

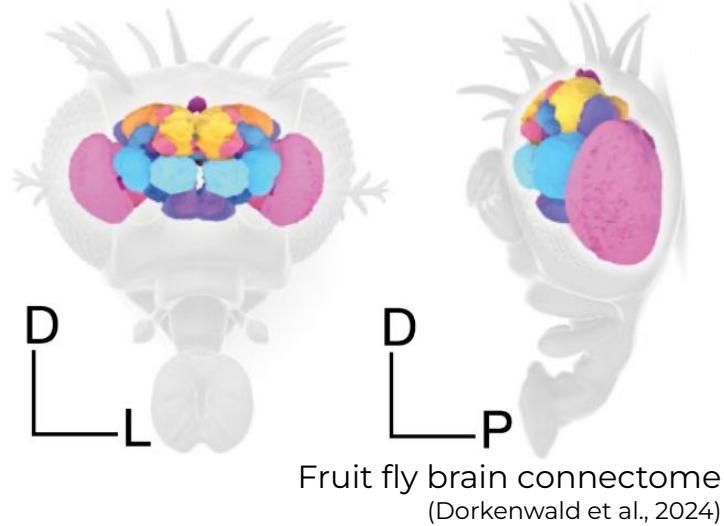
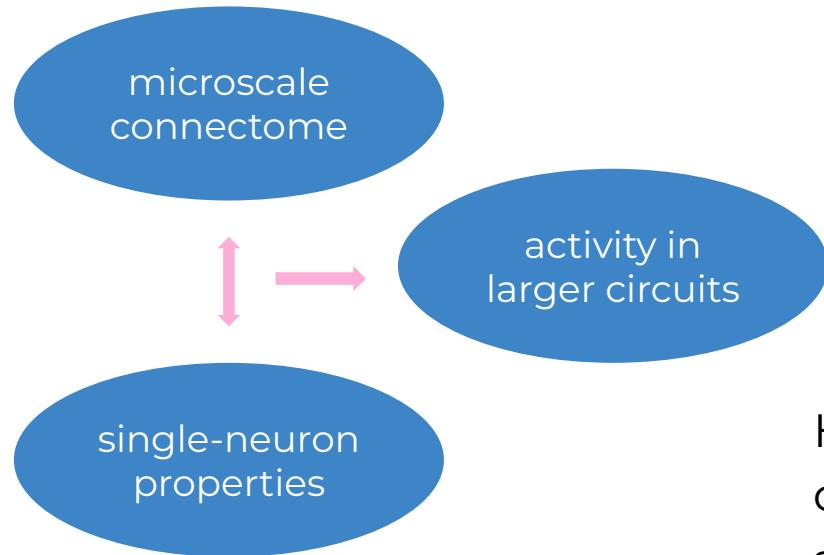
Connectome-constrained SNNs

Recreating the odor pathway of the fruit fly *in silico*

Maren, Marcus, Jeffrey, Kathryn

Motivation

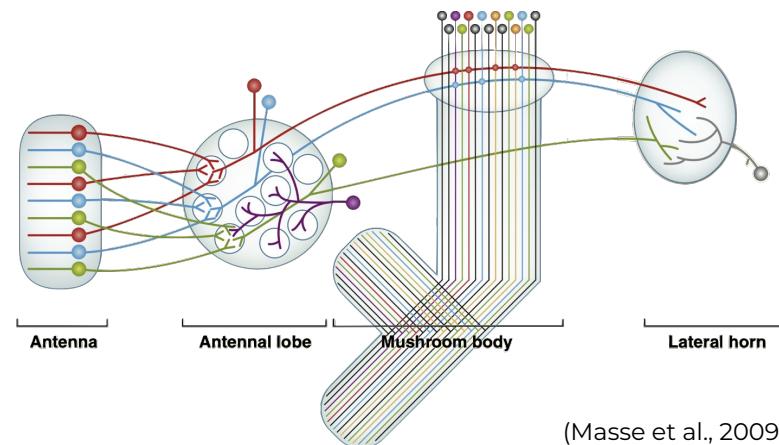
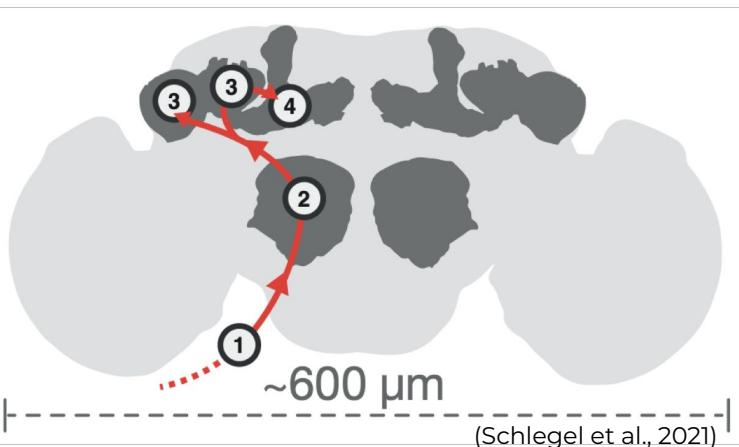
Brain's structure-function relationship



How much does the microscale connectome tell us about single-neuron activity patterns?

Goal

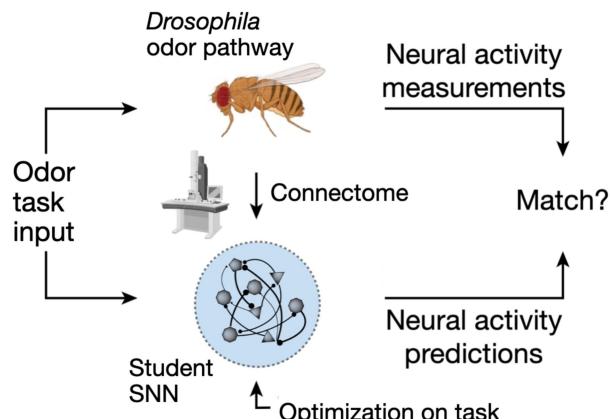
Recreate a function of circuit of the fruit fly brain



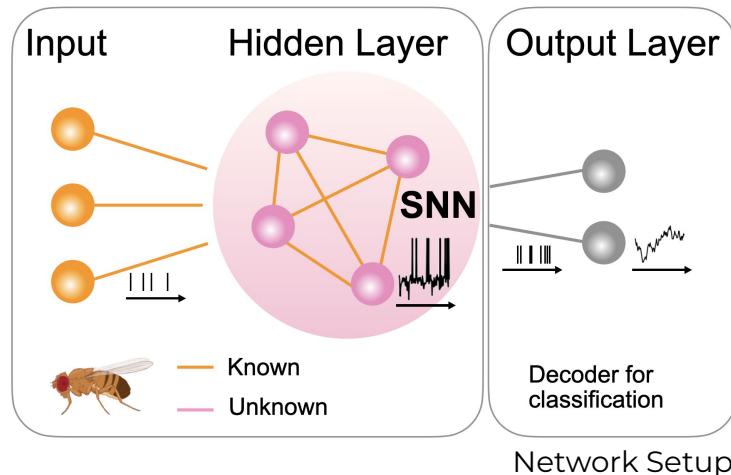
- For each **biological neuron** in the fruit fly olfactory pathway, we create an **artificial neuron** in our Spiking Neural Network (SNN)
- We use the **number of synapses** between biological neurons as **weights** for the SNN
- We use the **neurotransmitter** (GABA, Ach, Glut) per synapse as a guess for its **sign** (-, +, -)

Approach

Connectome-constrained mechanistic model

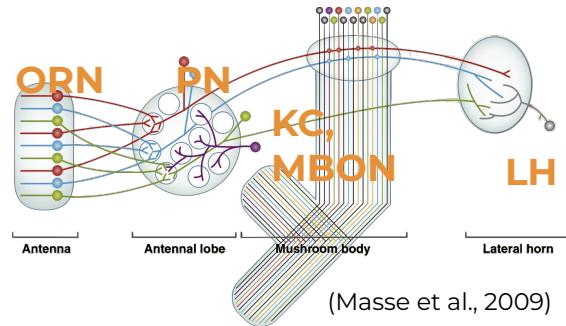


Idea (adapted from Lappalainen et al., 2024)

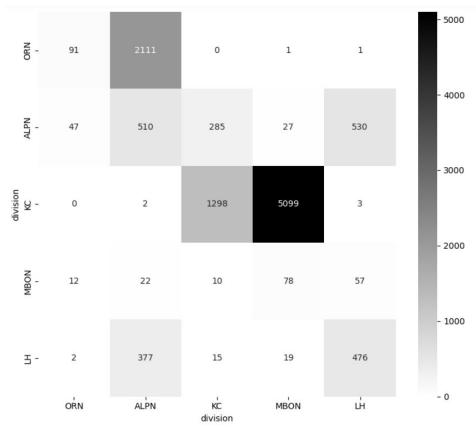


- To match network function, we train the SNN on an **odor classification task** (Münch & Galizia, 2016; Nanami et al., 2024)
- We optimize using BPTT and surrogate gradients (Neftci et al., 2019; Perez-Nieves et al., 2021)
 - a. the **membrane time constant** and **background current** per neuron
 - b. The decoder to read out the odor

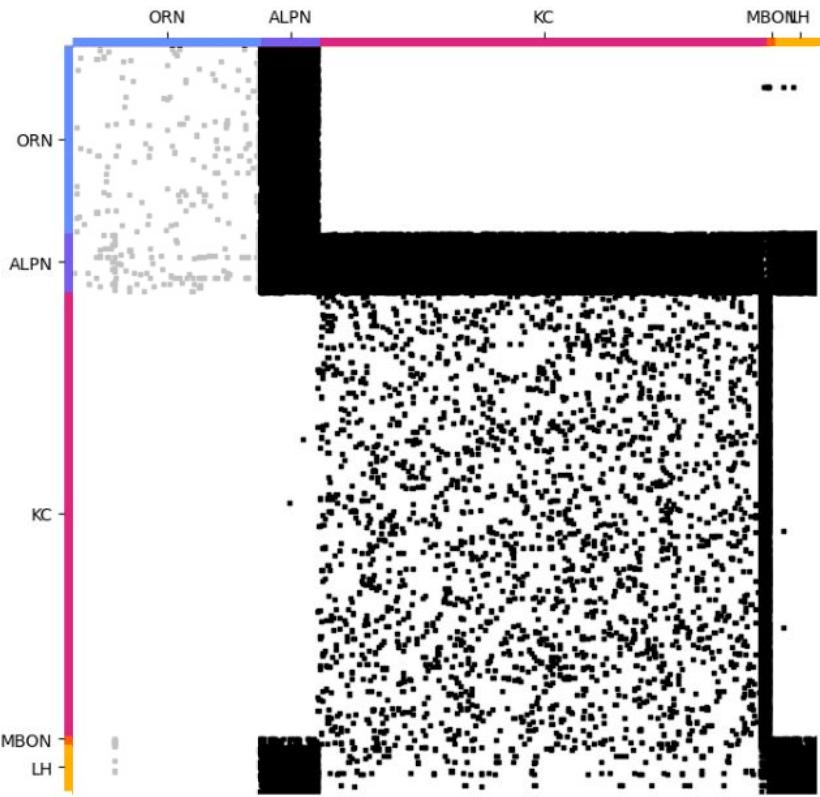
Cell Types and Connectome



Main cell types

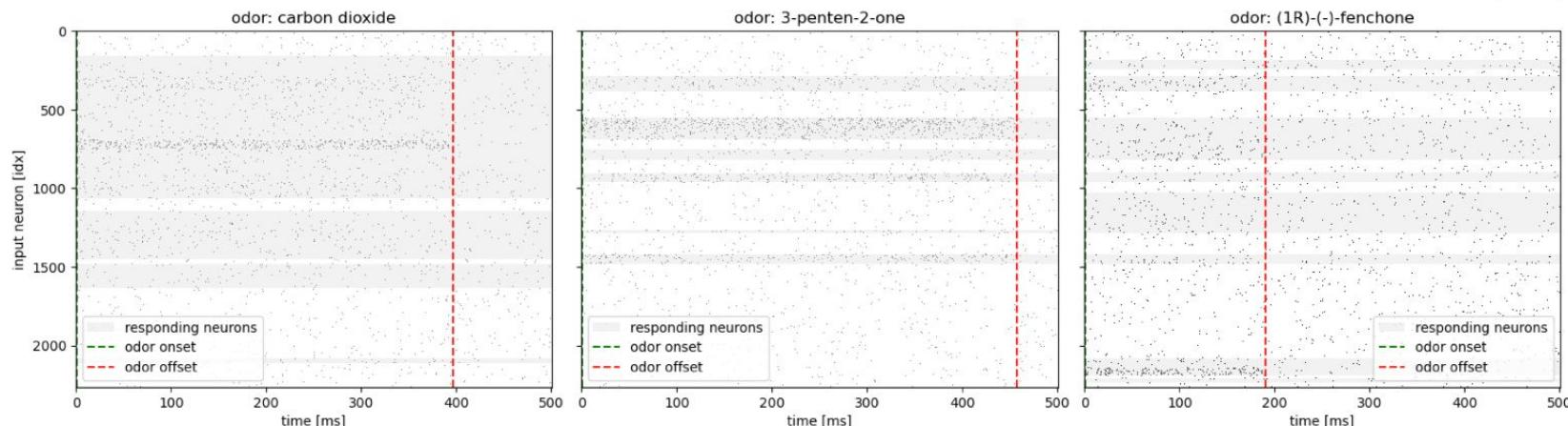
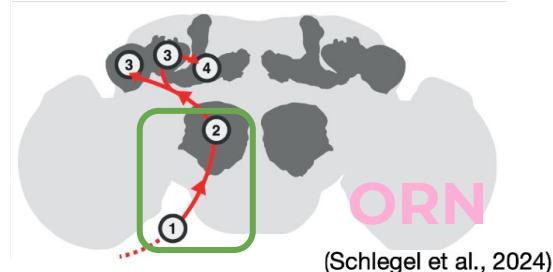


Single neurons



Odor classification task

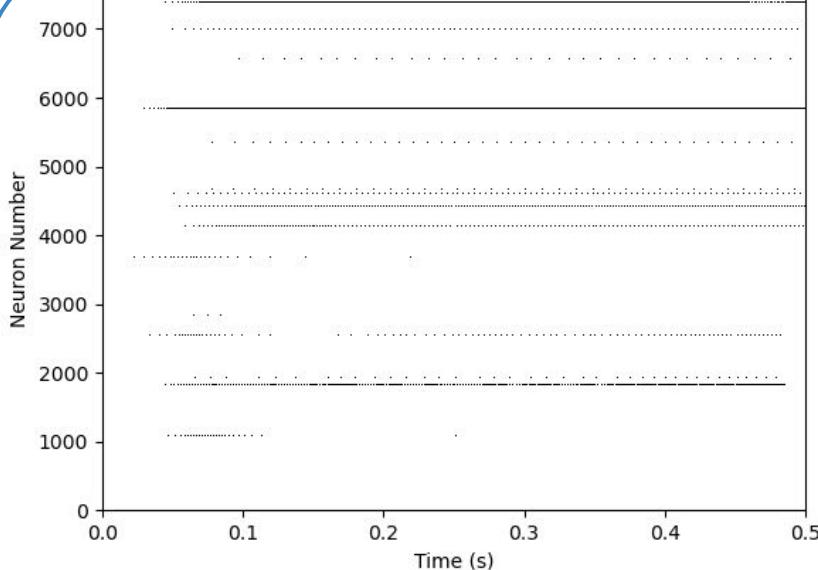
For spiking activity of odor receptor neurons



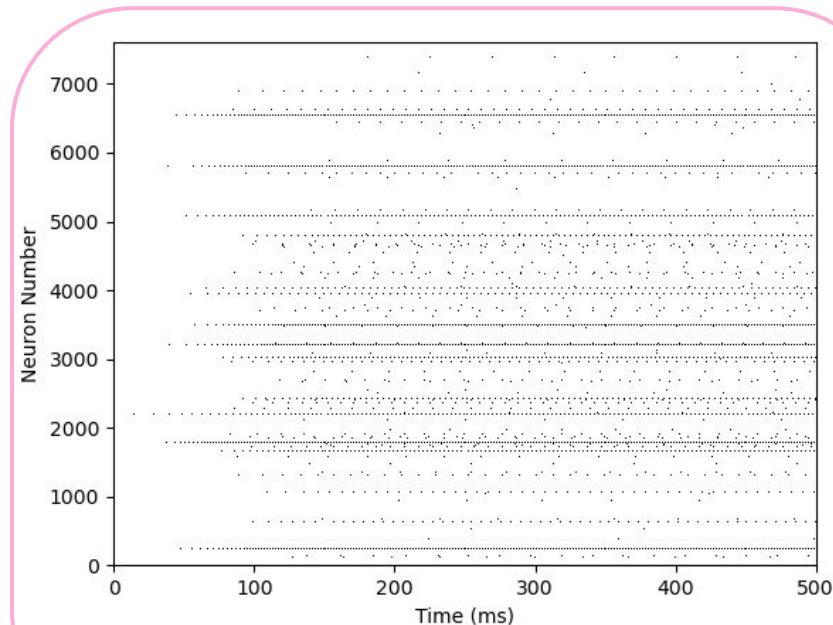
- 284 different odors are applied for a duration of 70-500ms
- Each odor has a distinct responding receptor types (-> DoOR dataset; Münch & Galizia, 2016)
- For each neuron in the responding receptor types, we draw a spike pattern with a Poisson process (Nanami et al., 2024)

Model on Spinnaker

Comparison to Pytorch simulation (hidden layer spikes)

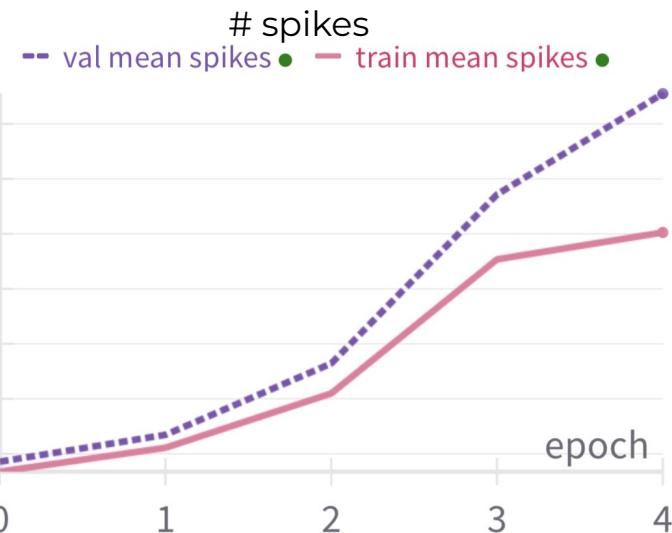
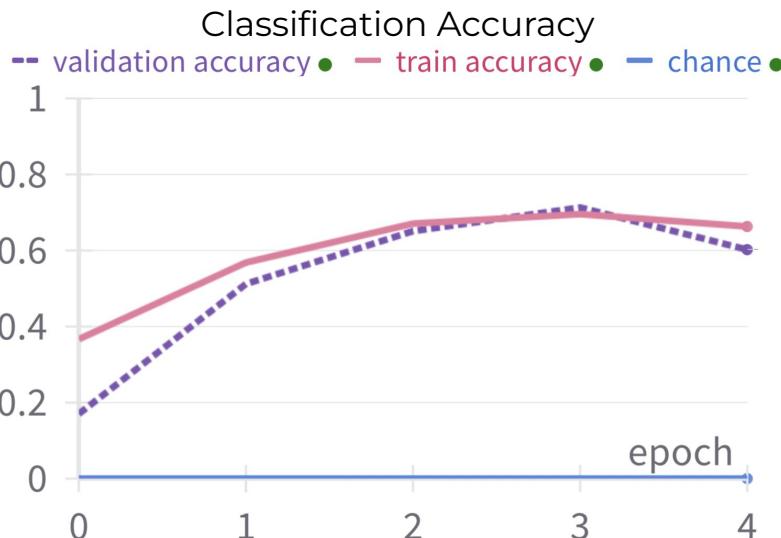
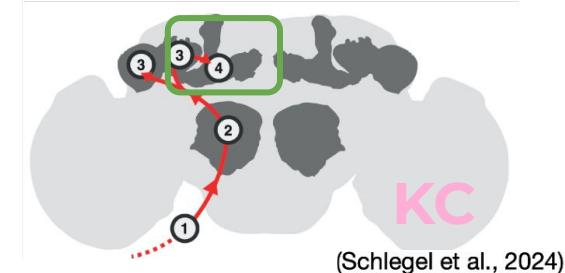


sPyNNaker



Pytorch

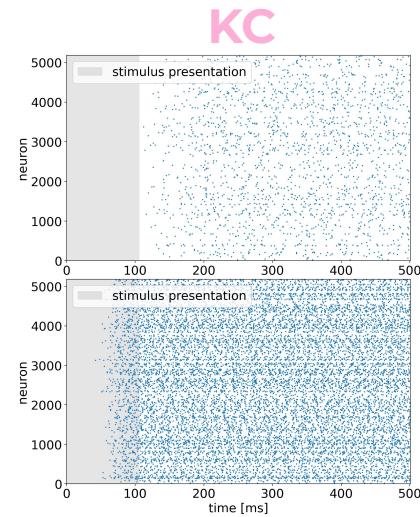
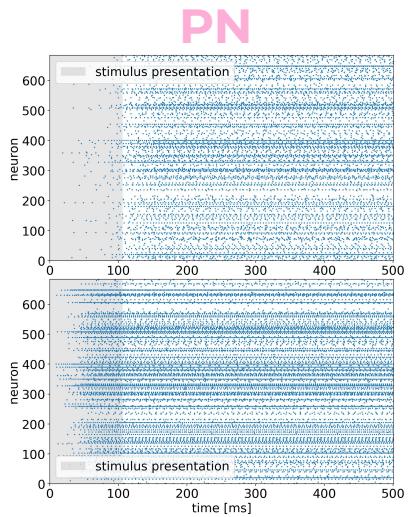
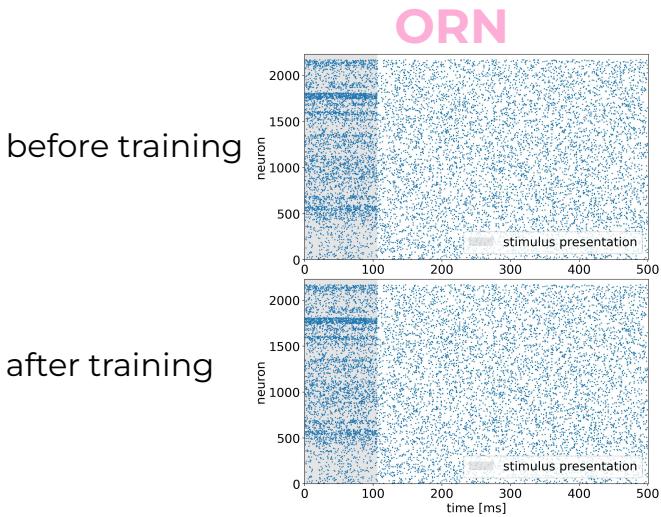
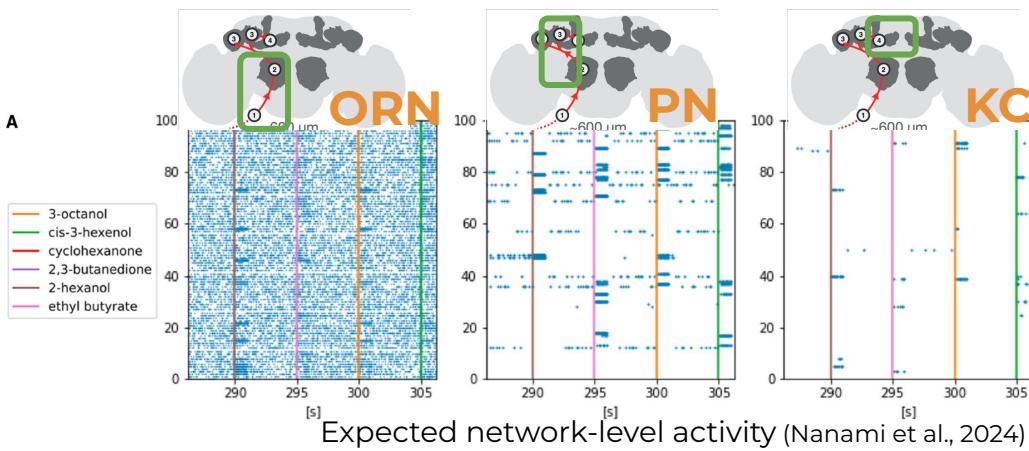
Task performance (Very preliminary results)



- Currently takes about 2h/epoch on HPC

Spike patterns Before and after training

-> Expectation: KC sparser than PN
(after training)



Next steps

Technical

- More complex neuron models
- Optimize synapse time constants per neurotransmitter
- Inference on Spinnaker

Conceptual

- Compare activity *in vivo* vs *in silico*
 - Network activity
 - Tuning profiles of single neurons (Turner et al., 2008)
- Predict innate attractive/aversive odors (Campbell et al., 2013)
- Activity/weights after associative learning task (Nanami et al., 2024)
- Compare to top-down model
- Long-term: derive hypotheses about the role of network components that can be tested experimentally (in the fruit fly)

