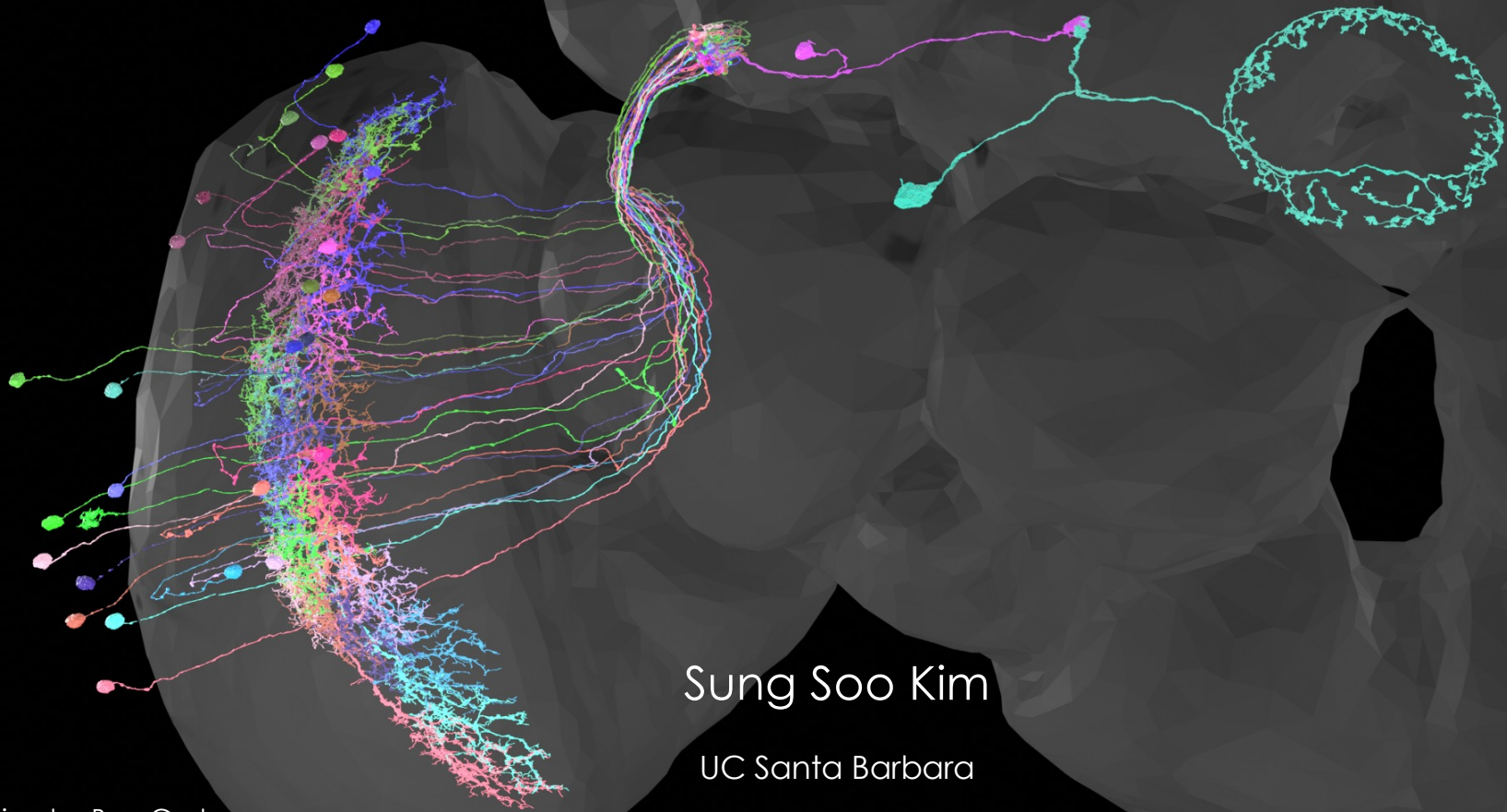


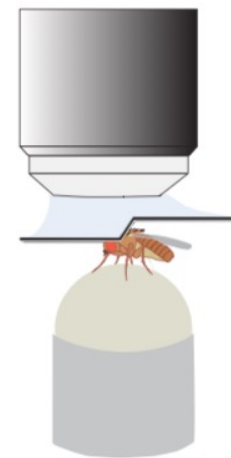
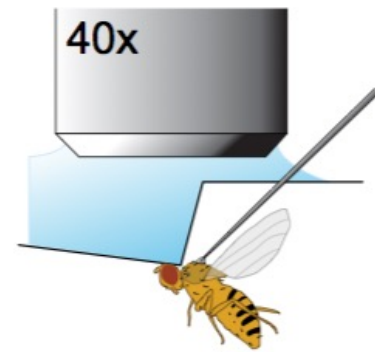
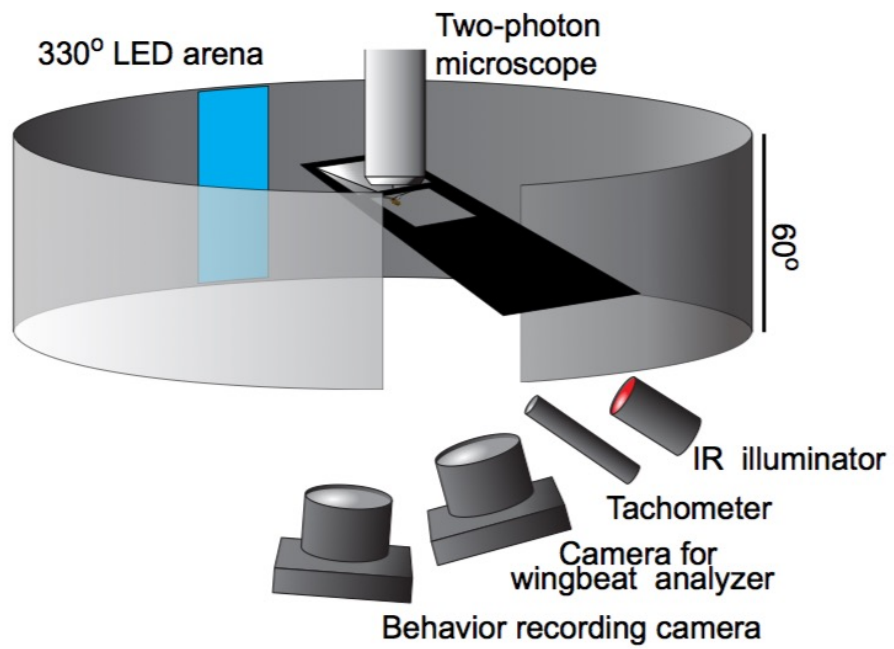
# Visual Processing during Navigation



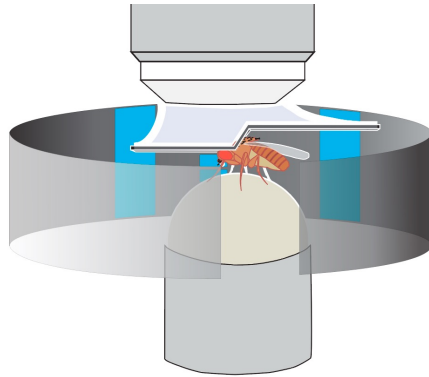
Sung Soo Kim

UC Santa Barbara





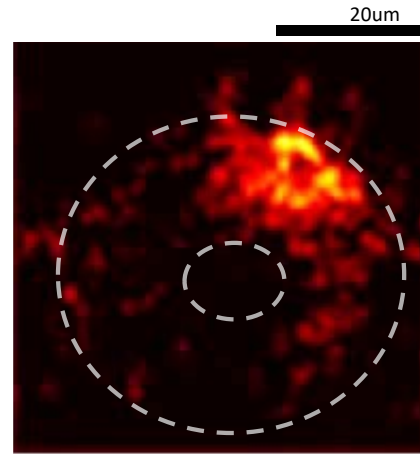
# An unique representation of orientation



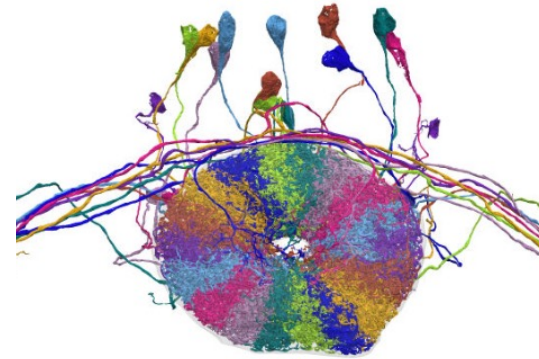
Visual arena



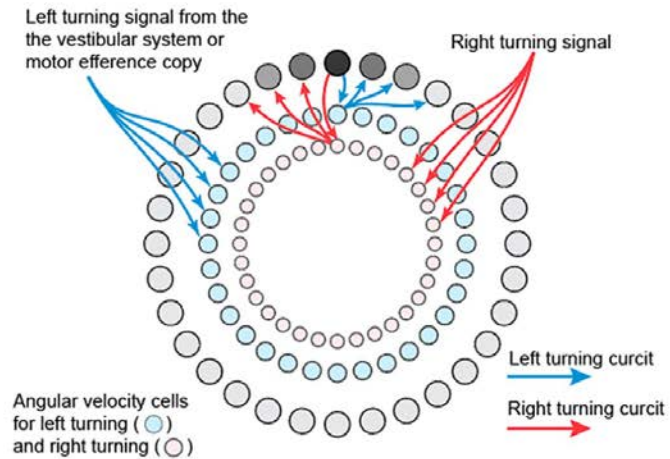
Tethered fly



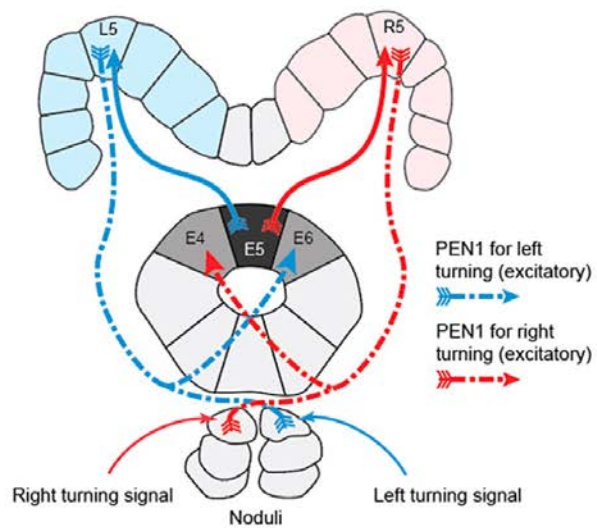
Calcium imaging of compass neurons with GCaMP



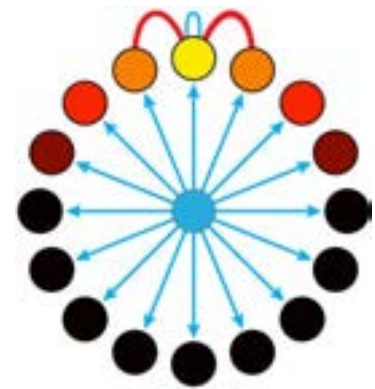
Johannes Seelig



Skaggs et al. 1995



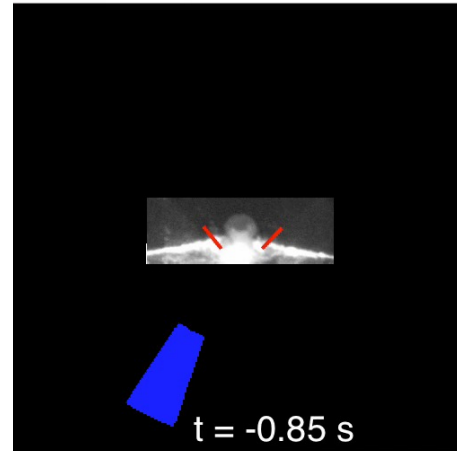
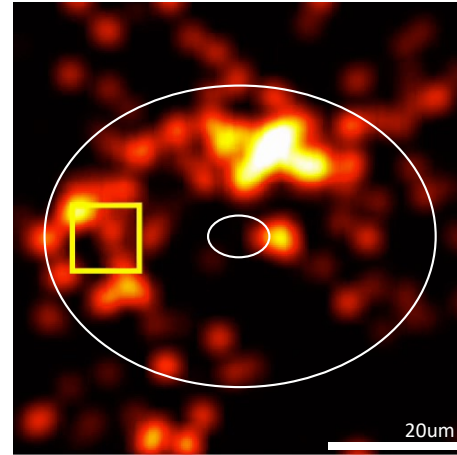
Turner-Evans, Wegener et al. 2017

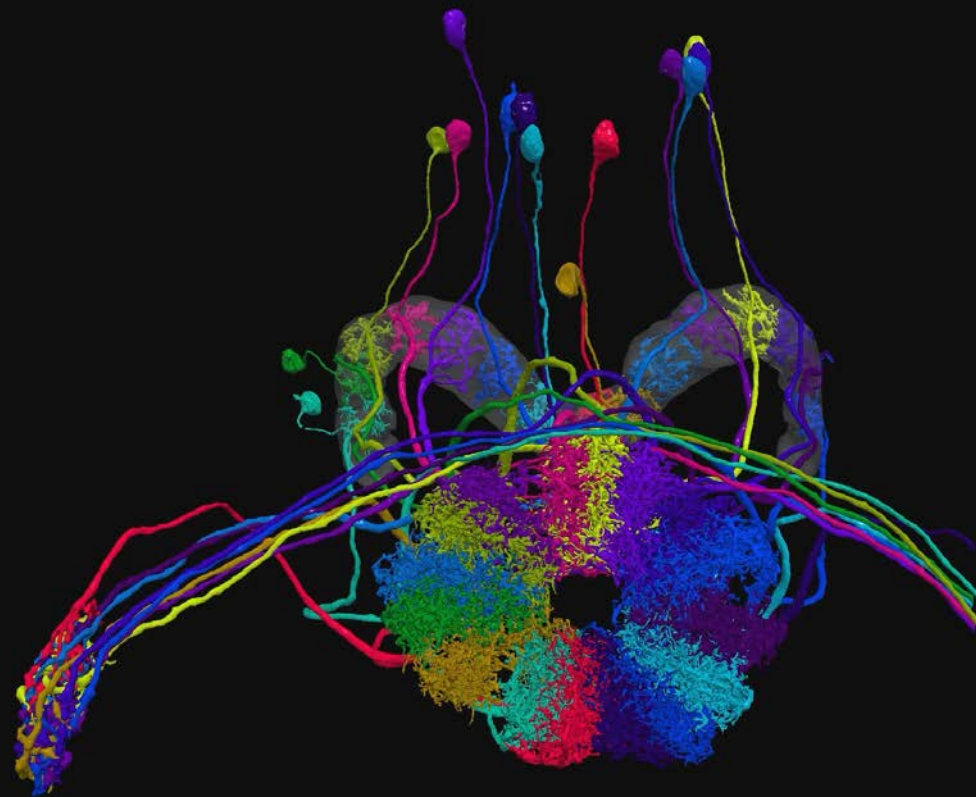


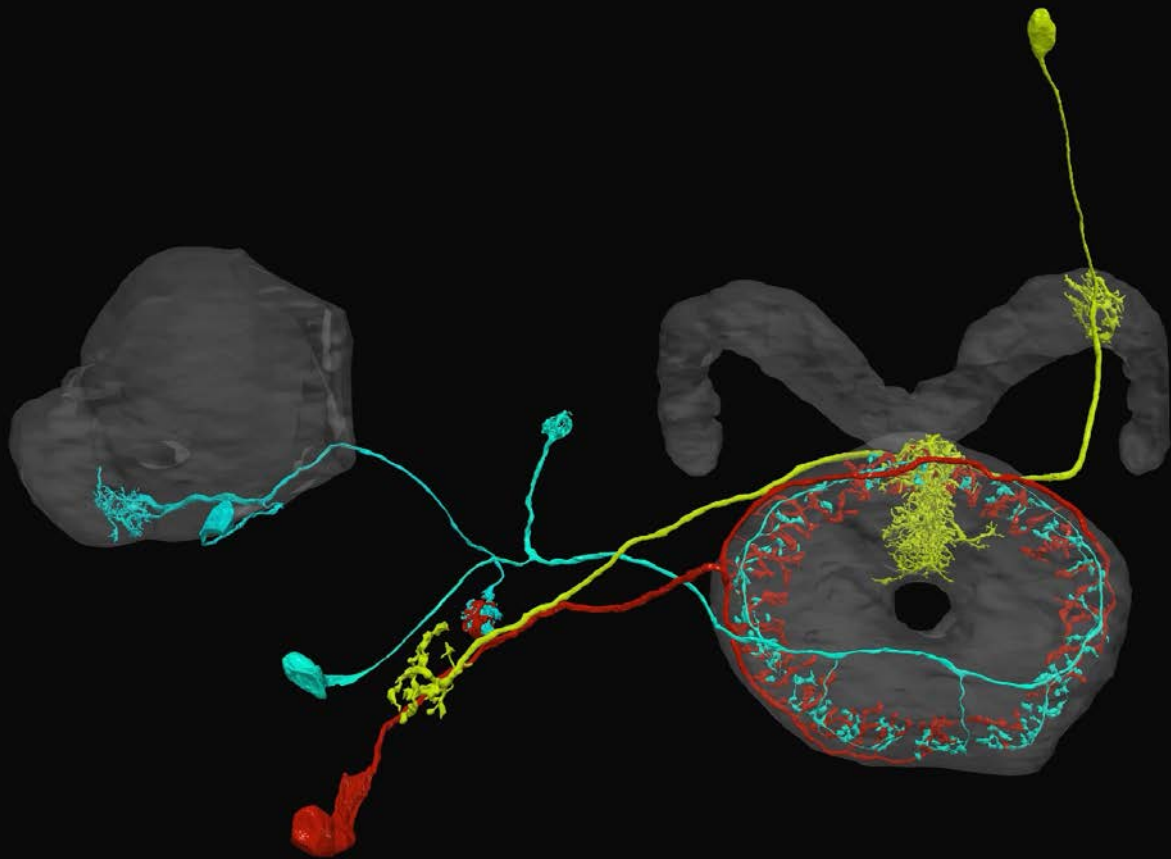
# Mutual suppression between compass neurons



Ring attractor



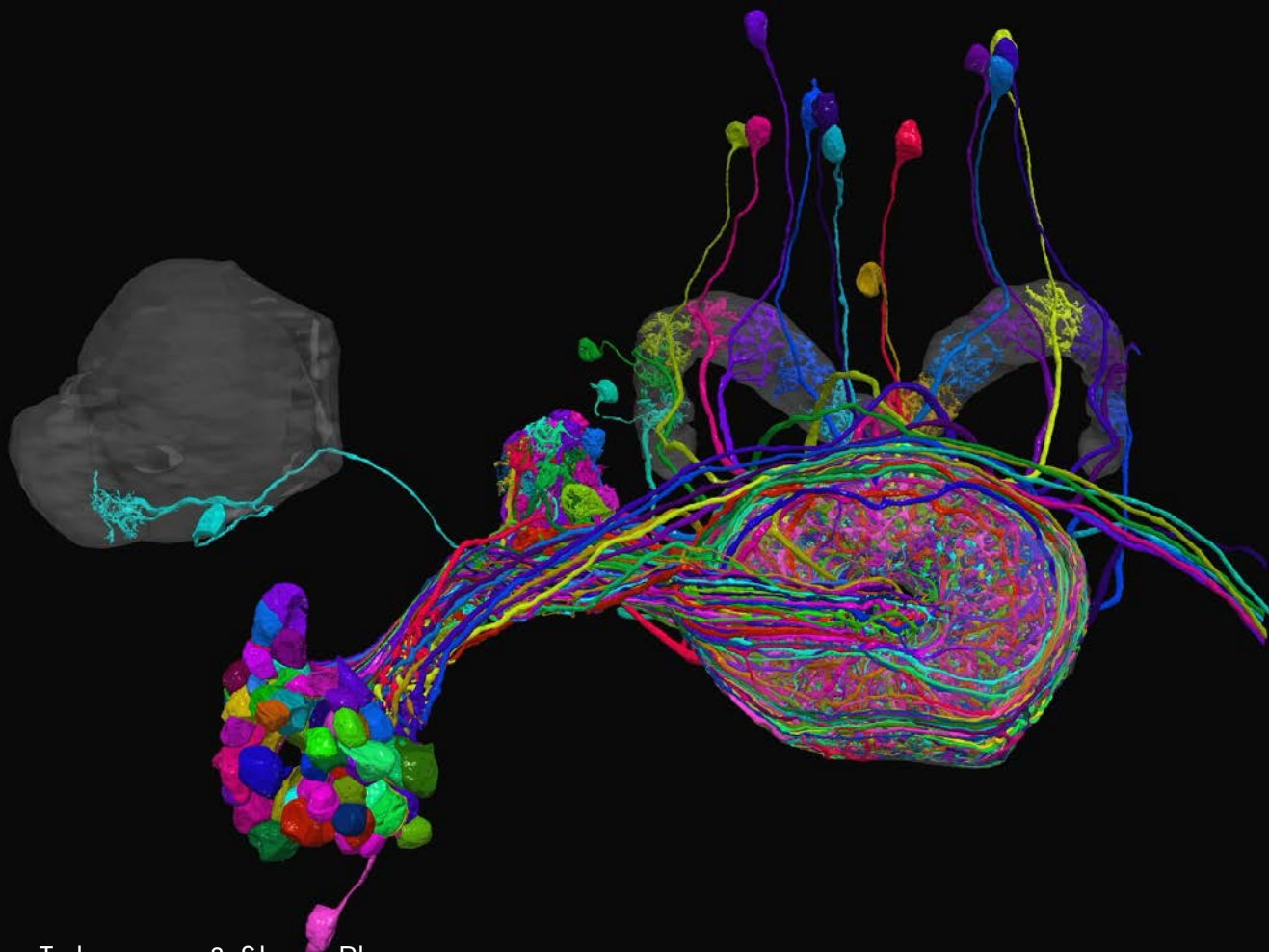


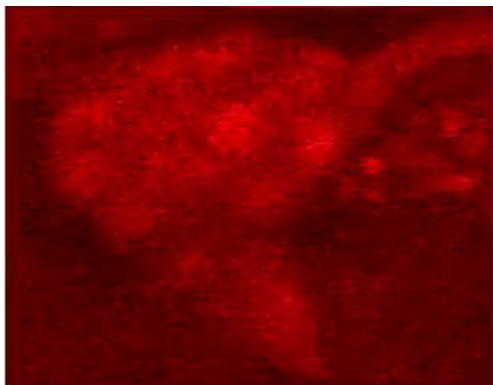
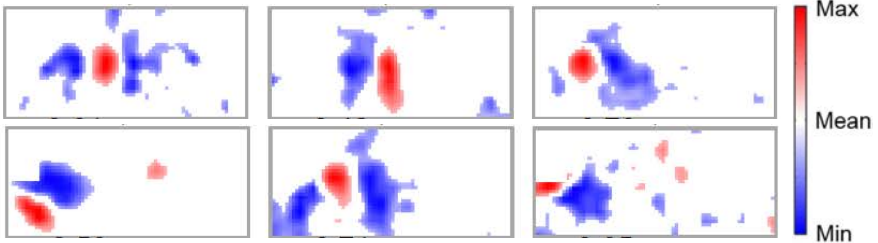


Movie credit: Shin-ya Takemura & Steve Plaza

Hulse et al. 2021

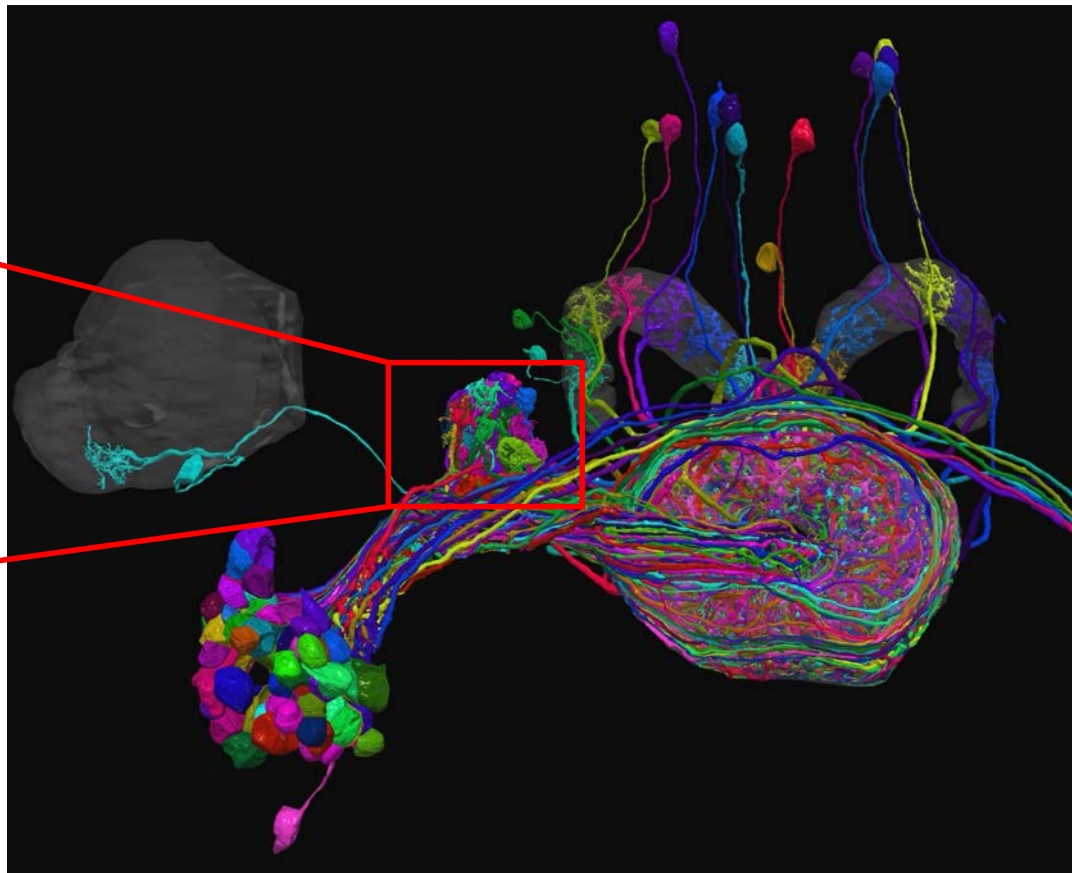






57C10-Gal4; UAS-GCaMP5

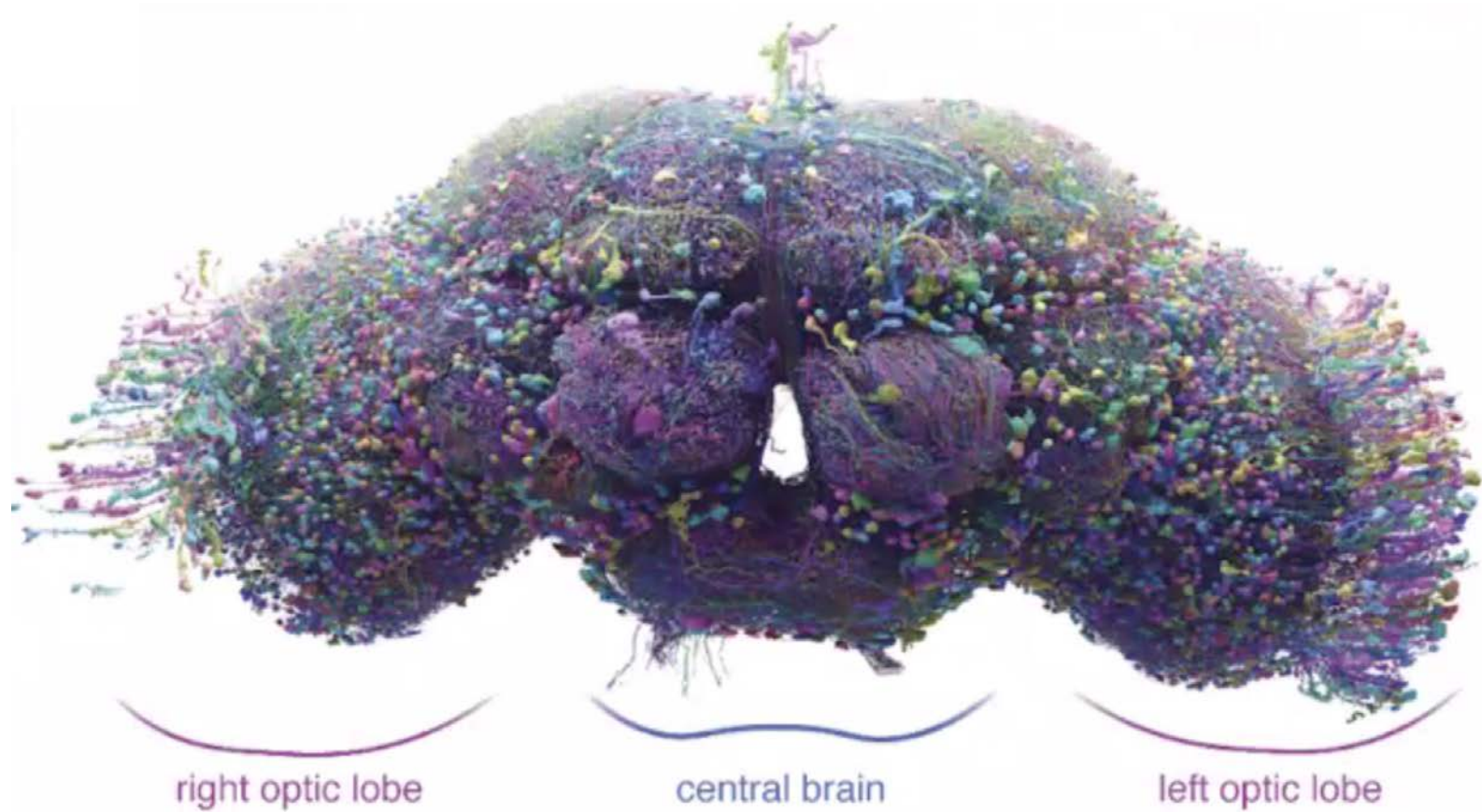
Seelig & Jayaraman, (2013)



Also see:  
Sun et al. (2017) Nat. Neurosci.  
Omoto et al. (2017) Curr. Biology

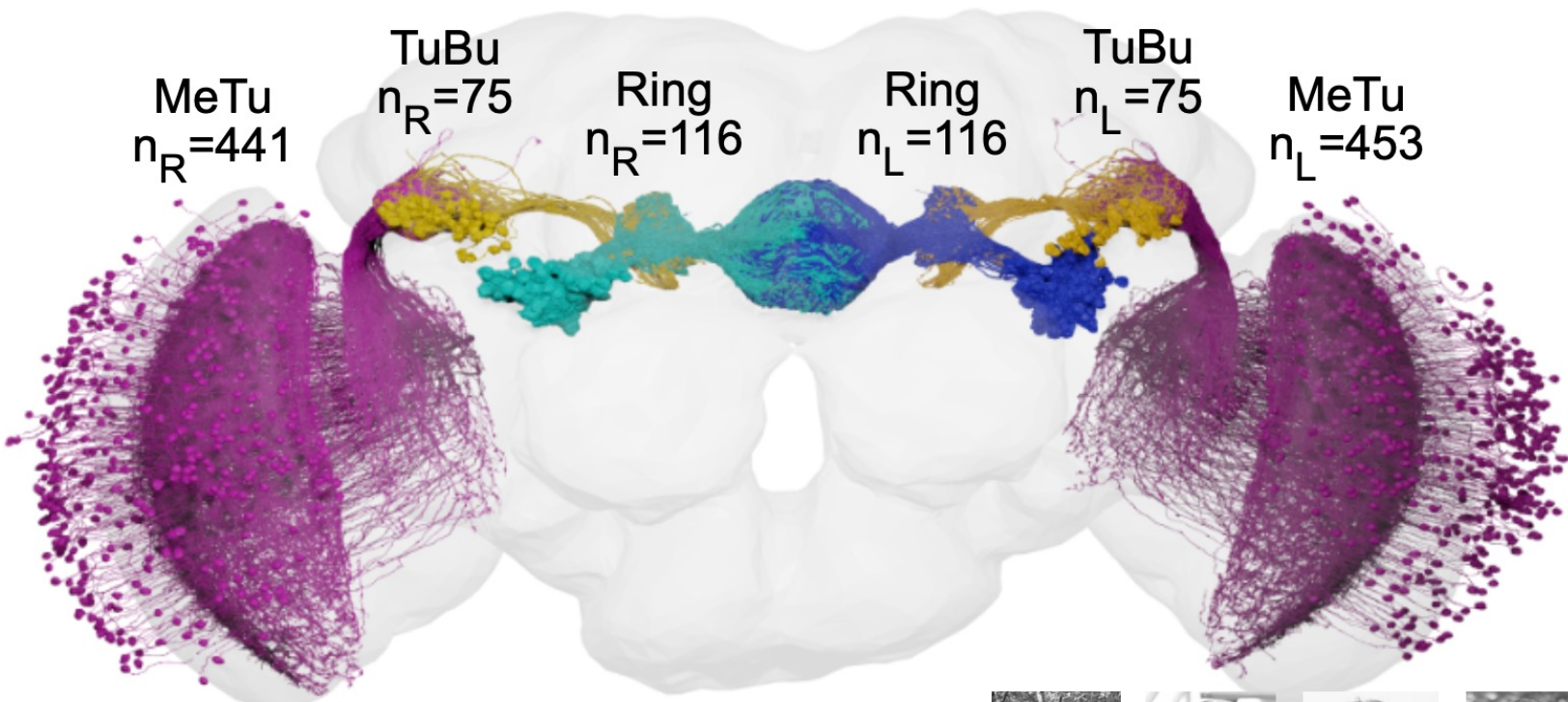


Johannes Seelig



Zheng et al. (2018; Bock lab), Dorkenwald et al. 2023 bioRxiv  
Rendering by FlyWire team at Princeton

# Anterior Visual Pathway



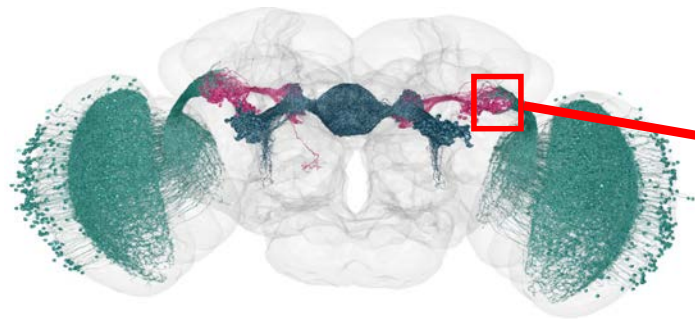
FAFB: Zheng et al. (2018) Cell



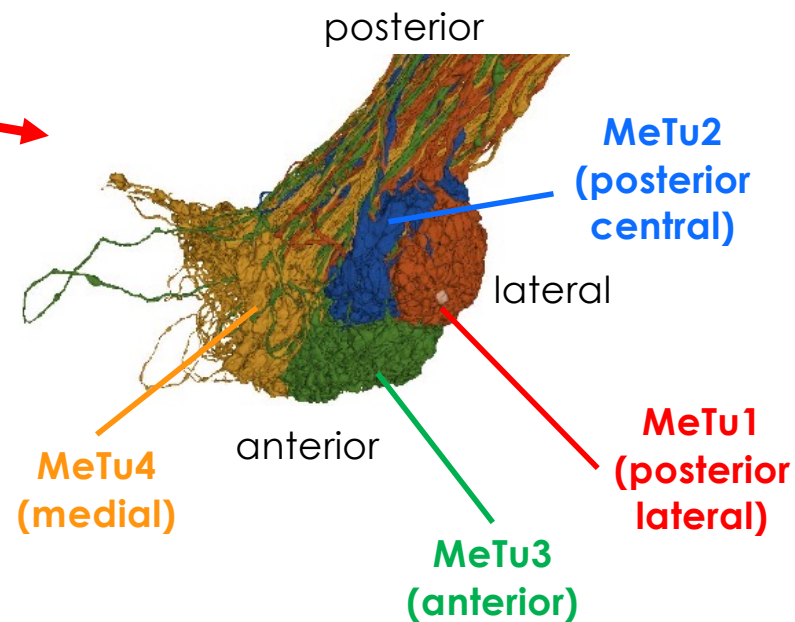
Dustin Garner    Lucy Houghton    Aljoscha Nern    Emil Kind    Mathias Wernet

Hulse, Haberkern, Franconville, Turner-Evans, et al. (2021)

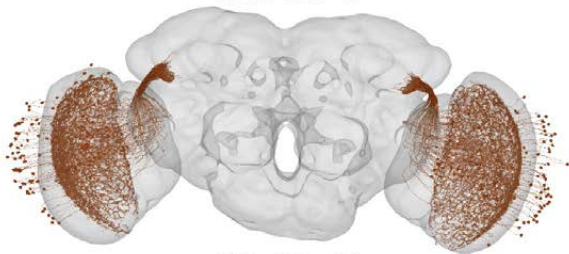
Garner, Kind et al. (2023) bioRxiv



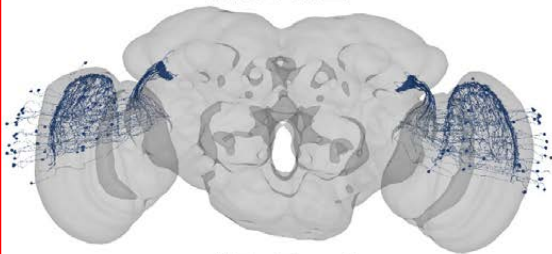
## AOTu Top-down view



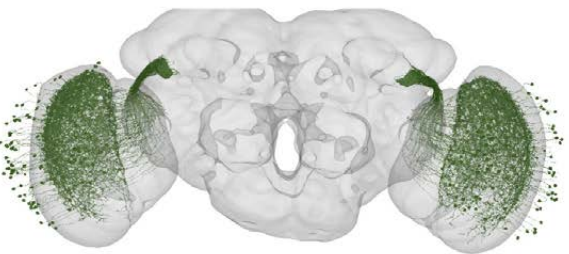
### MeTu 1



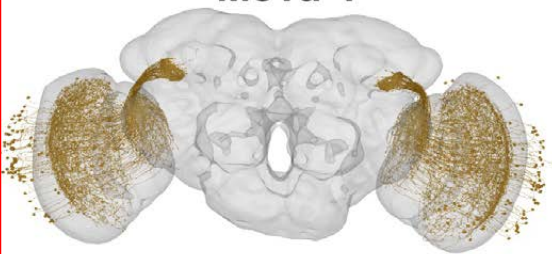
### MeTu 2



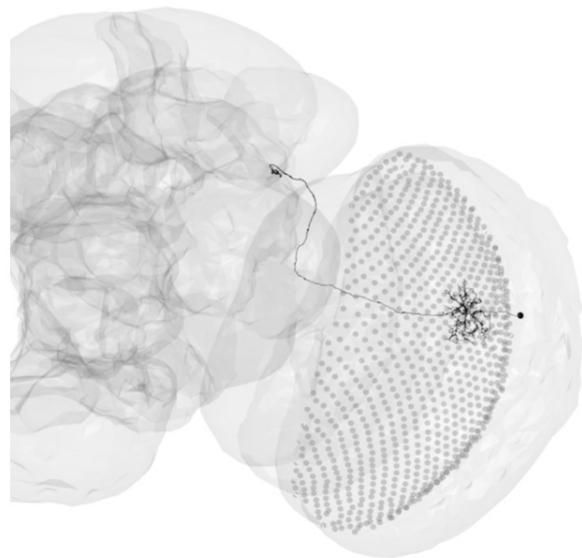
### MeTu 3



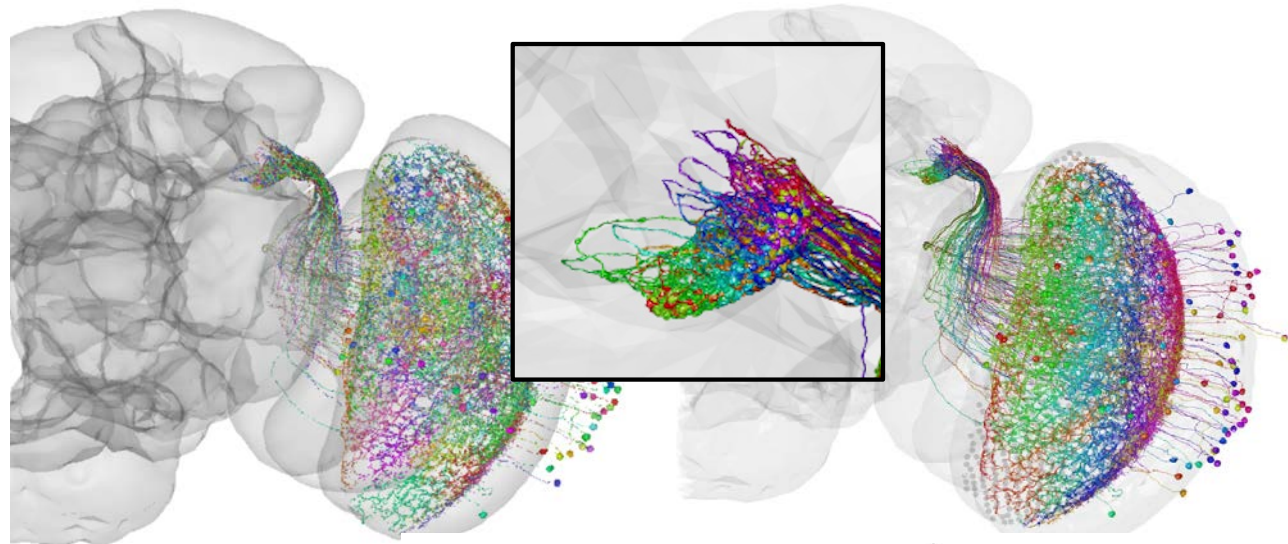
### MeTu 4



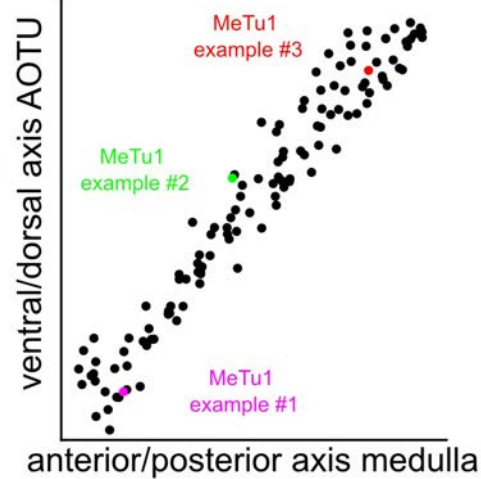
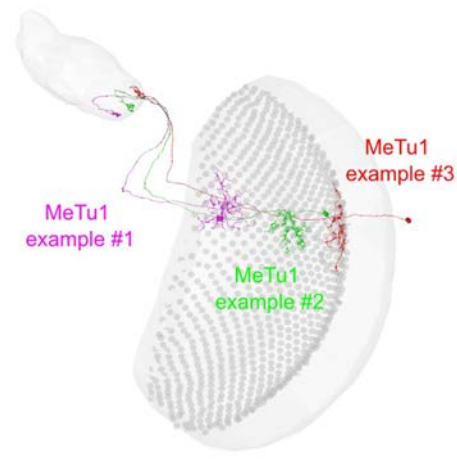
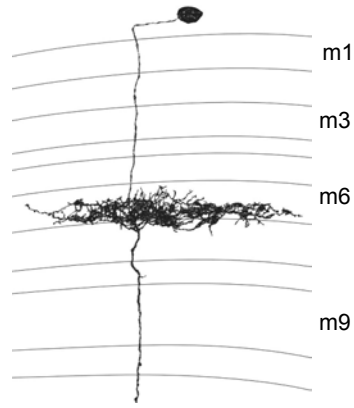
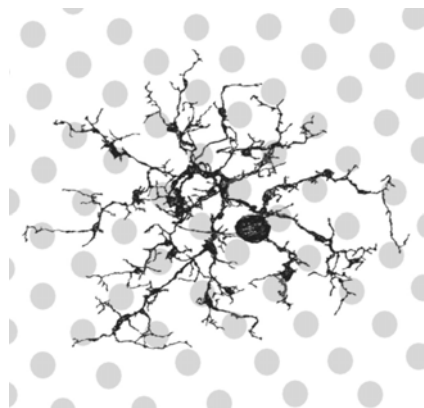
# MeTu1



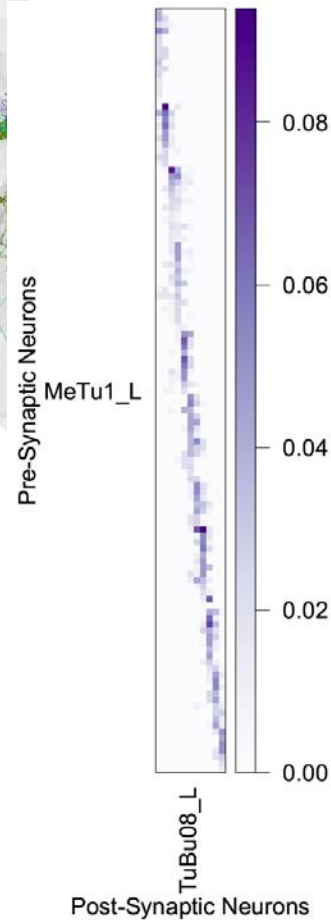
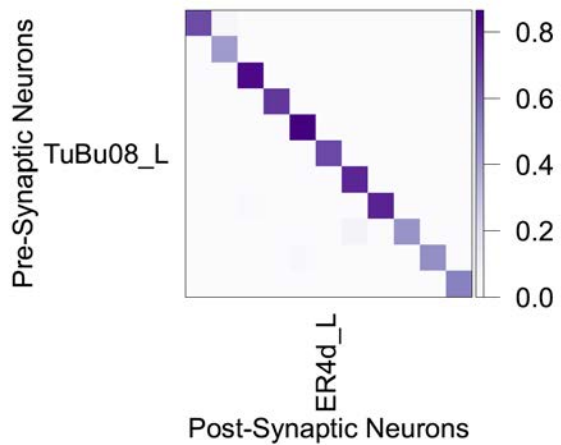
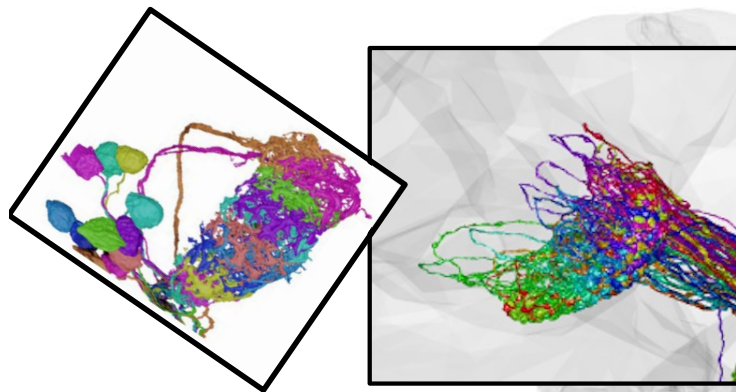
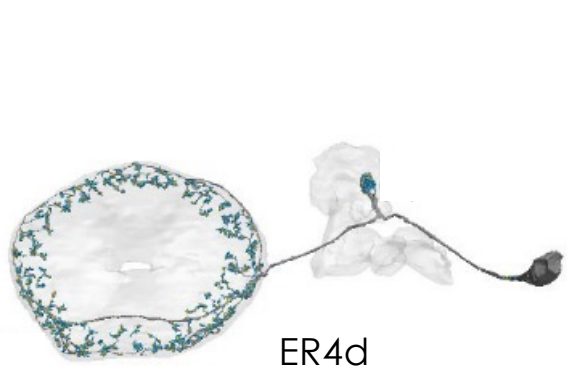
top view



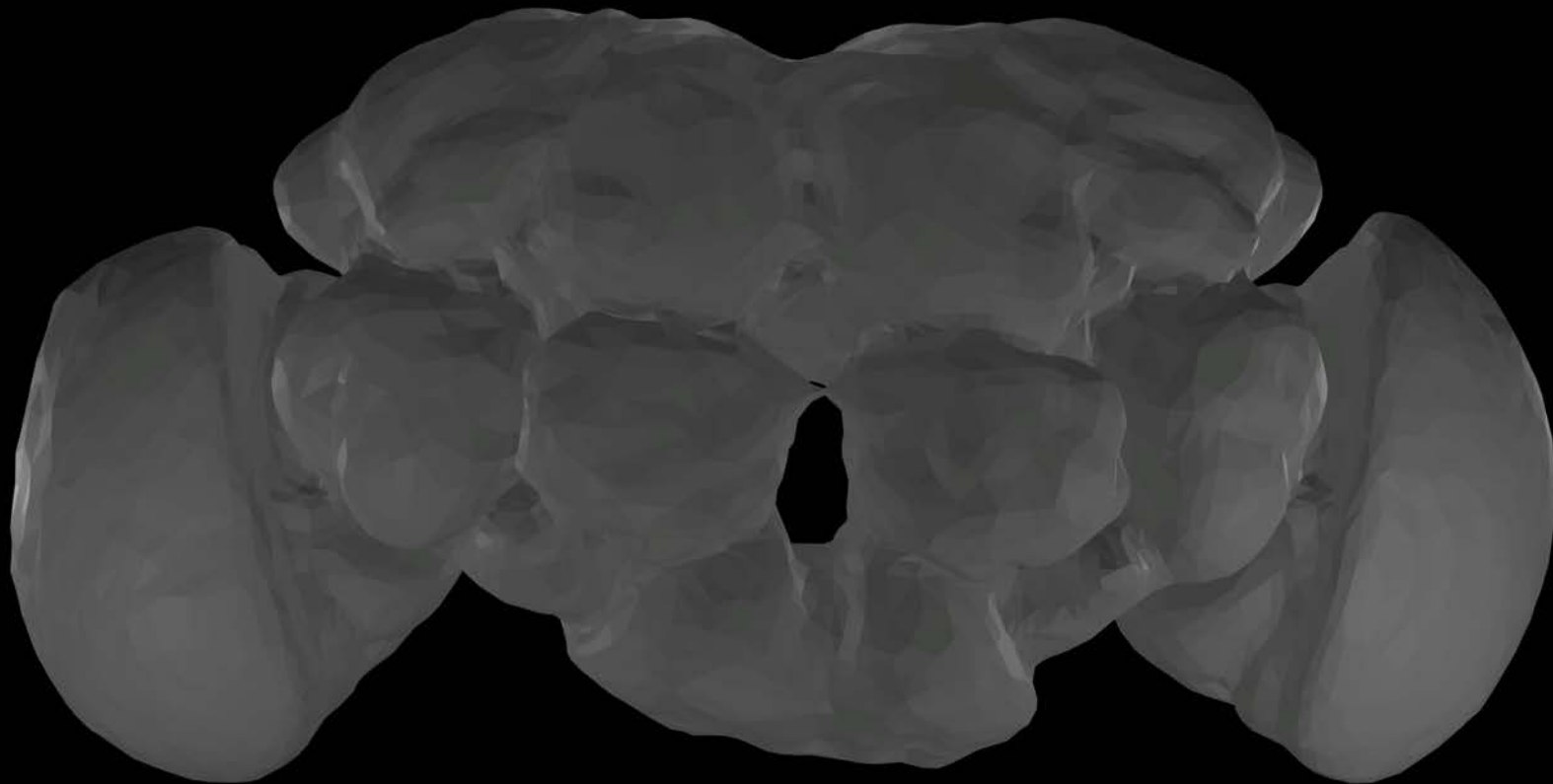
side view



# MeTu1



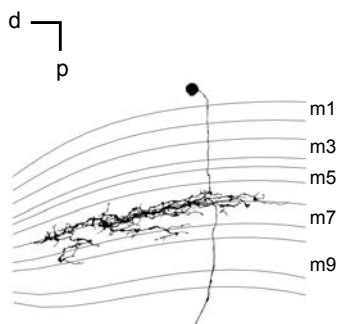
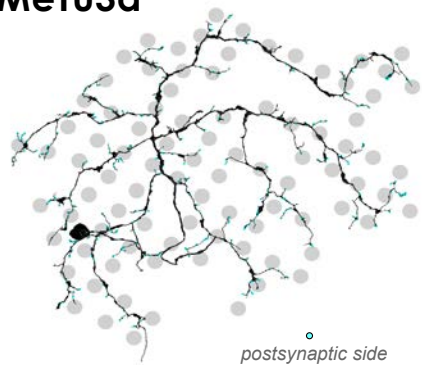
# MeTu1 pathway to ER4d neurons processes vertical stripes



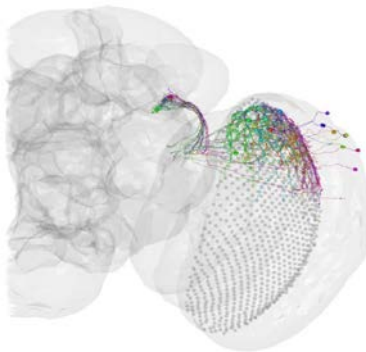


# MeTu3

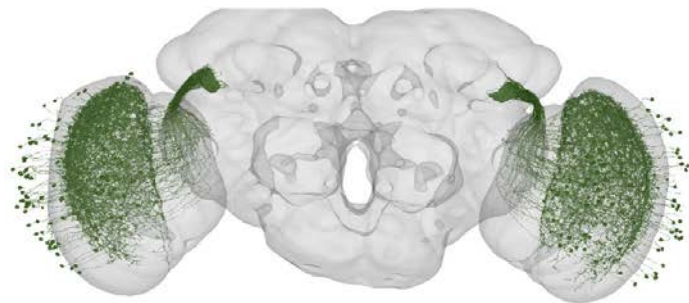
## MeTu3a



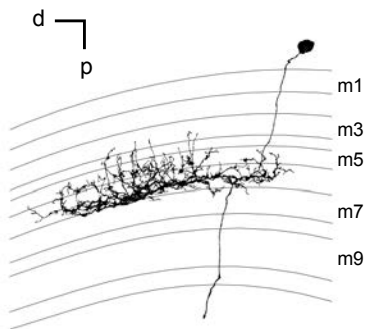
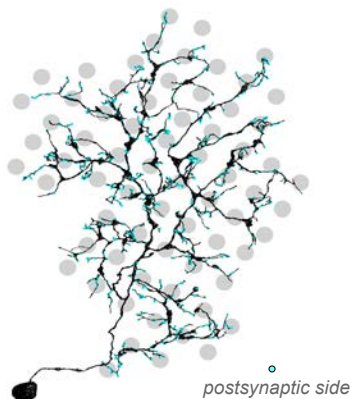
## MeTu3a



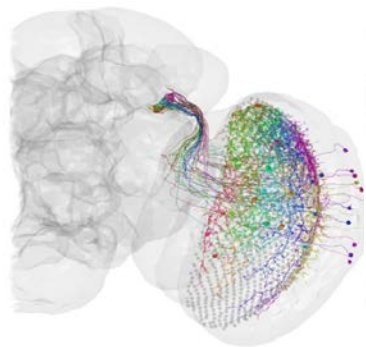
## MeTu 3



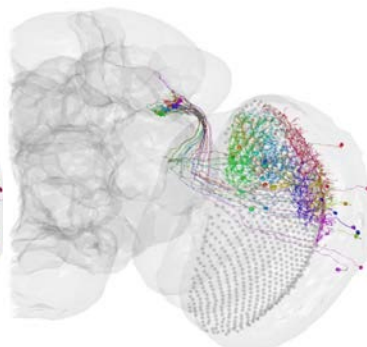
## MeTu3b and c



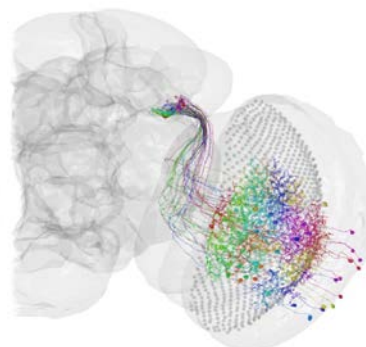
## MeTu3b



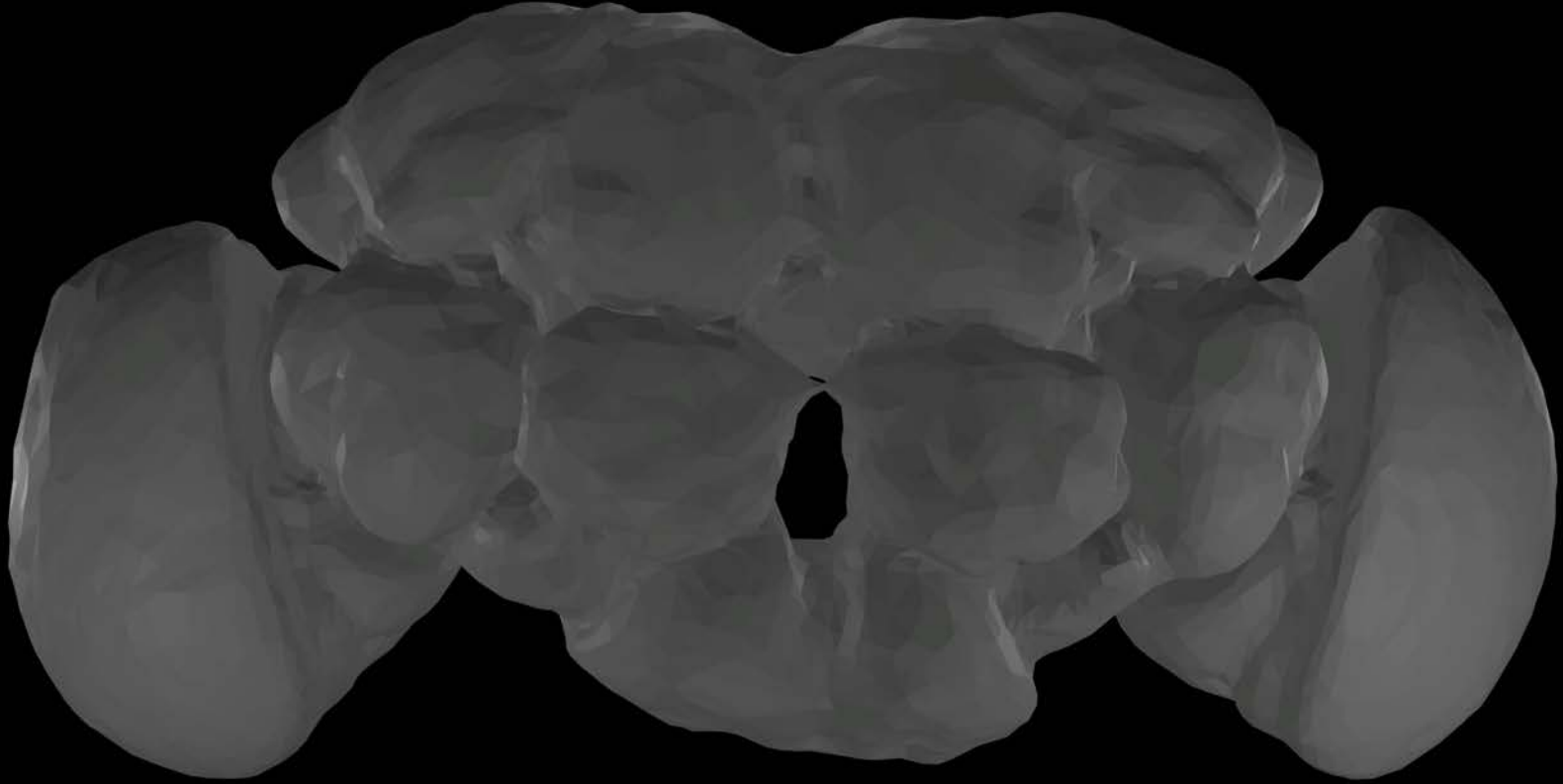
## MeTu3c\_dorsal



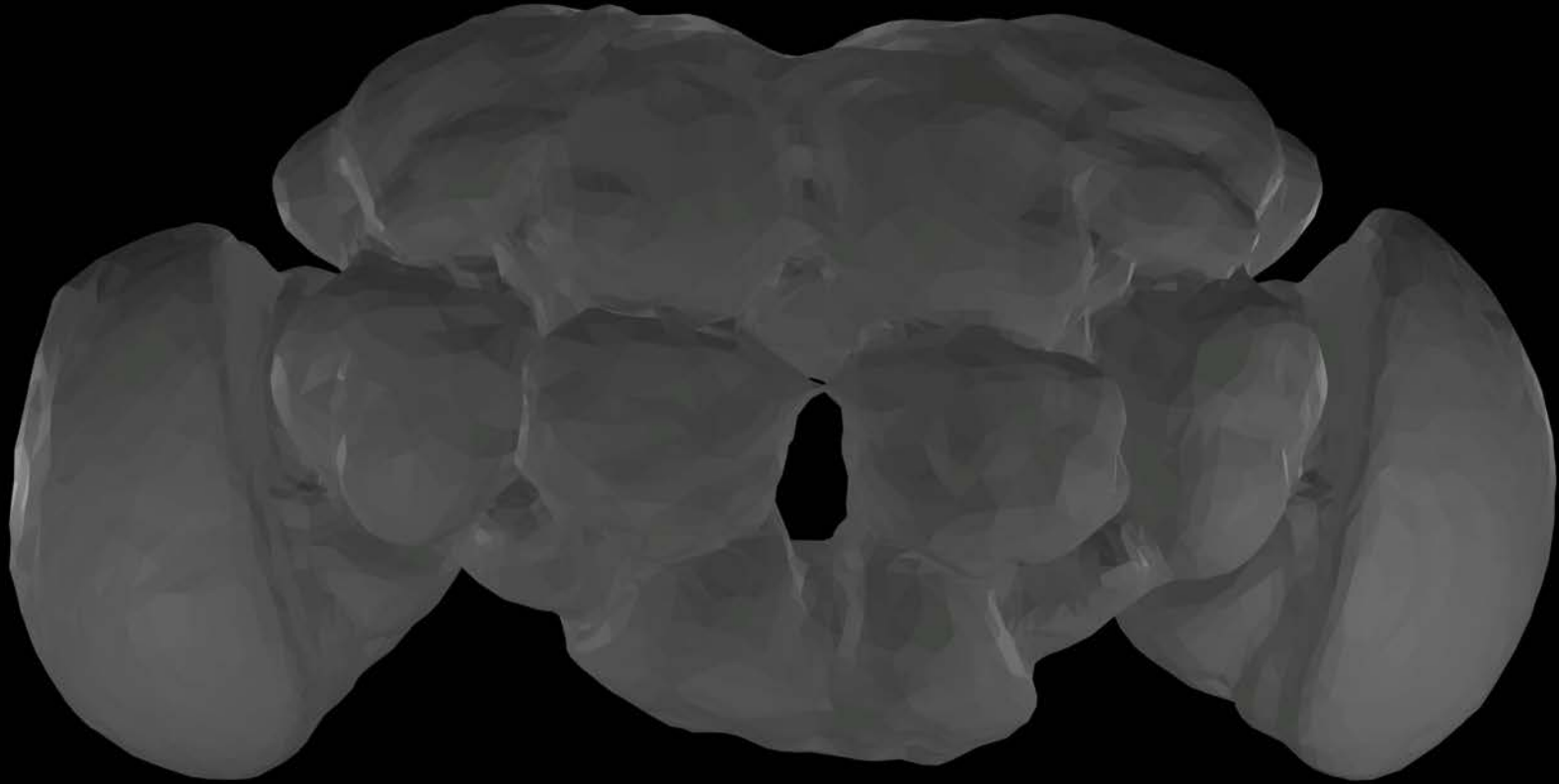
## MeTu3c\_ventral

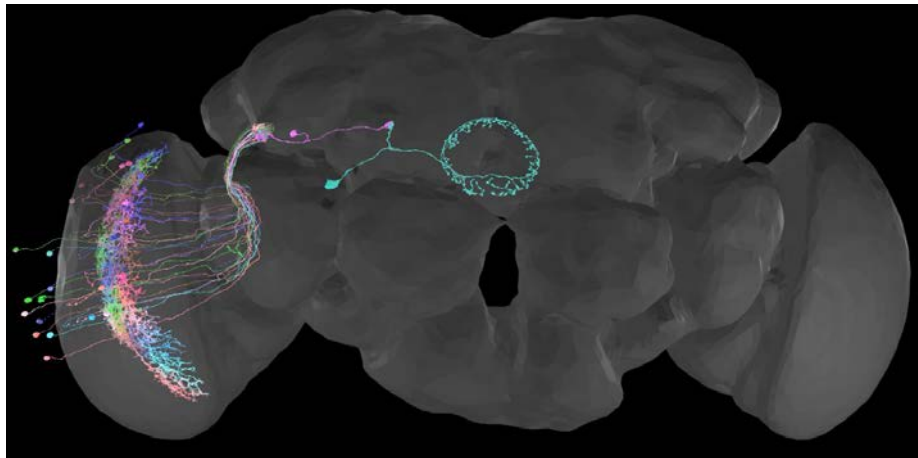


# MeTu3 pathway to ER2abd processes 2D scene (dorsal)

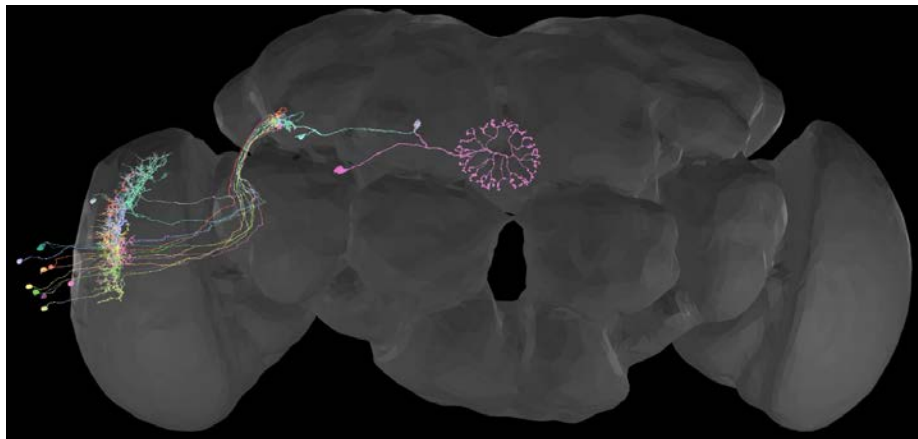


# MeTu3 pathway to ER2abd processes 2D scene (ventral)

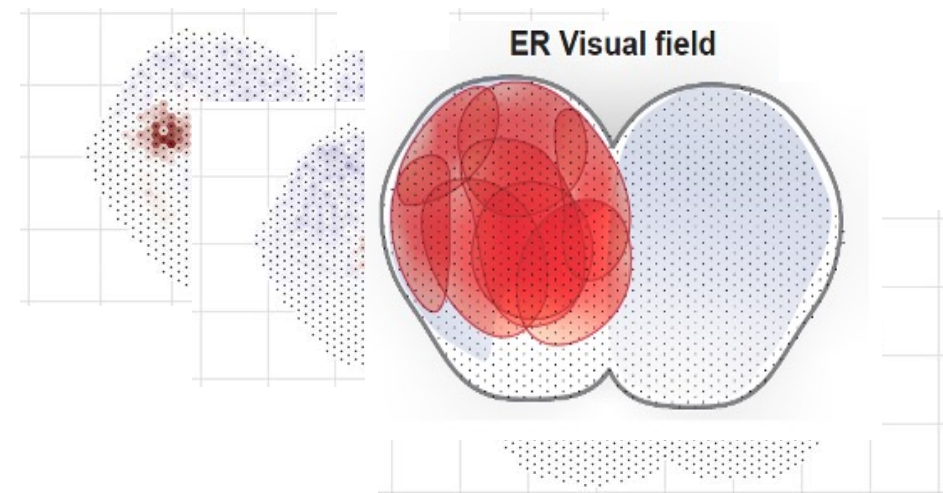
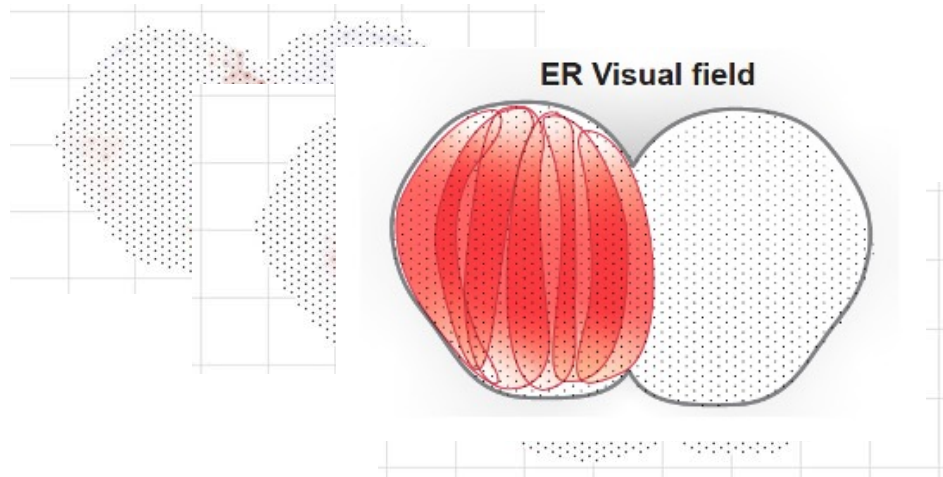


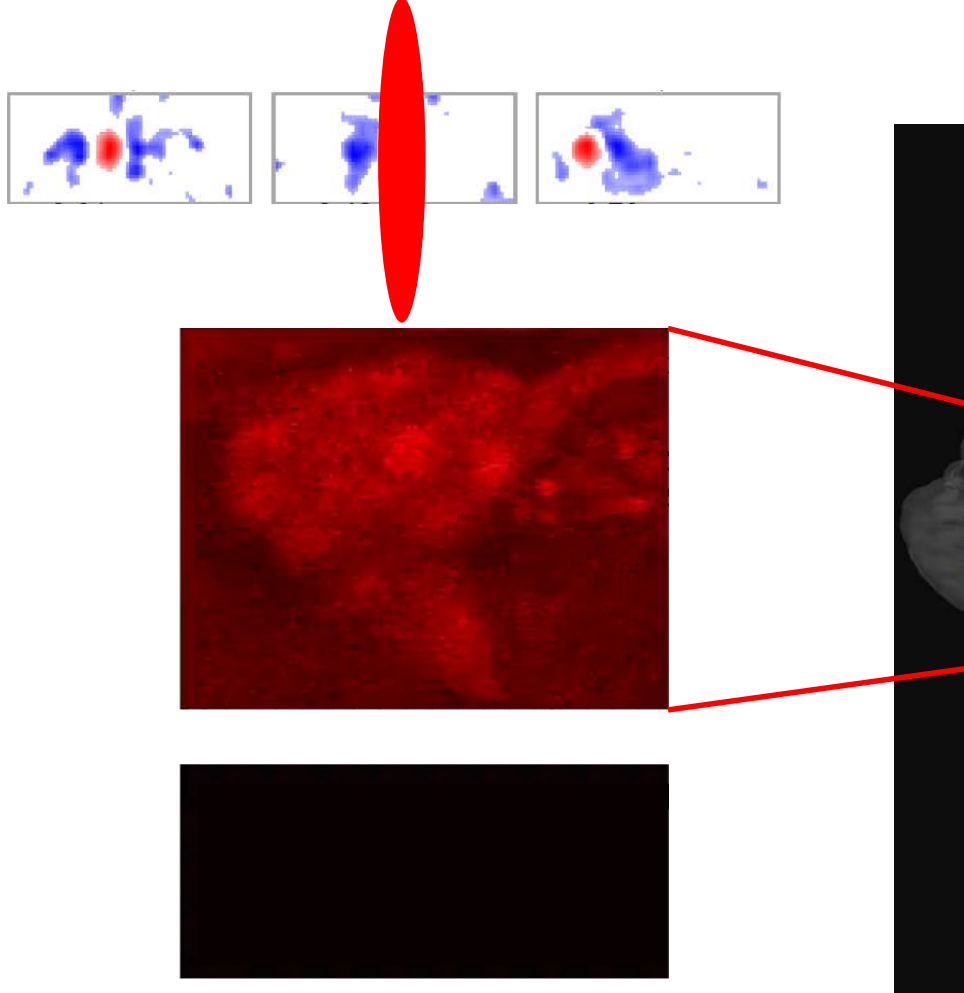


MeTu1 → ER4d



MeTu3 → ER2abd

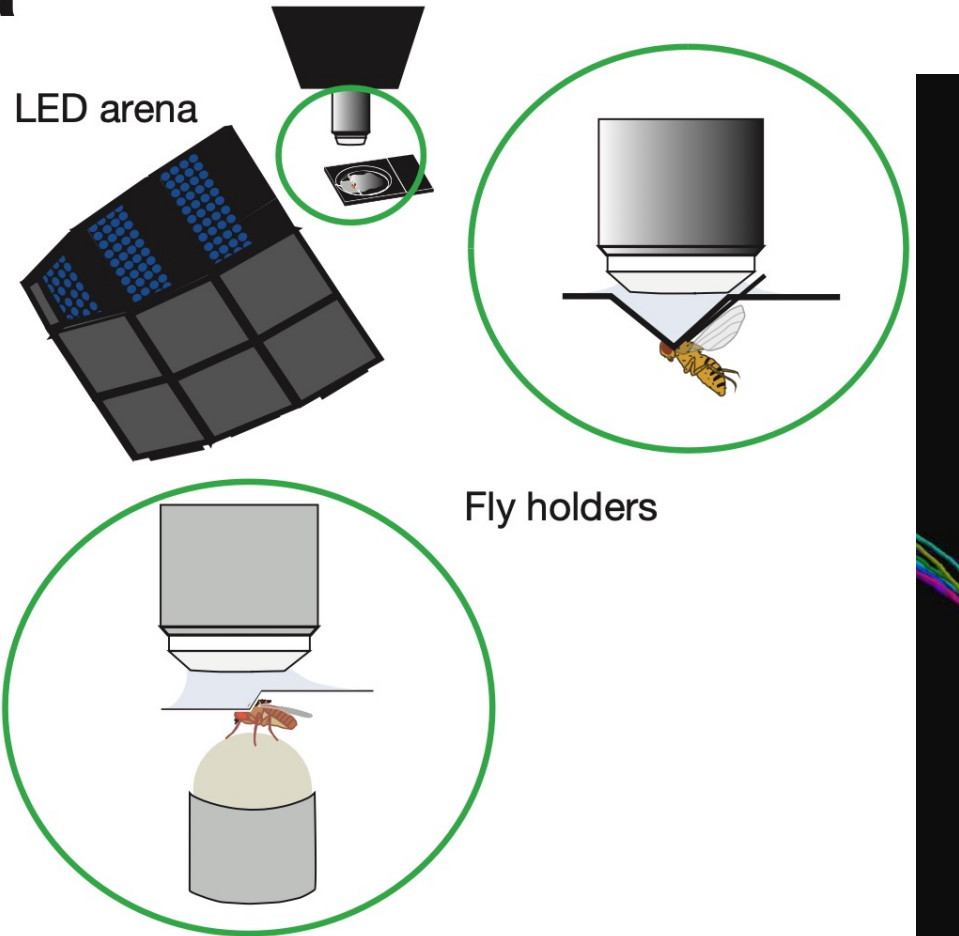




57C10-Gal4; UAS-GCaMP5

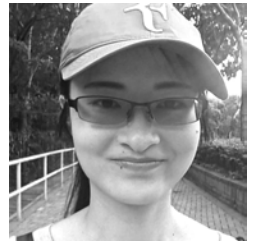
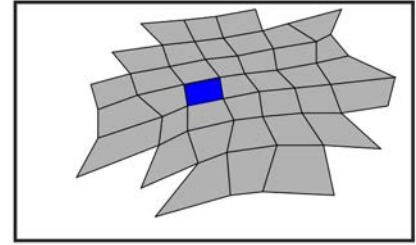
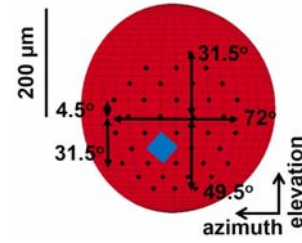
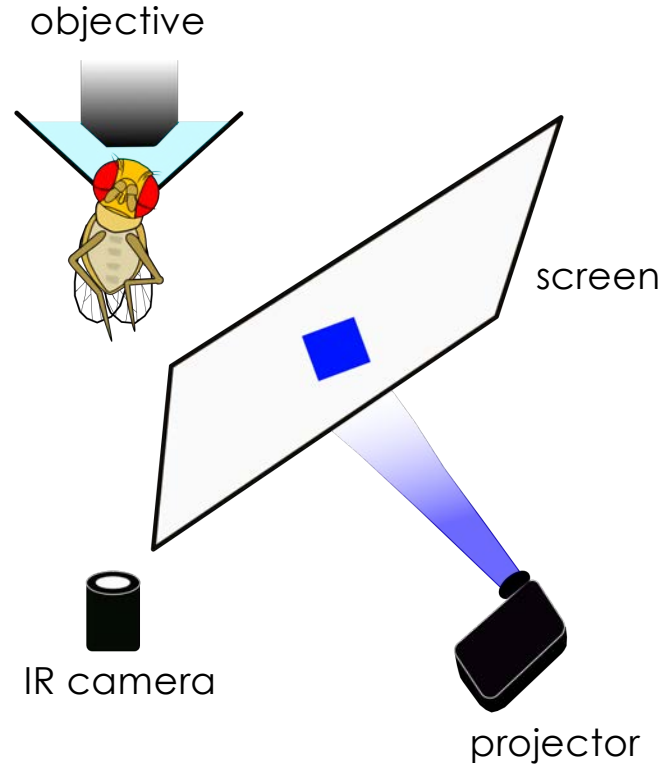
Seelig & Jayaraman (2013)

**a**



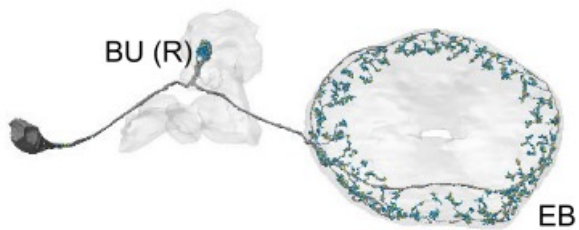
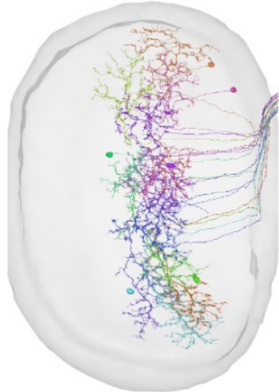
Also see:  
 Sun et al. (2017) Nat. Neurosci.  
 Omoto et al. (2017) Curr. Biology

# A novel visual stimulation setup

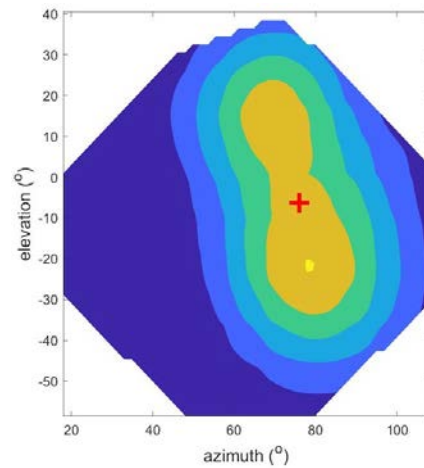


Jennifer  
Lai

MeTu1



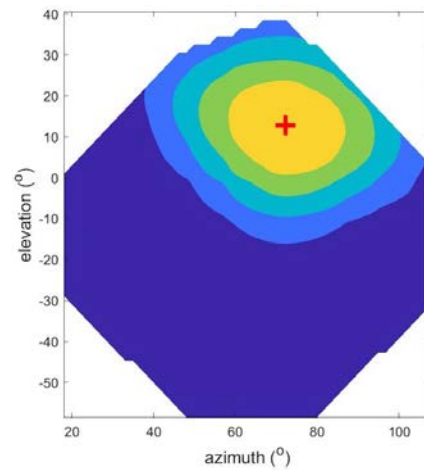
ER4d



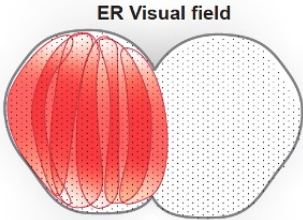
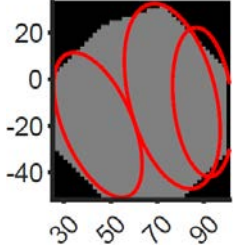
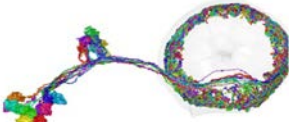
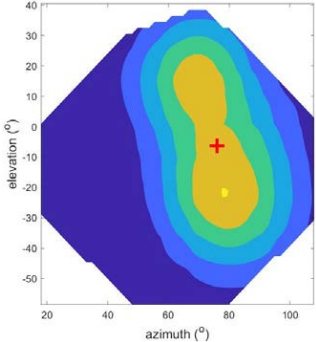
MeTu3



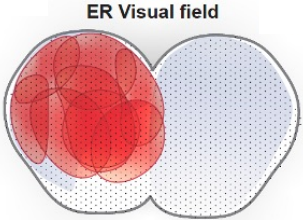
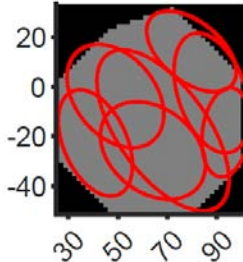
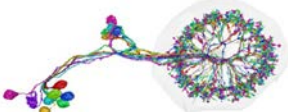
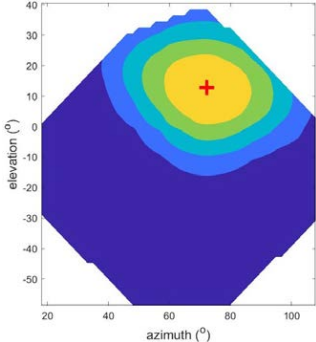
ER2



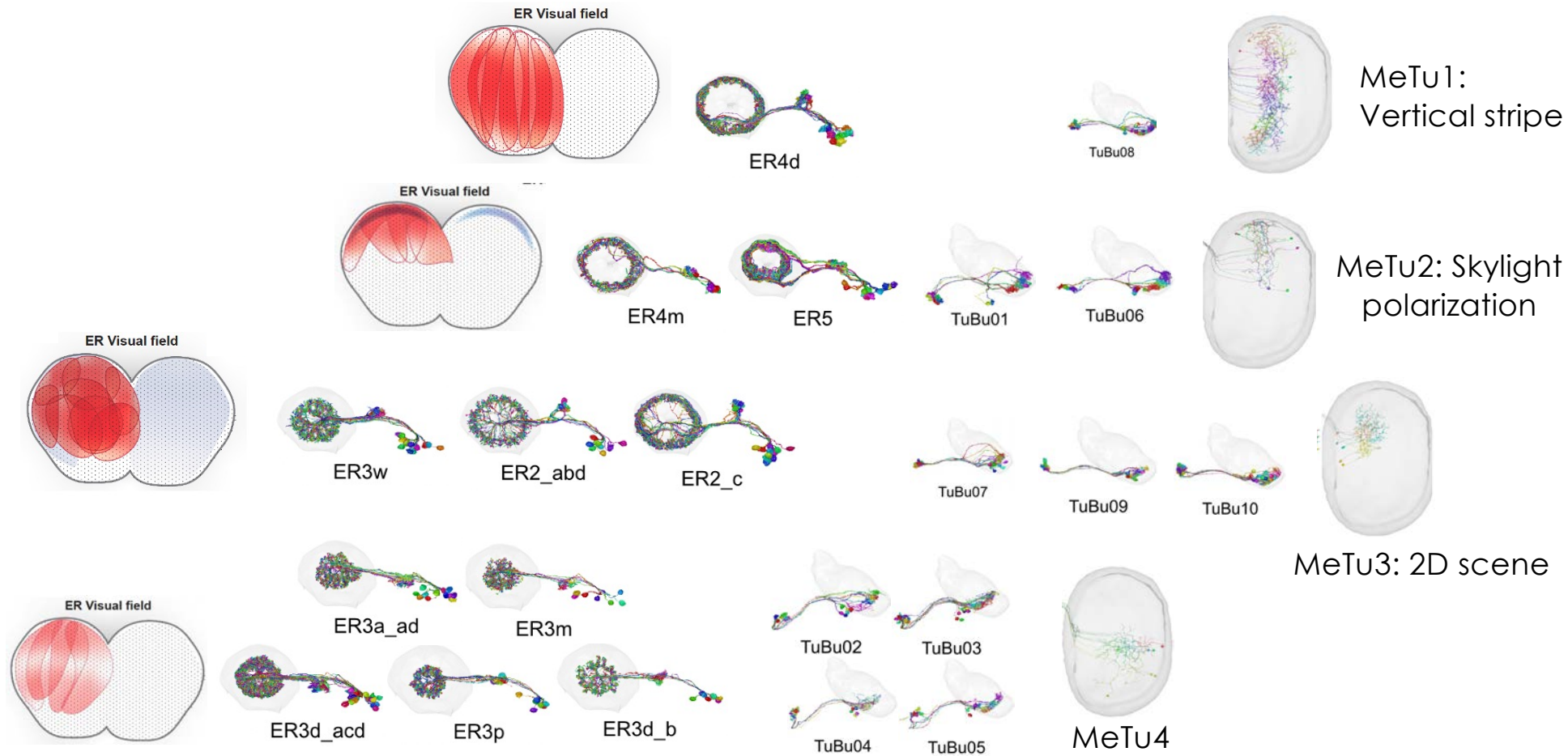
# ER4d: process vertical stripe



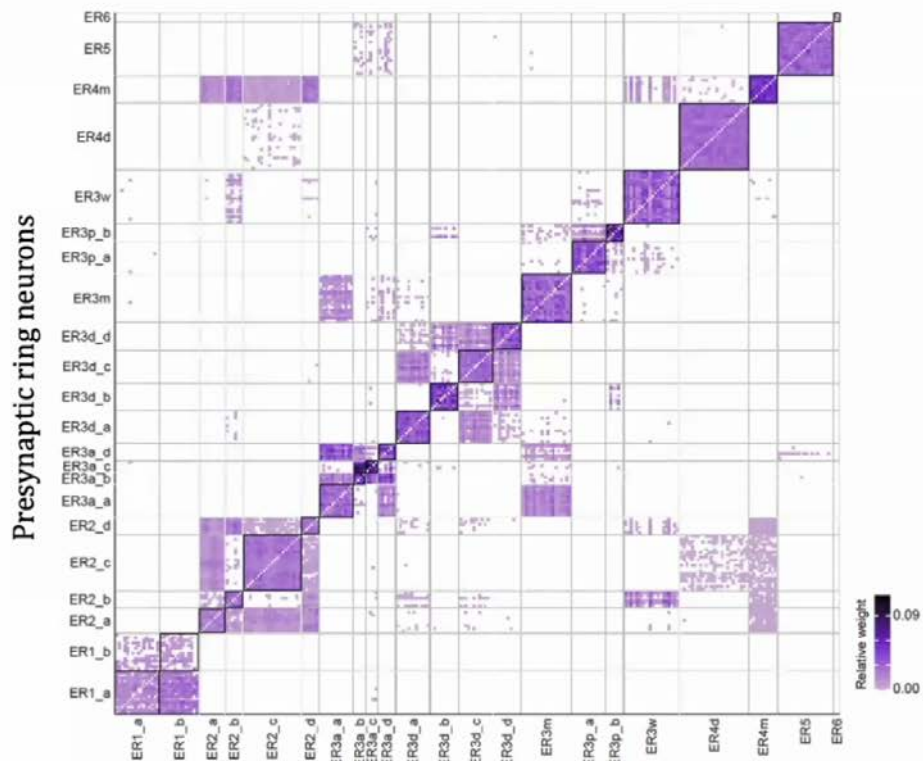
# ER2: process 2D scene



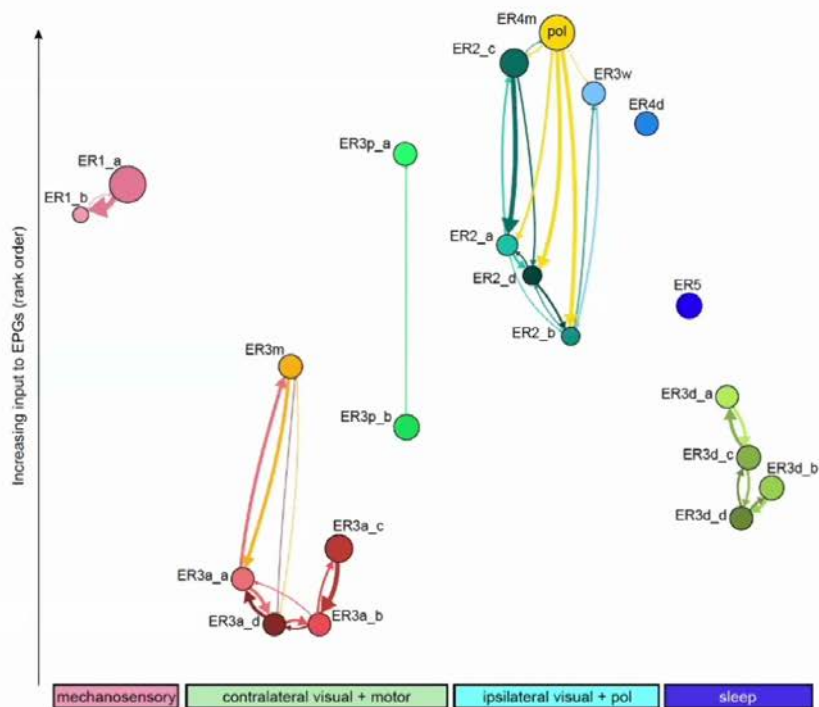




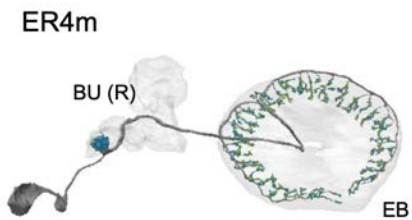
# A hierarchy of sensory inputs to the compass



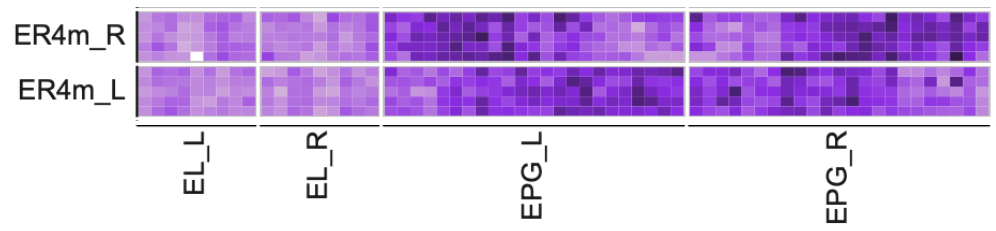
Postsynaptic ring neurons



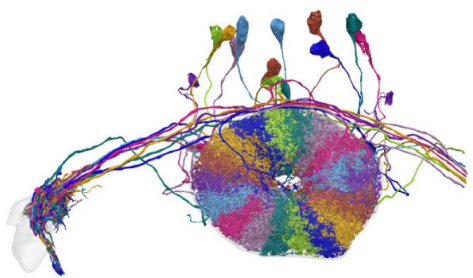
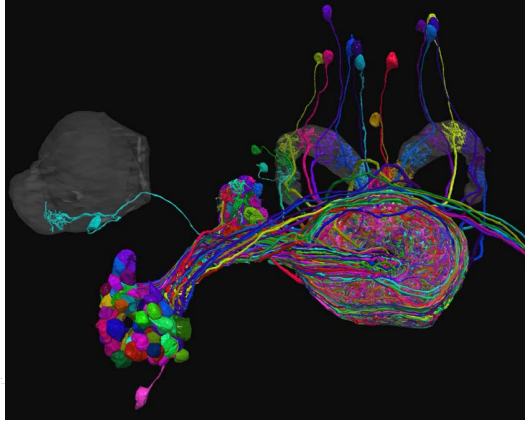
B.K. Hulse\*, H. Haberkern\*, R. Franconville\*, D.B. Turner-Evans\* et al. (2021)



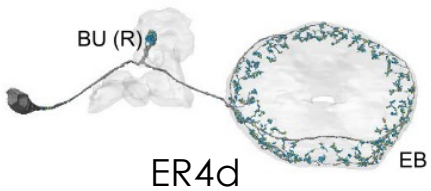
presynaptic neuron



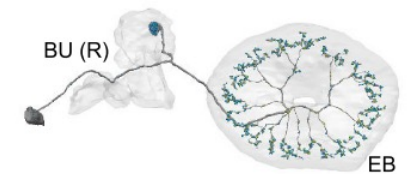
postsynaptic neuron



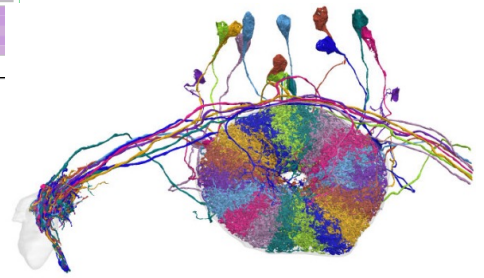
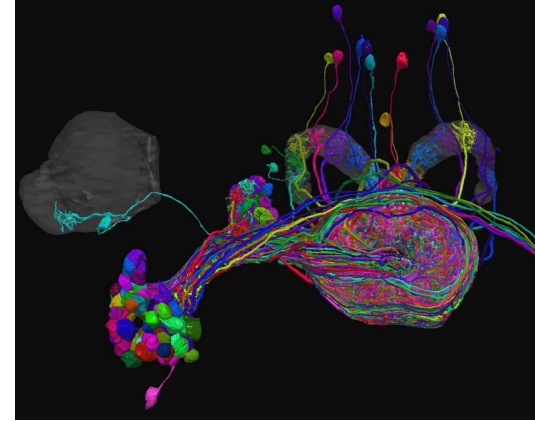
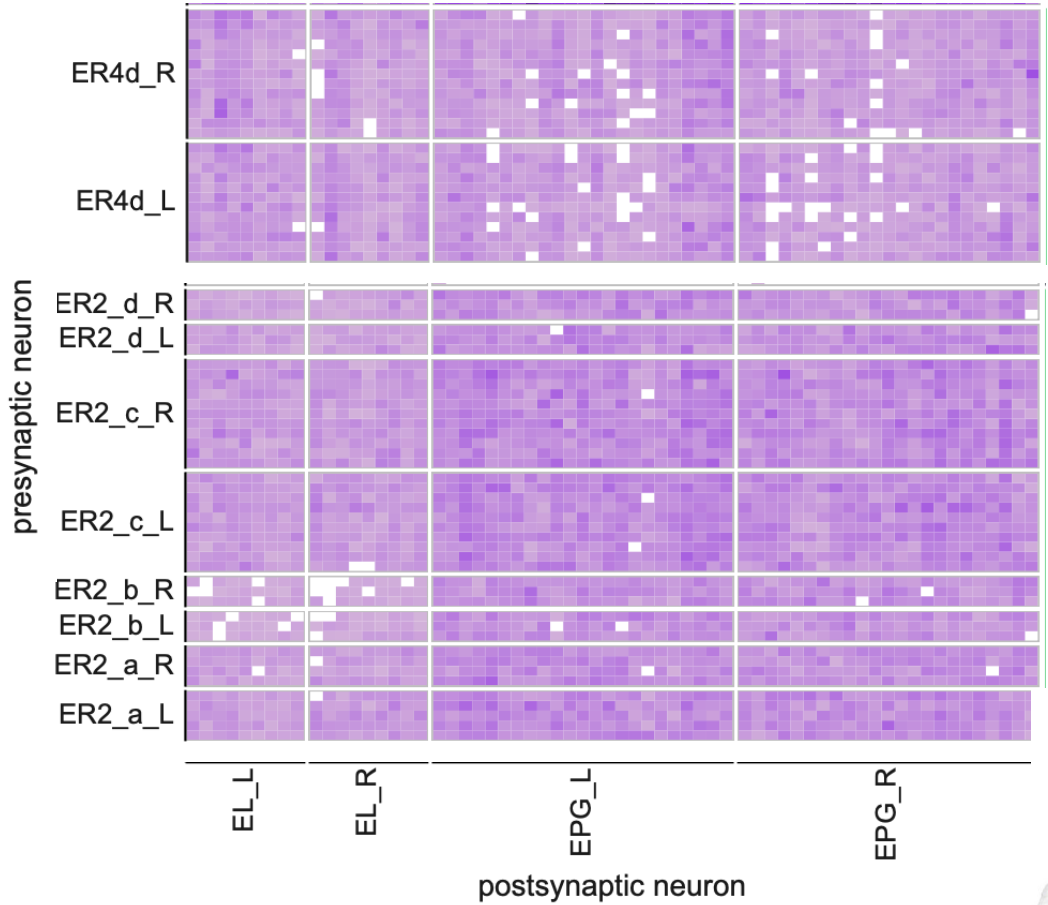
Compass neurons



ER4d



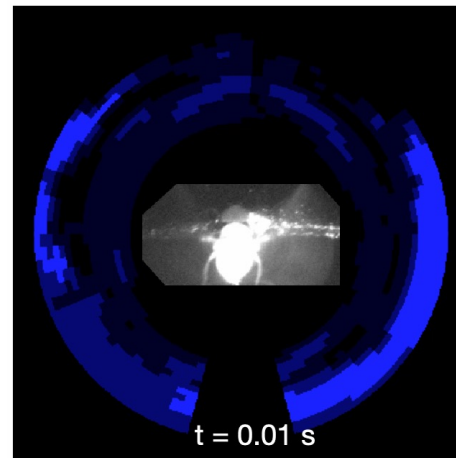
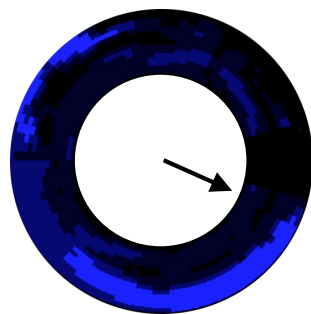
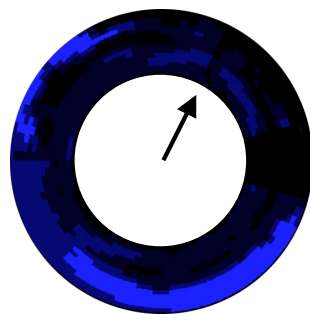
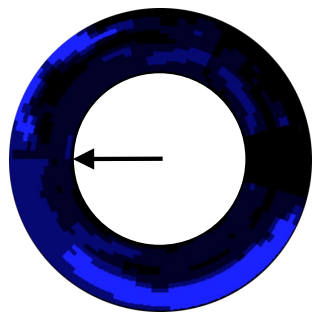
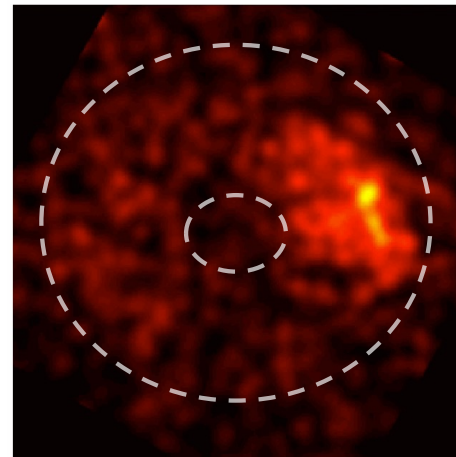
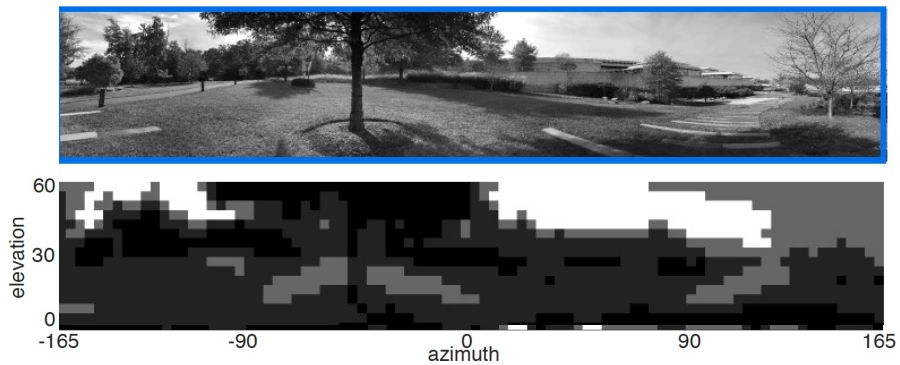
ER2

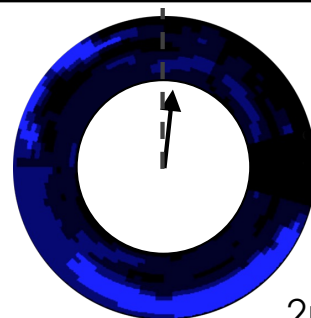
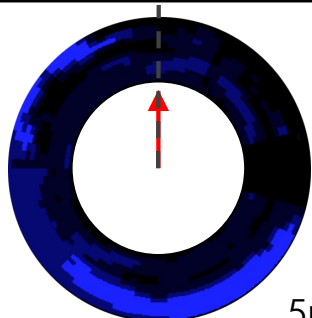
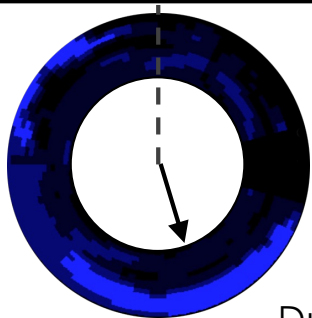
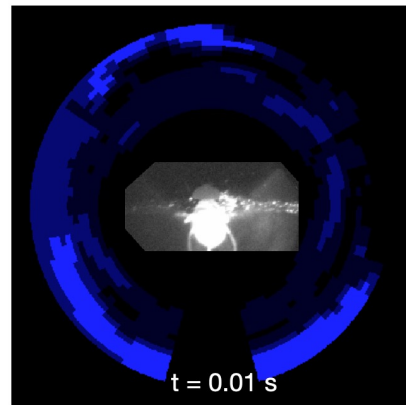
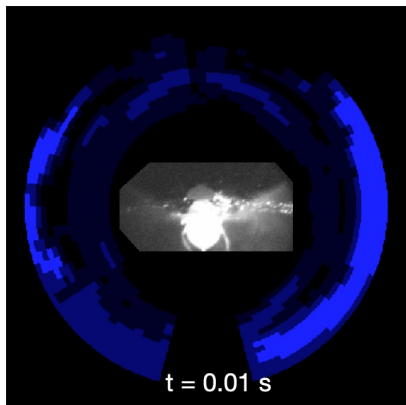
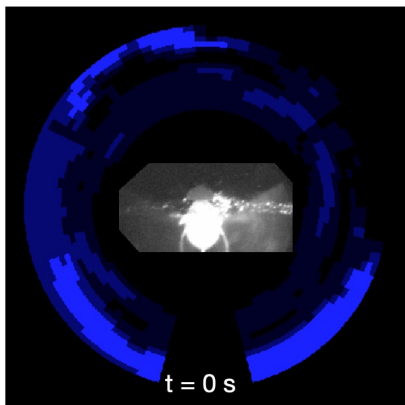
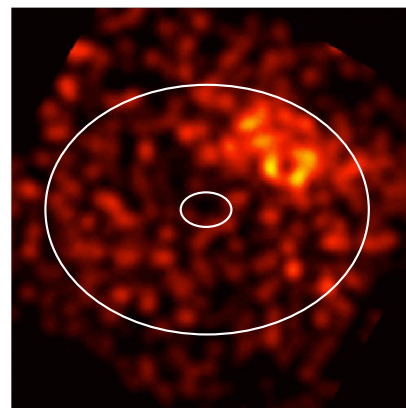
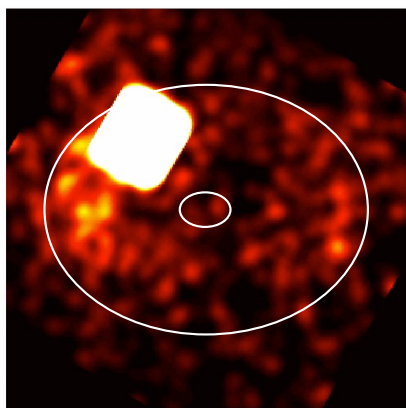
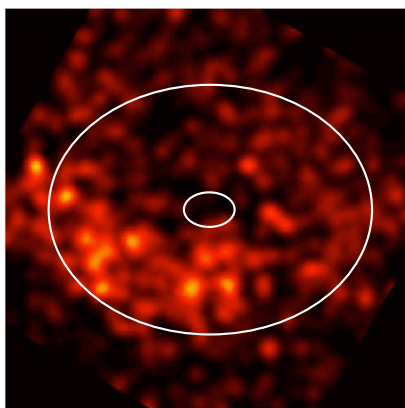


Compass neurons

Uniform synapse count = Uniform synaptic weights?

Calcium sensor GCaMP6f in compass neurons



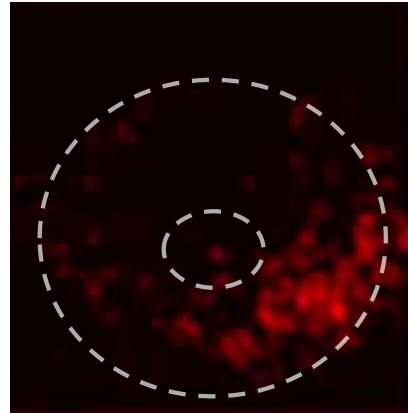
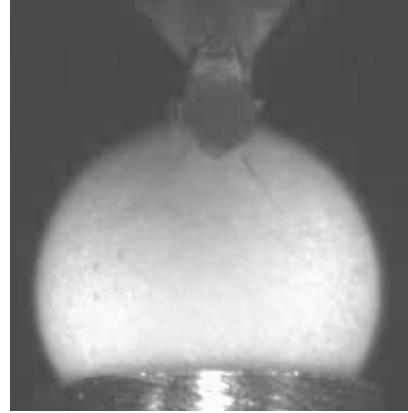
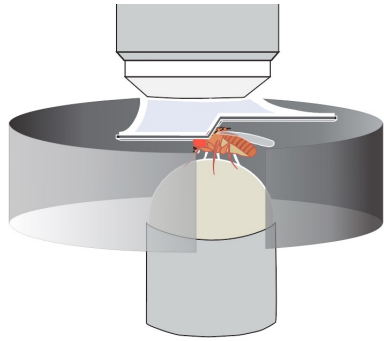


Duration: 2m

5m

2m

# Representation is maintained in darkness

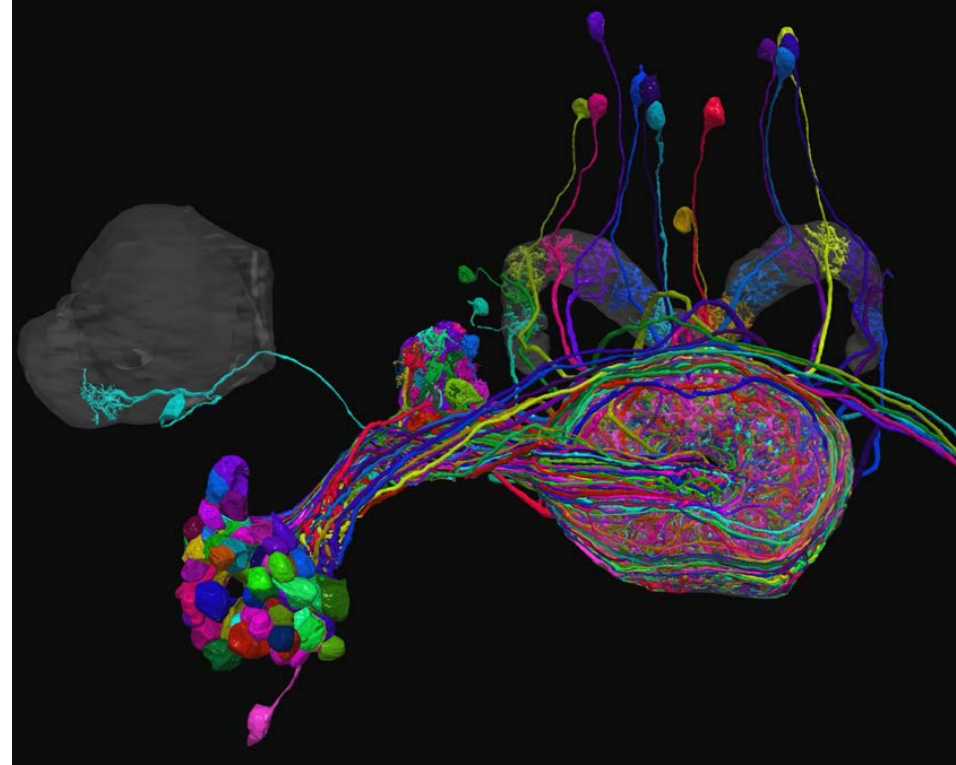
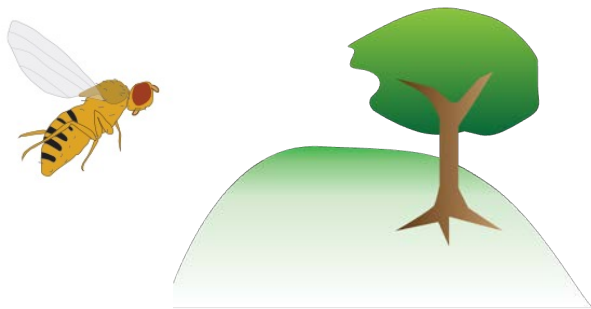
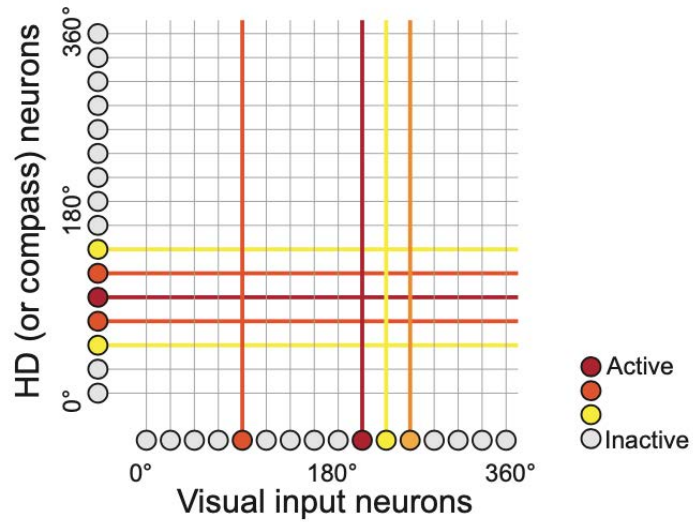


20um

Seelig & Jayaraman (2015)



Johannes Seelig



Ann Hermundstad



Sandro Romani

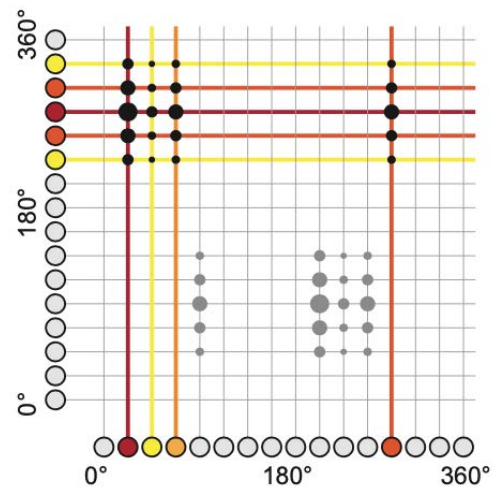
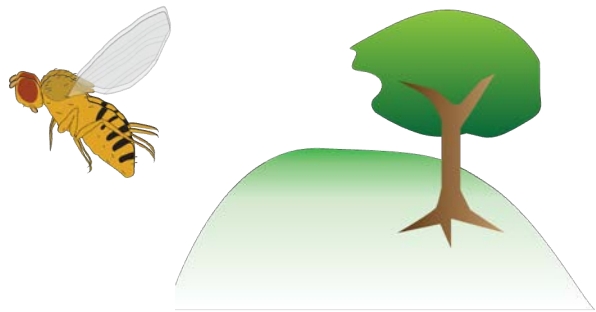
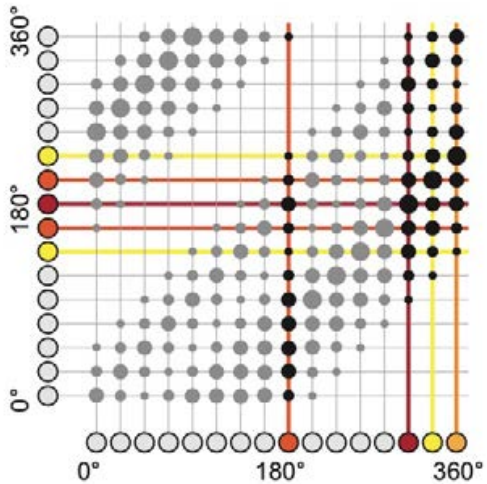


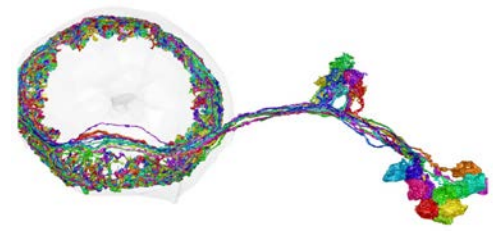
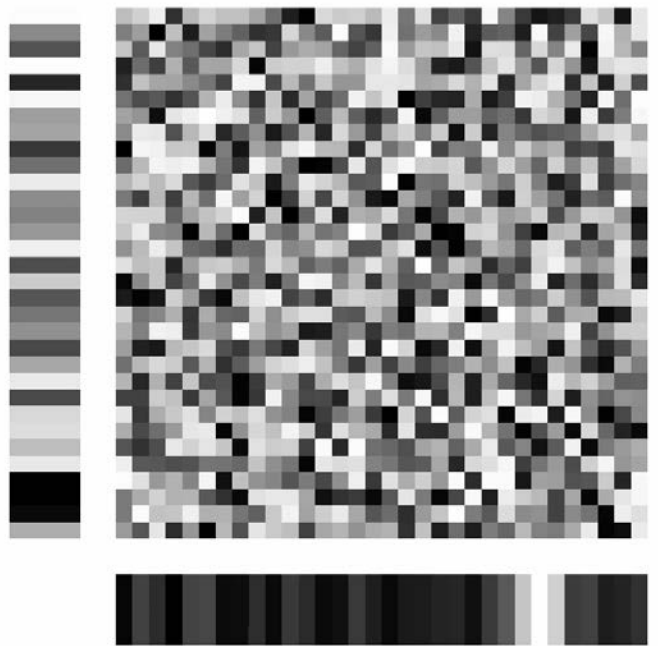
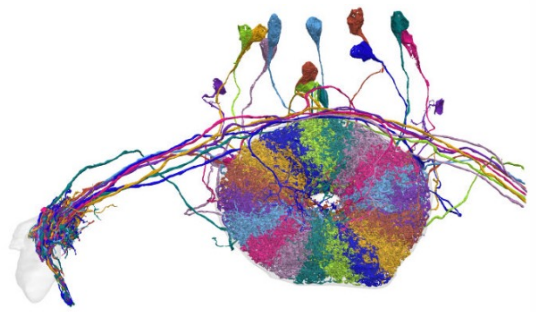
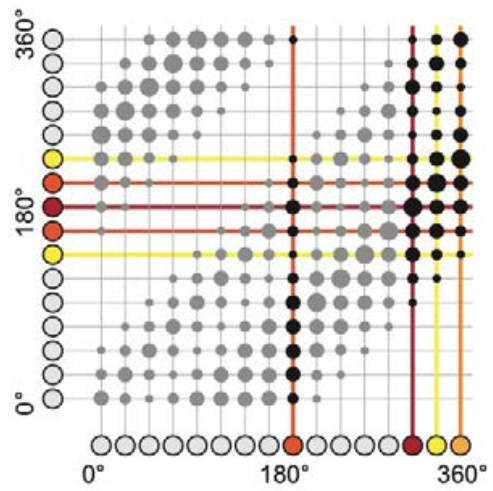
L. F. Abbott



Vivek Jayaraman







## Experience-dependent plasticity (Hebbian plasticity)

Skaggs, Knierim, Kudrimoti & McNaughton (1995) NIPS, "A model of the neural basis of the rat's sense of direction."

Ocko, Hardcastle, Giocomo & Ganguli (2018) PNAS, "The emergence of multiple retinal cell types through efficient coding of natural movies."

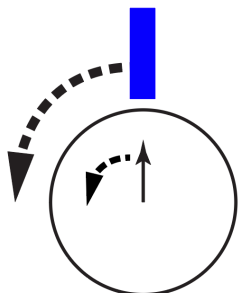
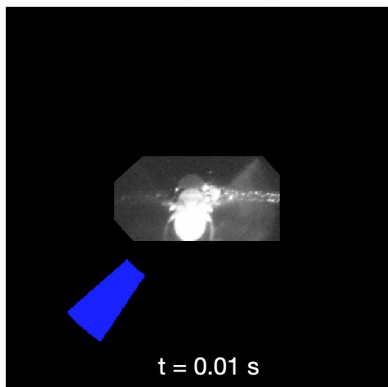
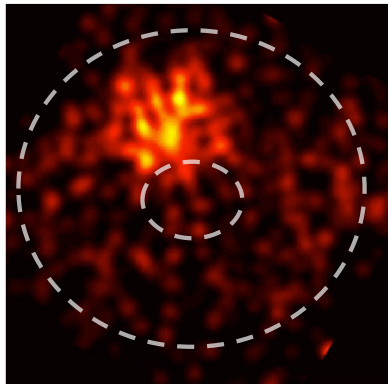
Page and Jeffery (2018) Front. Cell. Neurosci., "Landmark-Based Updating of the Head Direction System by Retrosplenial Cortex: A Computational Model."

Cope, Sabo, Vasilaki, Barron & Marshall (2017) Plos One, "A computational model of the integration of landmarks and motion in the insect central complex."

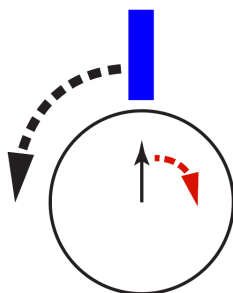
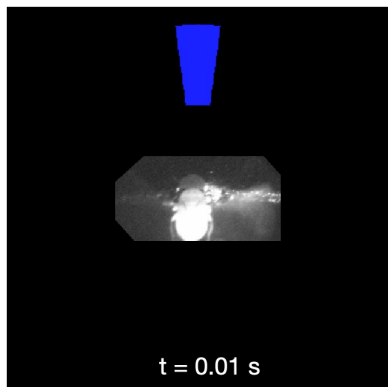
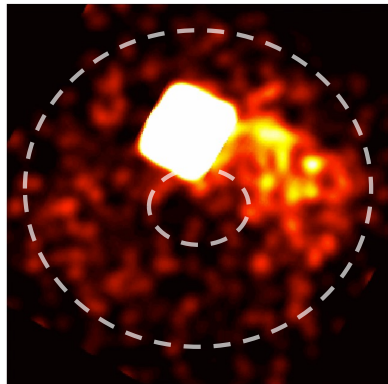
## Self Organizing Map (Competitive Hebbian learning, Unsupervised learning)

von der Malsburg (1973) Kybernetik, "Self-organization of orientation sensitive cells in the striate cortex."

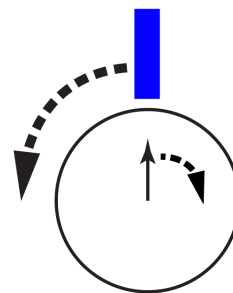
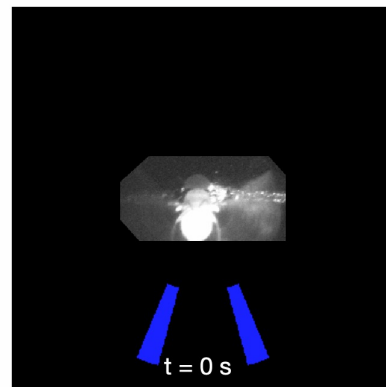
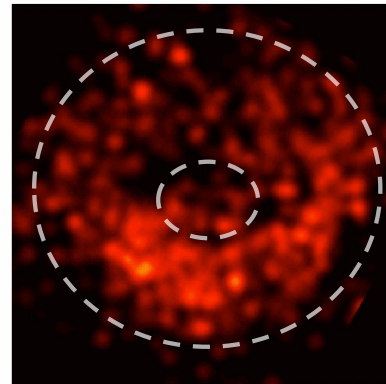
Kohonen (1982) Biological Cybernetics, "Self-organized formation of topologically correct feature maps."



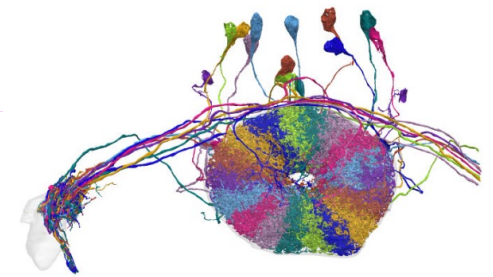
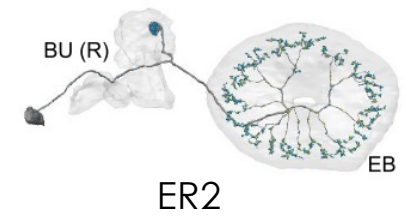
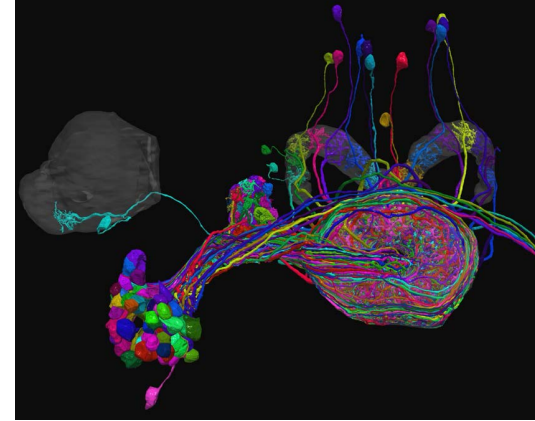
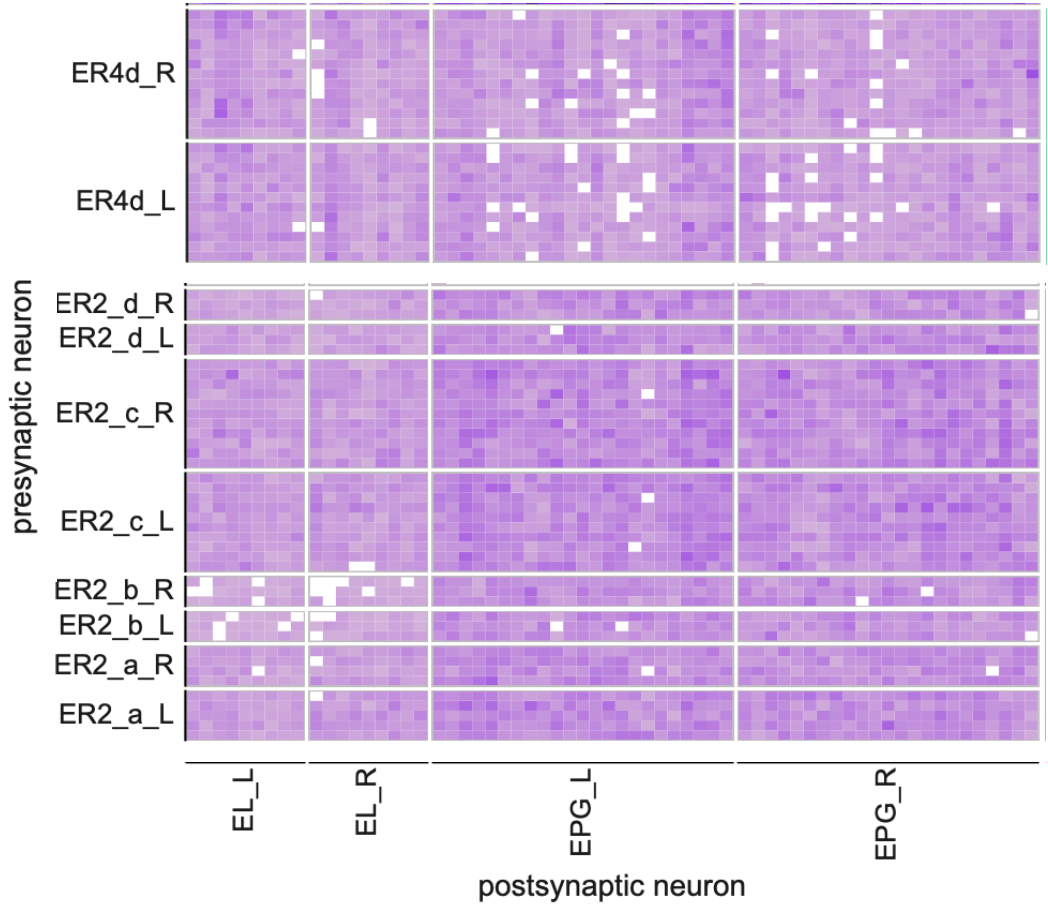
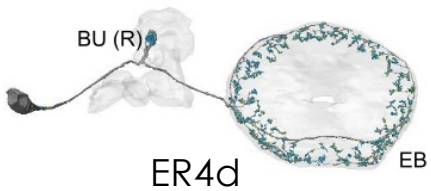
Duration: 2 minutes



5m

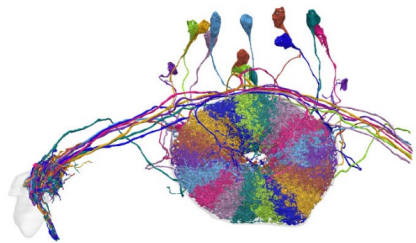


2m

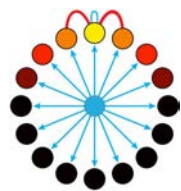


Uniform synapse count = Uniform synaptic weights?  
**Uniform synapse count  $\neq$  Uniform synaptic weights**

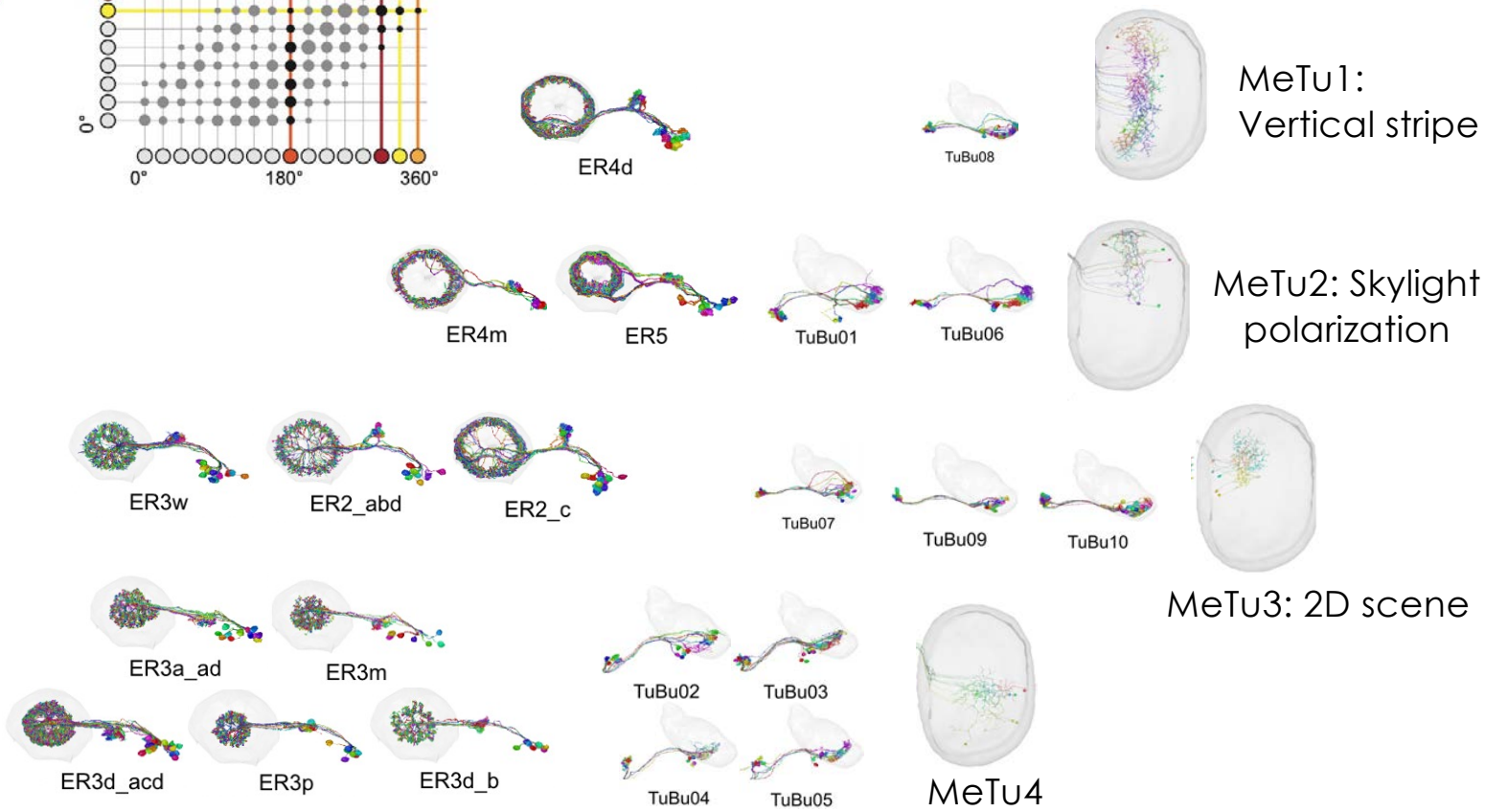
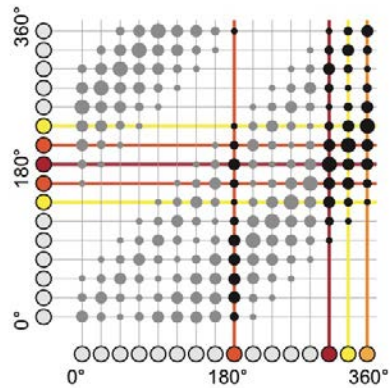
Compass neurons



Compass neurons



Ring attractor



# The Fellowship of the Ring



Dustin  
Garner



Jennifer  
Lai



Lucy  
Houghton



Mathias  
Wernet



Emil  
Kind



L.F.  
Abbott



Tanya  
Wolff



Vivek  
Jayaraman



Ben  
Gorko



Sanghun  
Jee



Dinesh  
Natesan



Aljoscha  
Nern



Ann  
Hermundstad



Sandro  
Romani

Postdocs wanted!  
Email me: [sungsoo@ucsb.edu](mailto:sungsoo@ucsb.edu)



**UC SANTA BARBARA**

Kim lab <https://sungsoo-kim.mcdb.ucsb.edu/>



SIMONS FOUNDATION  
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