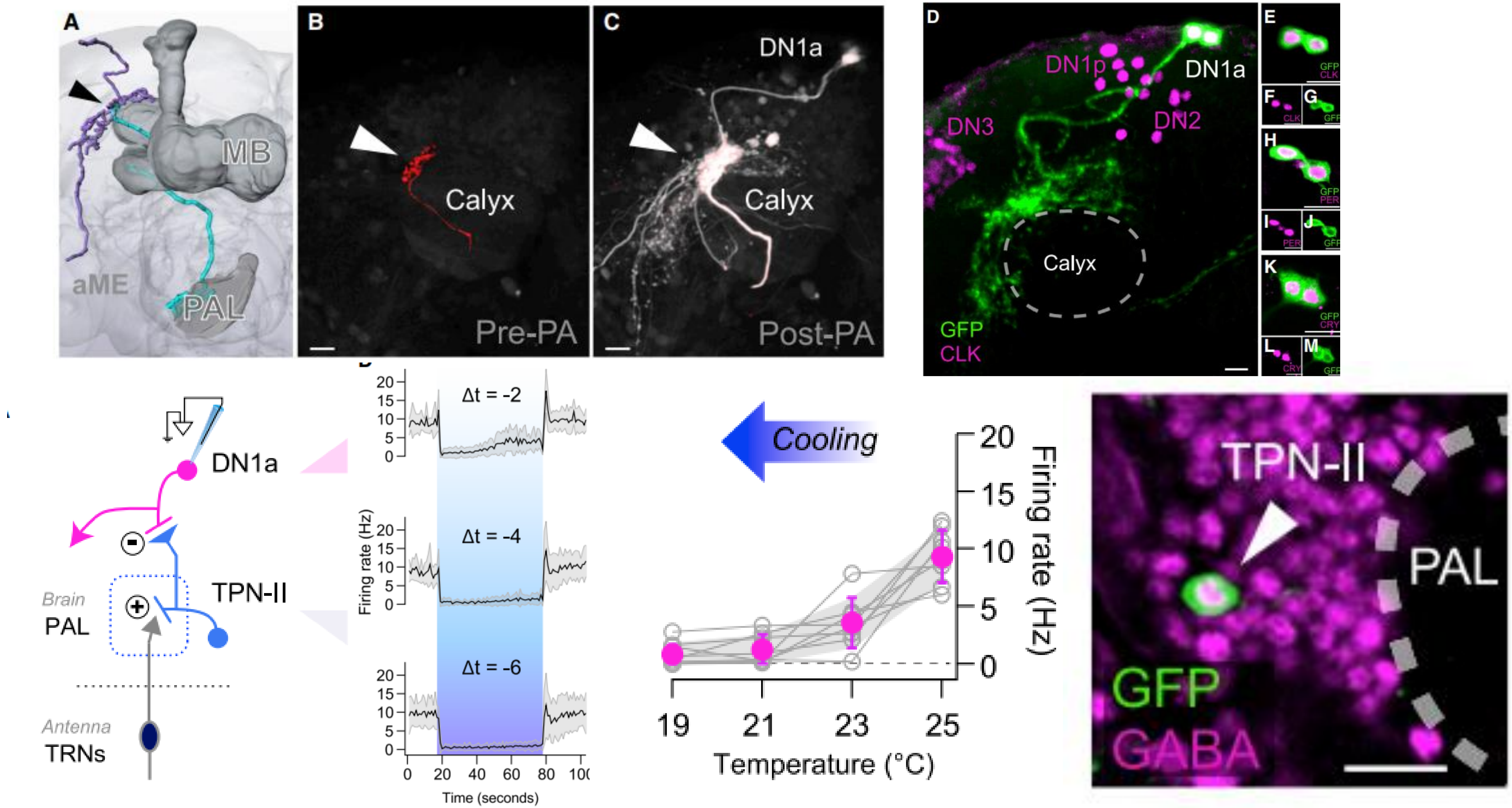


Three distinct populations of peripheral cold-sensing neurons drive the activity of TPN-IIs

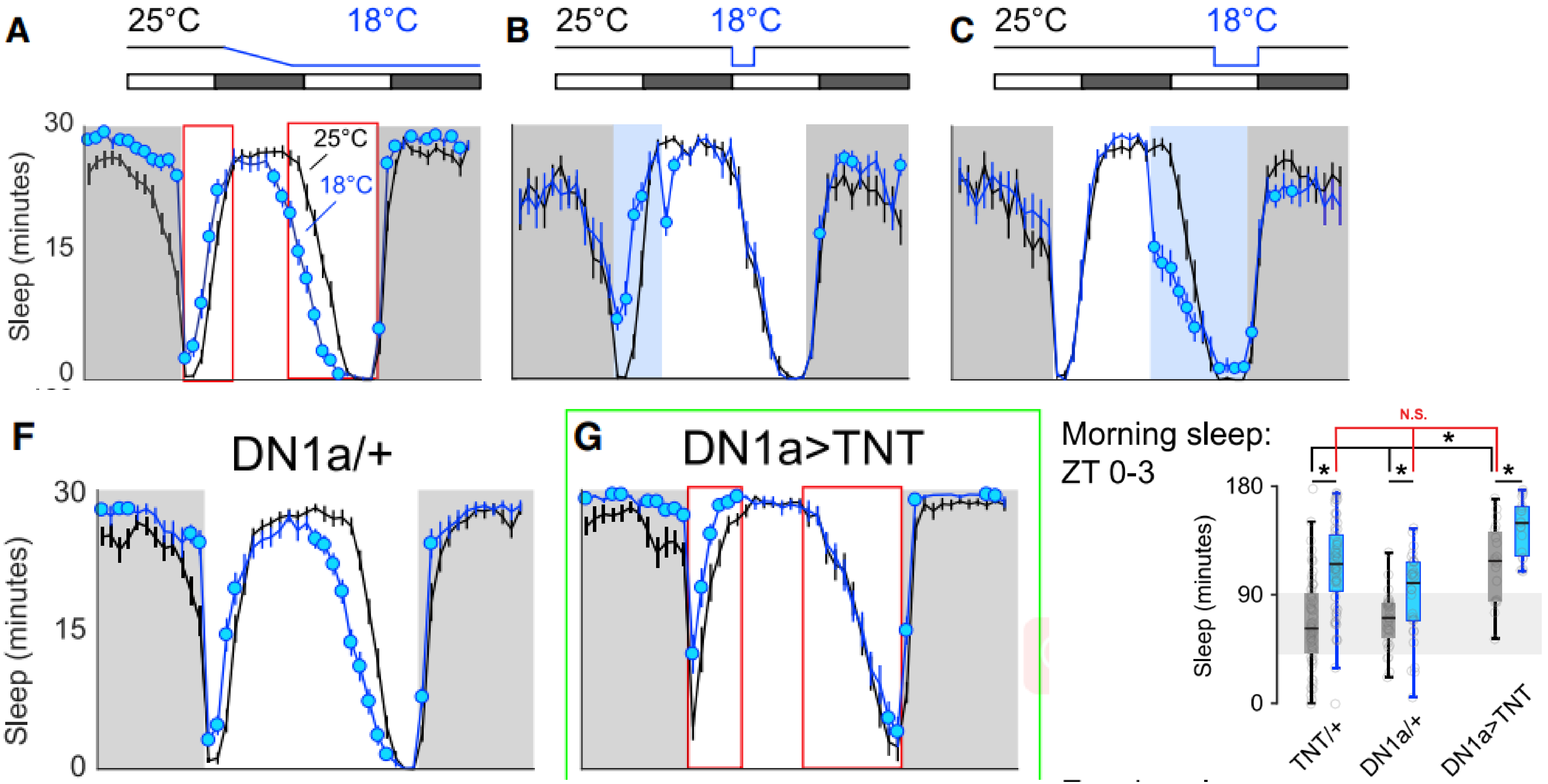




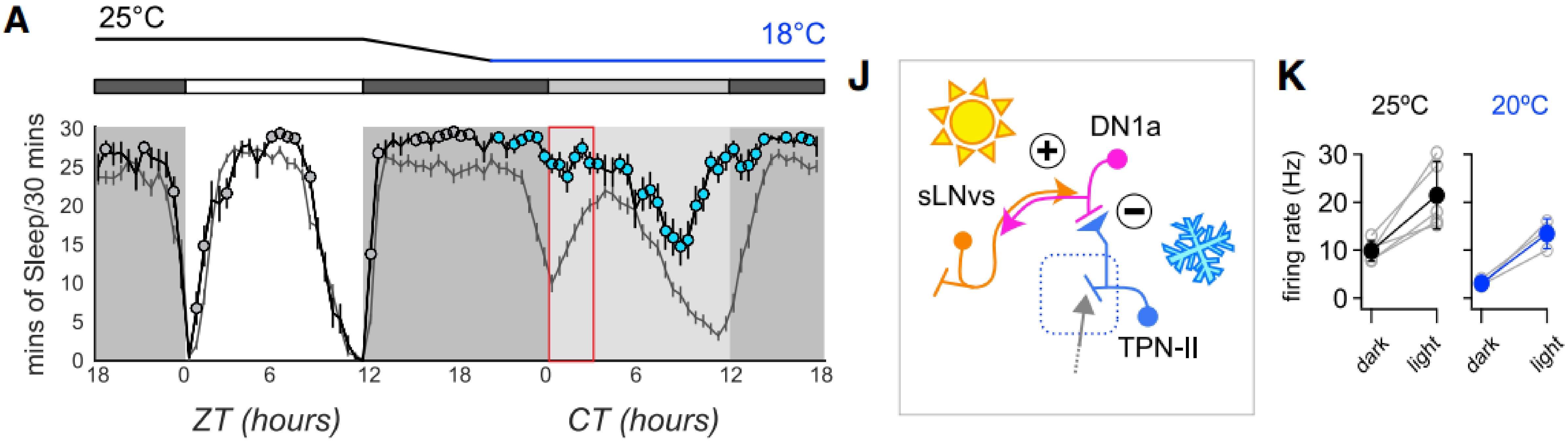
TPN-IIs robustly inhibit DN1a activity in cold conditions through GABA release



Cold temperature has both an acute and persistent effect on fly sleep



Dark and cold synergize to suppress morning wakefulness



Current Biology

Article

A subset of DN1p neurons integrates thermosensory inputs to promote wakefulness via CNMa signaling

Xi Jin,[1,5] Yao Tian,[1,5] Zi Chao Zhang,[1] Pengyu Gu,[1] Chang Liu,[3,4] and Junhai Han[1,2,6,*]
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[2]Co-innovation Center of Neuroregeneration, Nantong University, Nantong 226021, China
[3]CAS Key Laboratory of Brain Connectome and Manipulation, the Brain Cognition and Brain Disease Institute, Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China
[4]Shenzhen-Hong Kong Institute of Brain Science-Shenzhen Fundamental Research Institutions, Shenzhen 518055, China
[5]These authors contributed equally
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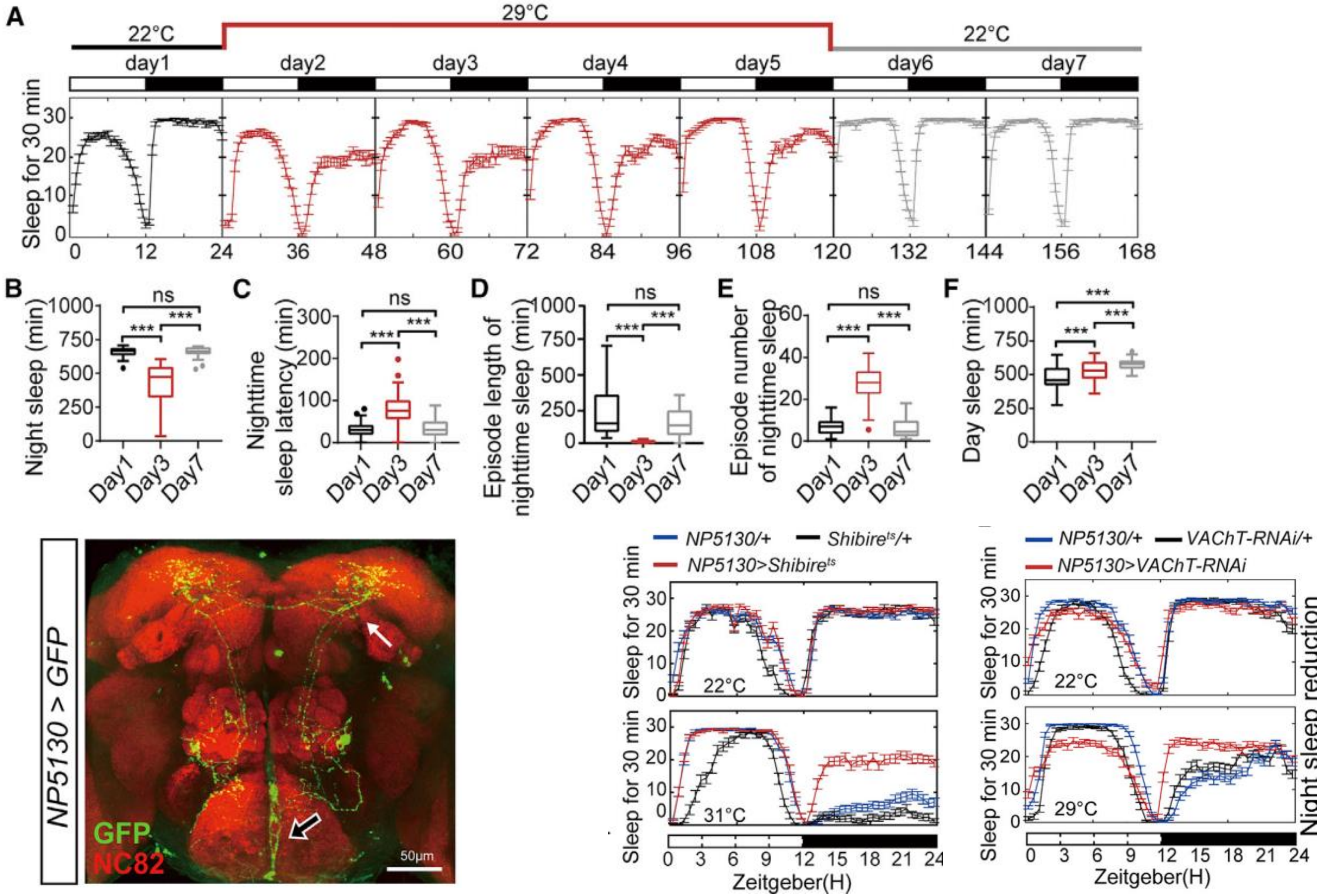
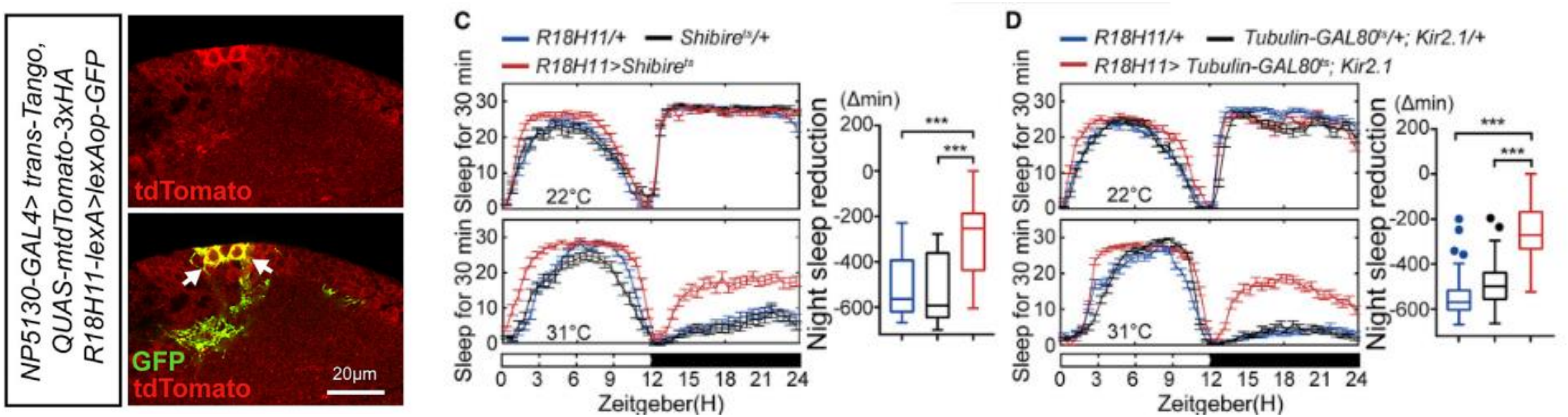
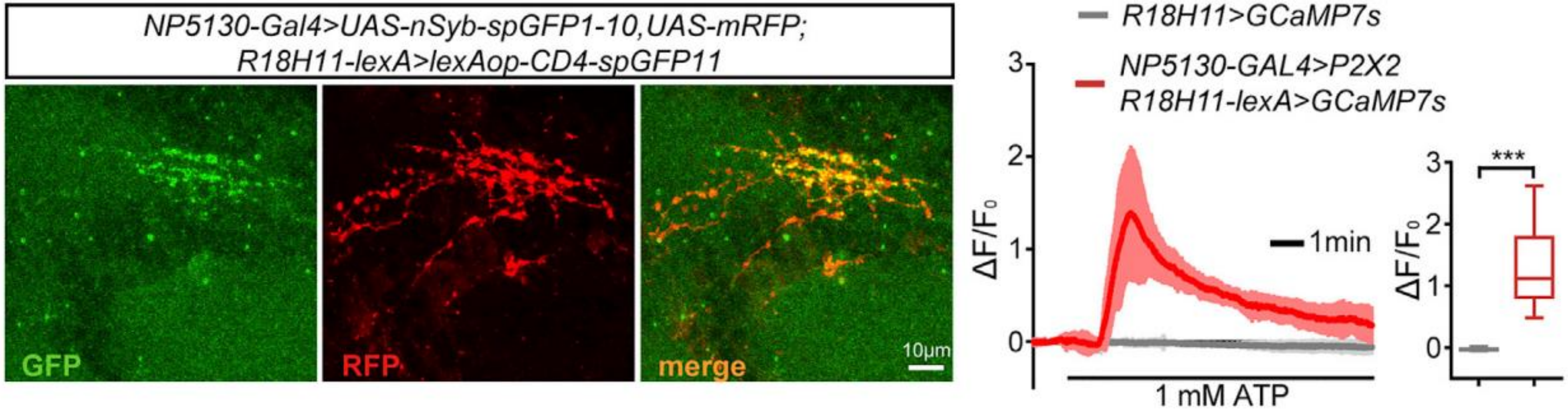
https://doi.org/10.1016/j.cub.2021.02.048

Thermal-sensing AC neurons monitor ambient temperature shifting to promote wakefulness

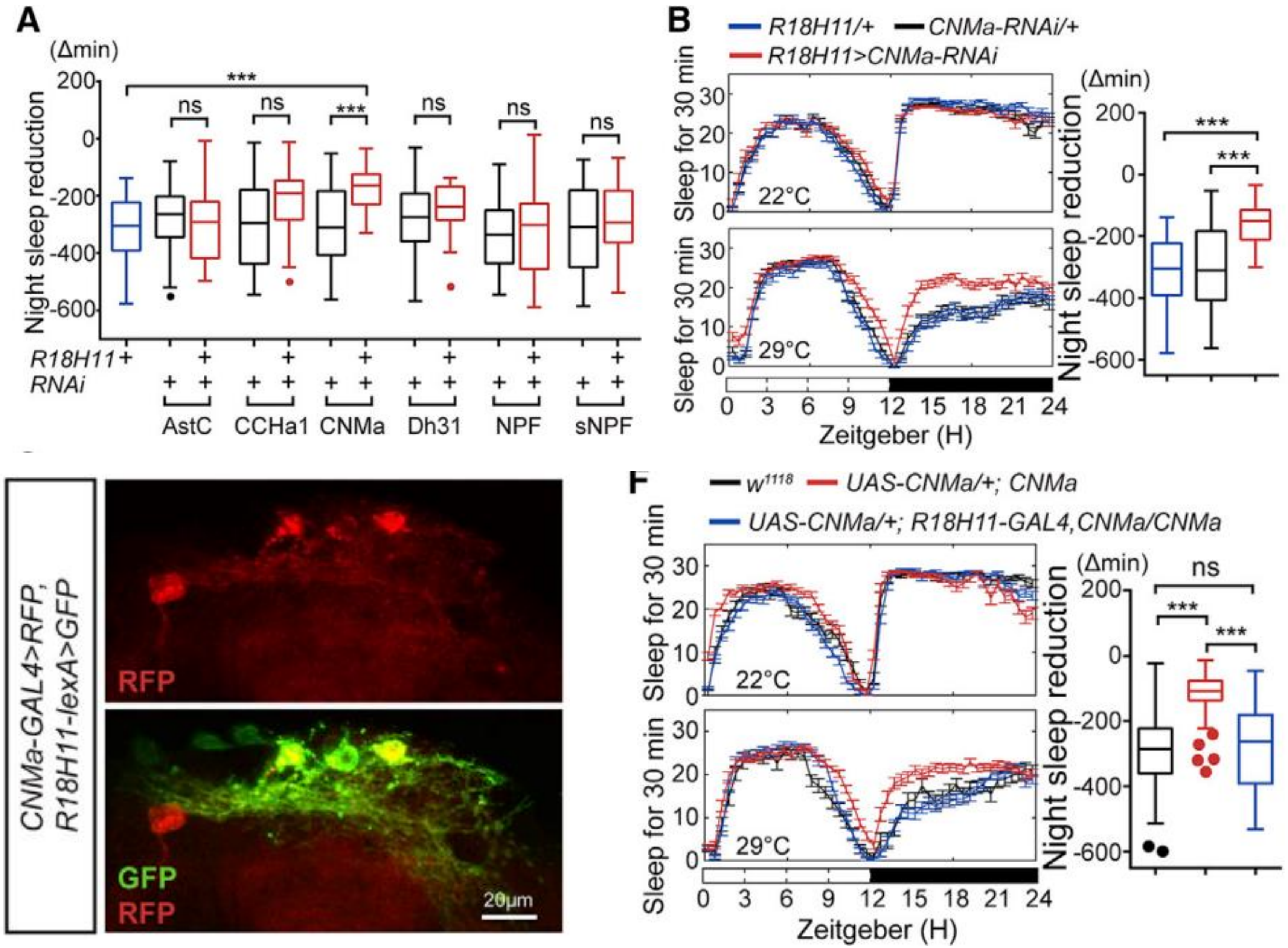


ACs synaptically contact with a subset of DN1p neurons

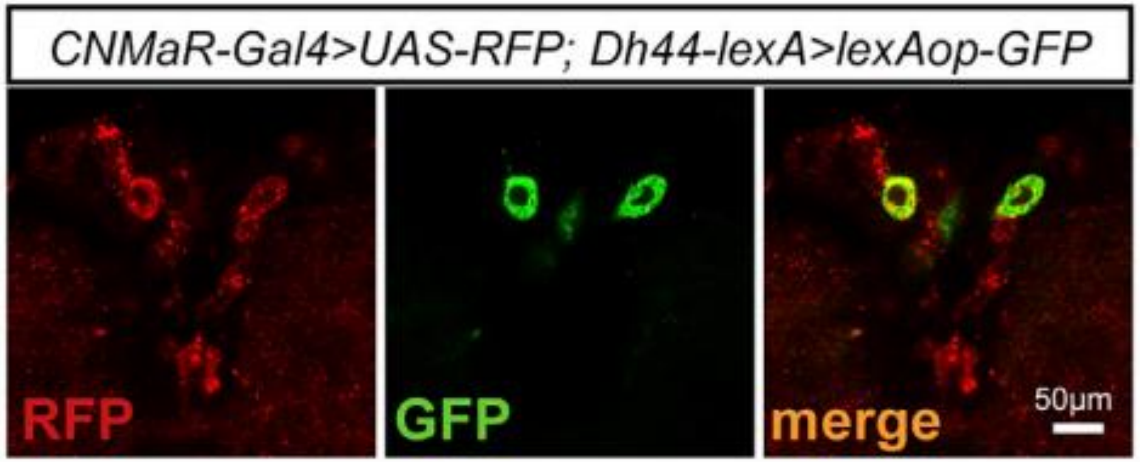


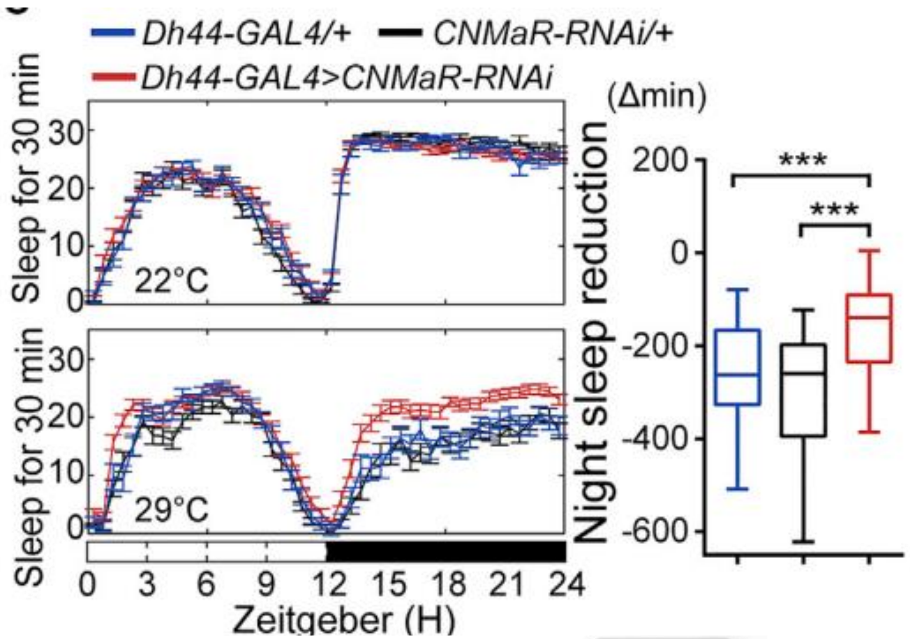


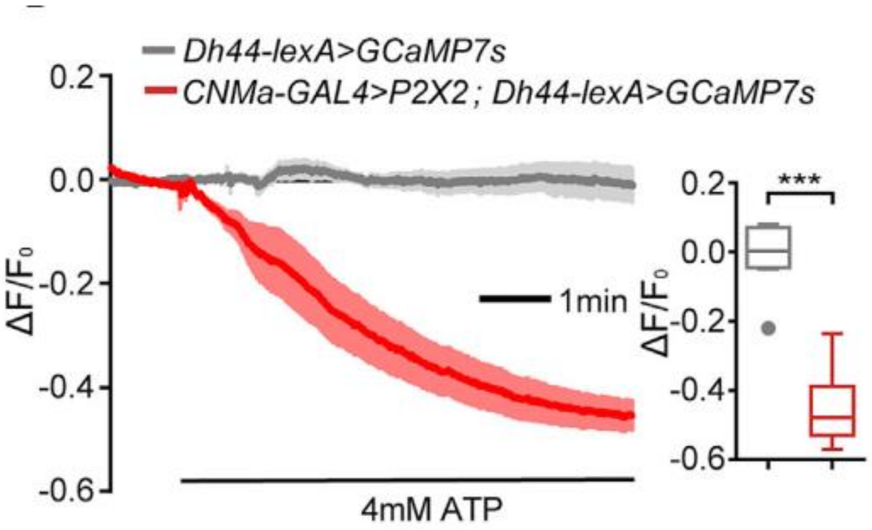
DN1ps release CNMa neuropeptide to promote wakefulness

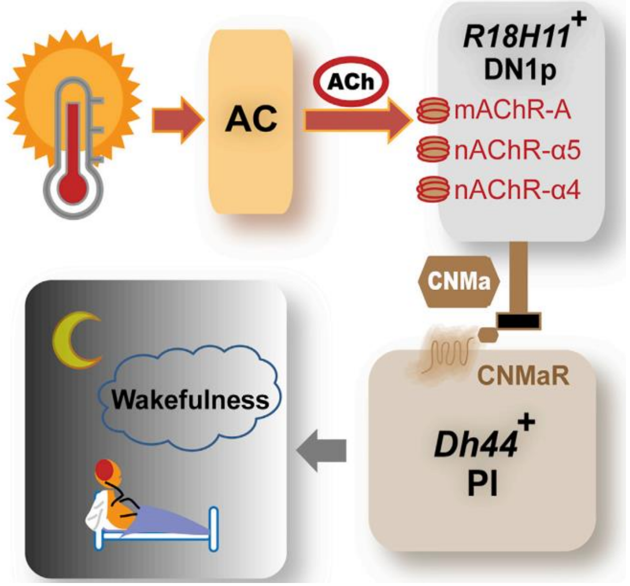


CNMaR in Dh44+ PI neurons is a target of CNMa signaling to promote wakefulness









Summary:

- Temperature changes are detected by dedicated hot and cold temperature receptors in the last antennal segment, the arista and anterior cells
- Second-order projection neurons relay peripheral thermosensory information to three target regions: MB,TH,PLP
- DN1ps play a central role for in temperature entrainment and the generation of sleep rhythm
- DN1a and DN1p are respectively involved in the regulation of sleep by cold and hot signals

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Thank you

feel sleepy?

It has already been confirmed that lack of sleep truly affect people's memory for over 100 years.

Intuitively, sleepiness blocks mind and thoughts.

Human Performs Better on Memory Tasks after Sleep.

MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

Communicated by E. B. TITCHENER

LXXII. OBLIVISCENCE DURING SLEEP AND WAKING

By JOHN G. JENKINS and KARL M. DALLENBACH

TABLE I

Number of Repetitions for the First Correct Recitation and Number of Syllables Correctly Reproduced

	INTERVAL															
	1 hr.				2 hr.				4 hr.				8 hr.			
	Sleep		*Waking*		*Sleep*		*Waking*		*Sleep*		*Waking*		*Sleep*		*Waking*	
O	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.	Rep.	Syll.
	23	9	23	5	25	6	16	5	15	5	21	4	31	2	20	1
	18	9	23	6	15	3	14	2	20	5	17	3	29	3	17	0
	22	7	22	4	13	5	17	3	16	5	15	2	32	7	28	1
H	14	4	21	4	18	9	26	3	16	5	15	1	20	9	22	0
	21	5	17	2	14	5	20	2	24	5	15	2	16	3	24	0
	19	6	19	4	10	6	12	2	23	5	18	2	12	7	17	0
	18	10	22	6	22	4			23	5	11	3	22	5	16	0
	20	7	14	4	14	5			15	7			16	8	15	1
	36	8	33	7	28	6	17	2	20	8	26	2	22	5	18	1
	29	7	31	3	23	5	20	2	19	5	25	2	28	7	16	0
	24	6	20	3	23	5	16	2	19	5	25	2	19	4	20	2
Mc	22	8	26	5	22	5	13	5	22	5	23	2	24	6	19	1
	18	7	17	5	21	5	17	5	22	7	16	2	20	7	20	3
	16	8	18	6	23	5	16	5	25	4	21	1	20	5	19	1
	17	5			20	7	20	2	22	7	13	2	25	4	22	3
	18	7			19	5	19	4	22	5	15	4	20	8	14	0

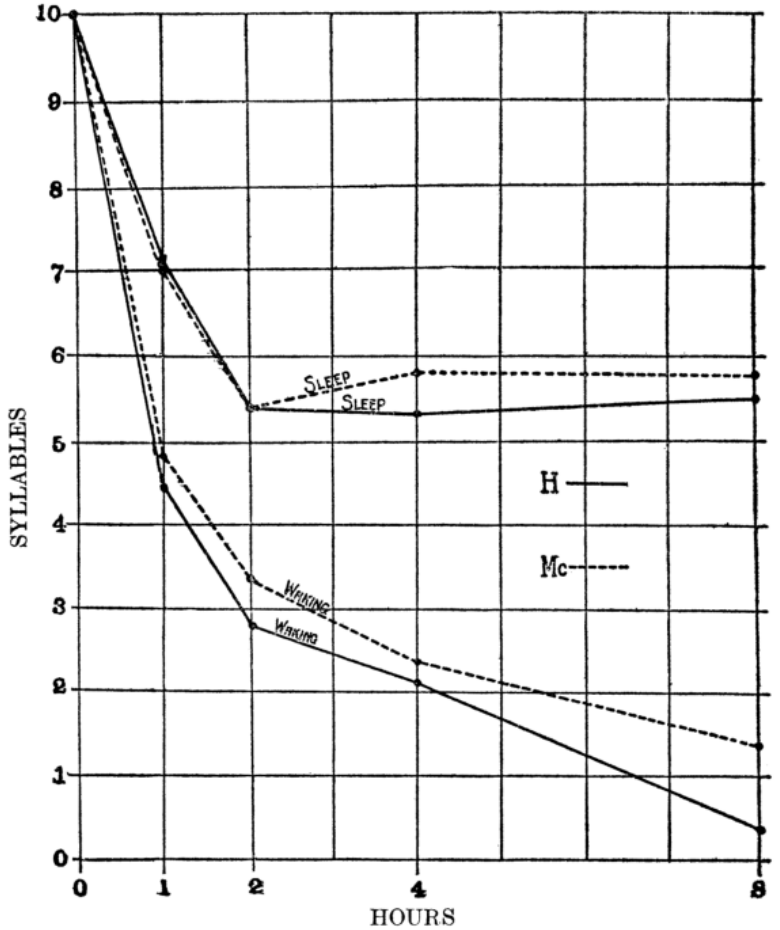


FIG. I. Average Number of Syllables Reproduced by each *O* after the Various Time-Intervals of Sleep and Waking

(John G. Jenkins and Karl M. Dallenbach , 1924)

Invertebrate Also has Sleep-like Behavior

Behavioural Brain Research, 8 (1983) 351–360
Elsevier Biomedical Press

EFFECT OF FORCED LOCOMOTION ON THE REST–ACTIVITY CYCLE OF THE COCKROACH

IRENE TOBLER

Institute of Pharmacology, University of Zürich, Gloriastrasse 32, 8006 Zürich (Switzerland)

(Received January 11th, 1983)
(Revised version received January 26th, 1983)
(Accepted February 2nd, 1983)

Key words: rest–activity cycle – forced locomotion – cockroach

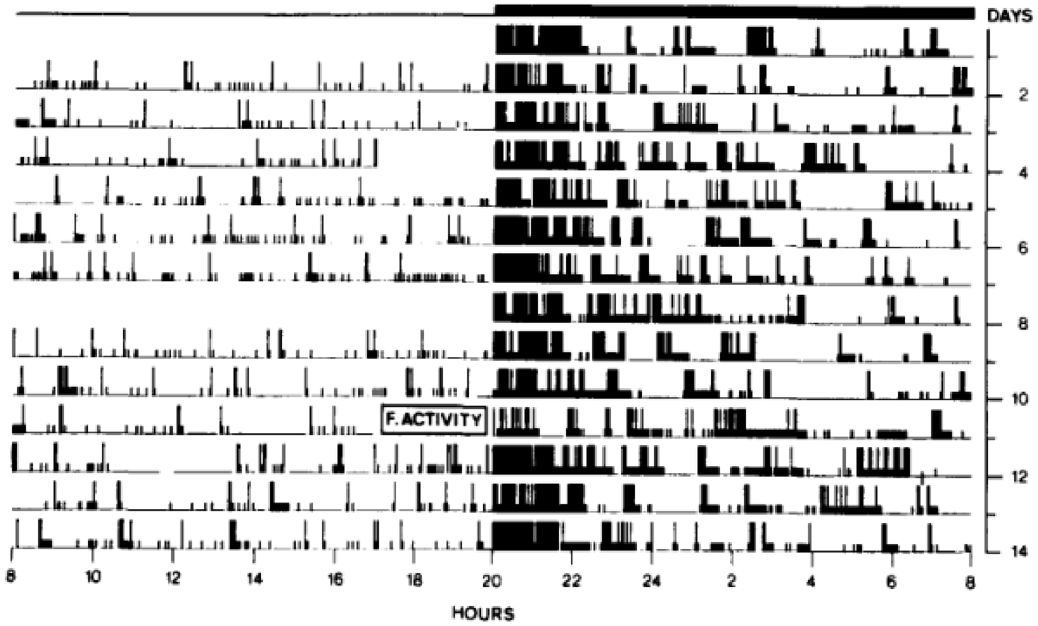


Fig. 1. Activity plot of an individual cockroach recorded for 14 consecutive days. High bars, locomotor activity; low bars, limb or antenna movements without locomotion; intervals between bars, immobility. Interruption of recordings on Day 4 was due to disturbance by other individuals submitted to forced activity; on Day 8 to visual scoring of the preceding week; and on Day 11 to forced activity. Abscissa: time of day. Dark period indicated by horizontal bar on top.

(IRENE TOBLER , 1983)

HOW THING GOES ON DROSOPHILA?

Sleep and Memory

views from drosophila research

1 Sleep Disruption Impairs Learning

Current Biology *18*, 1110–1117, August 5, 2008 DOI 10.1016/j.cub.2008.07.028

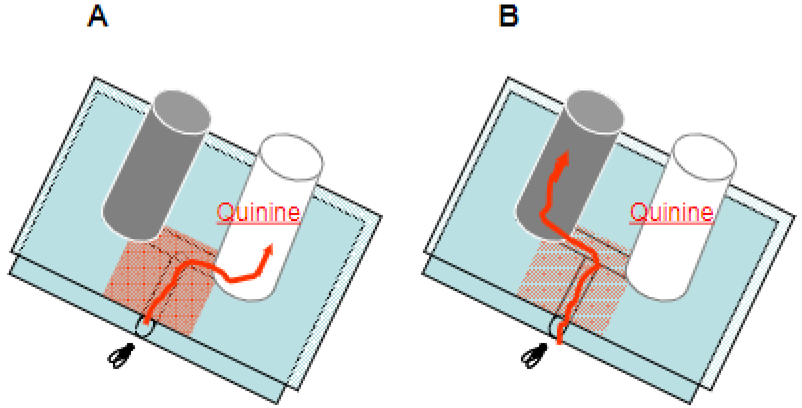
Article

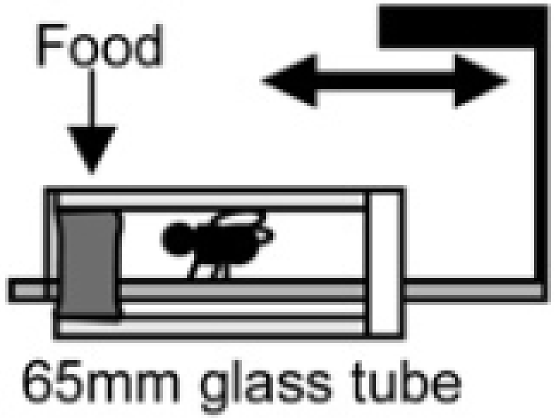
D1 Receptor Activation in the Mushroom Bodies Rescues Sleep-Loss-Induced Learning Impairments in *Drosophila*

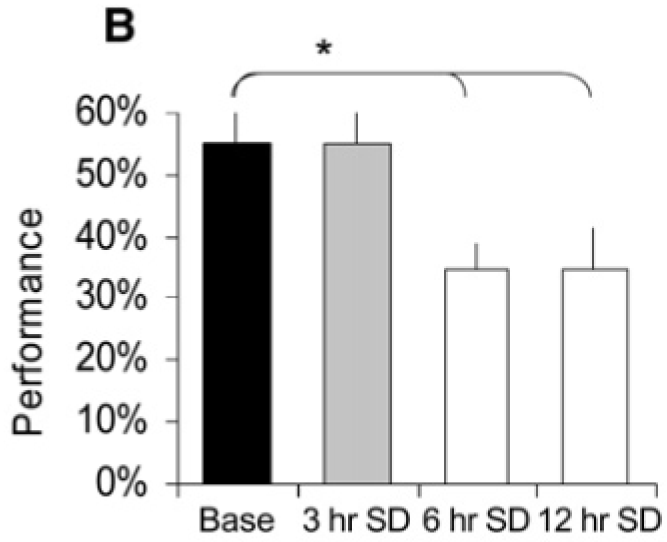
Laurent Seugnet,[1] Yasuko Suzuki,[1] Lucy Vine,[1] Laura Gottschalk,[1] and Paul J. Shaw[1,*]
[1]Anatomy and Neurobiology
Washington University School of Medicine
660 S. Euclid Ave. Campus Box 8108
St. Louis, Missouri 63110

not be due to global brain impairments but may reflect a molecular vulnerability in specific neuronal circuits. Thus, it may be possible to manipulate a single molecular pathway in specific cell groups to prevent cognitive impairments associated with waking. We demonstrate that the effects of extended waking could be prevented by activating the dopamine D1 receptor in a specific circuit known to be involved in learning and memory [5, 6]. These data provide the first demonstration that the

1. Sleep Deprivation Leads to Poor Performance in Learning.

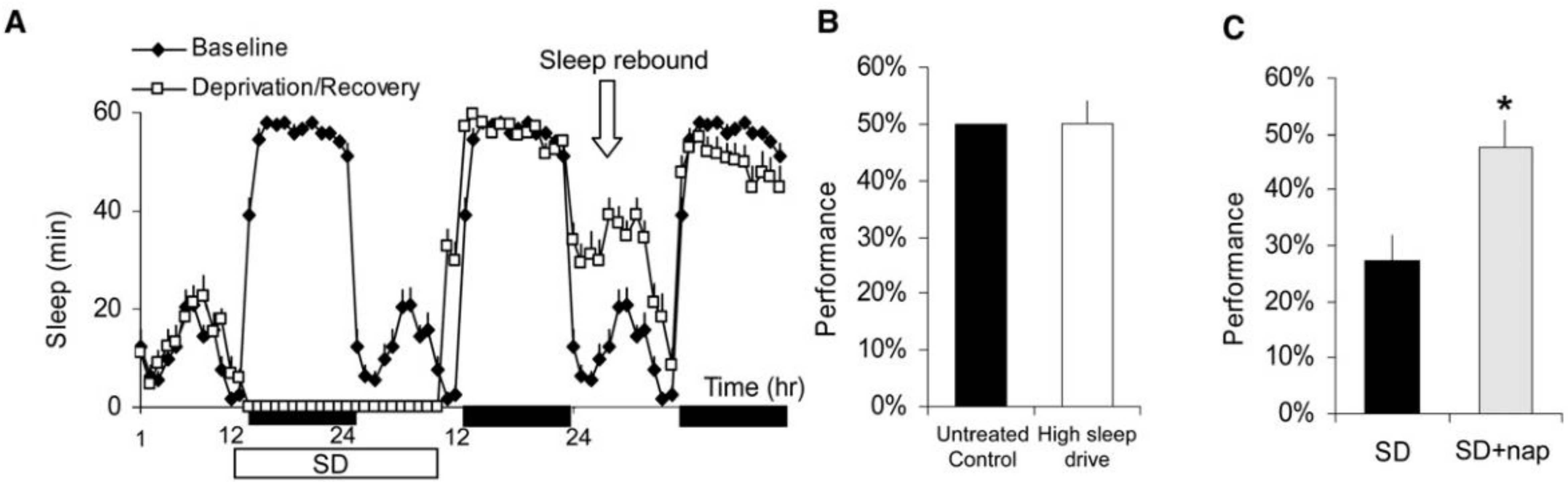






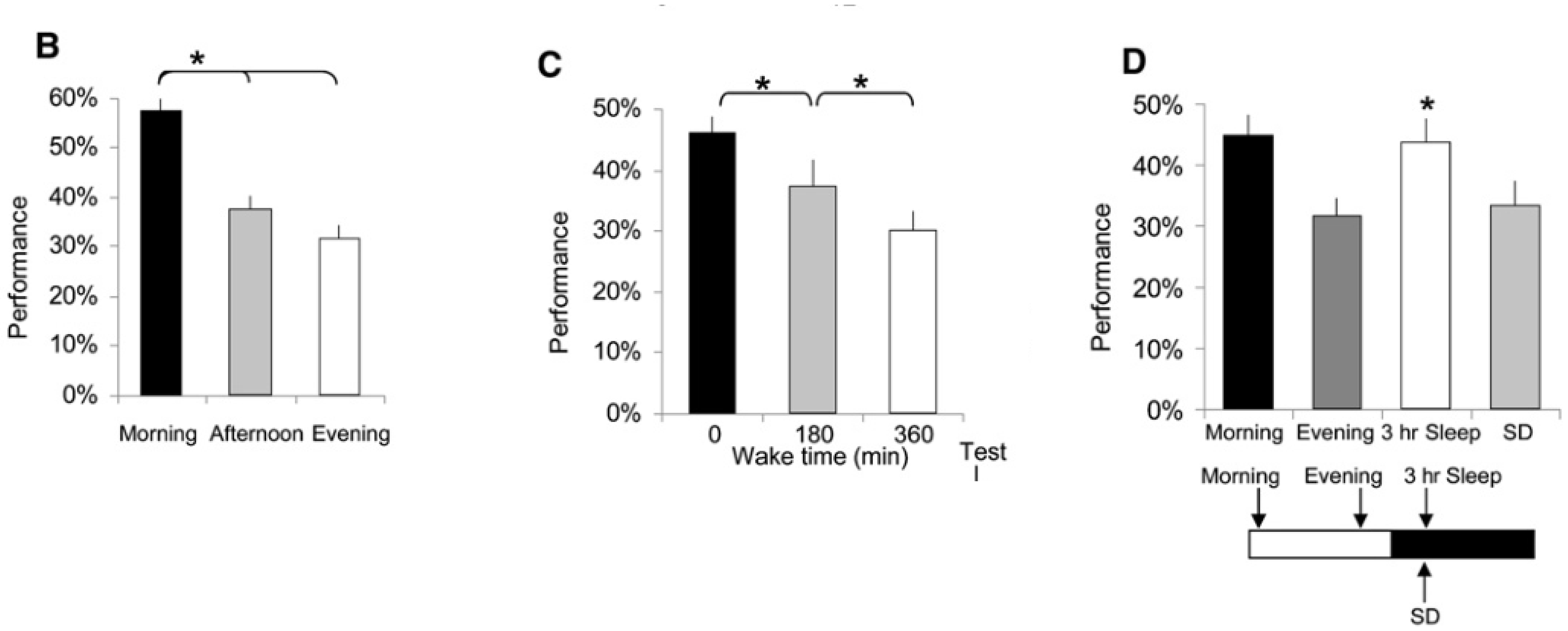
(Laurent Seugnet , *et al*, 2008)

2. Sleep Drive do not Affects Performance.



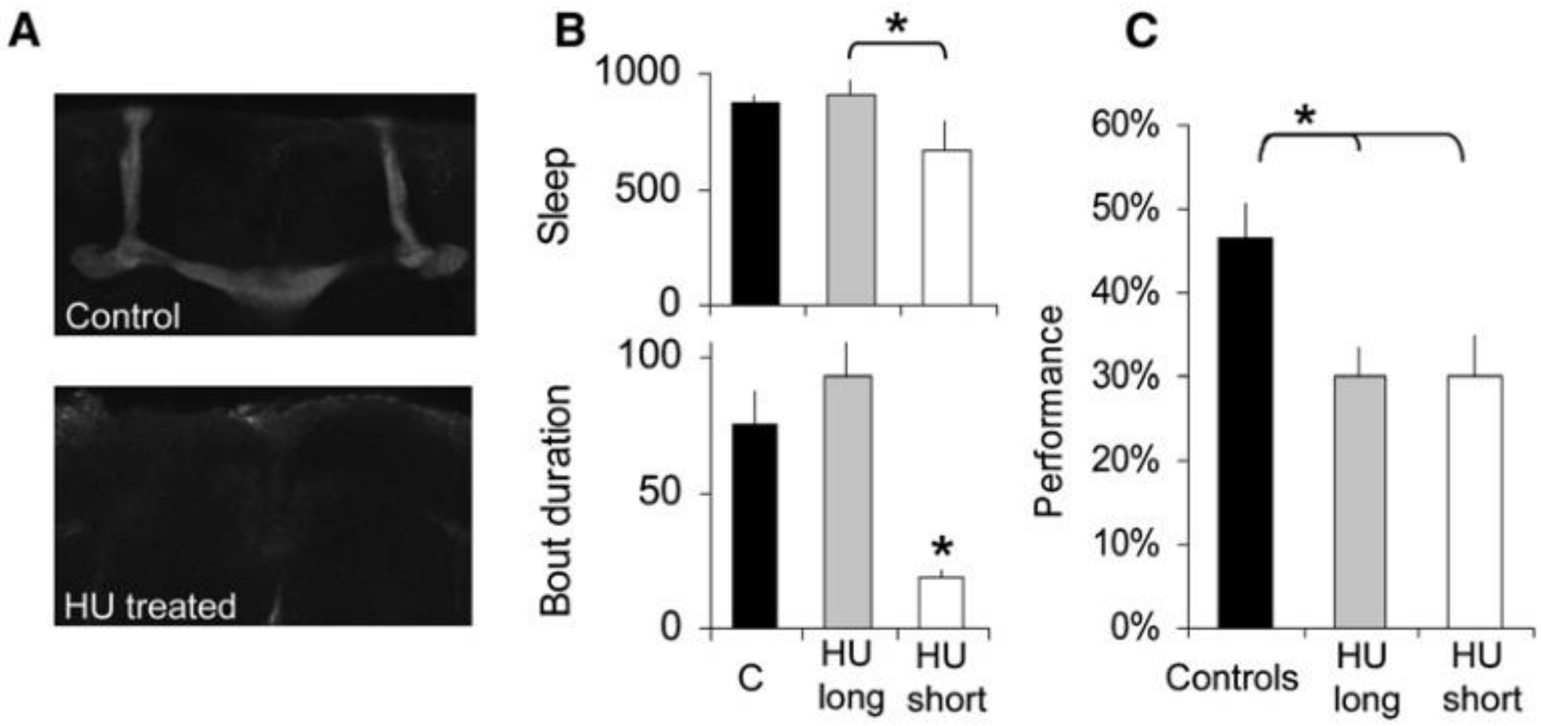
(Laurent Seugnet , *et al*, 2008)

3. It is Prior Time of Wake is the Key.



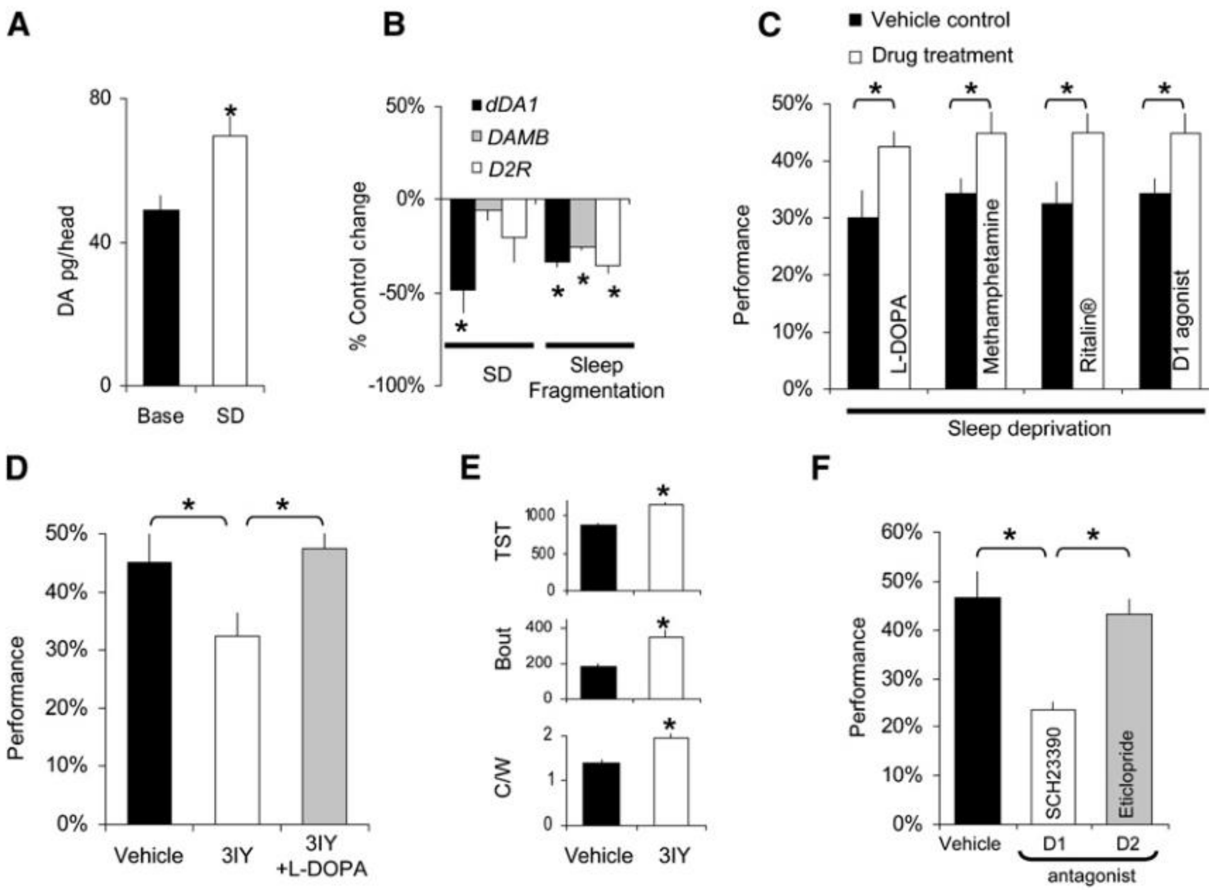
(Laurent Seugnet , *et al*, 2008)

4. Learning Needs MB.



(Laurent Seugnet , *et al*, 2008)

5. Learning Dependent dDA1 Receptor Extends Waking and Learning.



(Laurent Seugnet , *et al*, 2008)

0 . Sleep Deprivation Impairs Human Memory Formation.

1.That Works On Drosophila!

2.It’s Waking Period Matters!

3.How Memory Get Affected? By Mushroom Body.

How About Reversely?

2 Sleep Induction Facilitates Memory Formation

Inducing Sleep by Remote Control Facilitates Memory Consolidation in *Drosophila*

Jeffrey M. Donlea,[1] Matthew S. Thimgan,[1] Yasuko Suzuki,[1] Laura Gottschalk,[1] Paul J. Shaw[1]*

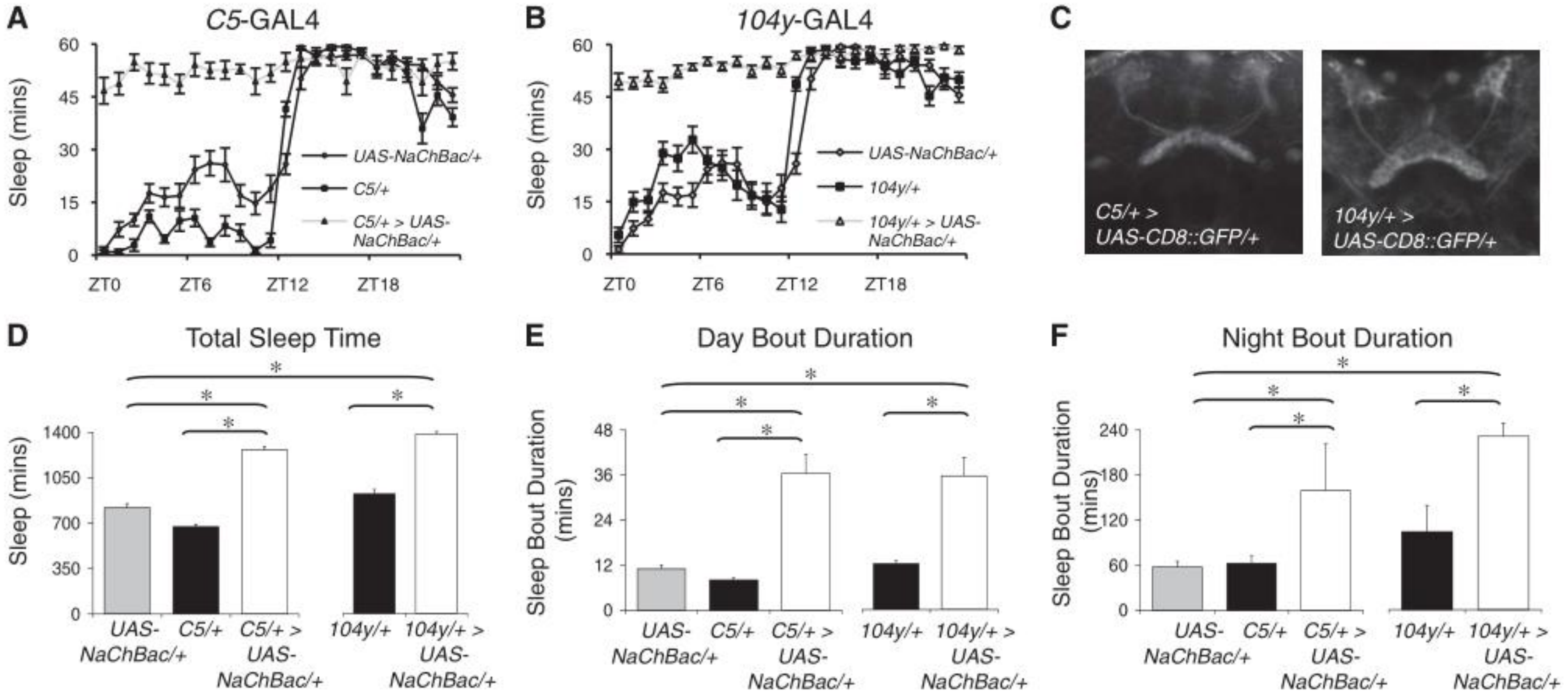
Sleep is believed to play an important role in memory consolidation. We induced sleep on demand by expressing the temperature-gated nonspecific cation channel *Transient receptor potential cation channel* (*UAS-TrpA1*) in neurons, including those with projections to the dorsal fan-shaped body (FB). When the temperature was raised to 31°C, flies entered a quiescent state that meets the criteria for identifying sleep. When sleep was induced for 4 hours after a massed-training protocol for courtship conditioning that is not capable of inducing long-term memory (LTM) by itself, flies develop an LTM. Activating the dorsal FB in the absence of sleep did not result in the formation of LTM after massed training.

Although the functions of sleep remain unknown, sleep is believed to be important for maintaining optimal performance in a large and diverse number of biological processes (*1*, *2*). Historically, the importance of sleep has been most convincingly established by demonstrating negative consequences that accrue in its absence (*3*). In contrast, methods that allow an experimenter to induce sleep on demand are lacking. Thus, it has been difficult to demonstrate that sleep serves a beneficial role per se. Studies in humans indicate sleep may play an active role in the strengthening or stabilizing of new memories (*4*, *5*). With this in mind, we conducted experiments

[1]Department of Anatomy and Neurobiology, Washington University in St. Louis, 660 South Euclid Avenue, St. Louis, MO 63110, USA.

*To whom correspondence should be addressed. E-mail: shawp@pcg.wustl.edu

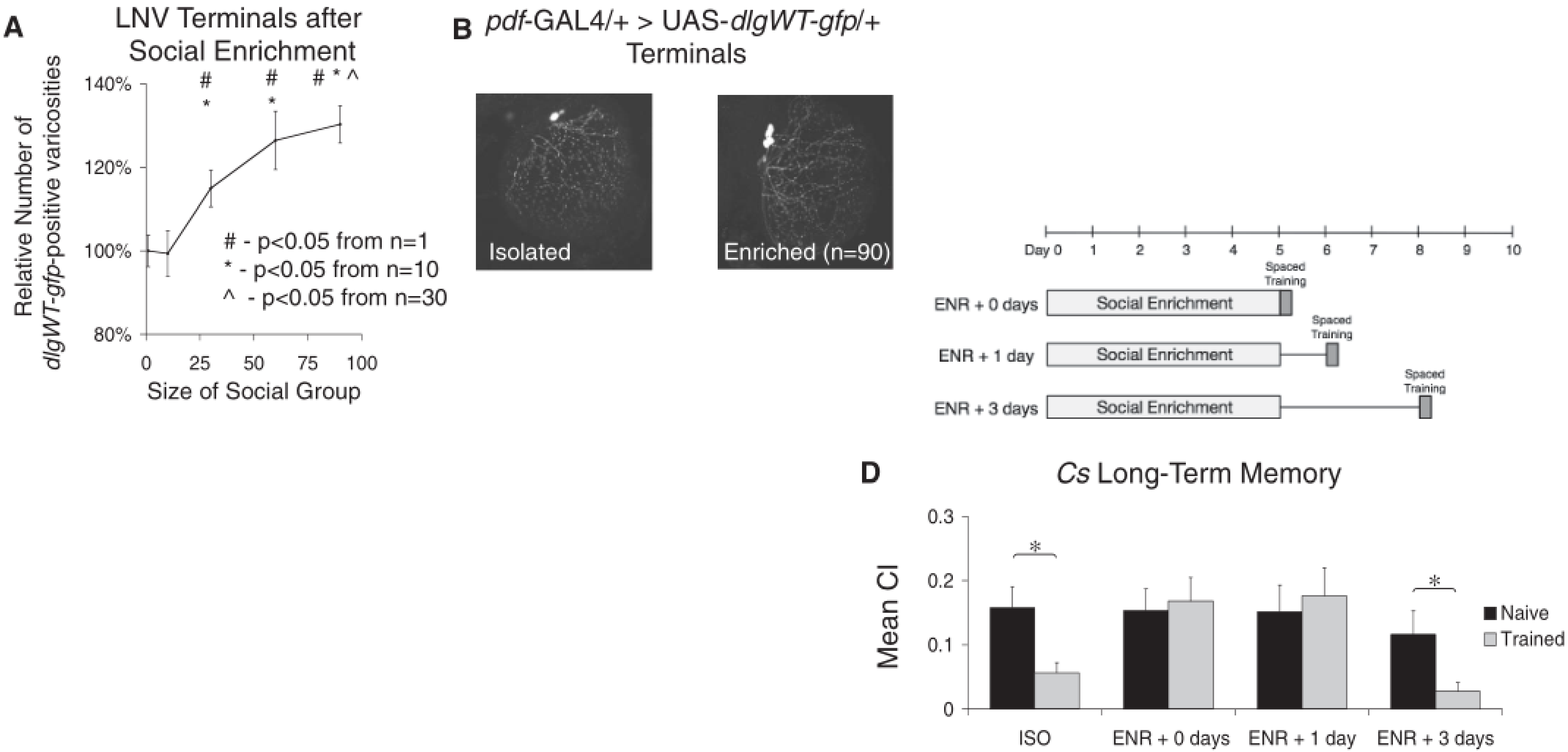
1. Learning Dependent dDA1 Receptor Extends Waking and Learning.



(Jeffrey M. Donlea , *et al*, 2011)

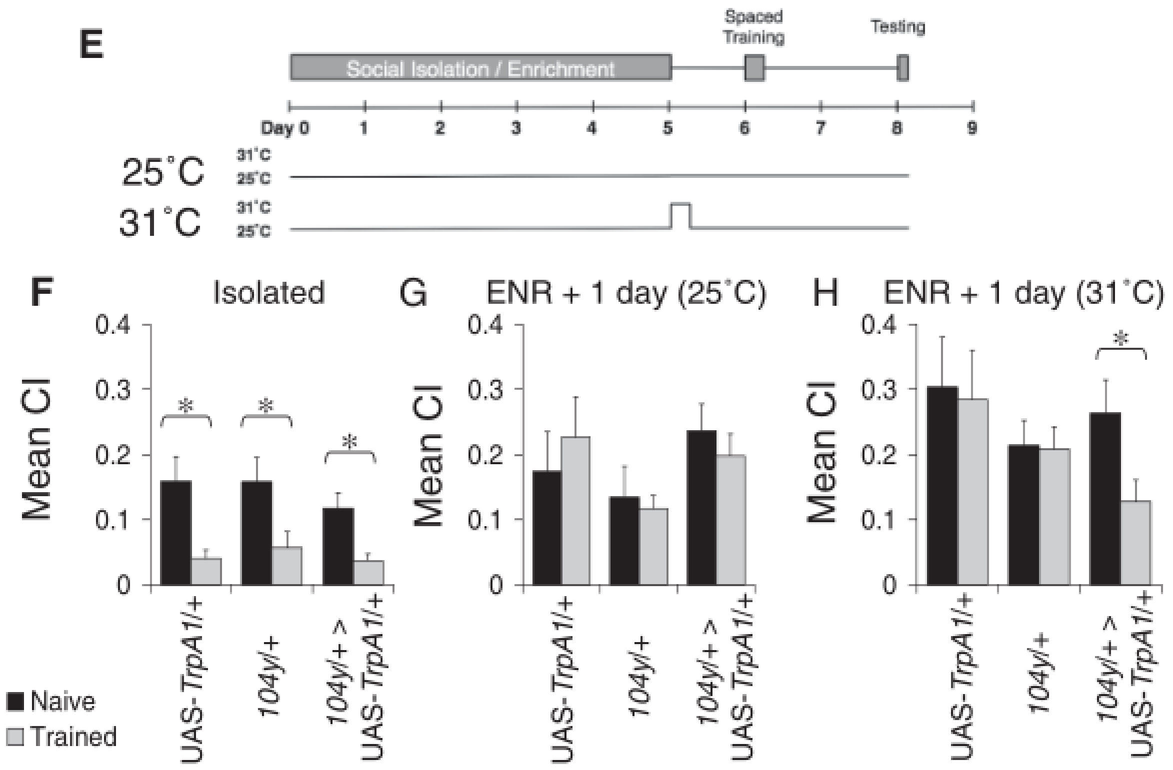
2. Social Enrichment Induces Deficits in LTM

LN_V Synaptic Terminals after Social Enrichment



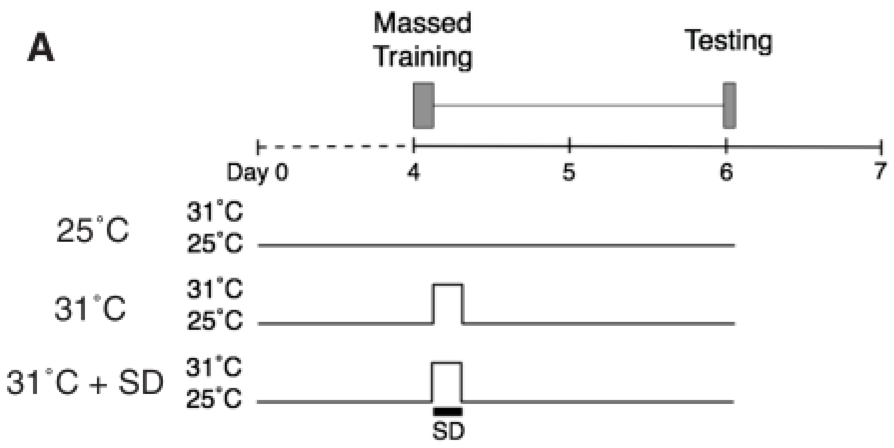
(Jeffrey M. Donlea , *et al*, 2011)

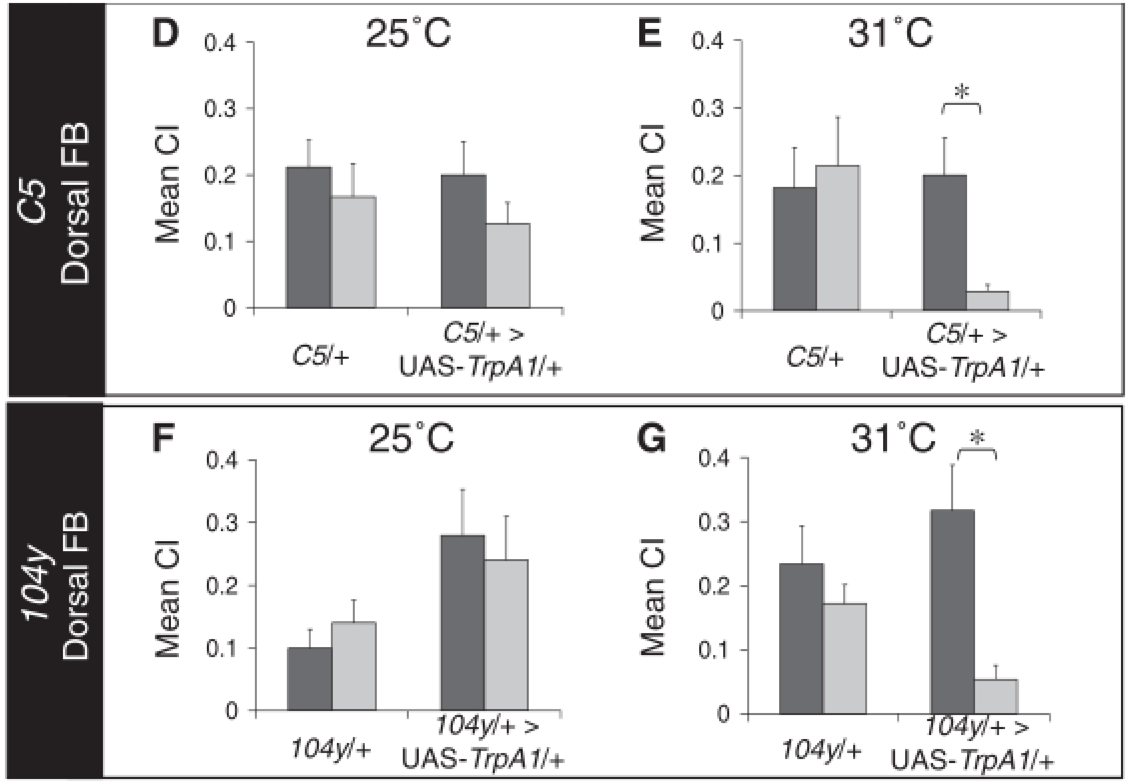
2.5 . Induced Memory Reverses Social Enrichment Induced LTM Deficits



(Jeffrey M. Donlea , *et al*, 2011)

3 . Even Effective for LTM Formation after Massed Training





(Jeffrey M. Donlea , *et al*, 2011)

0 . Sleep is Import to maintain Optimal Performance in Memory Task.

1.Sleep can be Controlled by Fan-Shaped Body Activation.

2.And Social Enrichment Induced LTM Deficits can be Reversed.

3.Induced Sleep Do Facilitate Memory Formation.

3 Sleep and Synaptic Homeostasis

Sleep and Synaptic Homeostasis: Structural Evidence in *Drosophila*

Daniel Bushey, Giulio Tononi, Chiara Cirelli*

The functions of sleep remain elusive, but a strong link exists between sleep need and neuronal plasticity. We tested the hypothesis that plastic processes during wake lead to a net increase in synaptic strength and sleep is necessary for synaptic renormalization. We found that, in three *Drosophila* neuronal circuits, synapse size or number increases after a few hours of wake and decreases only if flies are allowed to sleep. A richer wake experience resulted in both larger synaptic growth and greater sleep need. Finally, we demonstrate that the gene *Fmr1* (*fragile X mental retardation 1*) plays an important role in sleep-dependent synaptic renormalization.

Sleep is present in every species that has been carefully studied (*1*), including *Drosophila melanogaster* (*2*, *3*), but its functions remain elusive. Increasing evidence points to a link between sleep need and neuronal plasticity (*1*, *4*, *5*). A recent hypothesis (*6*) suggests that a consequence of staying awake is a progressive increase in synaptic strength, as the awake brain learns and adapts to an ever-changing environment mostly through synaptic potentiation (*7*). However, such increase would soon become unsustainable, because stronger synapses consume more energy, occupy more space, require more supplies, and cannot be further potentiated, saturating the ability to learn. Thus, according to the synaptic homeostasis hypothesis, sleep may serve an essential function by promoting a homeostatic reduction in synaptic strength down to sustainable levels. Also, the hypothesis

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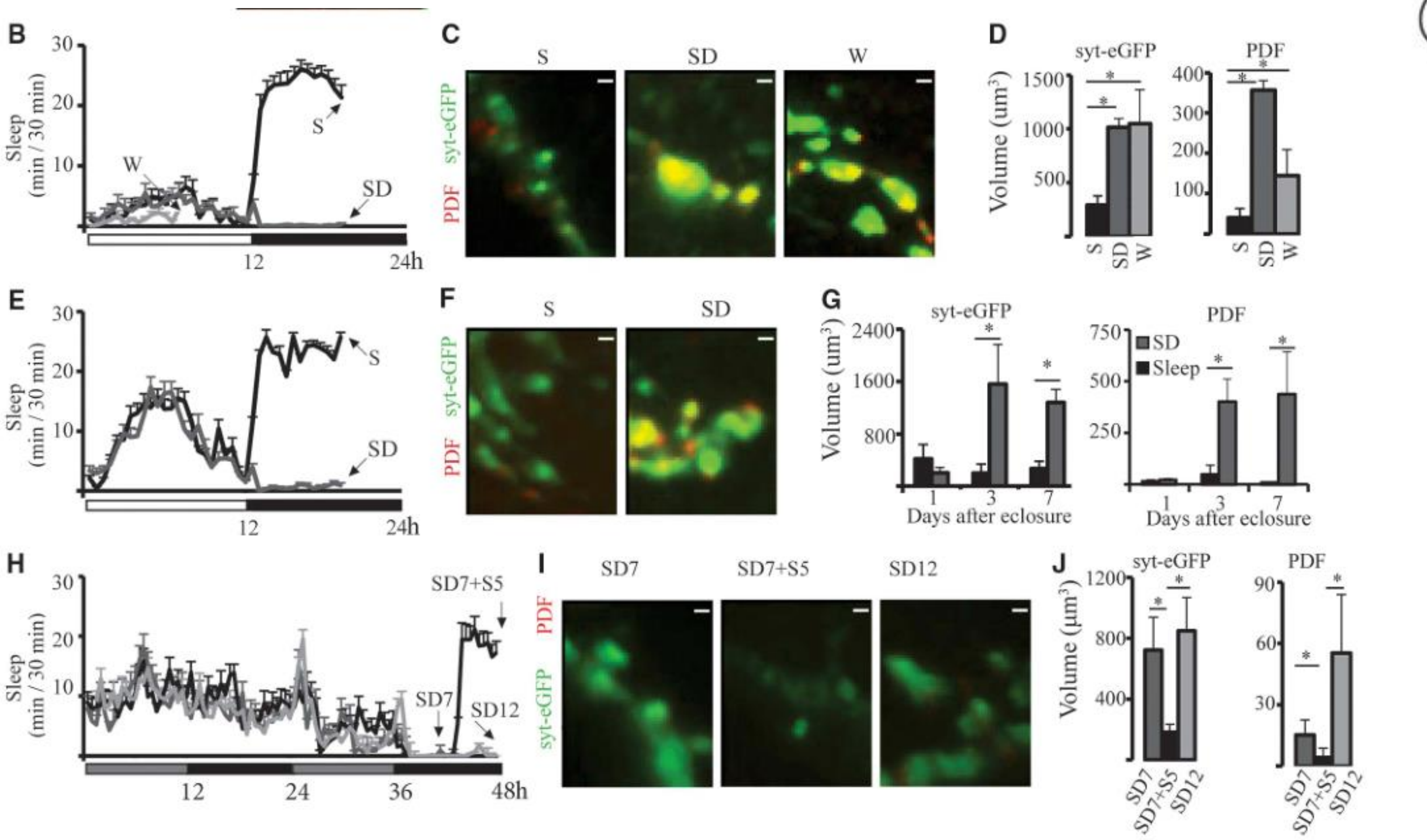
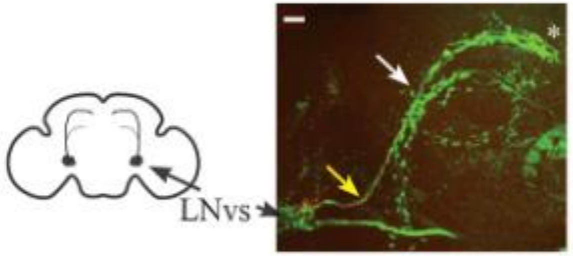
*To whom correspondence should be addressed: ccirelli@wisc.edu

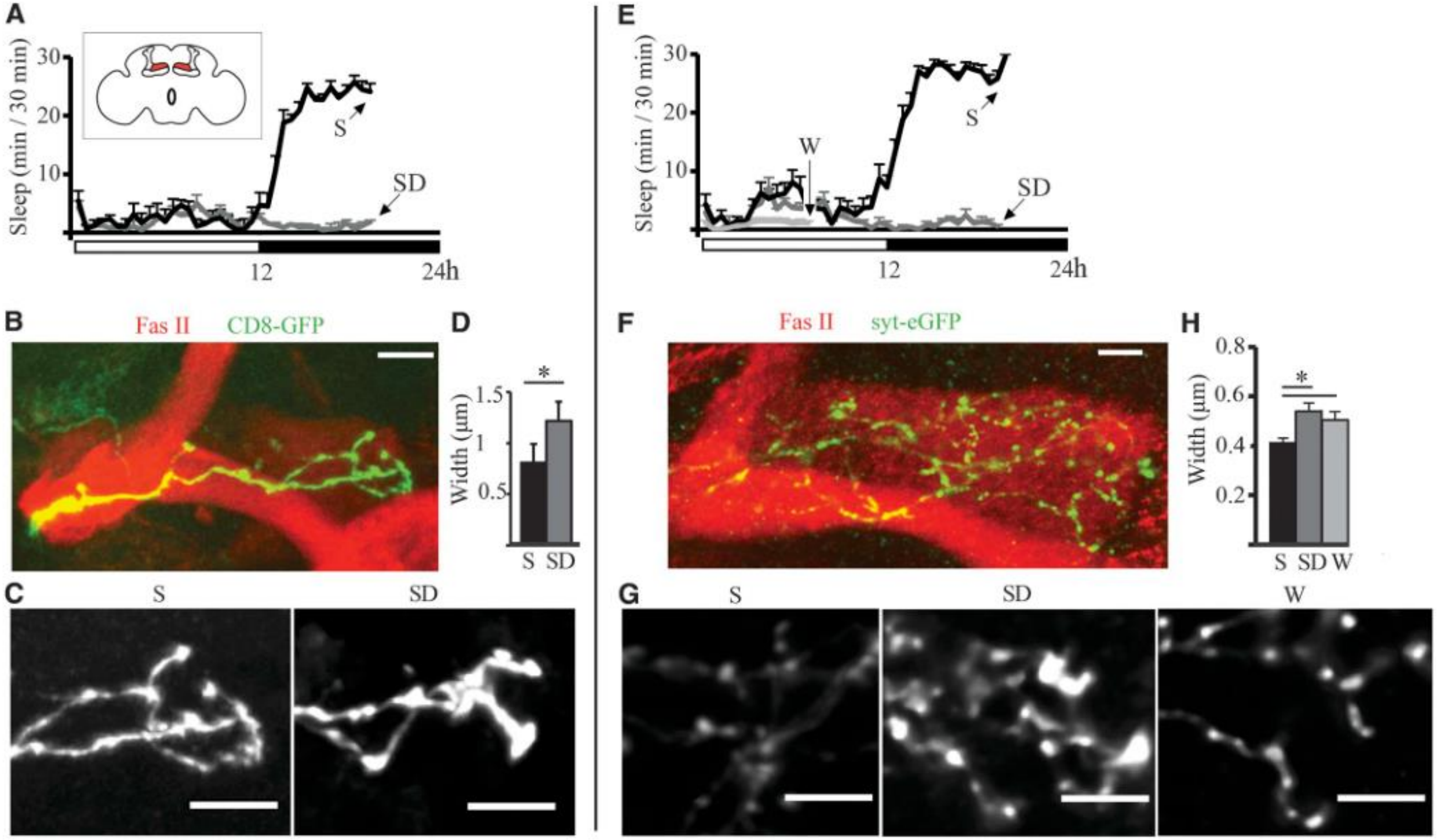
1. There are Presynaptic Changes in Small LNvs between Wake and Sleep.





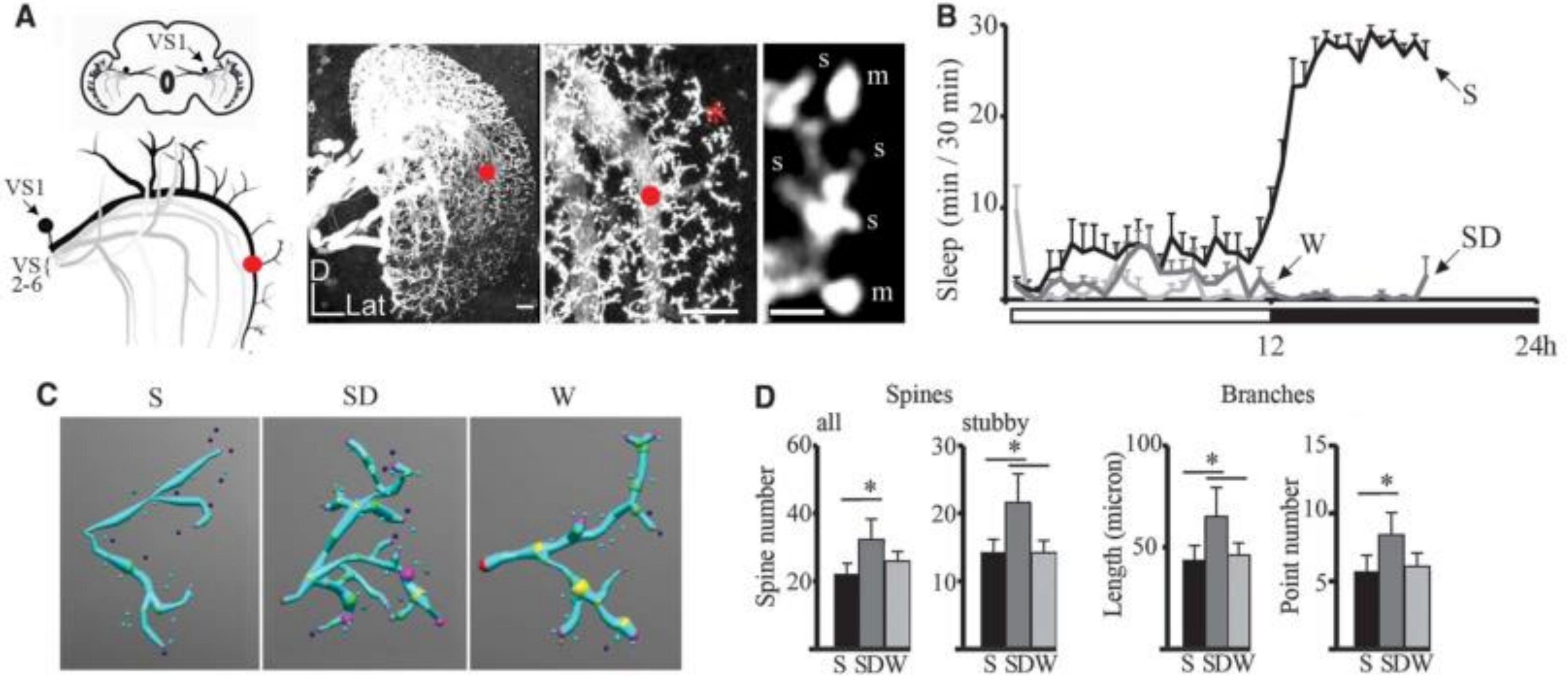
(Daniel Bushey, *et al*, 2011)

2. Things Goes the Same in MB gamma Lobes.



(Daniel Bushey, *et al*, 2011)

3. ……And in VS1



(Daniel Bushey, *et al*, 2011)

0 . Synaptic Strength Increases while Staying Awake [1], But Stronger Synapses Needs More Energy , Occupy More Space, and Code Less Information.
All of these are More Unsustainable

0.5.The More Time Individual Stay Awake, the Stronger Sleepiness Grows.

1.If Sleep Clears Overgrown Synapses ?

2.YES !

3.And This is Homeostatic!

[1] D. E. Feldman, Annu. Rev. Neurosci. 32, 33 (2009).

In a word:

In Drosophila, Sleep and Memory Formation are **Mutually Affected**.
There is a **Synaptic Homeostatic Process** Underlying the Phenomenon.

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