How Early Experience Can Induce Disorders: An Example of Visual Cortex Dysfunction

陈洁　关文月　葛瑶

2024-3-28

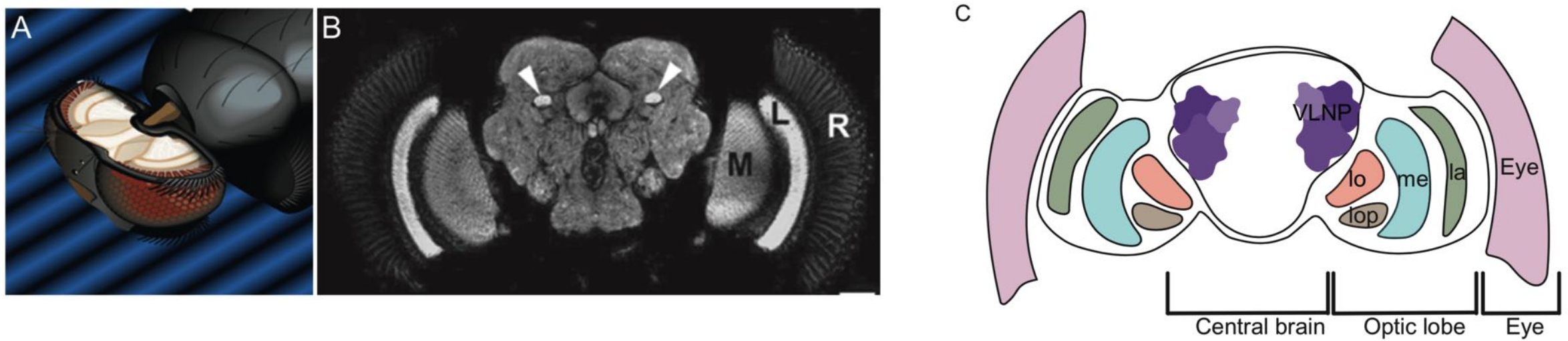
How Early Experience Can Induce Disorders: An Example of Visual Cortex Dysfunction

- A Comparison of the Structure and Function of Visual Systems in Fruit Flies and Mice（陈洁）
- Early Experiences Affect the Development and Function of the Visual Cortex（葛　瑶）
- Disorders Associated with Visual Cortex Dysfunction（关文月）

A Comparison of the Structure and Function of Visual Systems in Fruit Flies and Mice

陈洁

The visual system of *Drosophila*



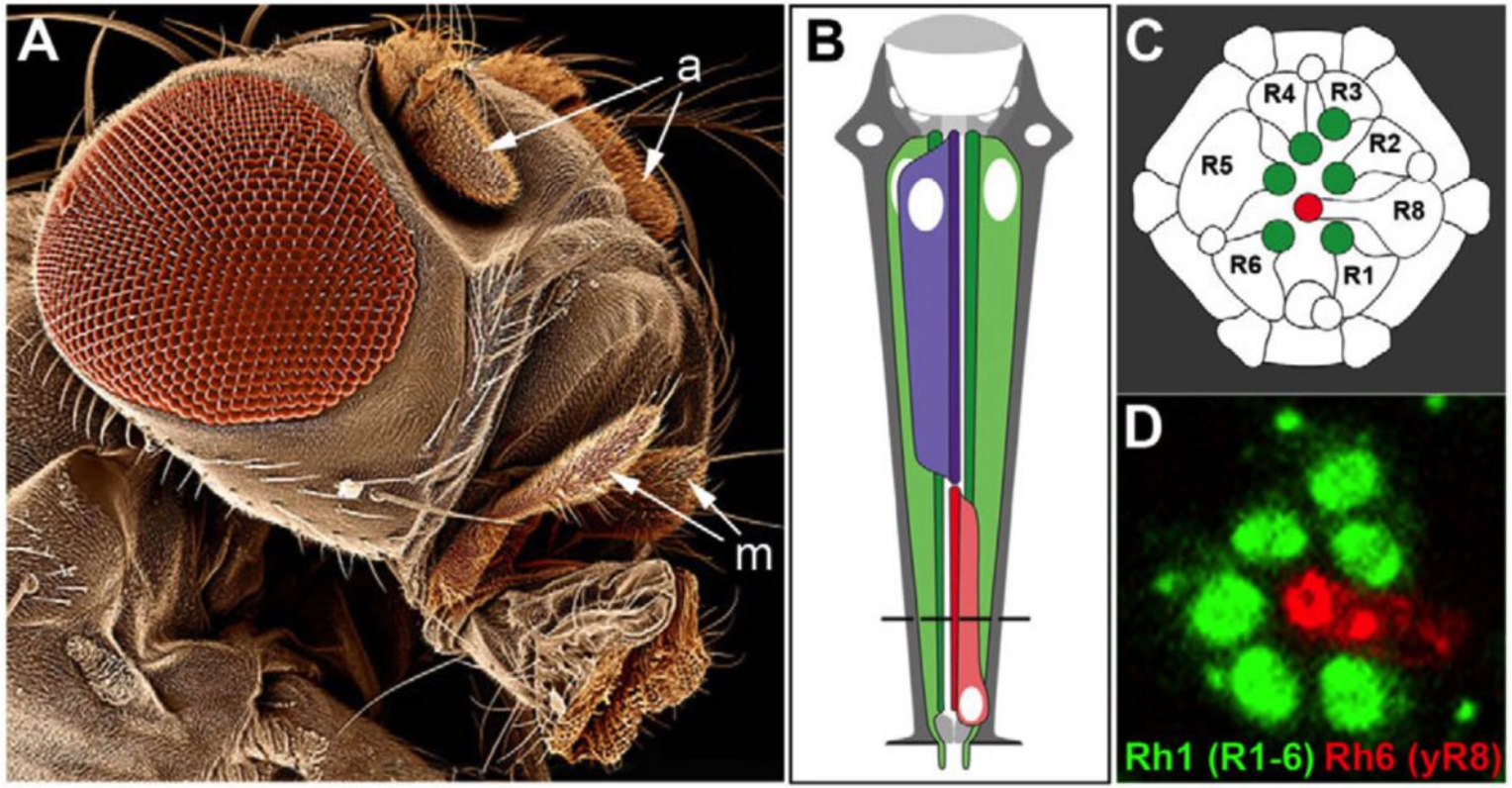
Adult *Drosophila* visual system contains ~ 150,000 neurons and glia cells.

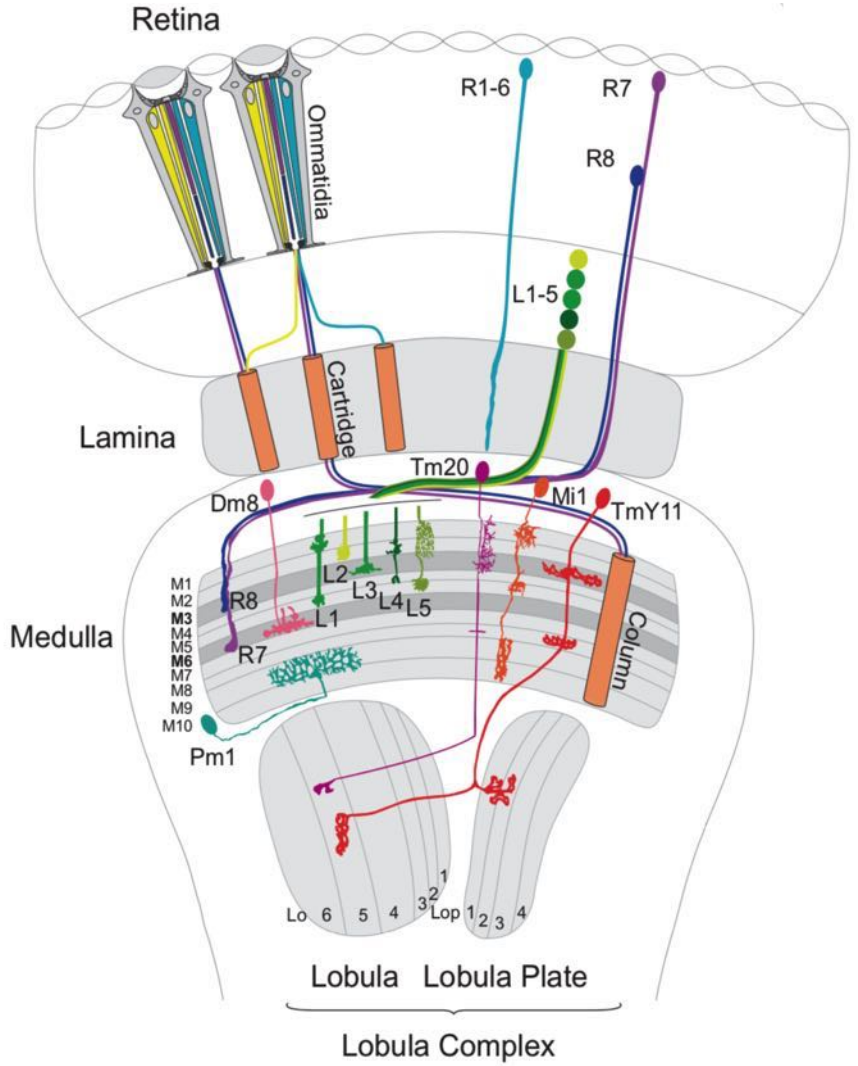
Four neuropils form the optic lobe: lamina (la), medulla (me), and lobula complex (subdivided into lobula and the lobula plate neuropils)

VLNPs: ventrolateral neuropils also called optic glomeruli

Nériec N, Desplan C. *Curr Top Dev Biol*. 2016

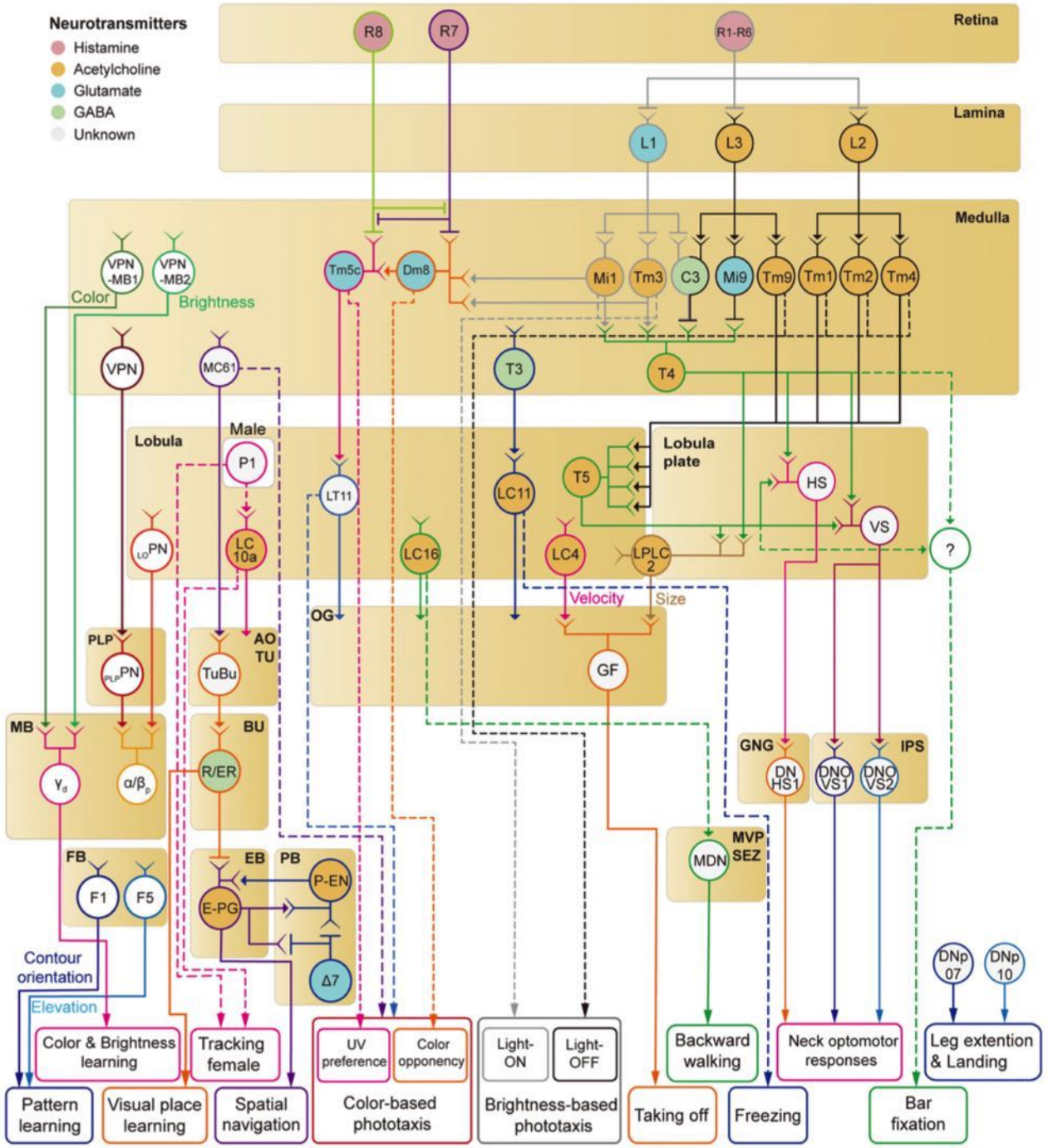
Structure of the *Drosophila* eye

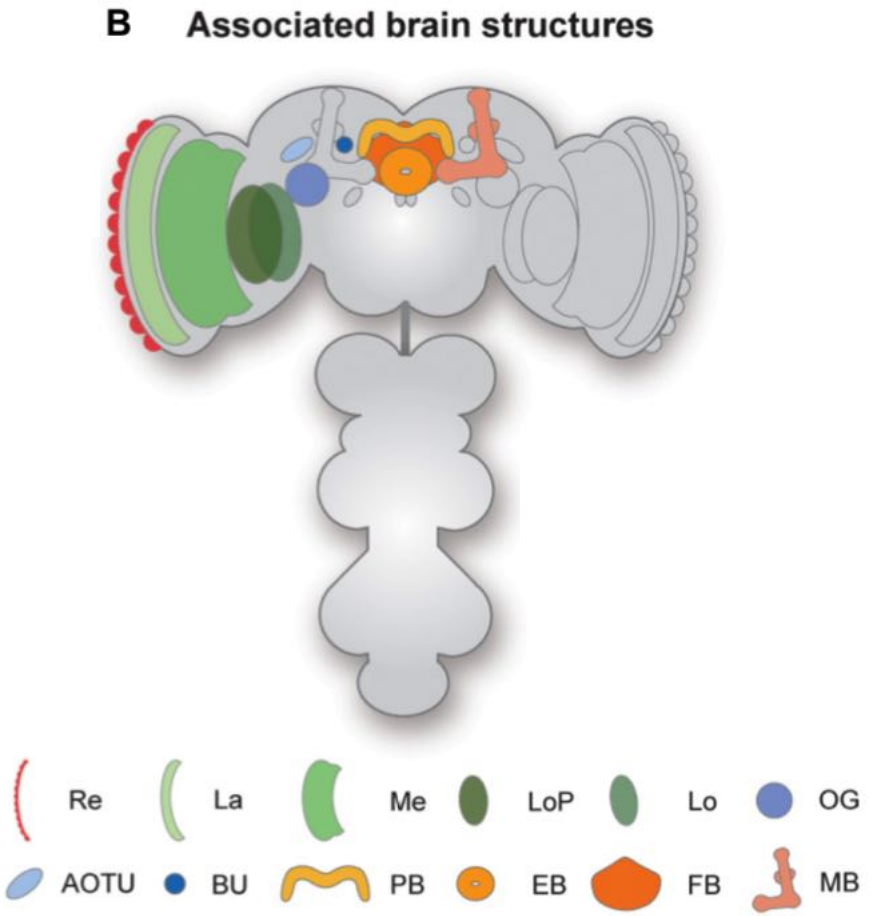




Rister, J et al. *Development*. 2013.
Plazaola-Sasieta H et al. *J Neurogenet*. 2017

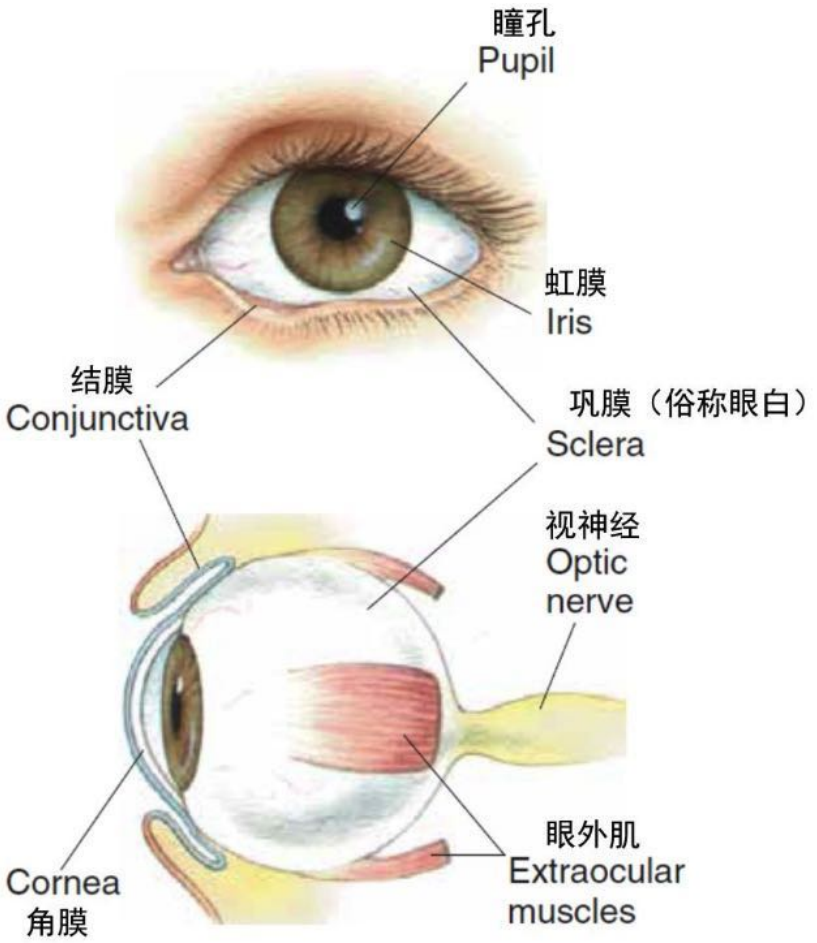
The visual system of *Drosophila*

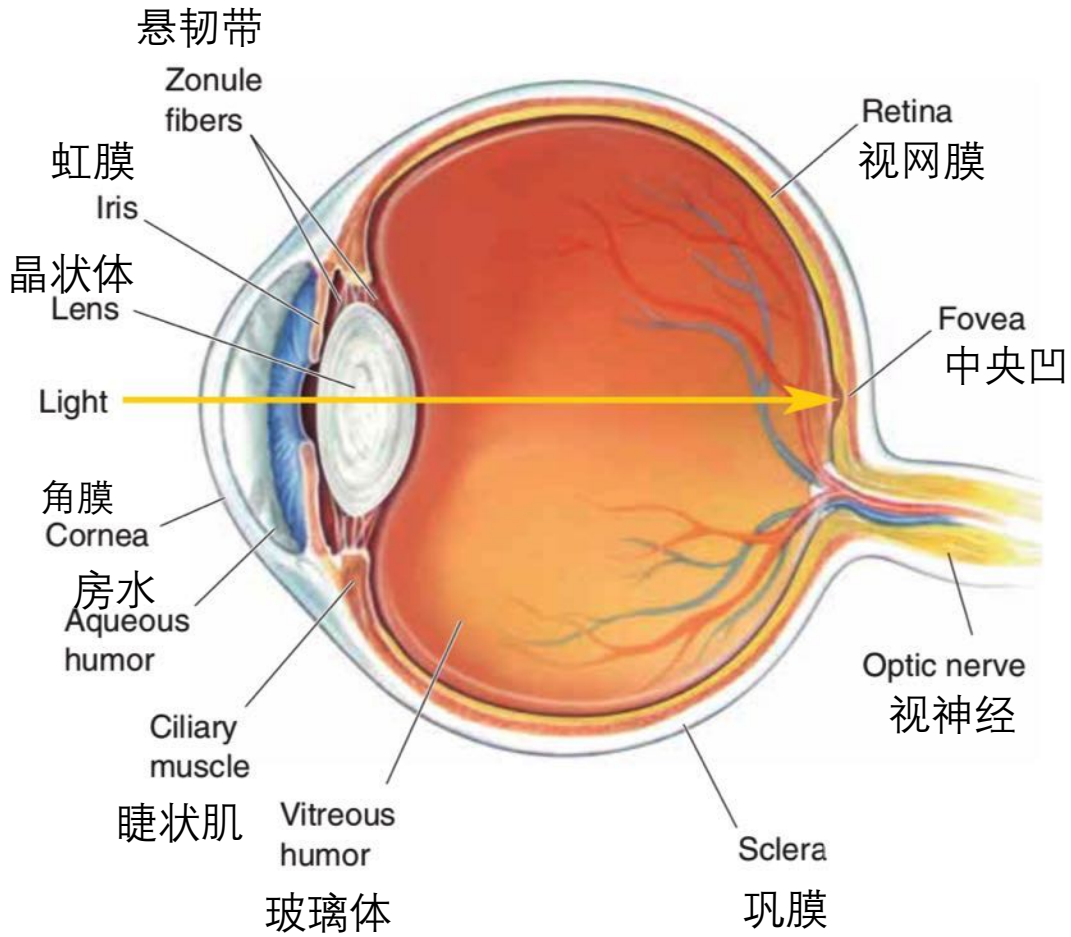




Leesun Ryu, Sung Yong Kim and Anmo J. Kim, 2022.

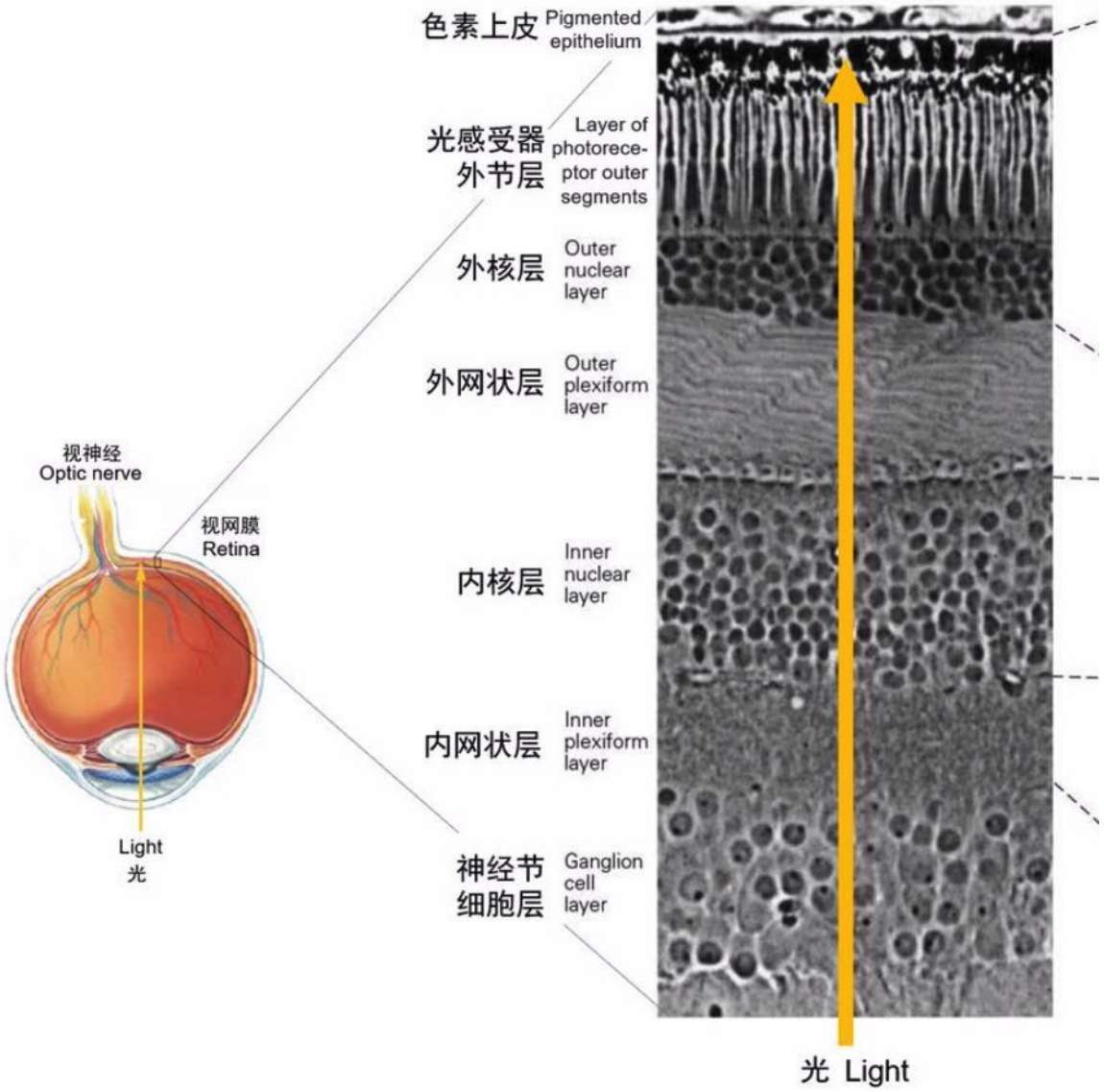
Gross anatomy of the human eye

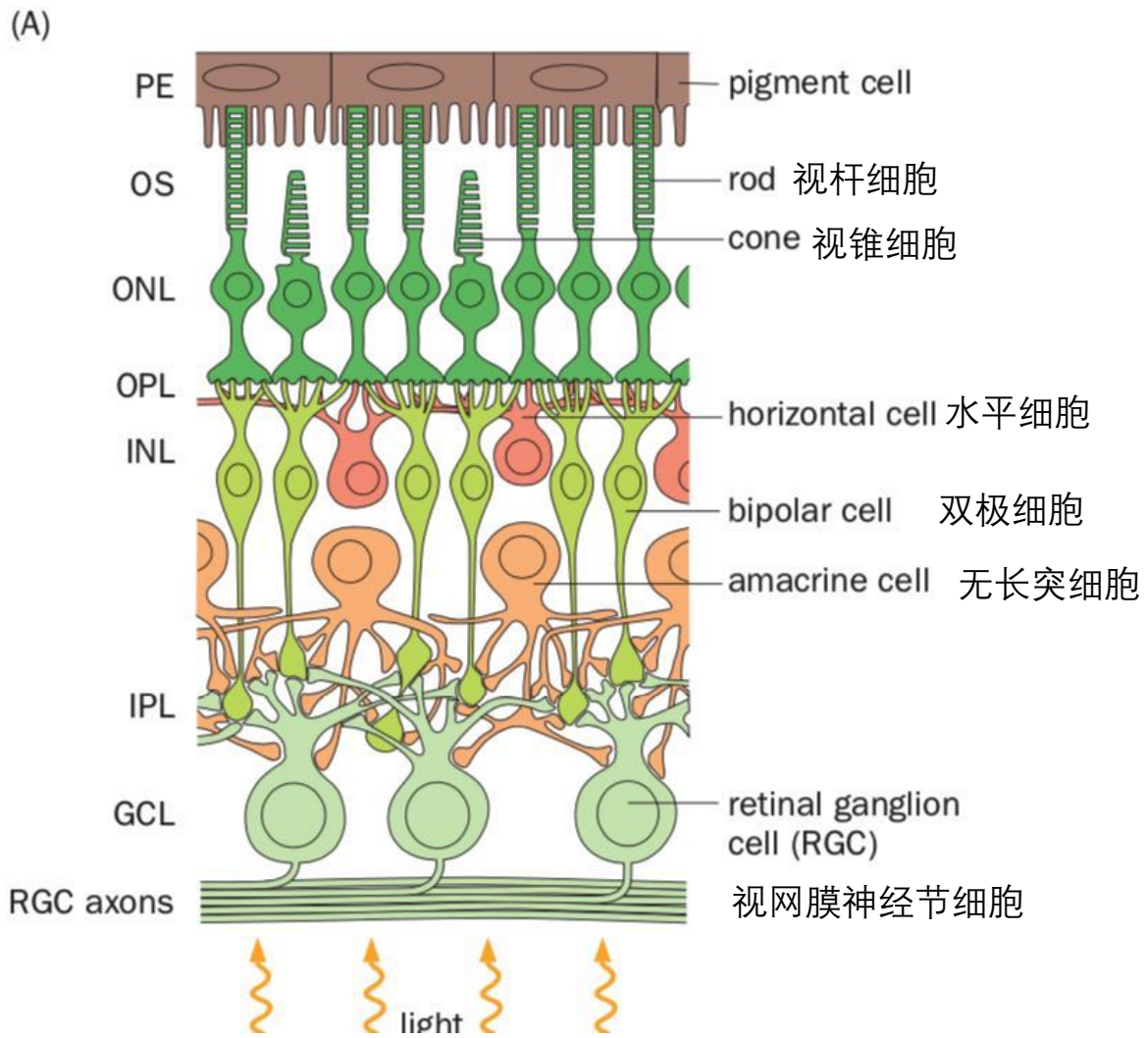




Bear, M.F., Connors, B.W., & Paradiso, M.A. 2015.

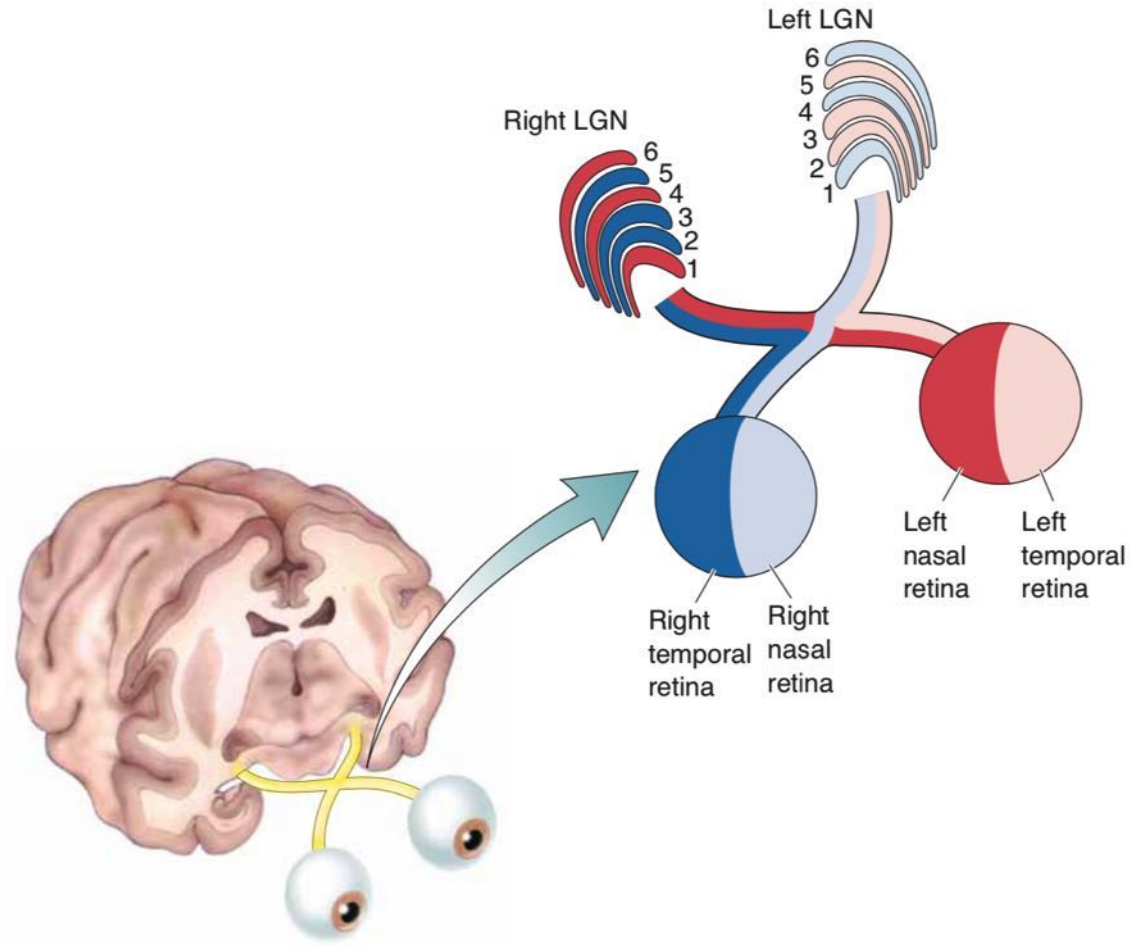
Organization of the retina



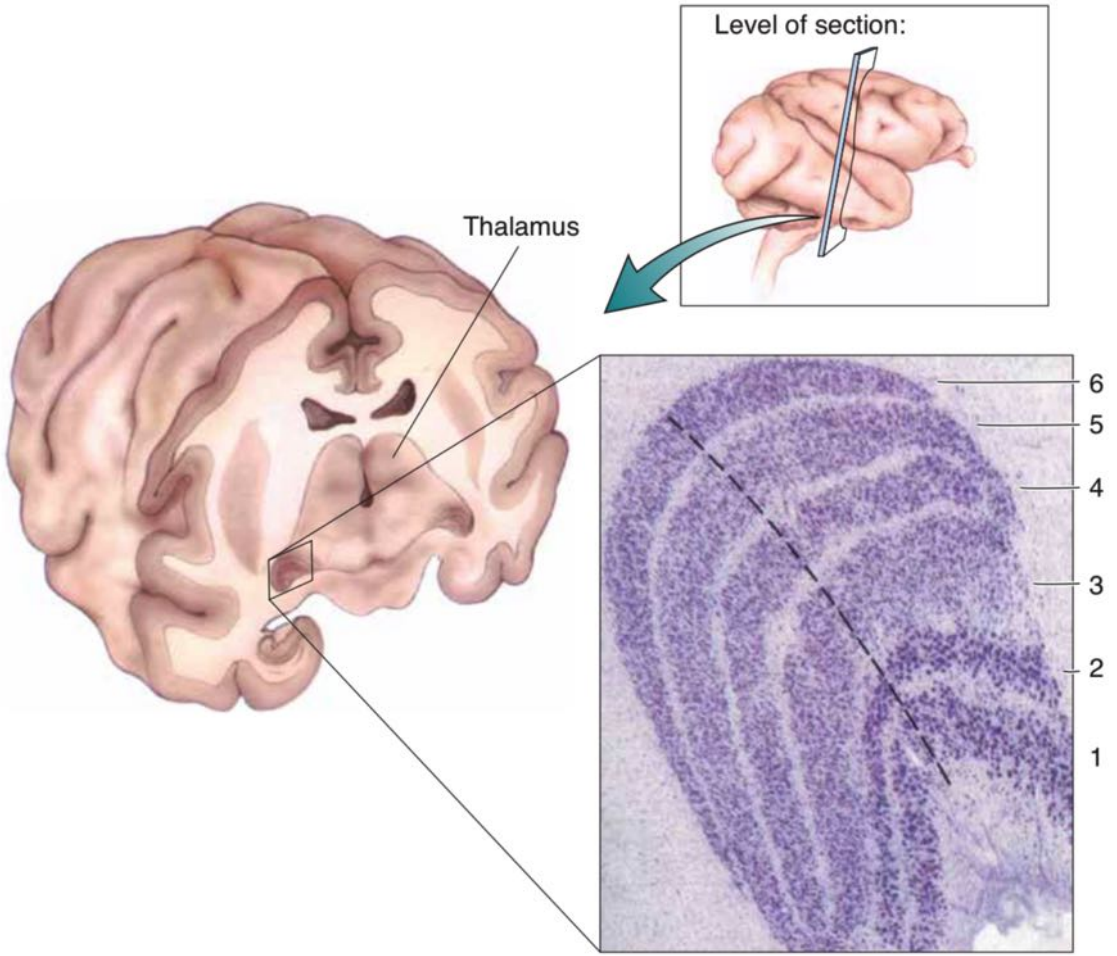


Luo, L. 2020.

Retinal inputs to the LGN layers



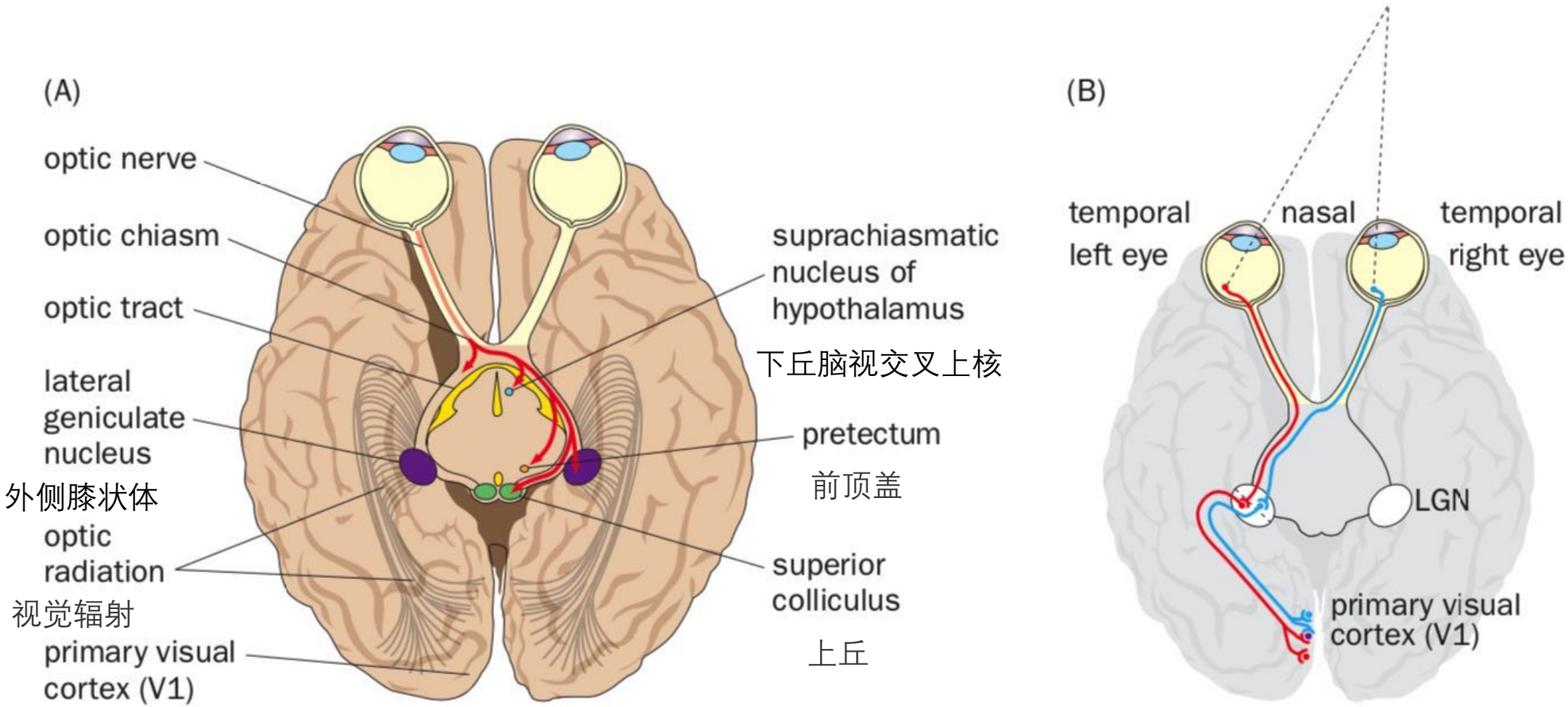
LGN: lateral geniculate nucleus 外侧膝状体



The LGN of the macaque monkey

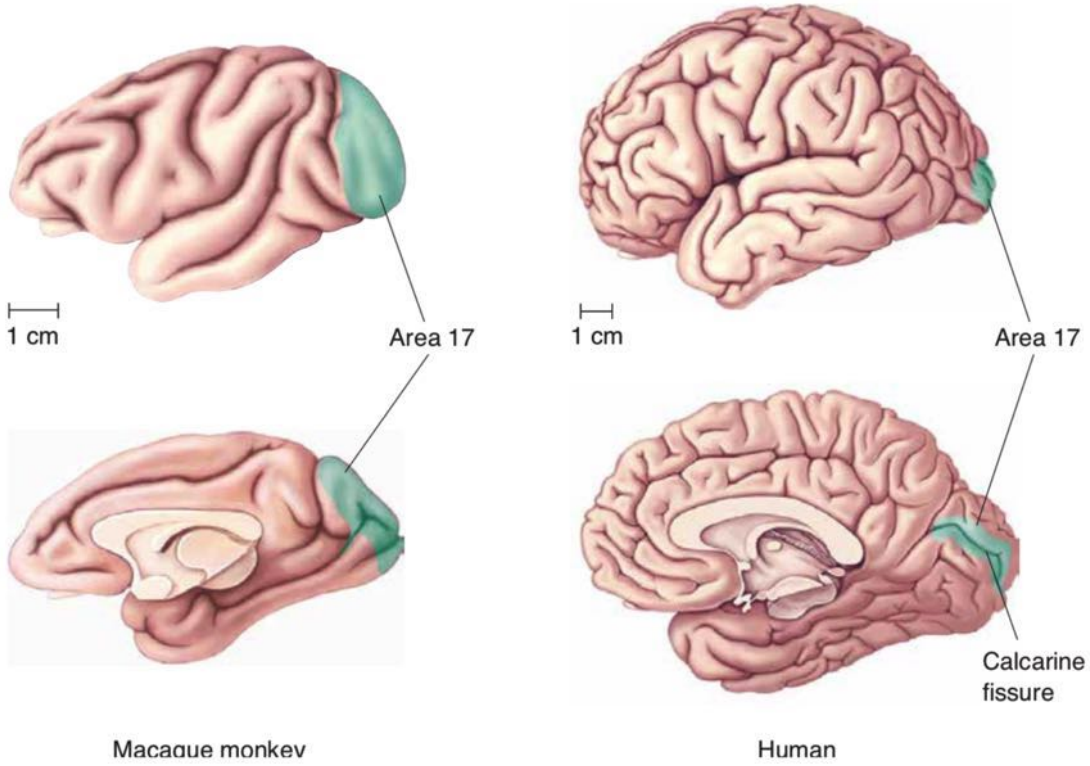
Bear, M.F., Connors, B.W., & Paradiso, M.A. 2015.

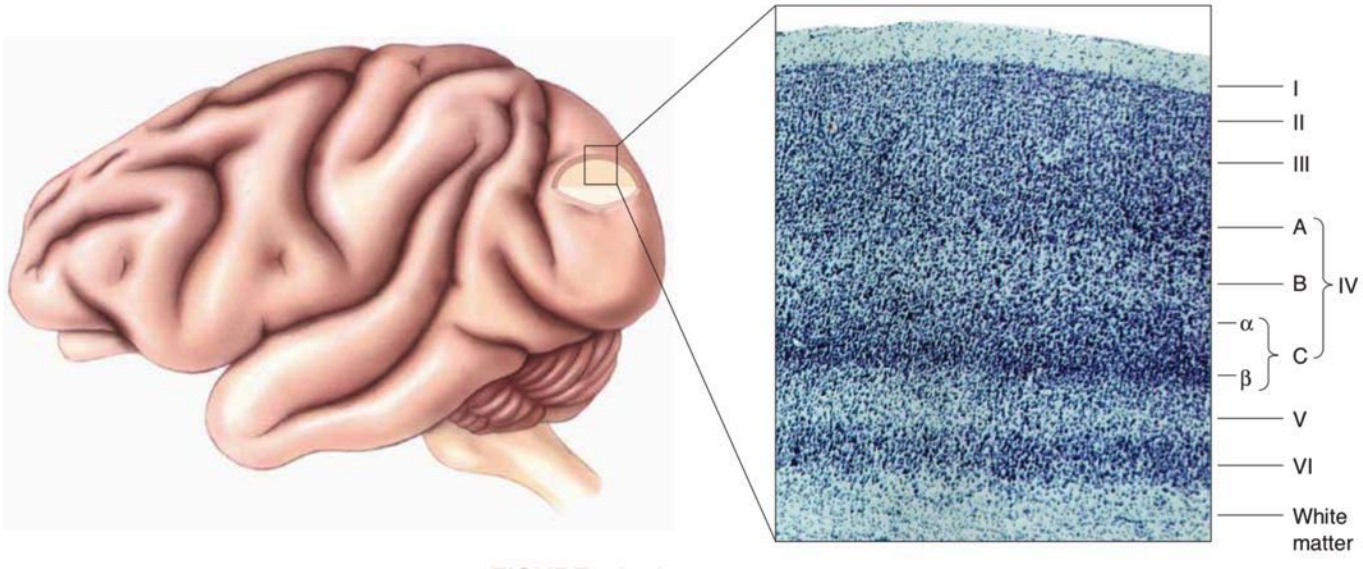
Organization of the visual pathways from the eye to the brain



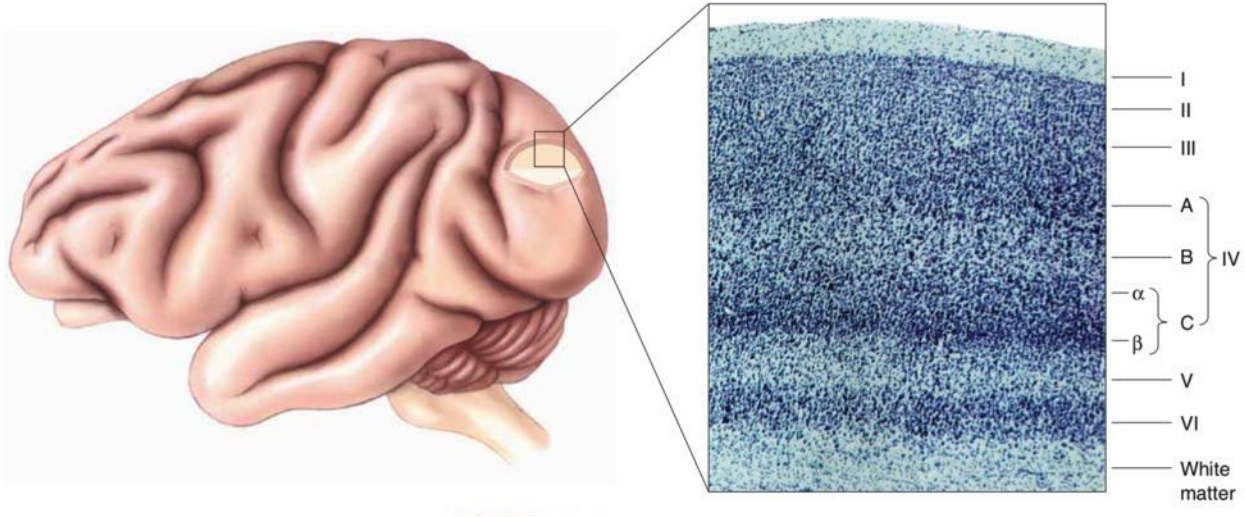
Luo, L. 2020.

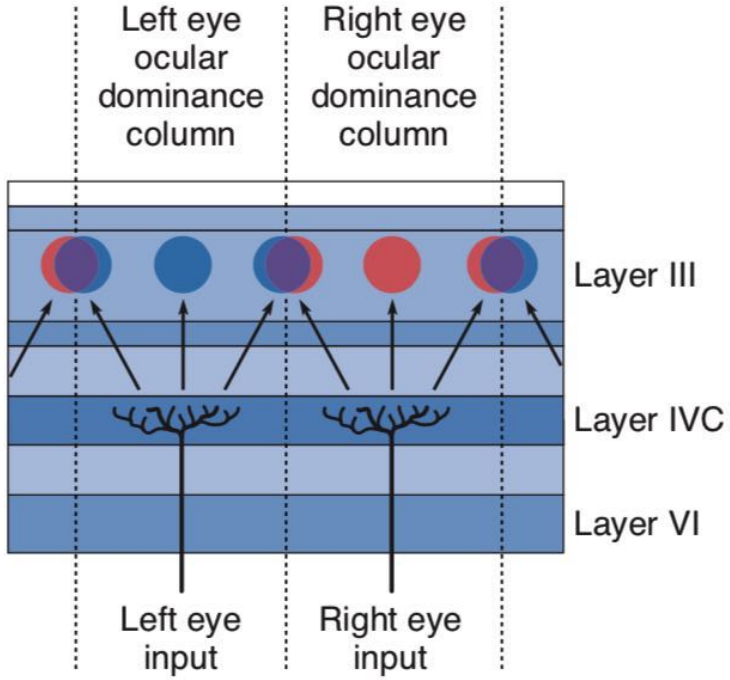
The primary visual cortex

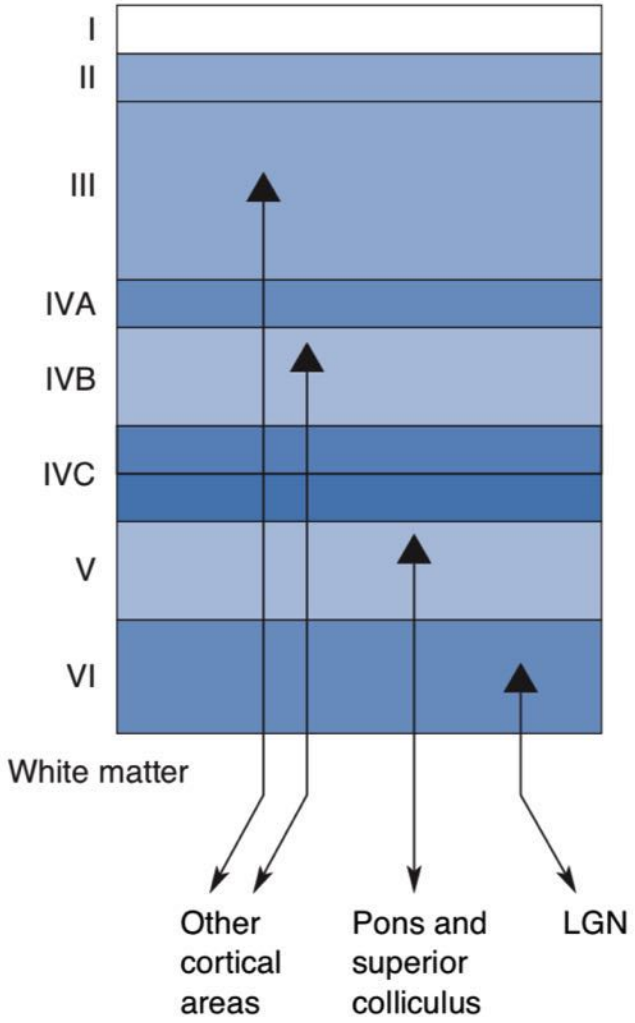




The primary visual cortex

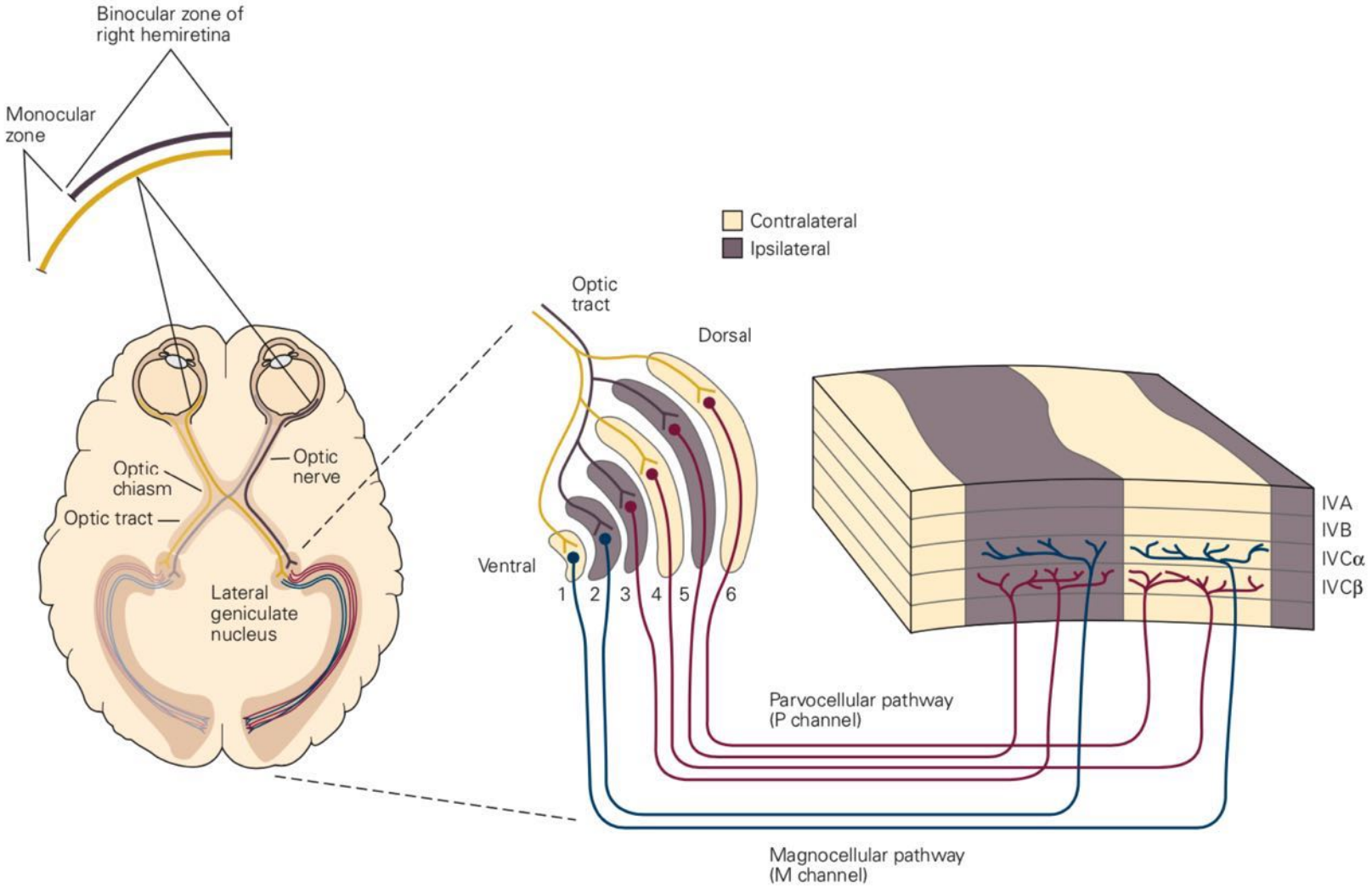






Bear, M.F., Connors, B.W., & Paradiso, M.A. 2015.

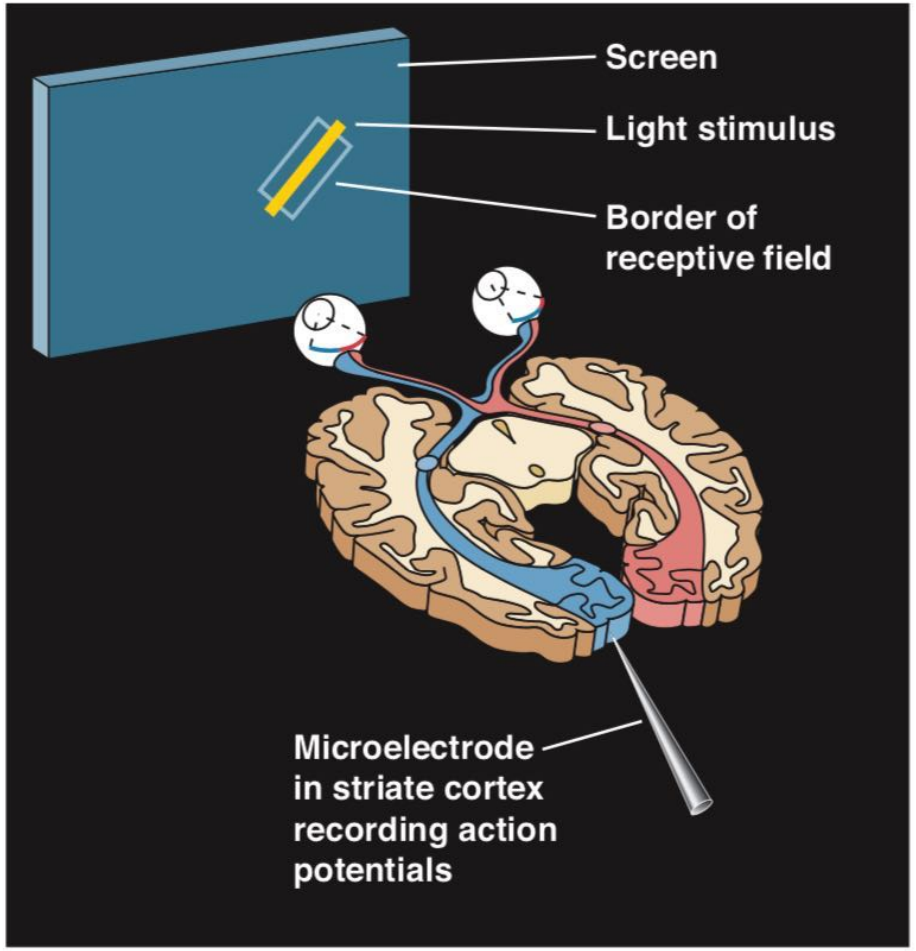
Projections from the LGN to the visual cortex

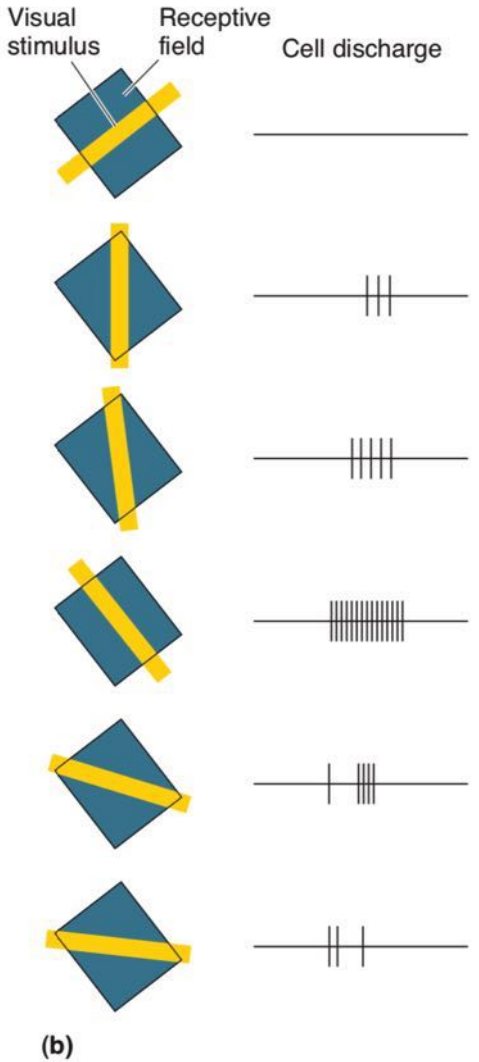


Bear, M.F., Connors, B.W., & Paradiso, M.A. 2015.

Functions of the primary visual cortex

1. Orientation selectivity（方位选择性）

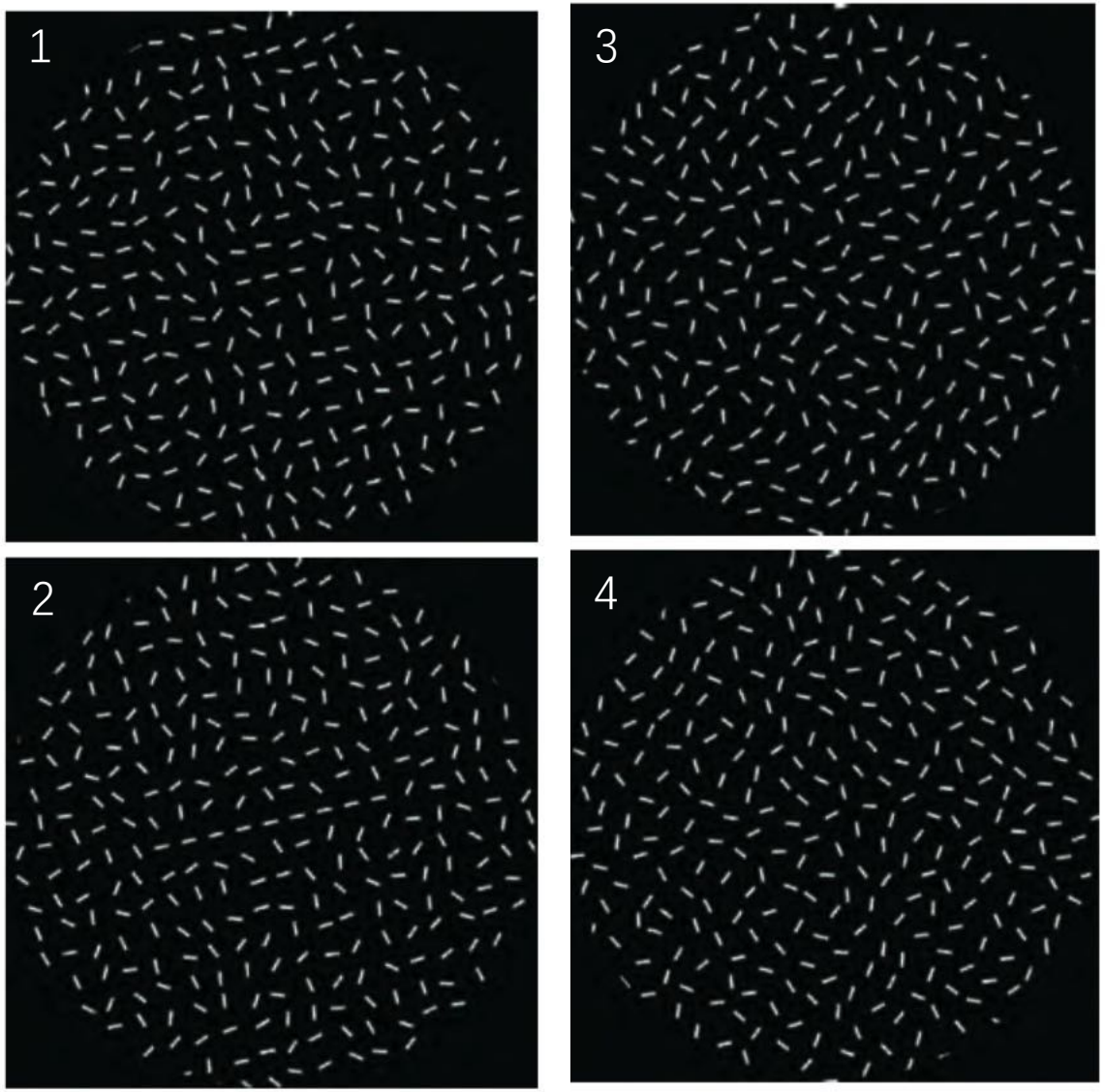




Bear, M.F., Connors, B.W., & Paradiso, M.A. 2015.

Functions of the primary visual cortex

2. Contour integration（轮廓整合）

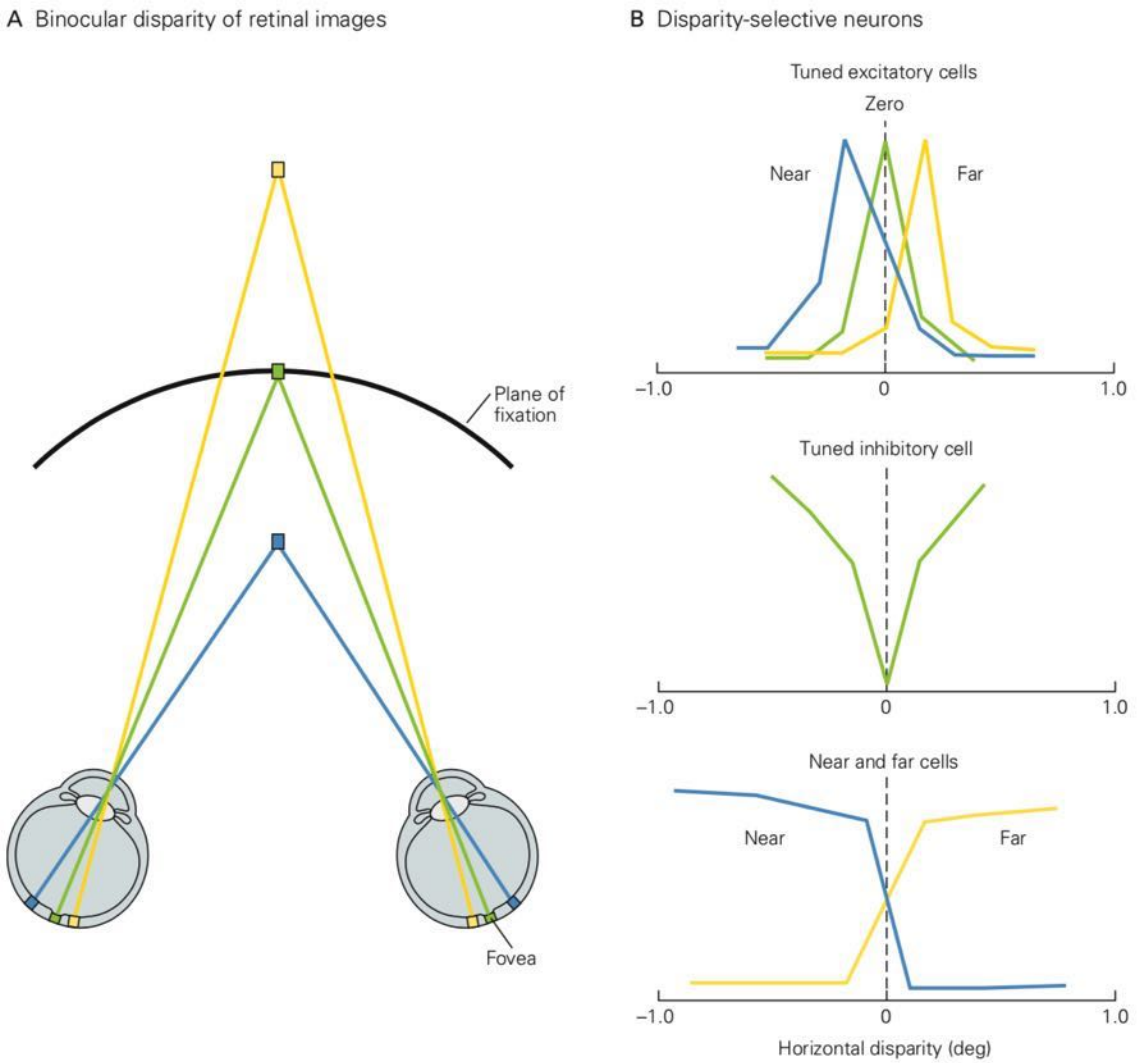


Factors that contribute to contour saliency include the number of contour elements (compare the first and second frames), the spacing of the elements (third frame), and the smoothness of the contour (fourth frame)

Kandel, E. R., Koester J. D., Mack, S. H., Siegelbaum, S. 2021.

Functions of the primary visual cortex

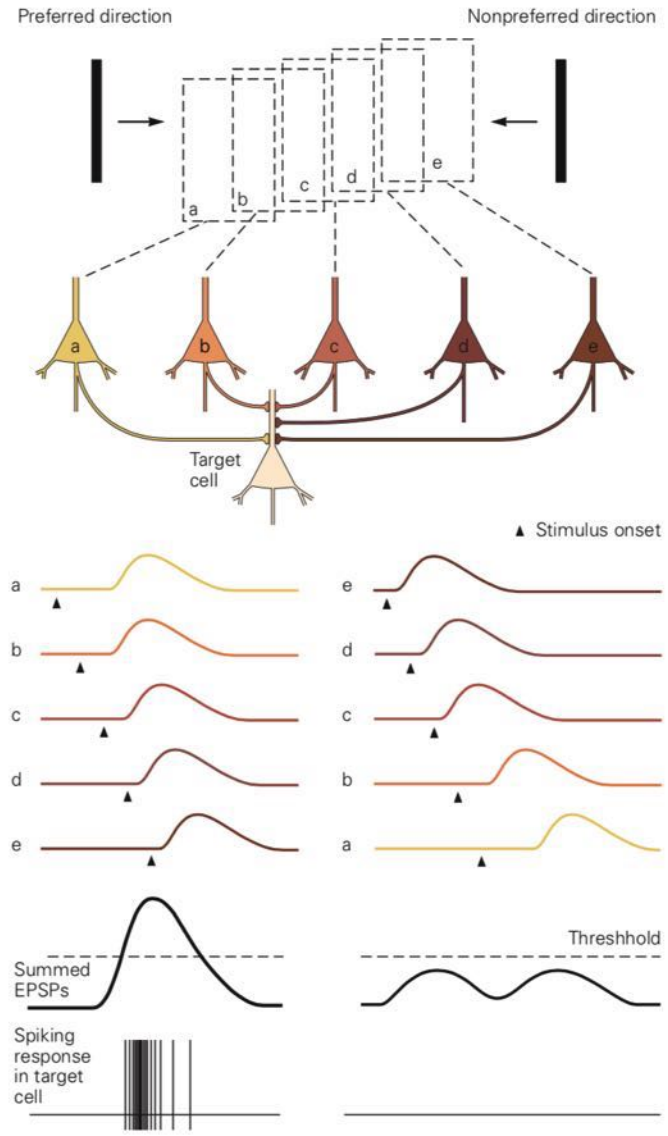
3. Stereopsis and binocular disparity（立体视觉和双眼视差）



Kandel, E. R., Koester J. D., Mack, S. H., Siegelbaum, S. 2021.

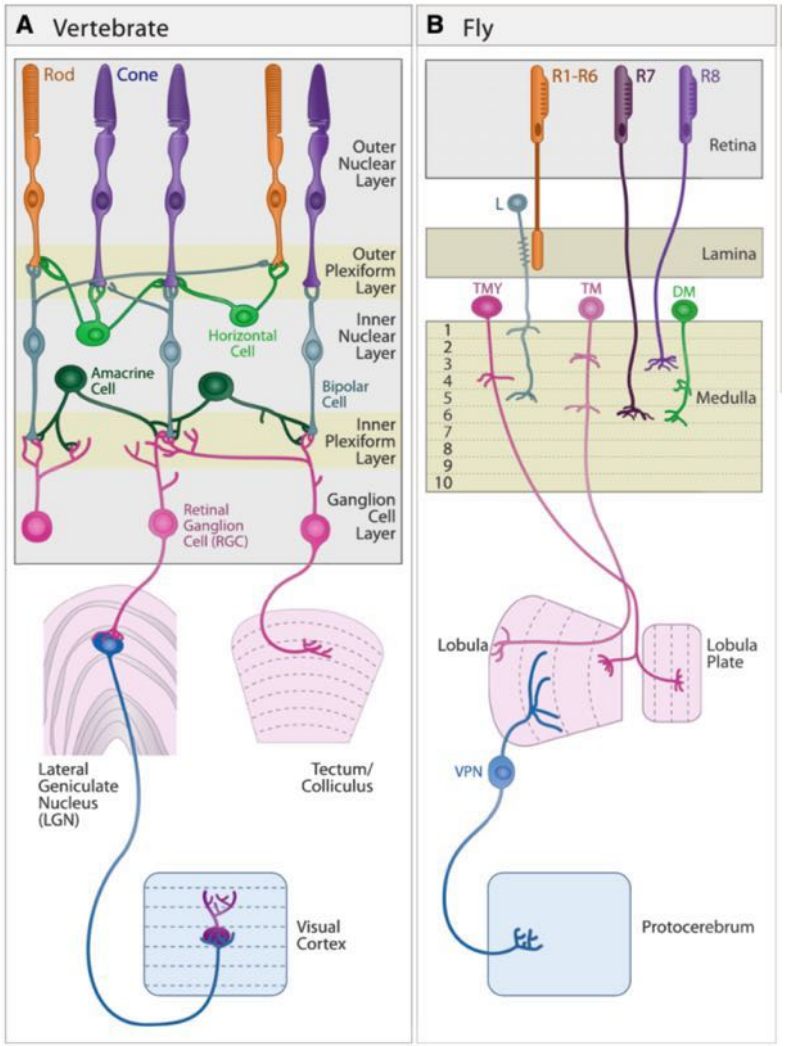
Functions of the primary visual cortex

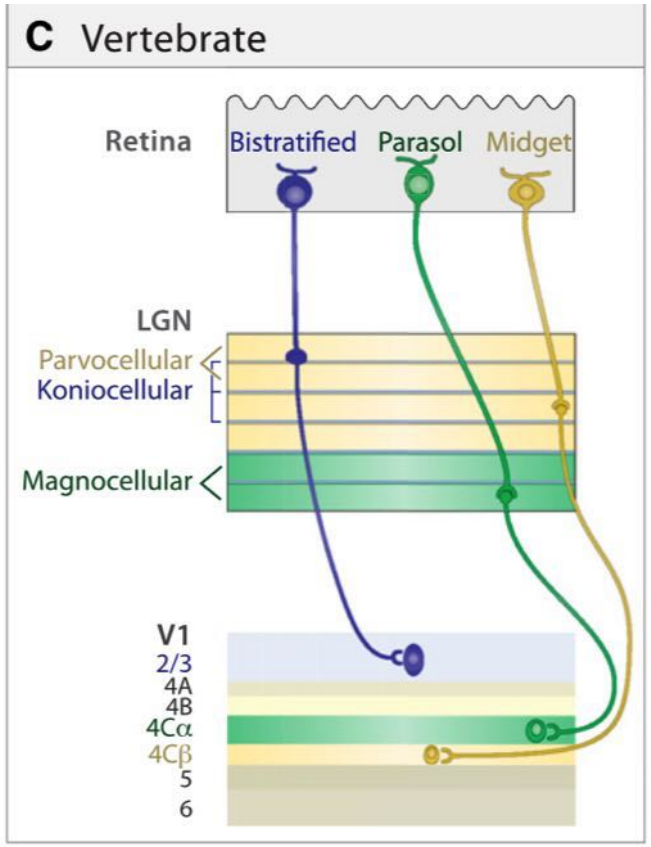
4. Directional selectivity of movement.(运动方向选择性)

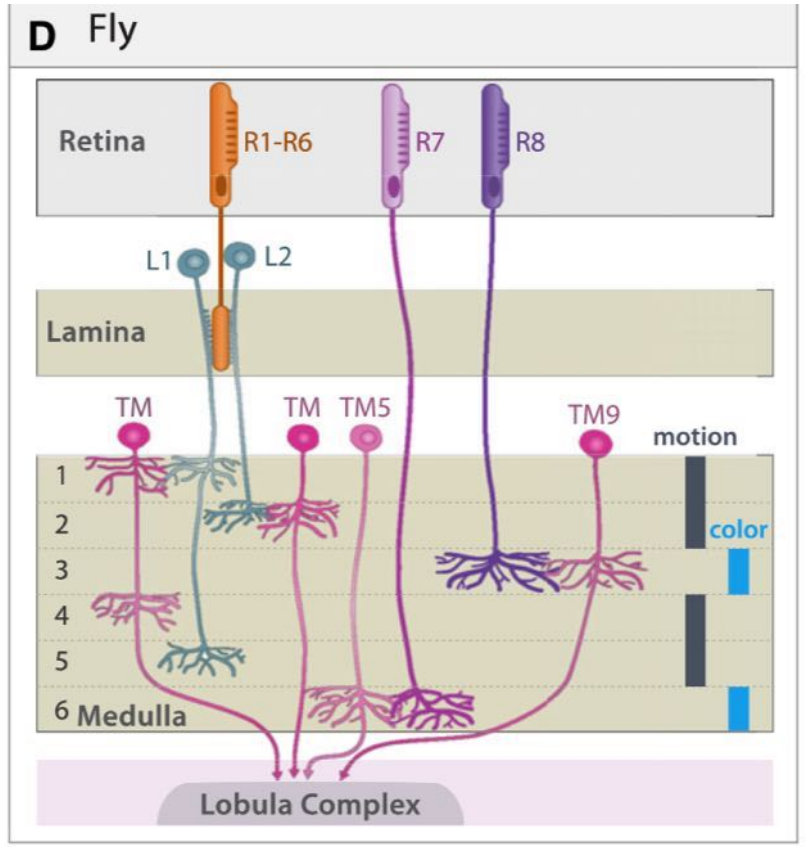


Kandel, E. R., Koester J. D., Mack, S. H., Siegelbaum, S. 2021.

Comparison of visual system system between flies and mammals

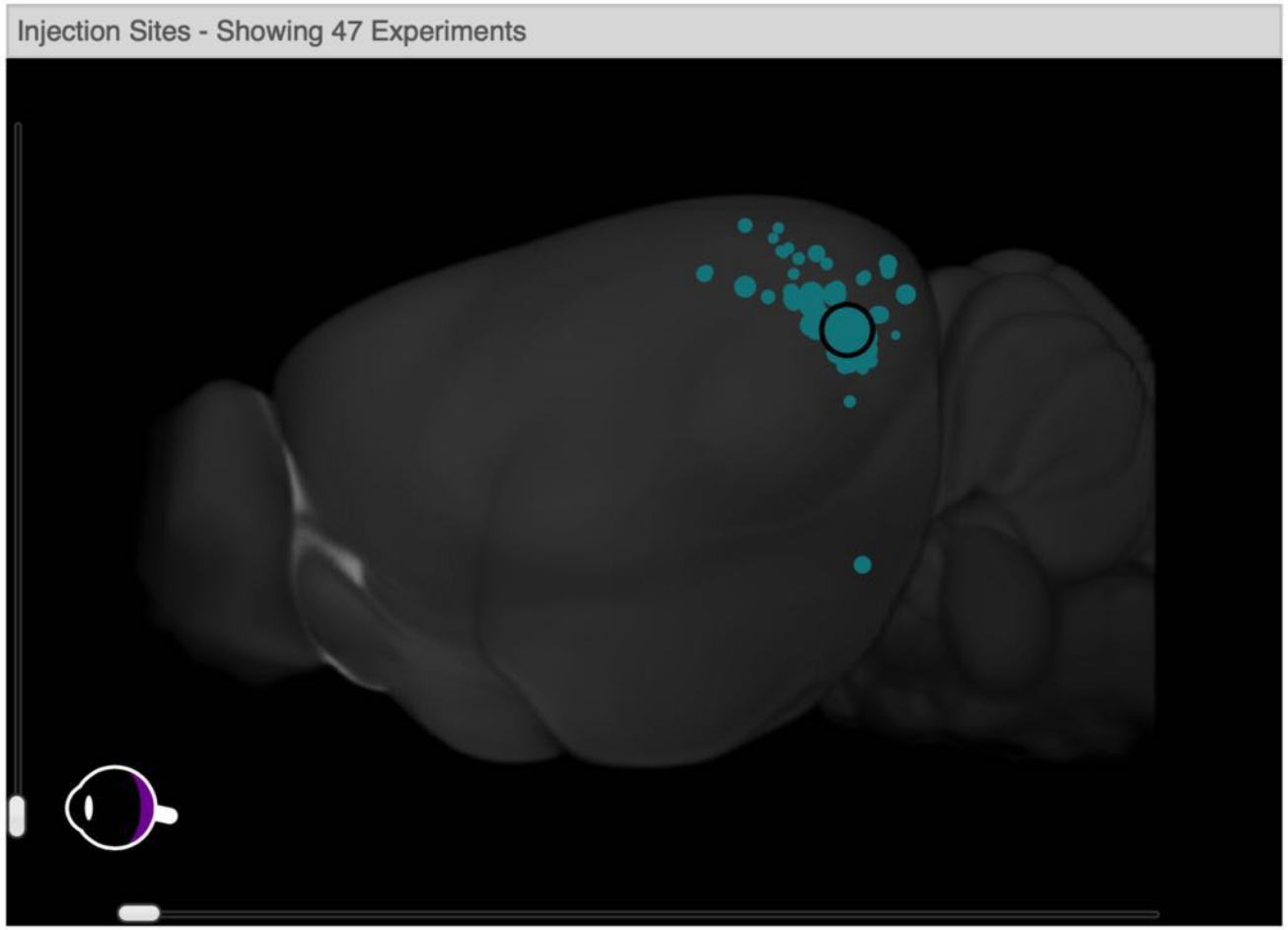


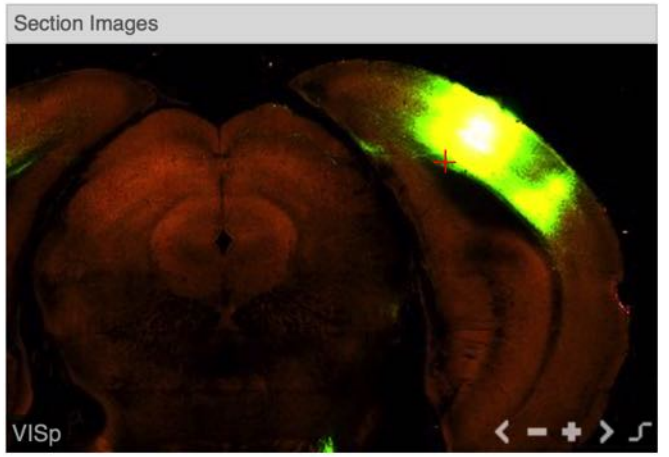


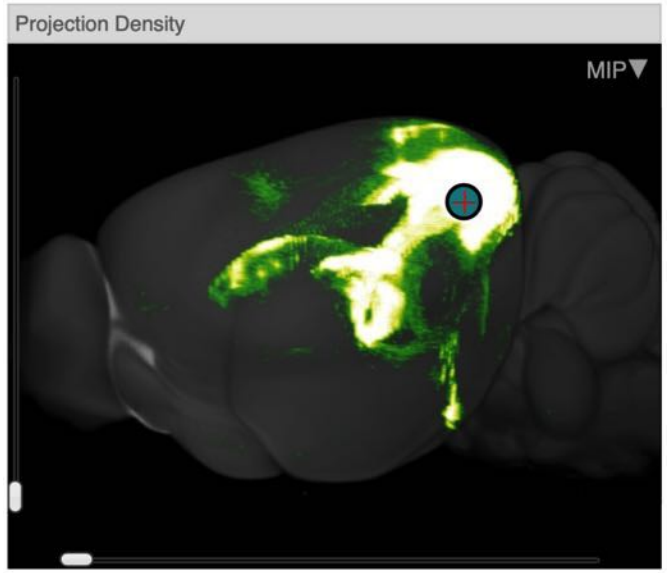


Sanes, J. R., & Zipursky, S. L. 2010.

http://connectivity.brain-map.org







Take home message

1. The visual pathway of mammals
   - Retinal-LGN-V1
2. Functions of the primary visual cortex
   - Orientation selectivity
   - Contour integration
   - Stereopsis and binocular disparity
   - Directional selectivity of movement

References

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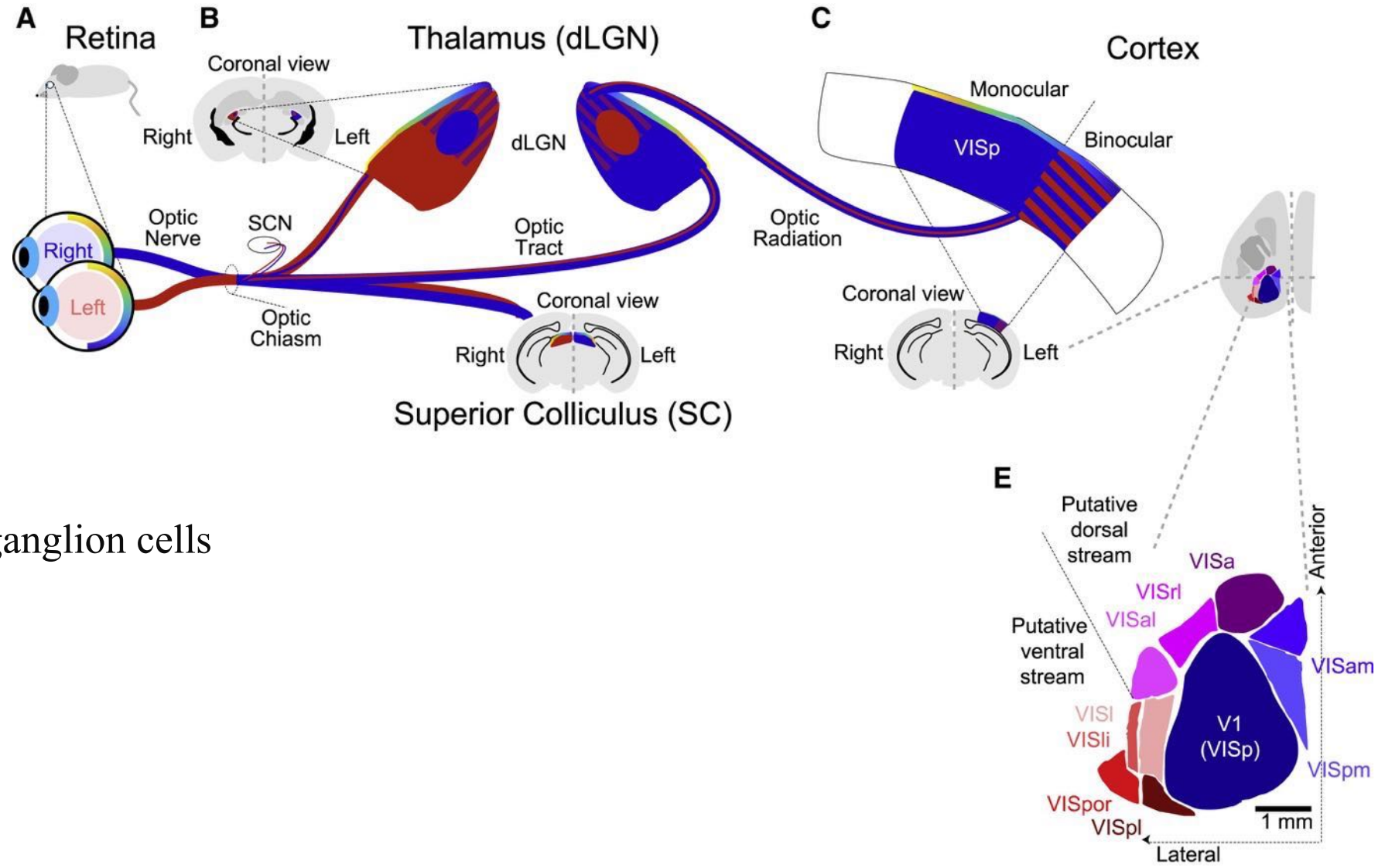
Early experience affects visual cortex development and function

GY

24.3.28

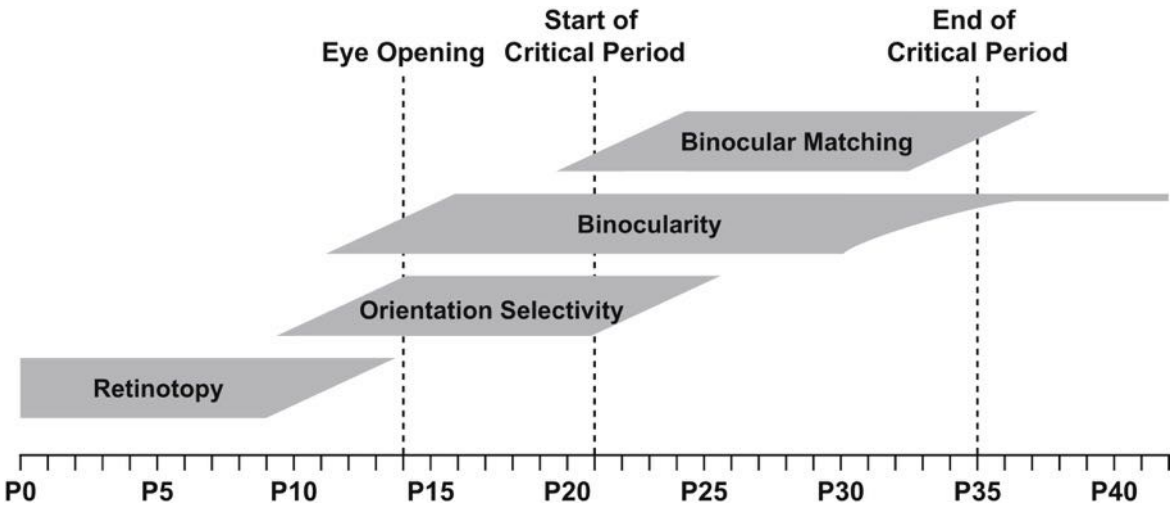
Binocular vision: compute the distances of objects

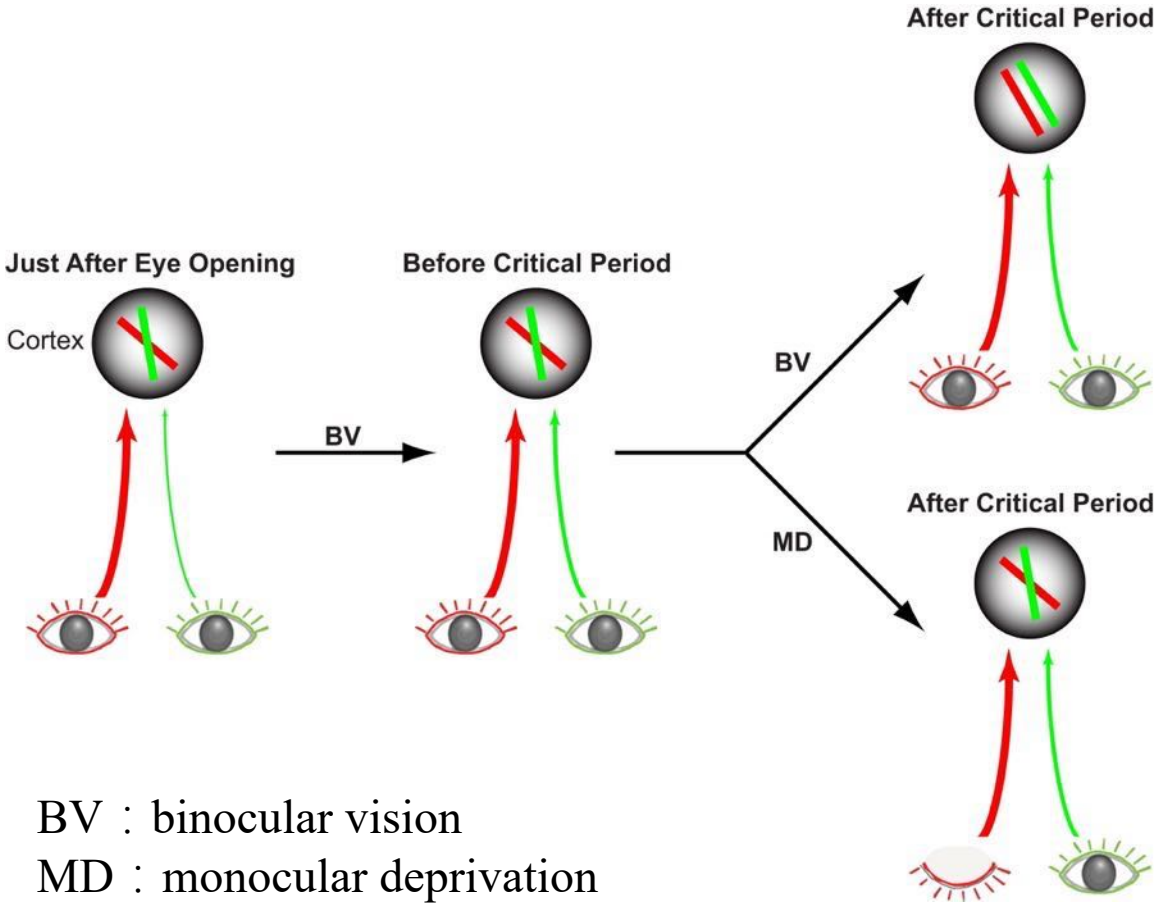


Retinal ganglion cells

Bryan M. Hooks, el ta. *Neuron*. 2020

Experience-dependent plasticity





BV：binocular vision
MD：monocular deprivation

J. Sebastian Espinosa, el ta. *Neuron*. 2012

What happens in the visual circuitry during the critical period ?

What impact does visual experience have on the development of the visual circuitry ?

Neuron

CellPress

Article

Vision Changes the Cellular Composition of Binocular Circuitry during the Critical Period

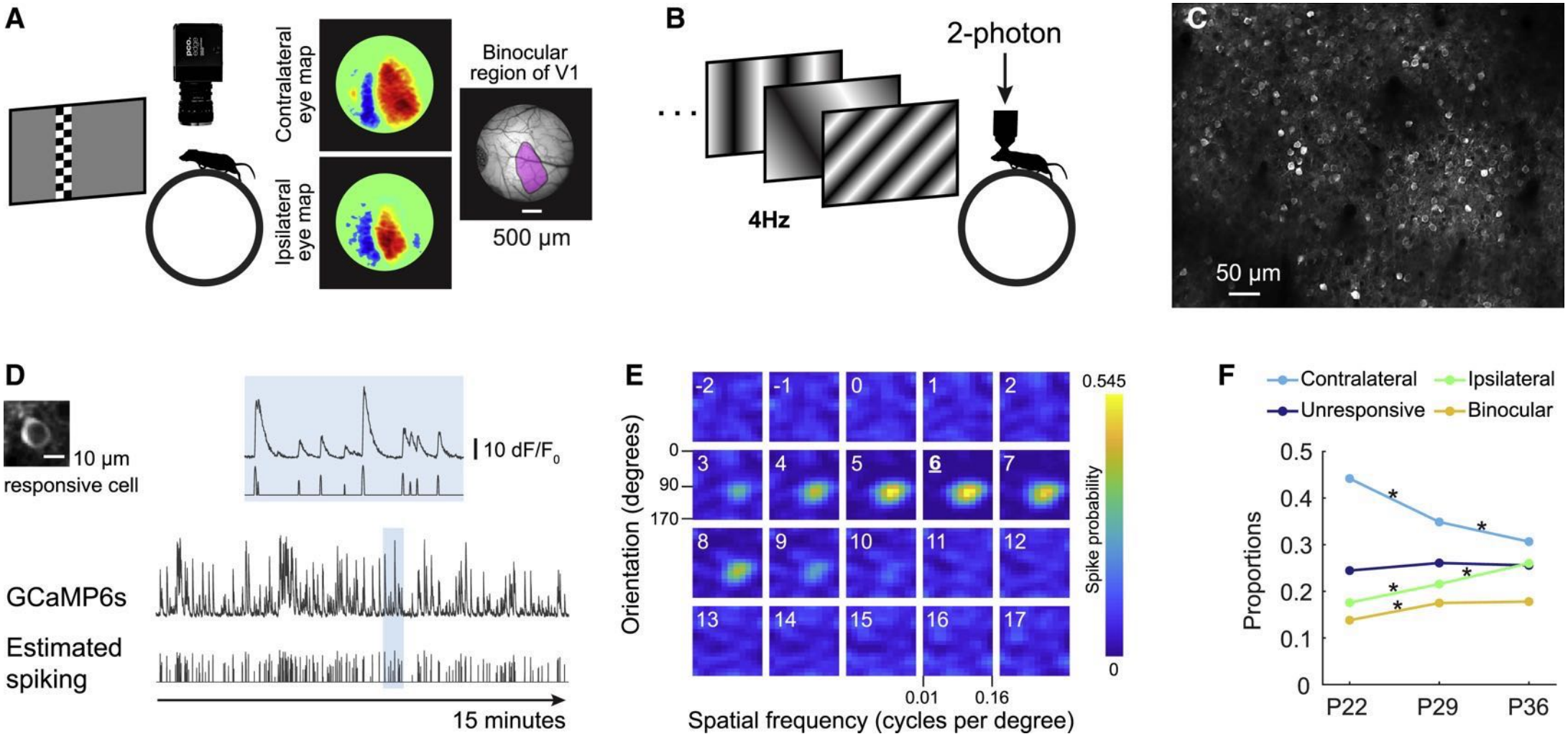
Liming Tan,[1,2] Elaine Tring,[3] Dario L. Ringach,[3,4] S. Lawrence Zipursky,[1,2] and Joshua T. Trachtenberg[3,5,*]
[1]Department of Biological Chemistry, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095, USA
[2]Howard Hughes Medical Institute
[3]Department of Neurobiology, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095, USA
[4]Department of Psychology, University of California, Los Angeles, Los Angeles, CA 90095, USA
[5]Lead Contact
*Correspondence: joshua.trachtenberg@gmail.com
https://doi.org/10.1016/j.neuron.2020.09.022

Joshua Trachtenberg

UCLA

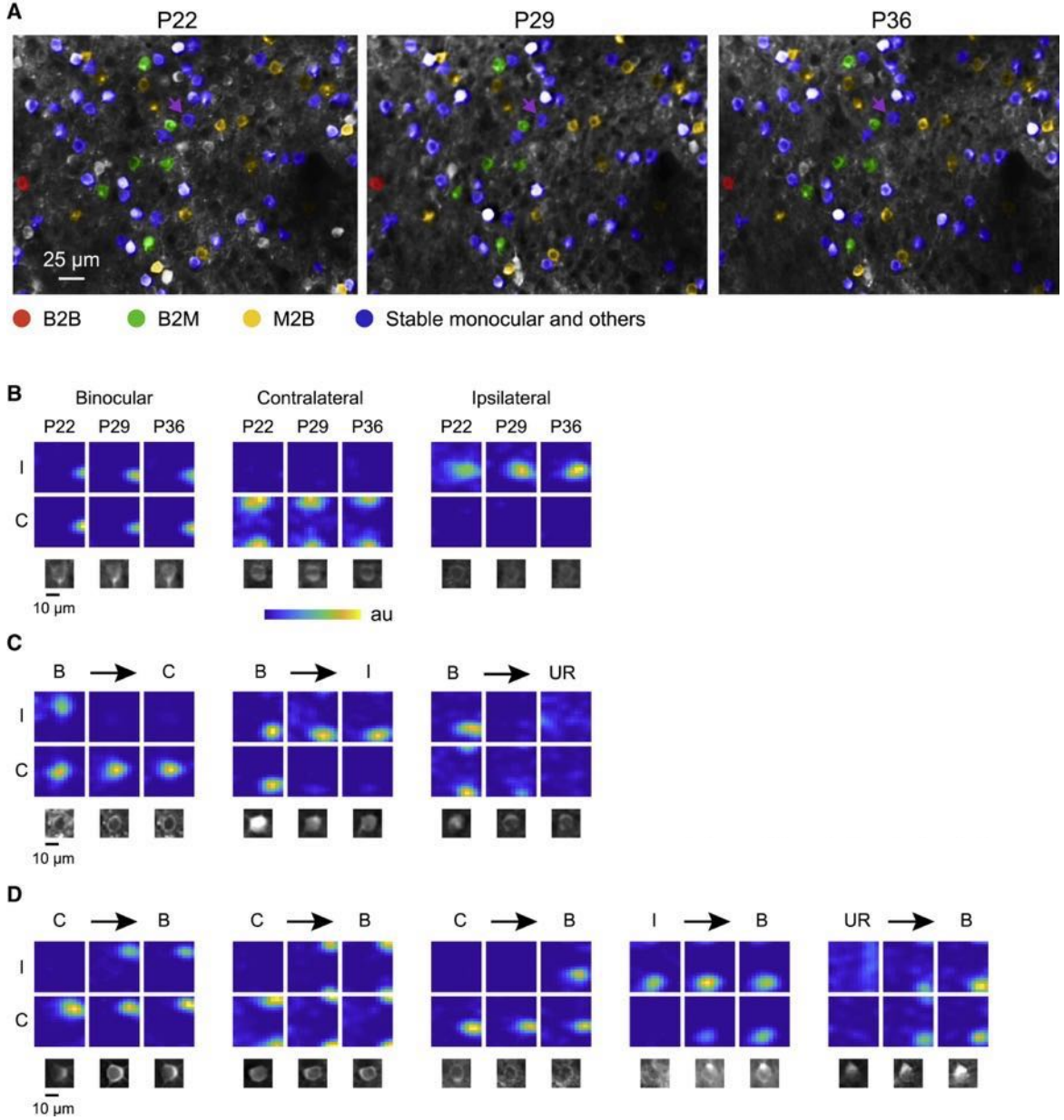
- Examines the cellular and synaptic mechanisms of experience-dependent plasticity in the neocortex

Figure 1. Binocular Field Mapping and Receptive Field Tuning



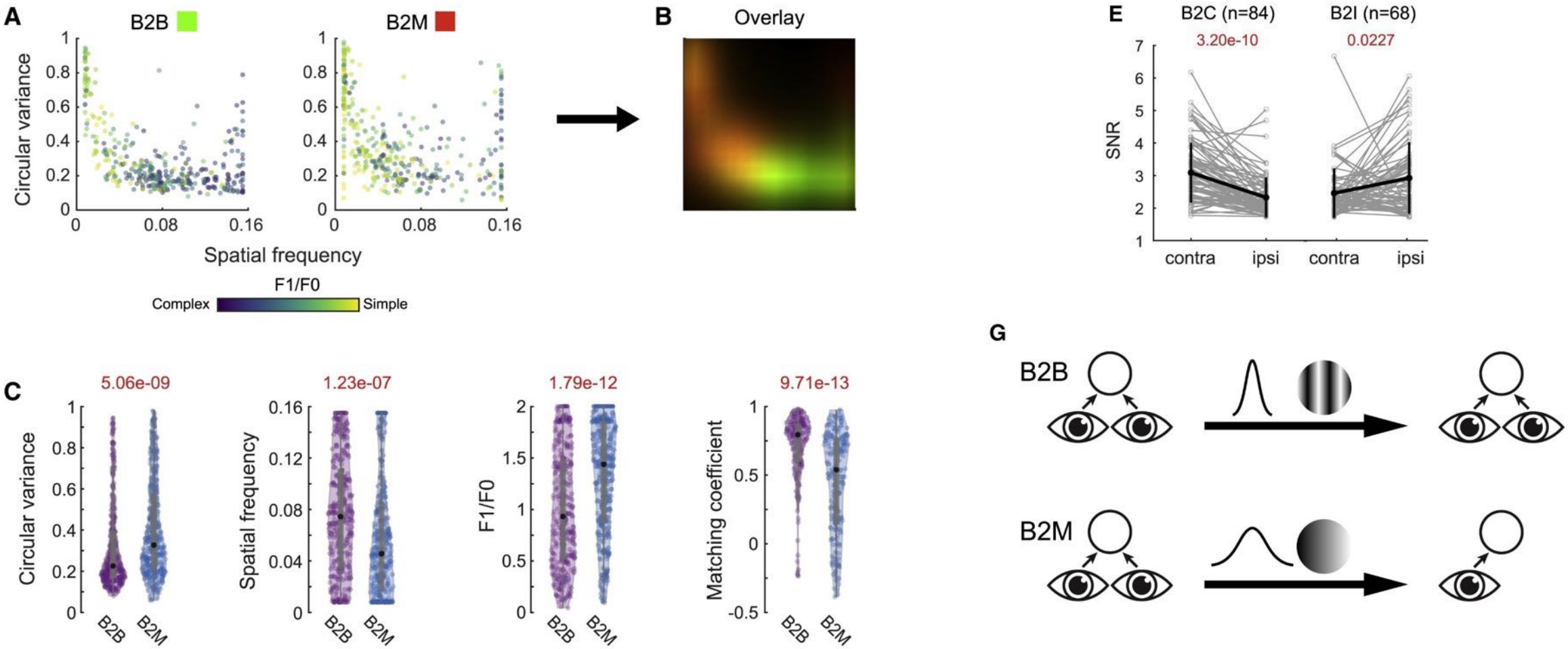
Liming Tan, el ta. *Neuron*. 2022

Figure 2. Longitudinal Tracking of Receptive Field Tuning Properties



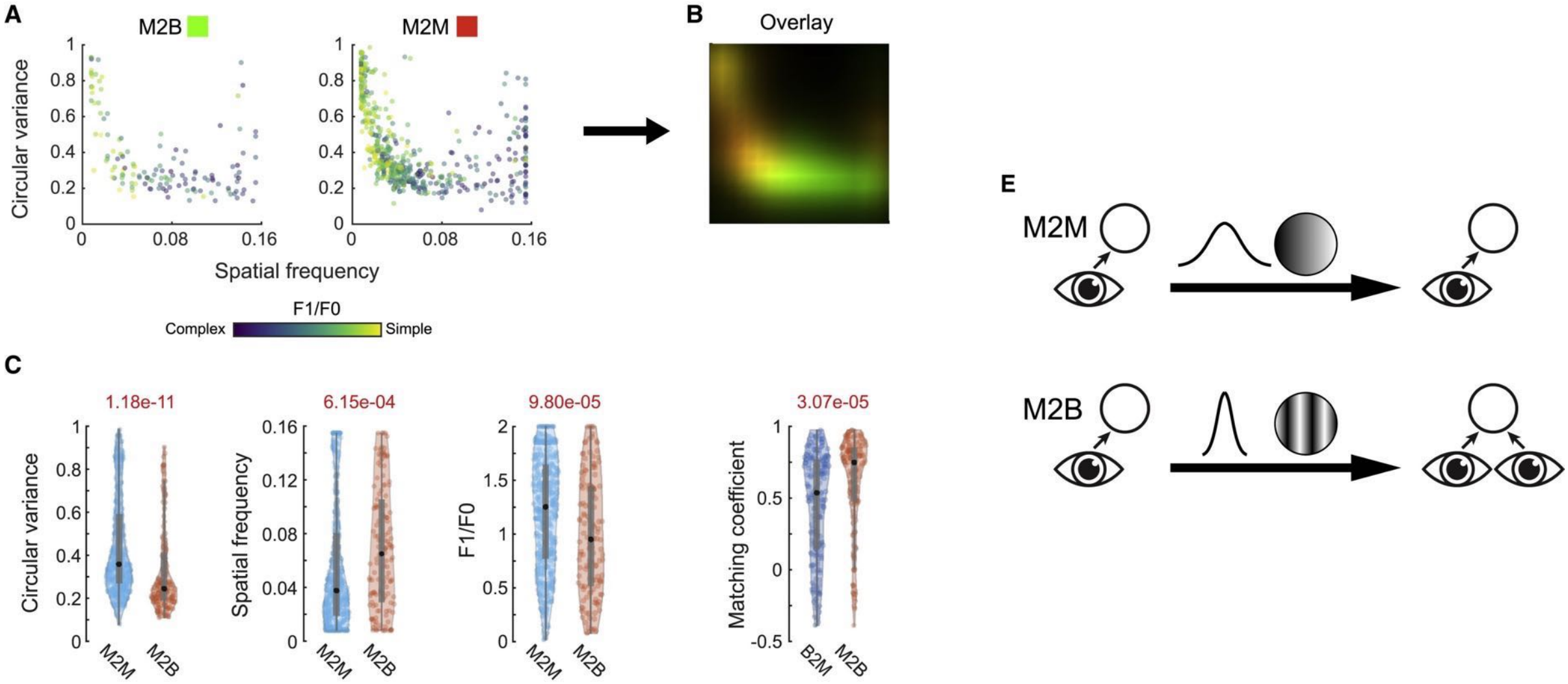
Liming Tan, el ta. *Neuron*. 2022

Figure 3. Poorly Tuned Binocular Neurons Lose Responsiveness to One Eye and Become Monocular



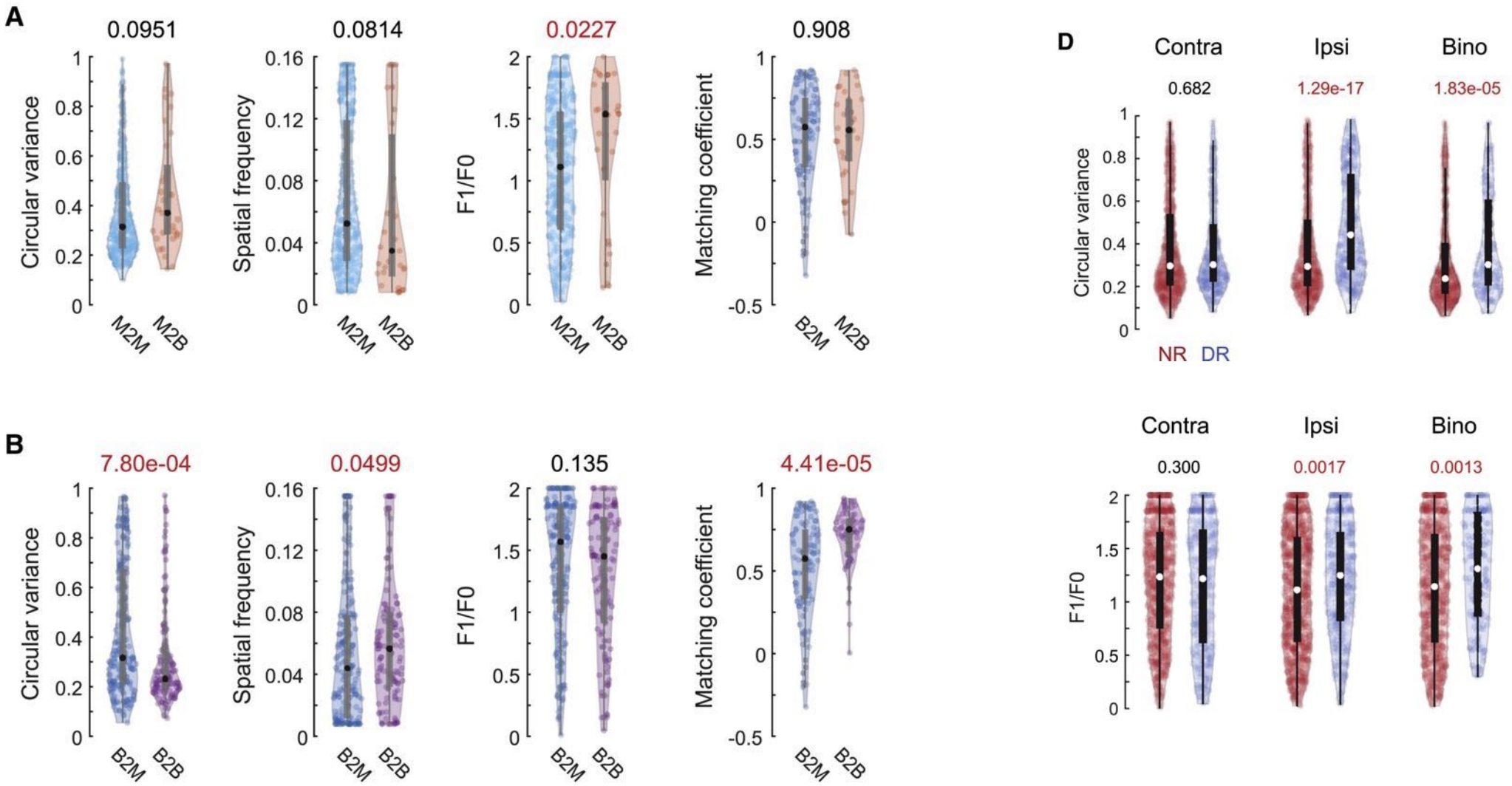
Liming Tan, el ta. *Neuron*. 2022

Figure 4. Sharply Tuned Monocular Neurons Gain Matched Responses from the Other Eye and Become Binocular



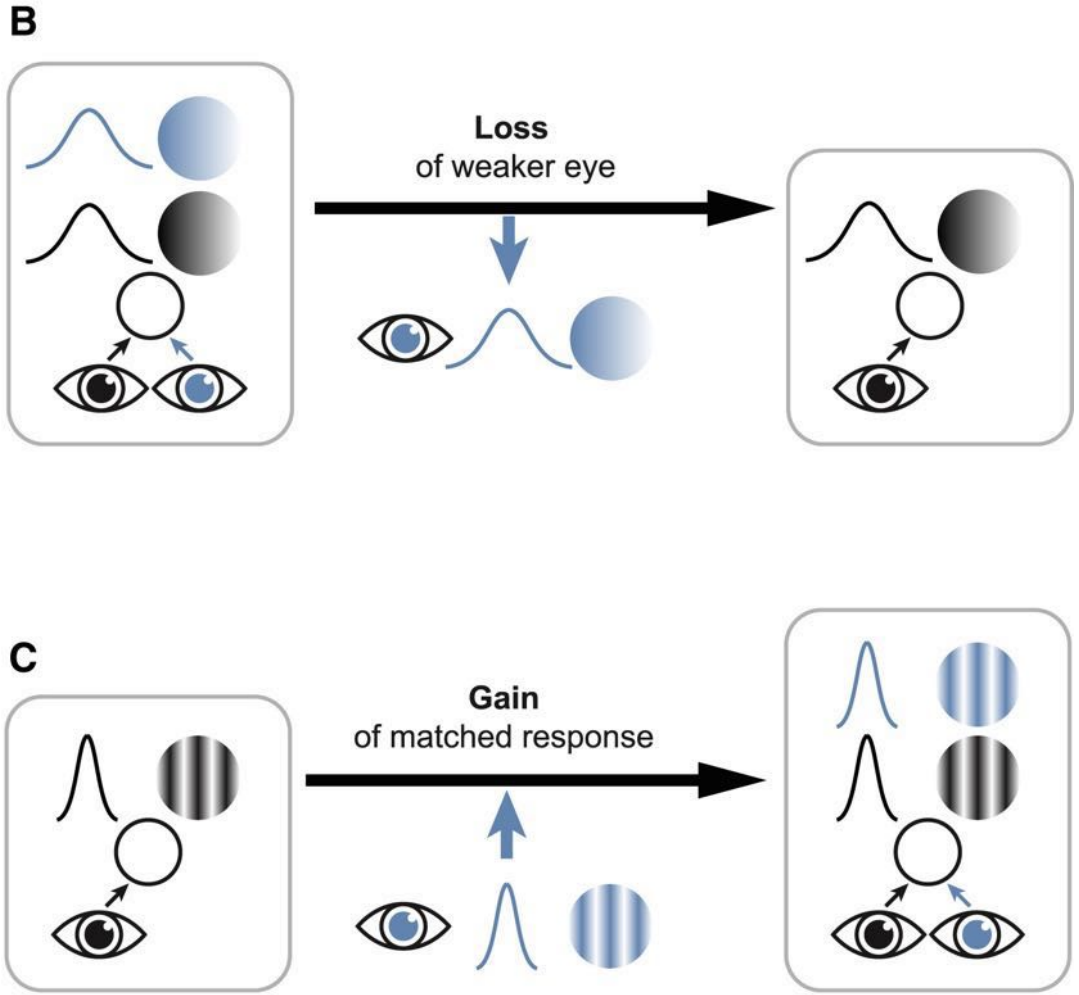
Liming Tan, el ta. *Neuron*. 2022

Figure 5. Vision Is Necessary for Conversion of Sharply Tuned Monocular Neurons into Binocular Neurons



Liming Tan, el ta. *Neuron*. 2022

Summary

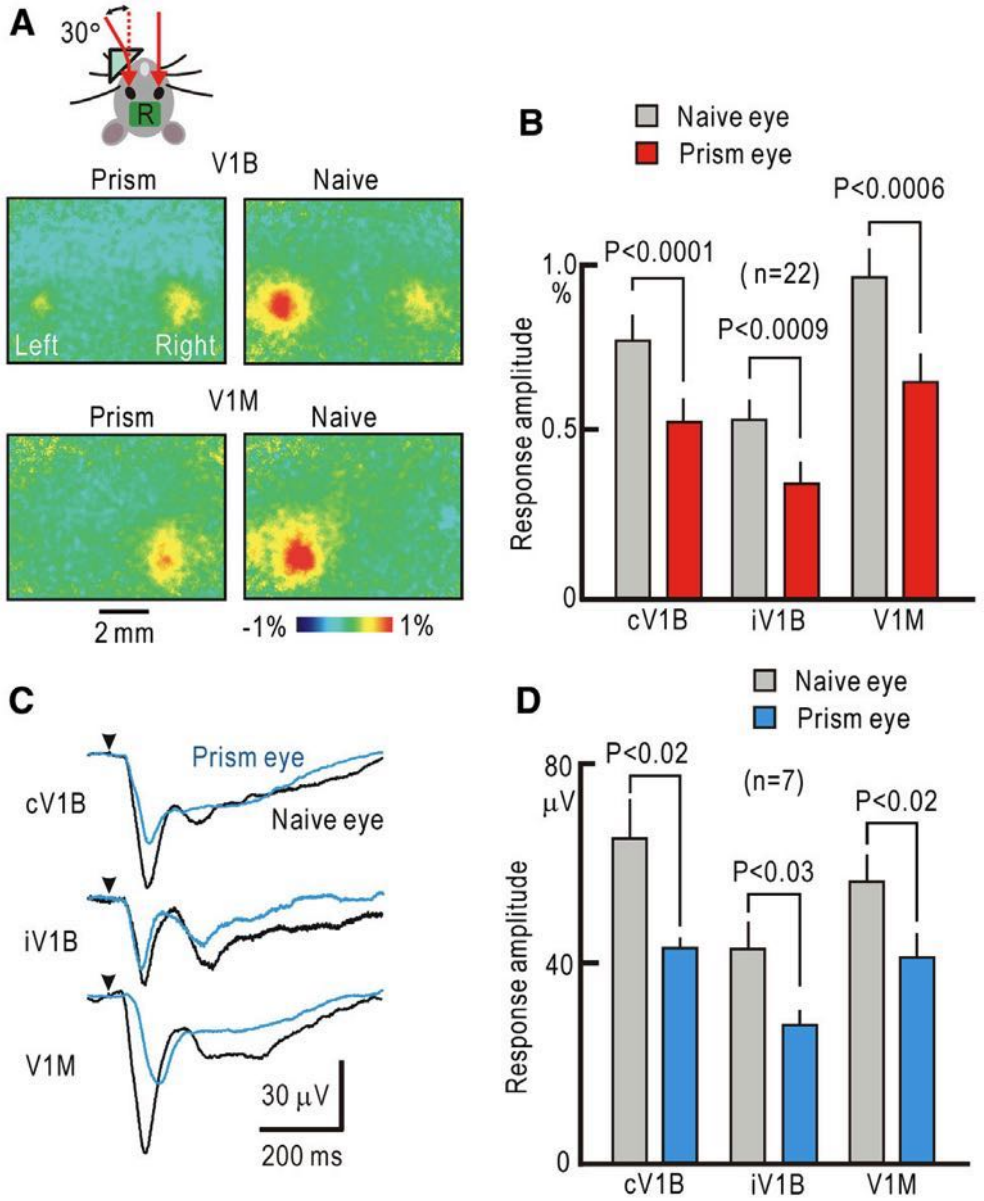


Liming Tan, el ta. *Neuron*. 2022

what other early experiences can affect visual cortex development and function ?

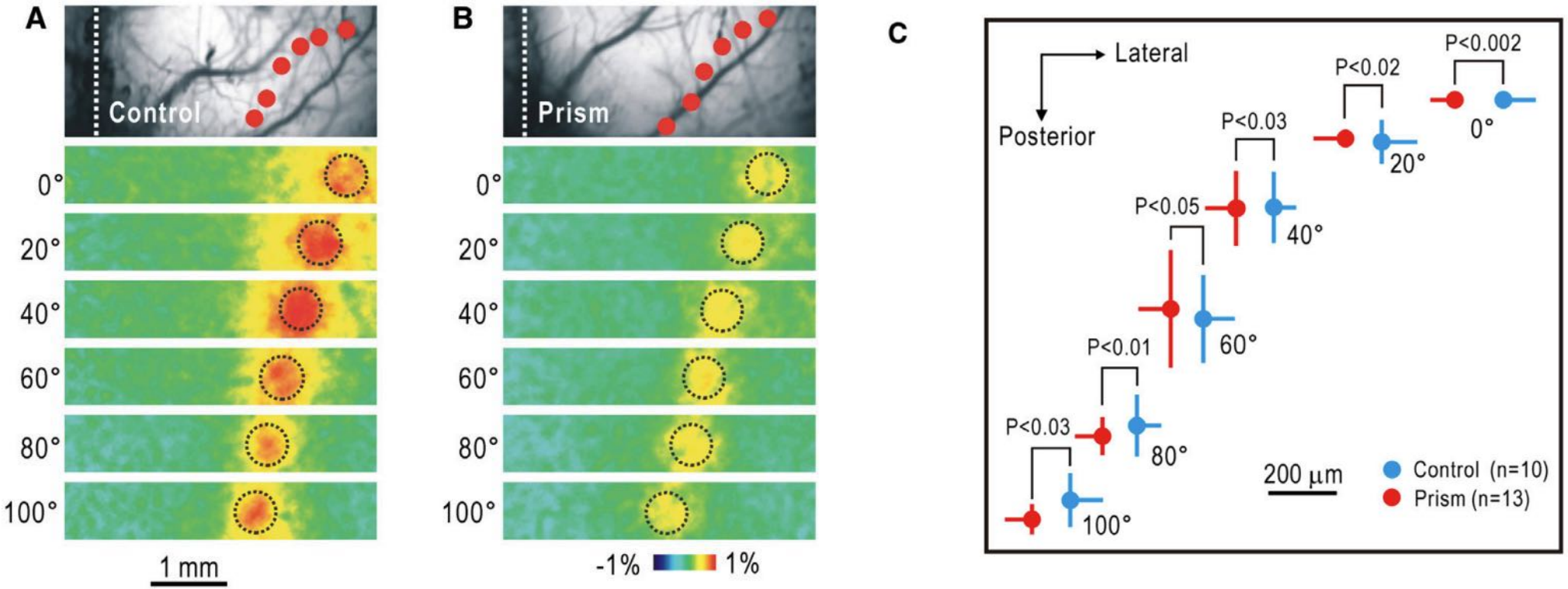
- Mismatch in multisensory integration
- Visuomotor uncoupling
- ... ...

Figure 1. Prism-Induced Cortical Depression in V1B and V1M



Kohei Yoshitake, el ta. *Cell Reports*. 2013

Figure 4. Retinotopic Map Shifts in V1 after Prism Wearing



Kohei Yoshitake, el ta. *Cell Reports*. 2013

Figure 2. Effects of Whisker Trimming on Prism-Induced Cortical Depression

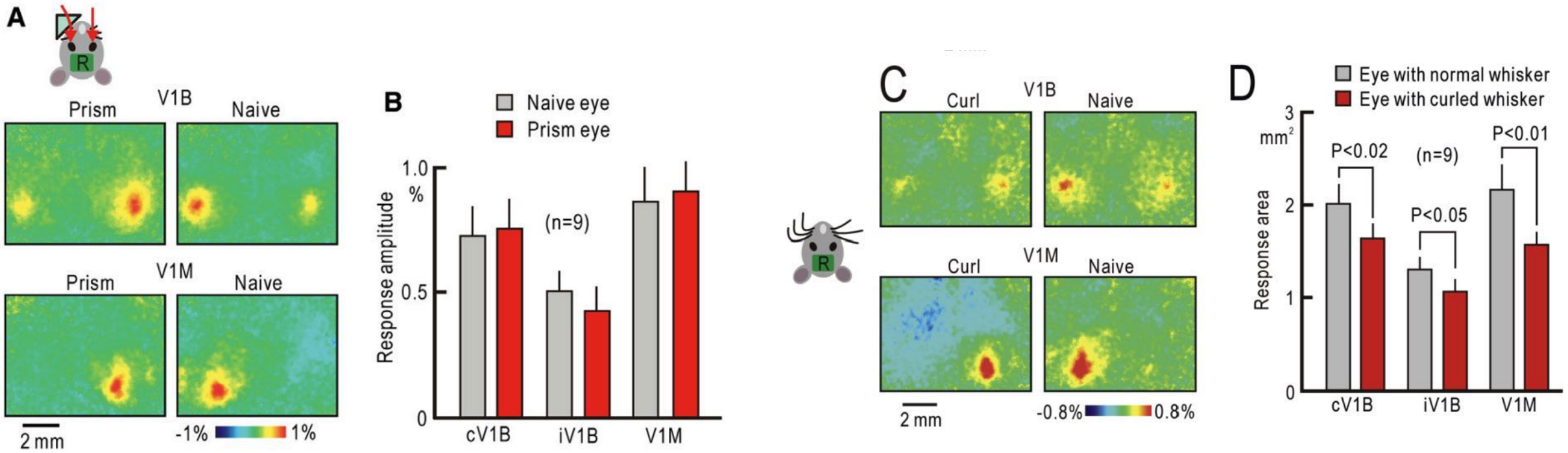
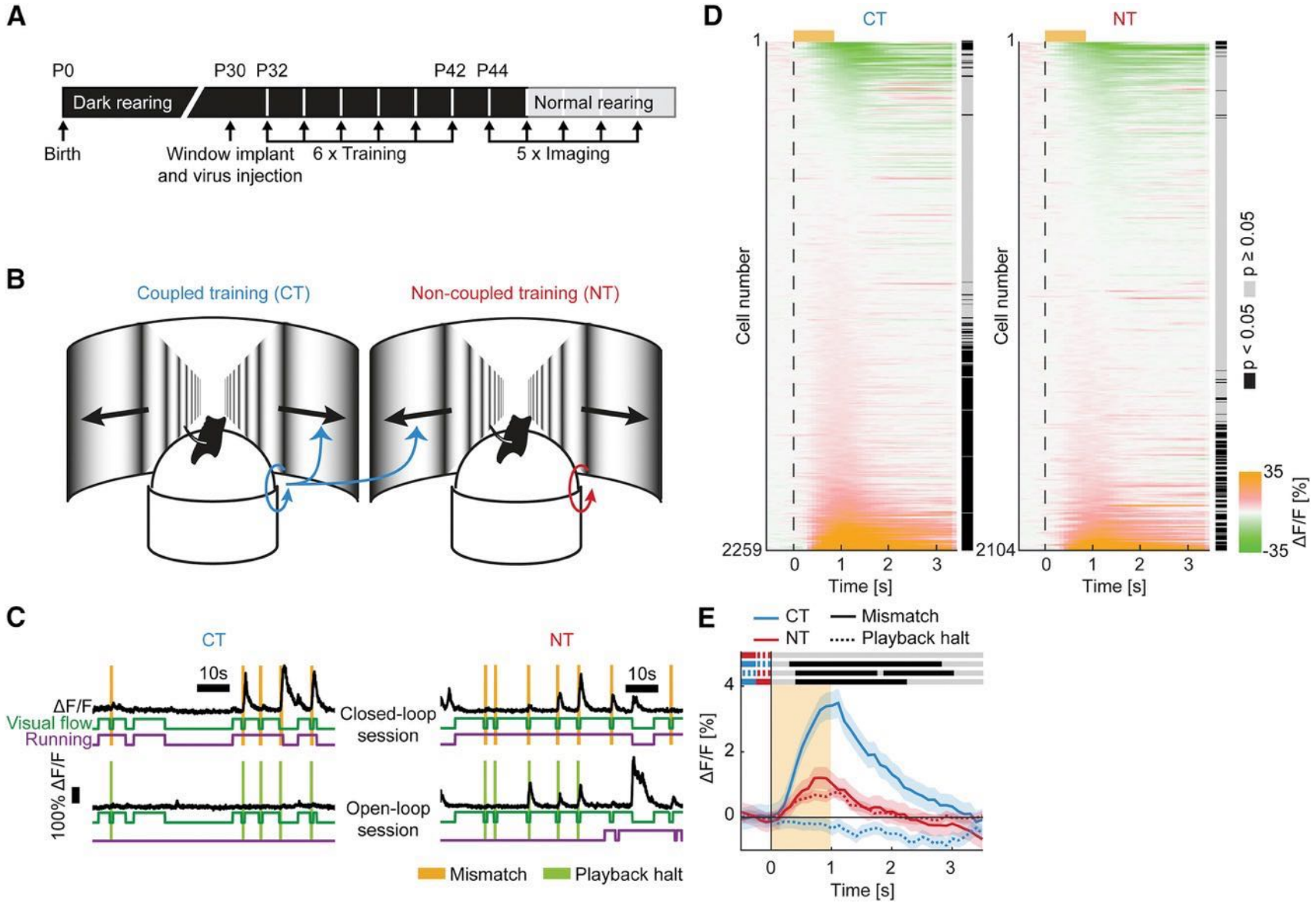


Figure S2

Kohei Yoshitake, el ta. *Cell Reports*. 2013

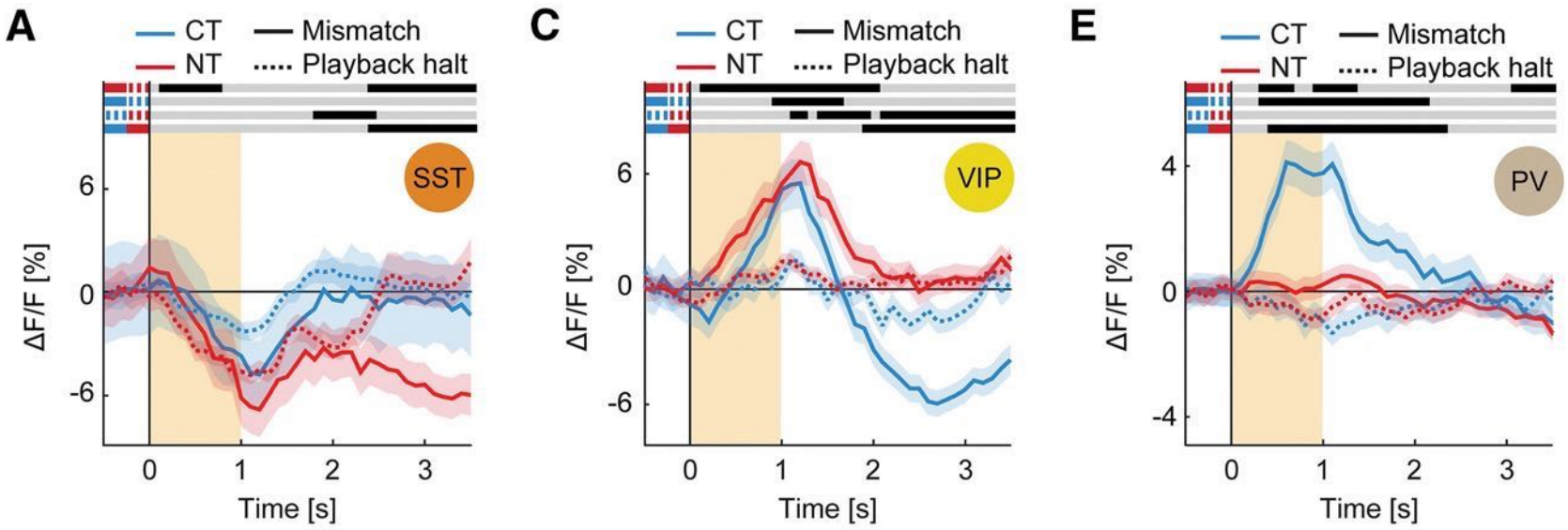
Figure 1. Mismatch Responses in Excitatory Neurons Depend on Visuomotor Experience



Alexander Attinger, el ta. *Cell*. 2017

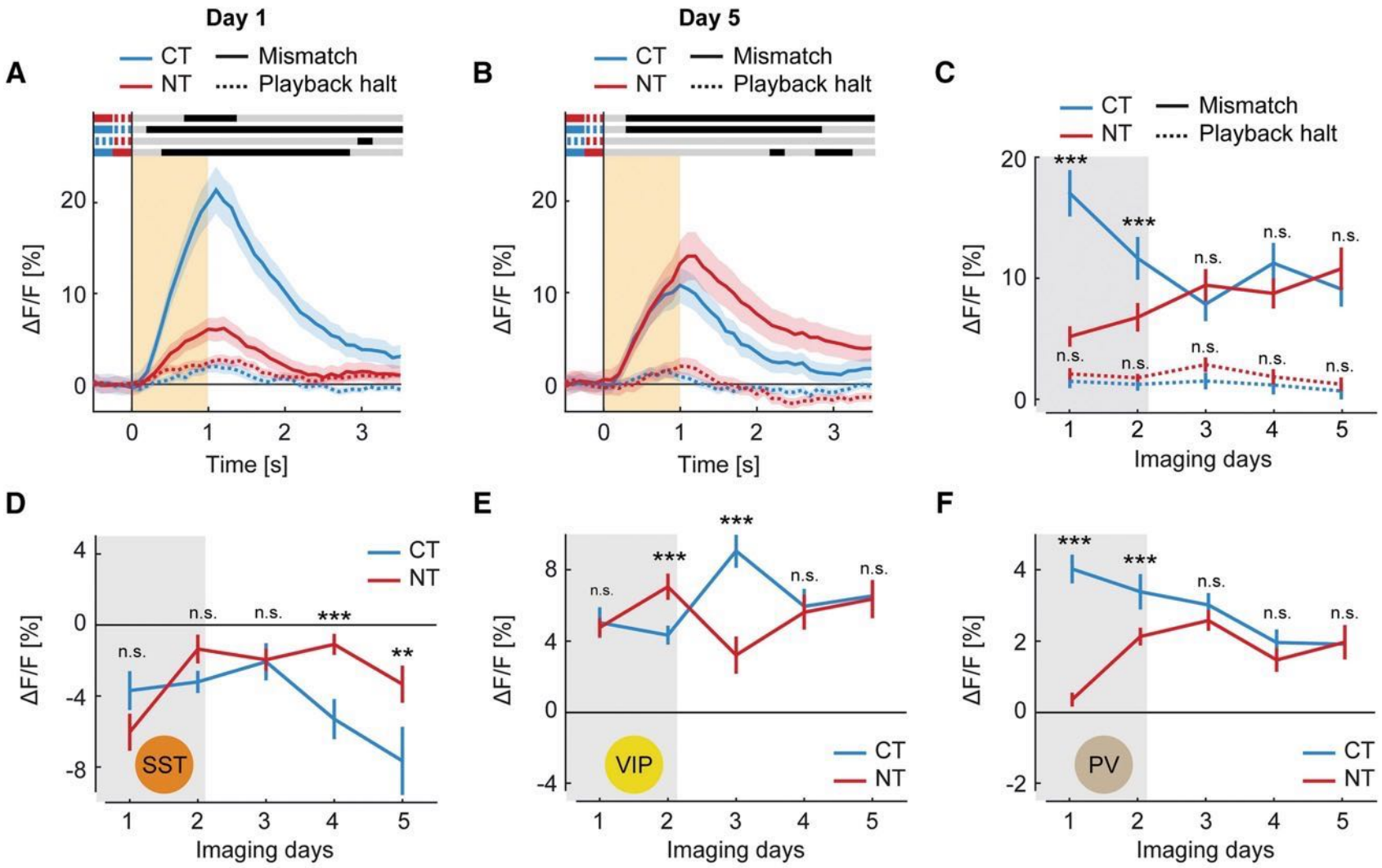
Figure 4

The mismatch reponse in PV interneurons was strongly experience dependent



Alexander Attinger, el ta. *Cell*. 2017

Figure 7. Normal Visuomotor Experience Restores Normal Visuomotor Integration



Alexander Attinger, el ta. *Cell*. 2017

Take home message

- Turnover between binocular and monocular cell groups happens during critical period
  - Poorly tuned binocular neurons lose weaker eye responsiveness and become monocular
  - Sharply tuned monocular neurons gain matched responses from the other eye and become binocular

  (visual experience dependent)
- Normal multisensory integration and visuomotor experience affect visual cortex development and function

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Disorders associated with visual cortex dysfunction

Wenyue GUAN

Disorders associated with visual cortex dysfunction--Autism Spectrum Disorder

J Autism Dev Disord. 2018 Apr;48(4):1397-1408. doi: 10.1007/s10803-016-2724-6.

Evidence of Reduced Global Processing in Autism Spectrum Disorder

Abstract

Frith's origi… spectrum d… emphasisec… place local … differences … measures o… processing. … geometric i… integration …

J AAPOS. 2018 Aug;22(4):304-308. doi: 10.1016/j.jaapos.2

Functional and cognitive visior… children with autism spectrum …

Results: A total of 30 children were included. The distribution of the nu… moderate versus severe ASD was nearly equal based on CARS autism s… had normal color vision (16/18), contrast (24), shape discrimination (26… directionality (28). Most were not able to identify optical illusions or dif… Ocular pursuits, saccades, and recognition of size differences were ofte… was noted in (11) subjects. The duration of fixation to Heidi face target … the severity of ASD. The study further established that cognitive visua… children with ASD irrespective of their severity of ASD.

Nature. 2022 Nov;611(7936):532-539. doi: 10.1038/s41586-022-05377-7. Epub 2022 Nov 2.

Broad transcriptomic dysregulation occurs across the cerebral cortex in ASD

Autism Res. 2023 Apr;16(4):831-840. doi: 10.1002/aur.2901. Epub 2023 Feb 7.

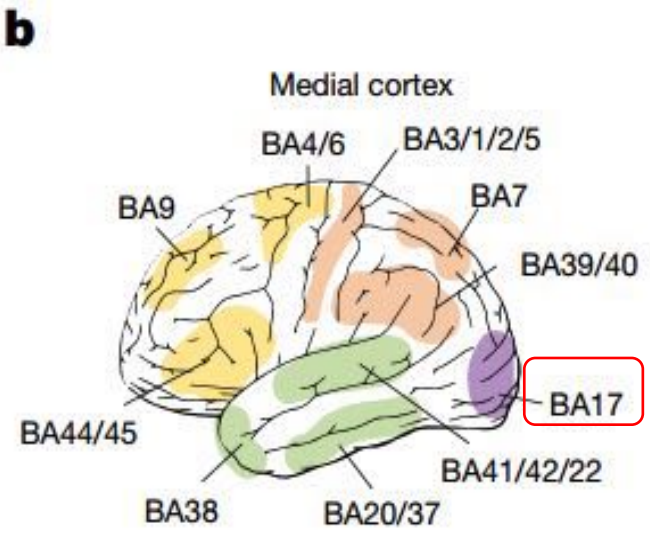
Visual processing in genetic conditions linked to autism: A behavioral study of binocular rivalry in individuals with 16p11.2 deletions and age-matched controls

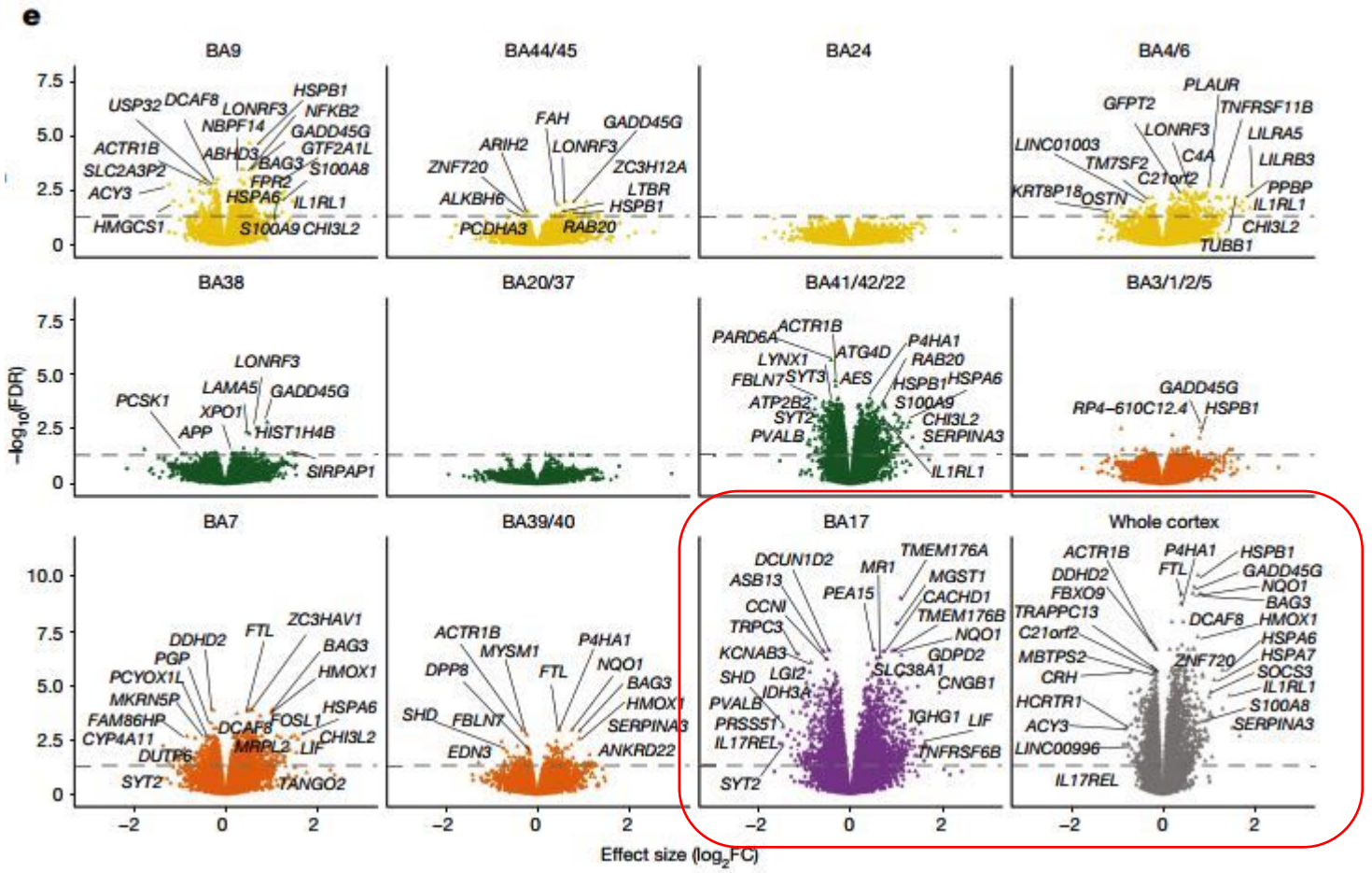
J Autism Dev Disord. 2009 Jul;39(7):965-75. doi: 10.1007/s10803-009-0705-8. Epub 2009 Feb 18.

Vision in children and adolescents with autistic spectrum disorder: evidence for reduced convergence

Cortex-wide transcriptomic dysregulation in ASD, with greatest differences in primary visual cortex

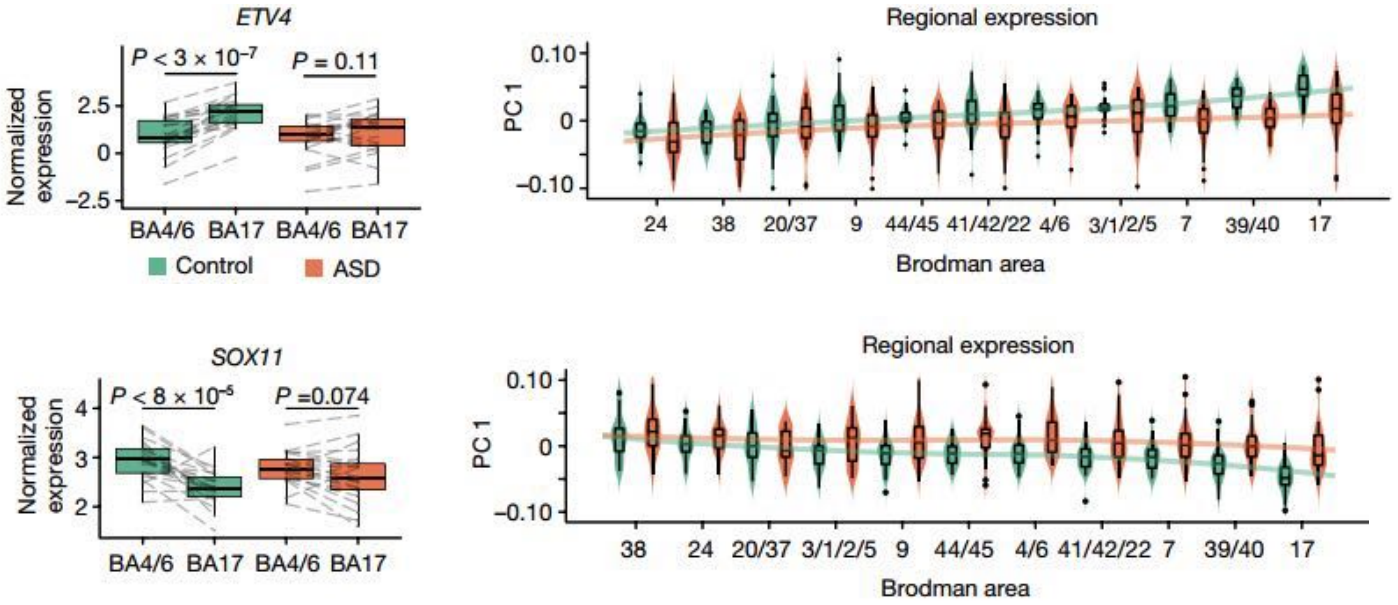
ASD *VS* Control

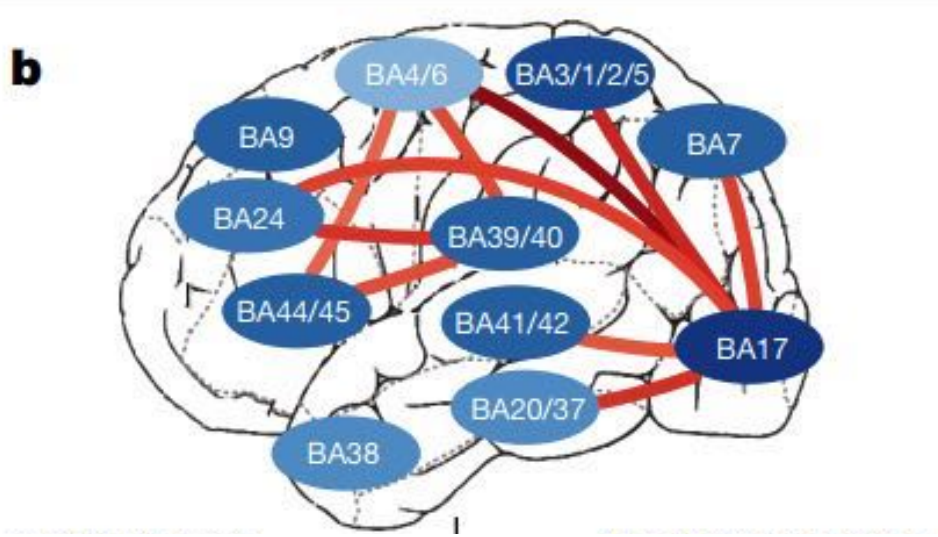




Gandal and Geschwind, Nature 2022

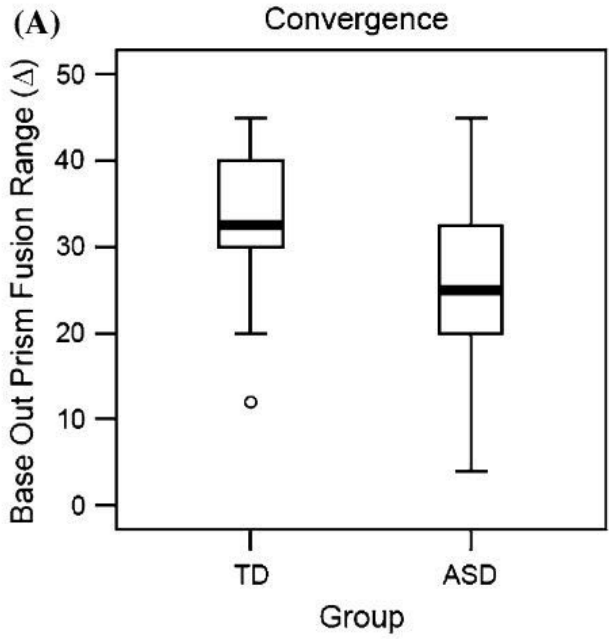
Attenuation of transcriptomic regional identity in ASD, with stronger attenuation in primary visual cortex

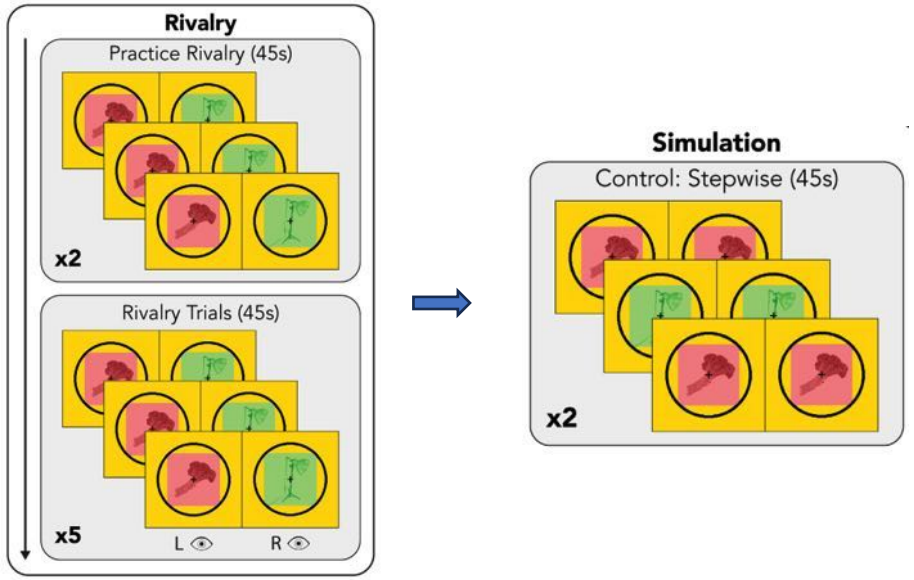


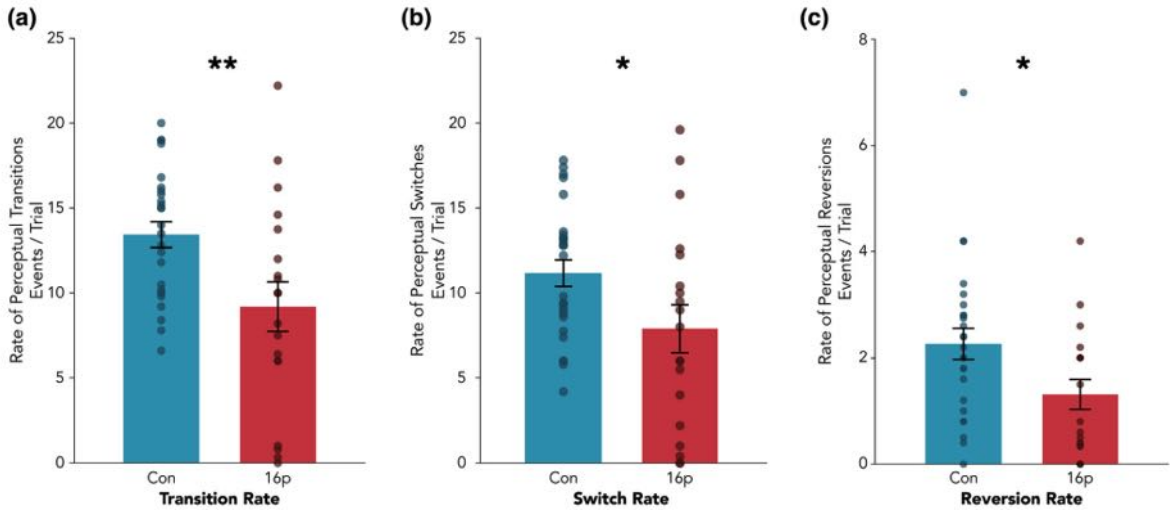


Gandal and Geschwind, Nature 2022

Binocular convergence and binocular rivalry perceptual transition were significantly impaired in ASD

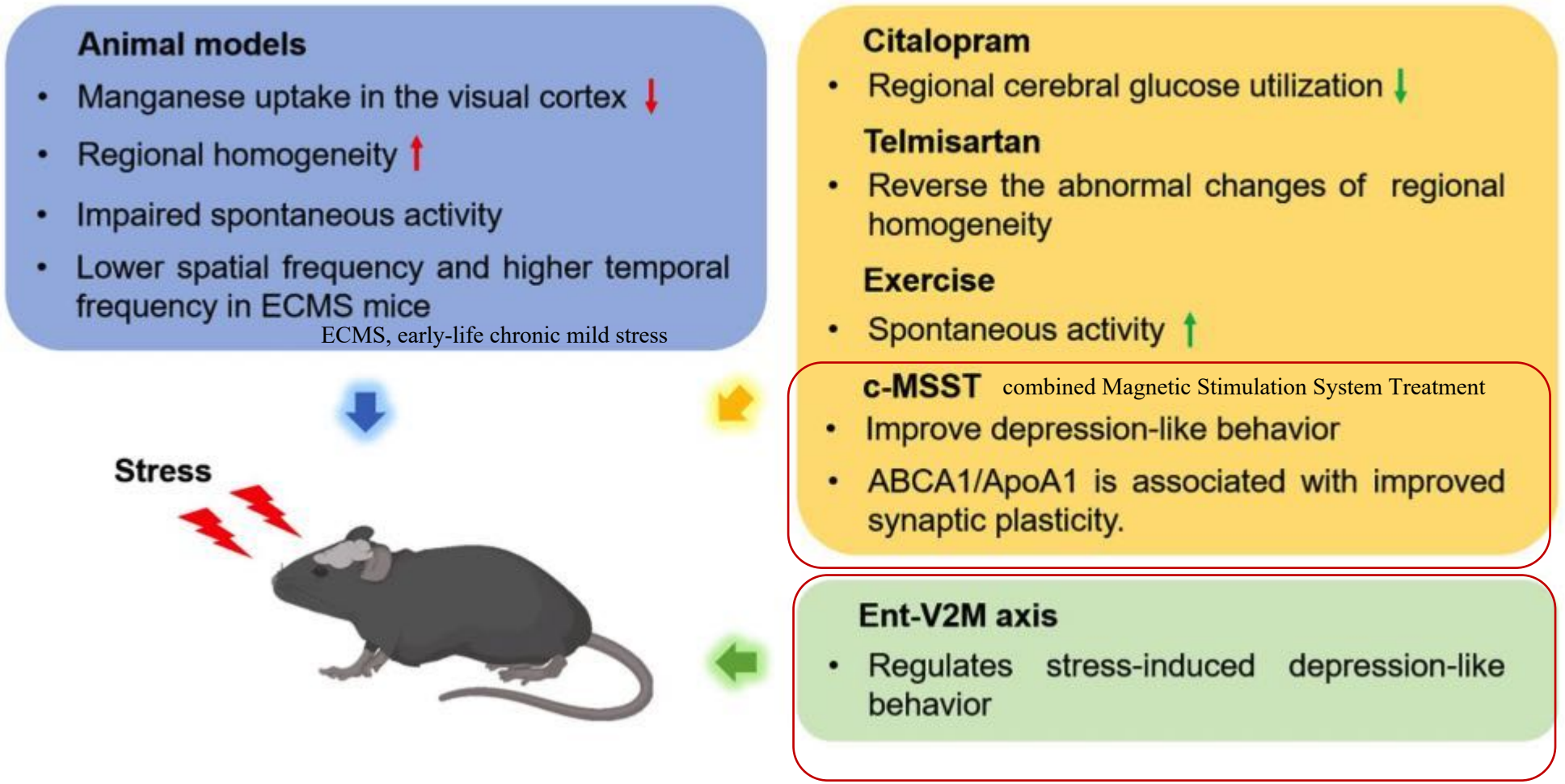






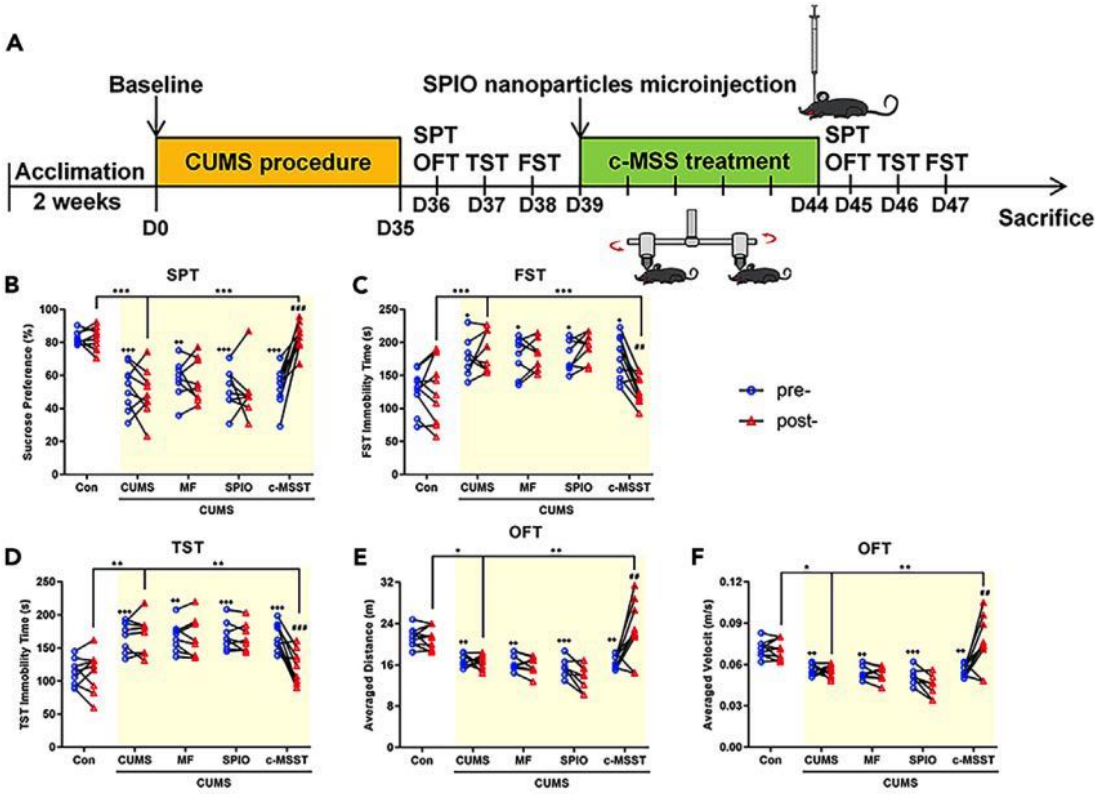
Milne et al 2009 ; Choi and Robertson 2023

Visual cortical dysfunction in animal models of depression

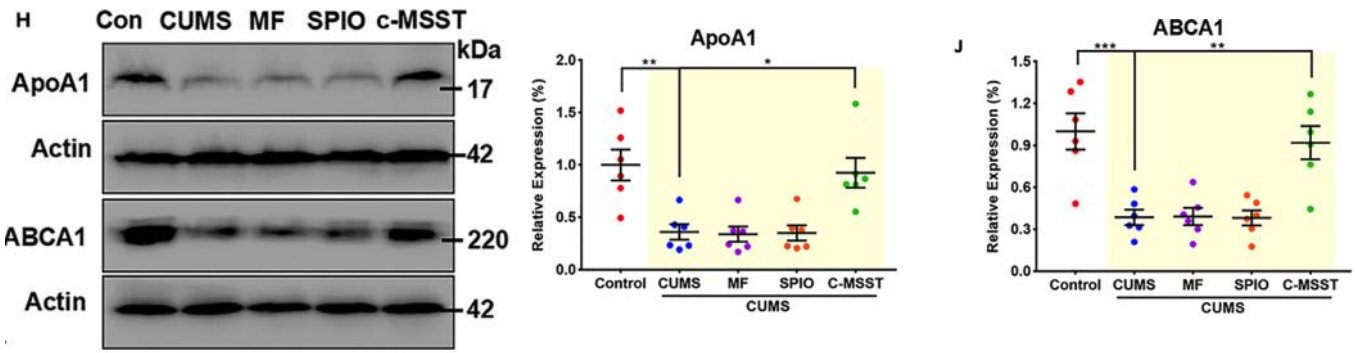


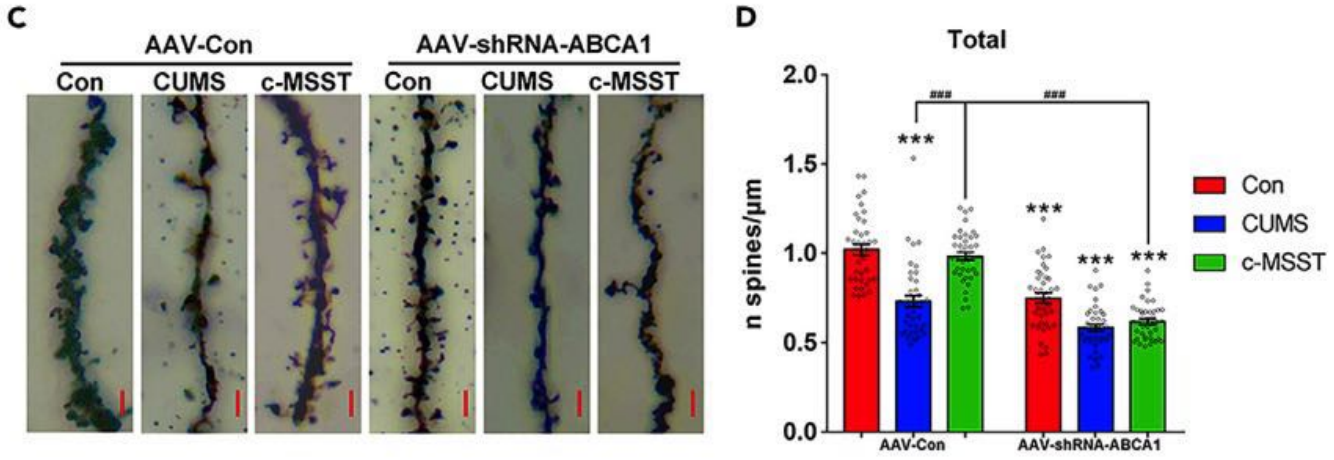
Wu et al., Neuroscience Bulletin 2023

Magnetoelectric stimulation in visual cortex ameliorates depression via ABCA1/ApoA1 associated regulation of synaptic plasticity



Apolipoprotein A-1 （ApoA1）
ATP-binding cassette transporter A1 (ABCA1)





CUMS: Chronic Unpredictable Mild Stress
SPT, sucrose preference test
FST, forced swim test
TST, tail suspension test
OFT, open field test
SPIO, superparamagnetic iron oxide
cMSS: combined Magnetic Stimulation System

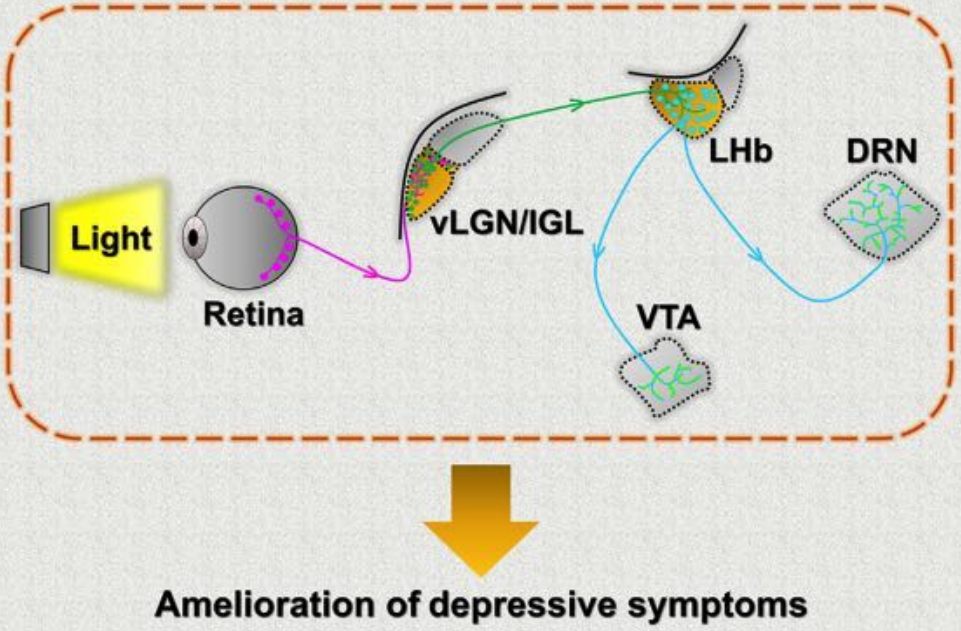
Lu et al., iScience. 2022

Visual circuit-Potential target antidepressant therapy

Neuron

A Visual Circuit Related to Habenula Underlies the Antidepressive Effects of Light Therapy

Improvement of depression-like behavior with Light therapy: through changing synaptic connection between retina and lateral habenula

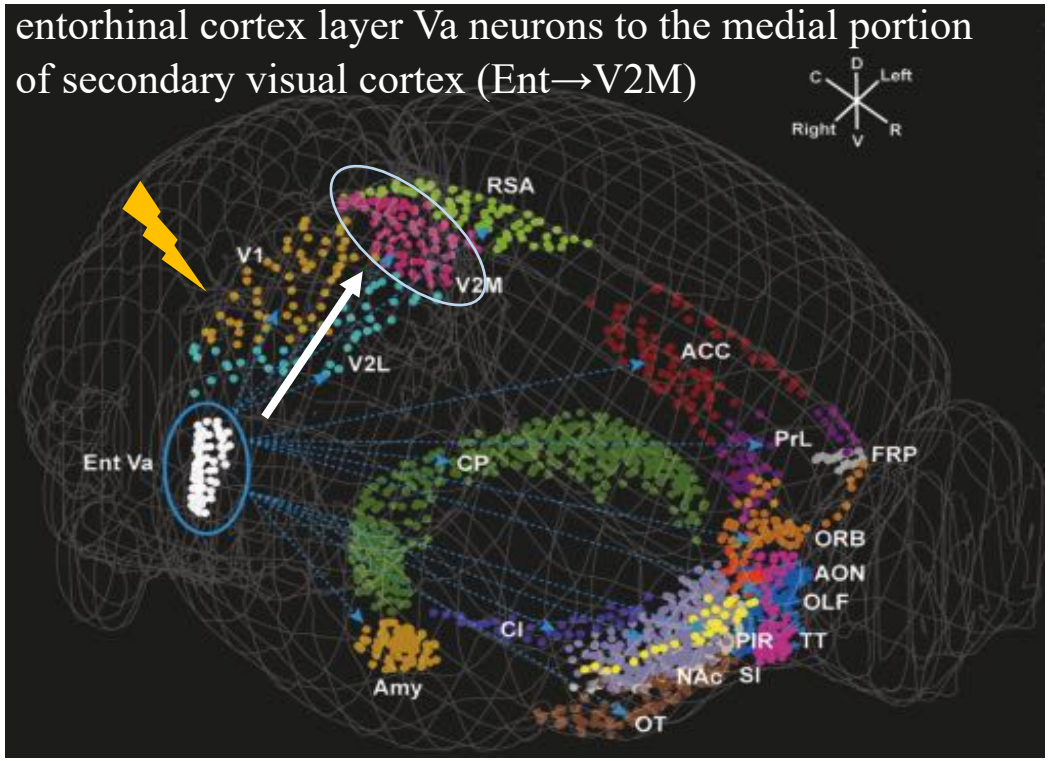


nature › molecular psychiatry › articles › article

Article | Published: 06 April 2022

An entorhinal-visual cortical circuit regulates depression-like behaviors

entorhinal cortex layer Va neurons to the medial portion of secondary visual cortex (Ent→V2M)



Regulates depression-like behaviors bidirectionally

Huang et al., Neuron. 2019; Lu and Guo, Molecular Psychiatry 2022

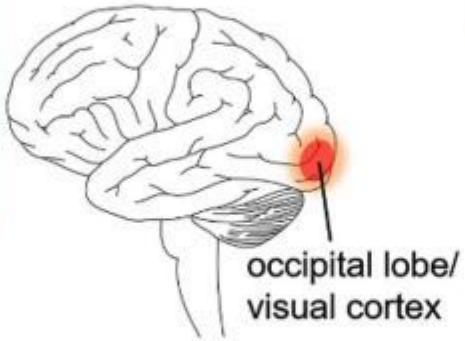
Visual cortical structure and function abnormalities in depressed patients

structural Magnetic Resonance Imaging (sMRI)

resting-state Functional Magnetic Resonance Imaging (rs-fMRI)

sMRI

- GMV ↑ grey matter volume
- Total volume ↓
- White matter volume ↓
- GMV and thickness of the visual cortex in adulthood ↓
- Visual cortex volume ↓
- OB ↑



rs-fMRI

- DC in the low frequency band ↓
- Autonomy of the dorsal/ventral visual network ↑
- Abnormal connections within and between the visual and auditory networks
- FC between the left BLA and V1 ↑ FC, functional connectivity

t-fMRI (task-Related fMRI (t-fMRI)

Non-emotion related visual tasks:

- Abnormal filtering of irrelevant information
- Abnormal changes in the FC between the frontoparietal network and the visual cortex

Visual perception ability changes:

- Enhanced motor awareness of typical inhibitory stimuli
- Longer to make a correct judgment, weakened in motor visual perception

Emotion related visual tasks:

- Attention bias
- Impairments in emotional processing

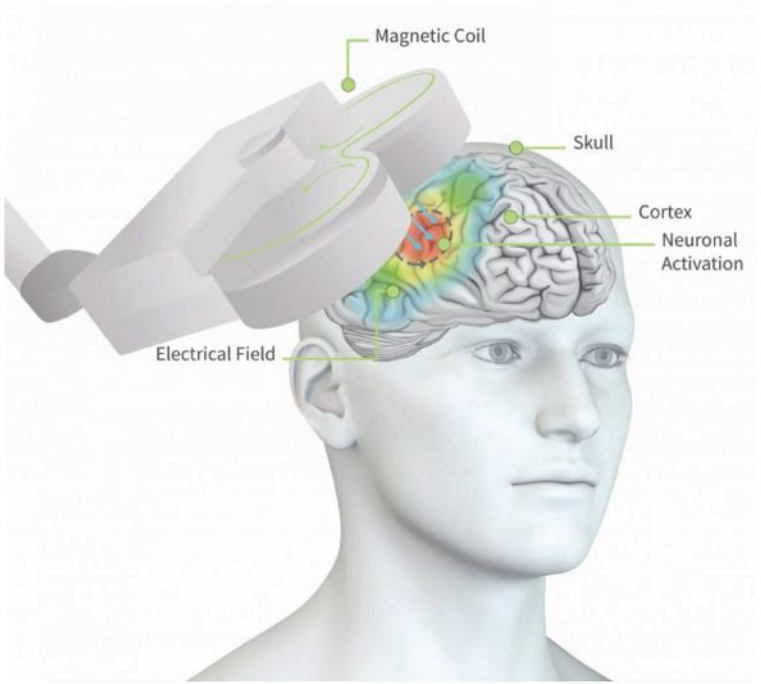
Abnormal occipital CBF

Cerebral Blood Flow

Wu et al., Neuroscience Bulletin 2023

Visual cortex -- a novel target for clinical stimulation therapy

repetitive Transcranial Magnetic Stimulation (rTMS)



Chronic treatment course:4-10 weeks
Adverse effects: headache, skin redness, tinnitus, nervousness

SCIENCE CHINA
Life Sciences

•RESEARCH PAPER•

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https://doi.org/10.1007/s11427-020-1730-5

Task-related functional magnetic resonance imaging-based neuronavigation for the treatment of depression by individualized repetitive transcranial magnetic stimulation of the visual cortex

Zhijun Zhang[1,2,6†*], Hongxing Zhang[2,3†], Chun-Ming Xie[1†], Meng Zhang[2†], Yachen Shi[1], Ruize Song[1], Xiang Lu[1,7], Haisan Zhang[3], Kun Li[2], Bi Wang[2], Yongfeng Yang[3], Xianrui Li[2], Jianli Zhu[2], Yang Zhao[4], Ti-Fei Yuan[5*] & Georg Northoff[1,6,7*]

Zhang et al., Science China. 2021

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3）Wu, F. A Comprehensive Overview of the Role of Visual Cortex Malfunction in Depressive Disorders: Opportunities and Challenges. (2023) doi:10.1007/s12264-023-01052-7.

4）Zhang, Z. *et al.* Task-related functional magnetic resonance imaging-based neuronavigation for the treatment of depression by individualized repetitive transcranial magnetic stimulation of the visual cortex. (2021).

5）Gandal, M. J. *et al.* Broad transcriptomic dysregulation occurs across the cerebral cortex in ASD. *Nature* **611**, 532–539 (2022).

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7）Lu, J. *et al.* An entorhinal-visual cortical circuit regulates depression-like behaviors. *Mol Psychiatry* **27**, 3807–3820 (2022).