Reverse-engineering the neural circuitry underlying multi-body part coordination in *Drosophila*

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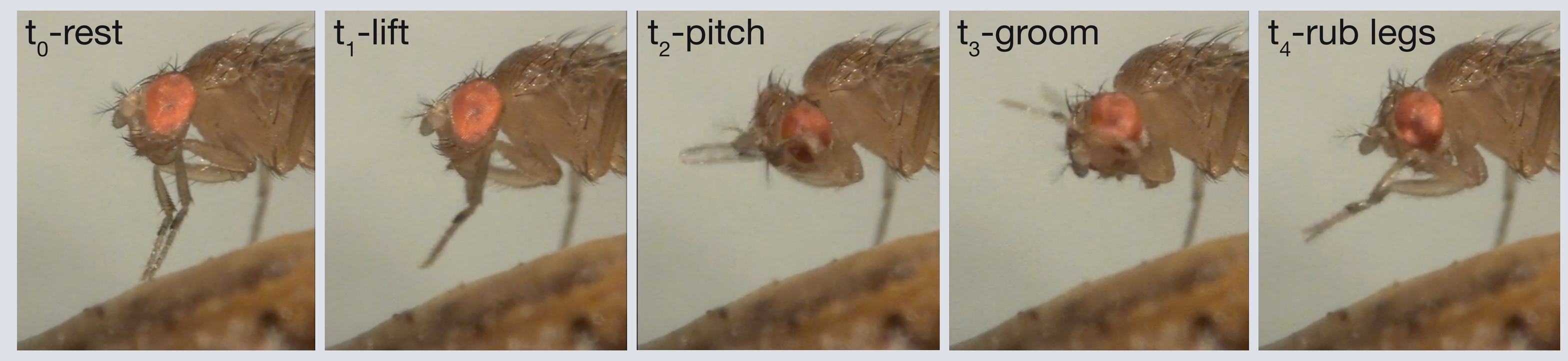
Goal-directed movements, such as self-grooming, are ubiquitous across limbed animals. However, it remains poorly understood **how these movements arise from an interplay between sensory feedback, central processing, and musculoskeletal dynamics**. The adult fly, *Drosophila melanogaster*, performs goal-directed reaching during antennal grooming. Although some neural elements of the antennal grooming circuit have been identified [1], we lack a clear and comprehensive picture of **how extensive brain networks coordinate multiple body parts during grooming**.

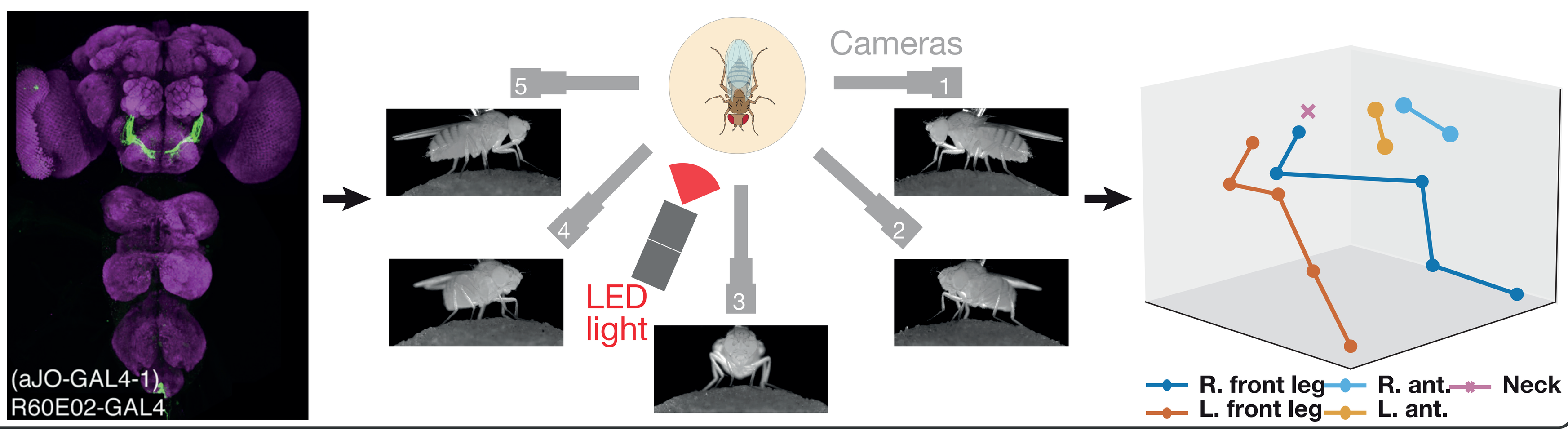
Here, we combine behavioral experiments, 3D kinematic analyses [2,3], and data-driven modeling using the connectome [4,5] to investigate the following questions:

- **How does the brain control different body parts?**
- **Which neural mechanisms drive the transition between distinct sub-behaviors?**

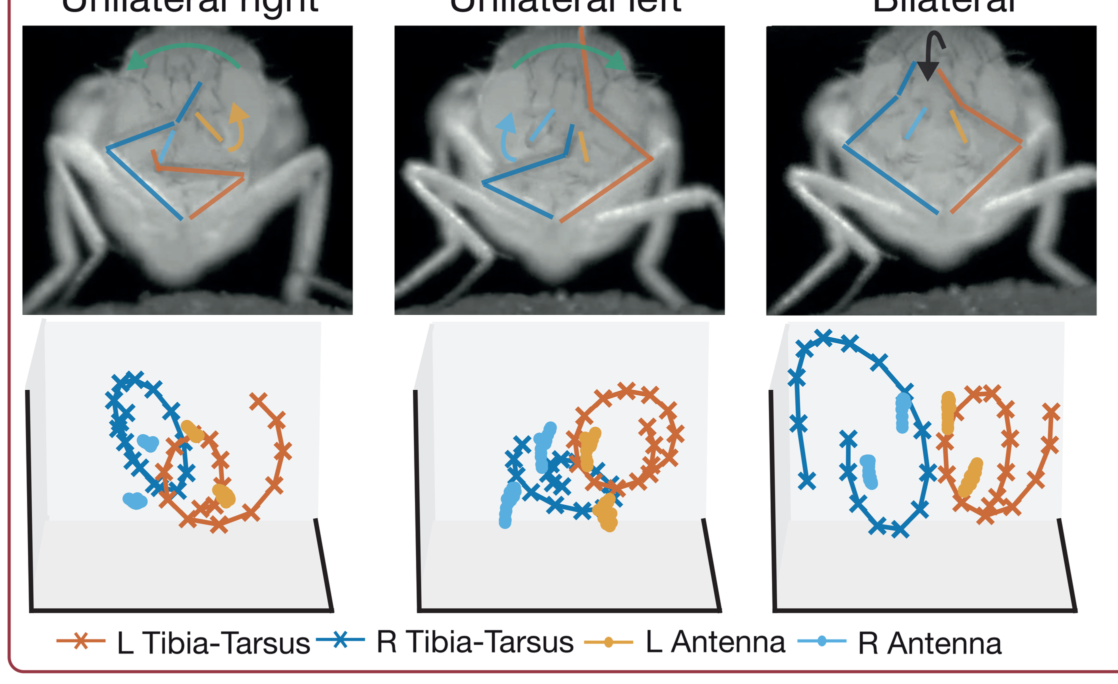


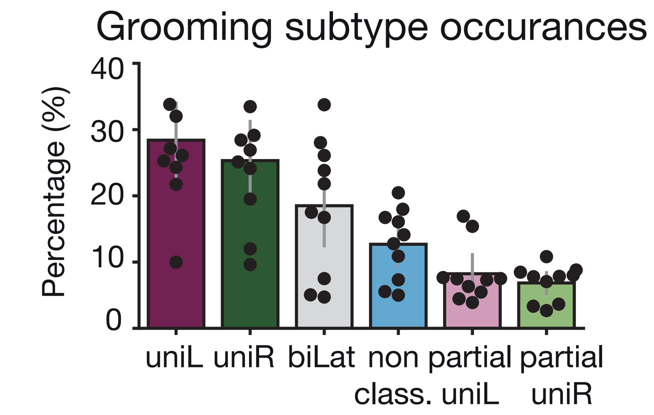
Stimulating and measuring antennal grooming

Optogenetically activate antennal mechanosensory neurons [1] (Johnston's Organ) to elicit antennal grooming.
Then process these recordings to obtain 2D pose estimates [2].
Finally, triangulate the key point predictions to obtain 3D pose [3].



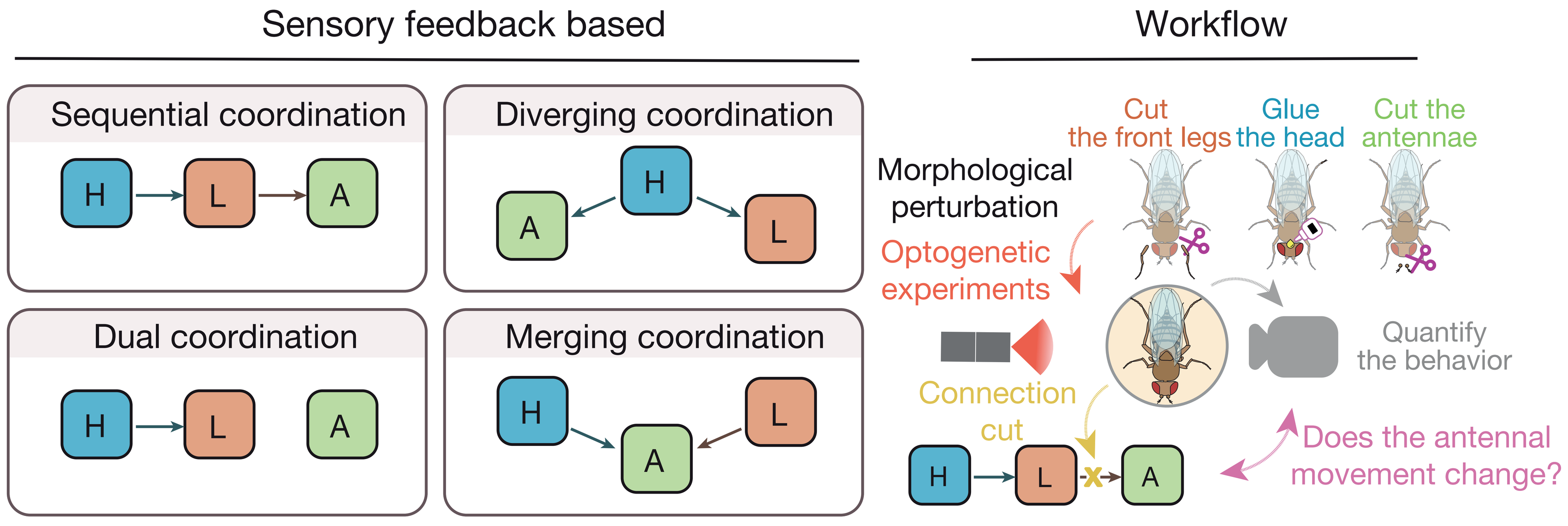
Antennal grooming requires multi-body part coordination

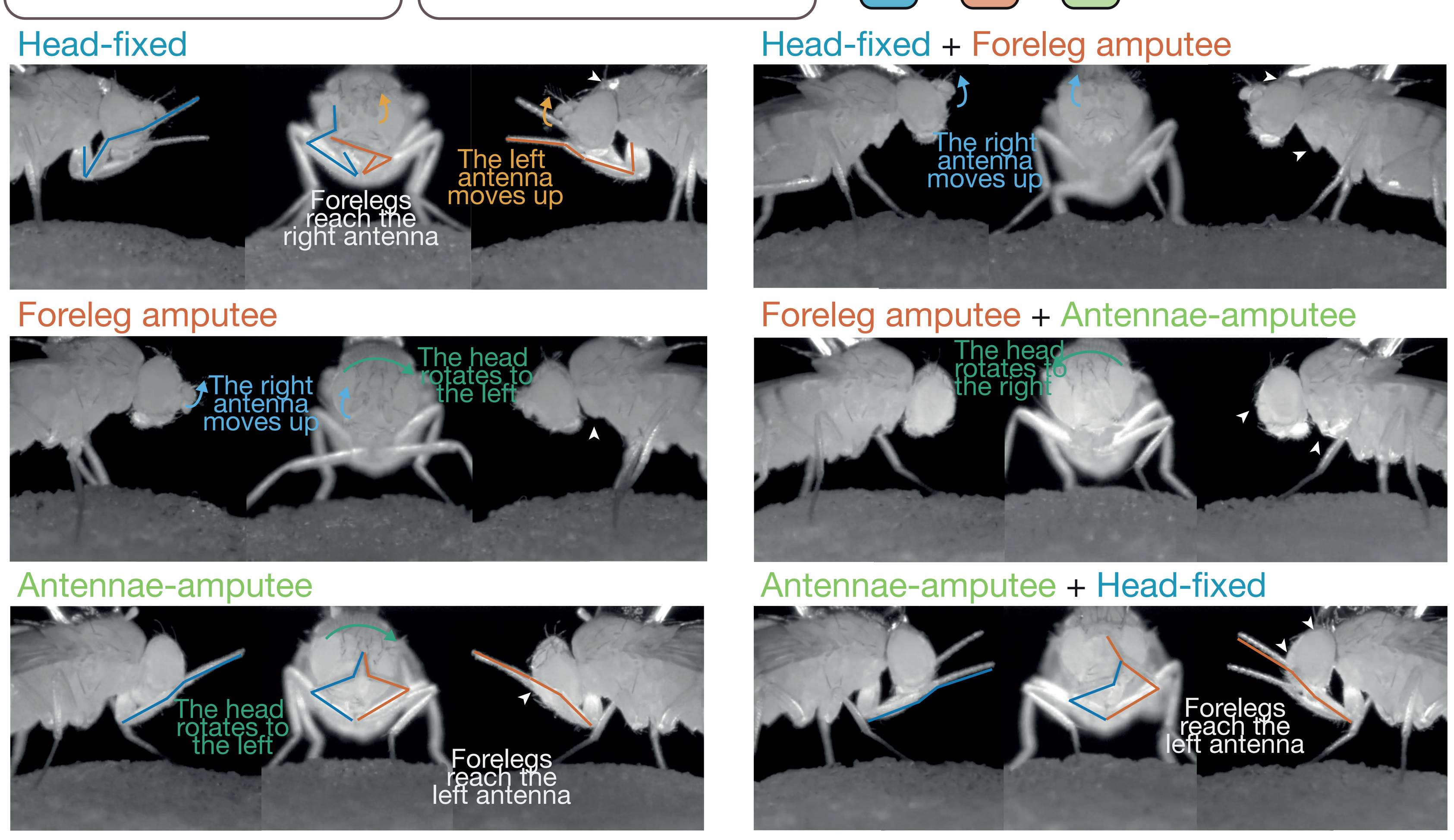




The fly controls the head, antennae, and forelegs in a coordinated way to achieve the grooming of one or both antennae.

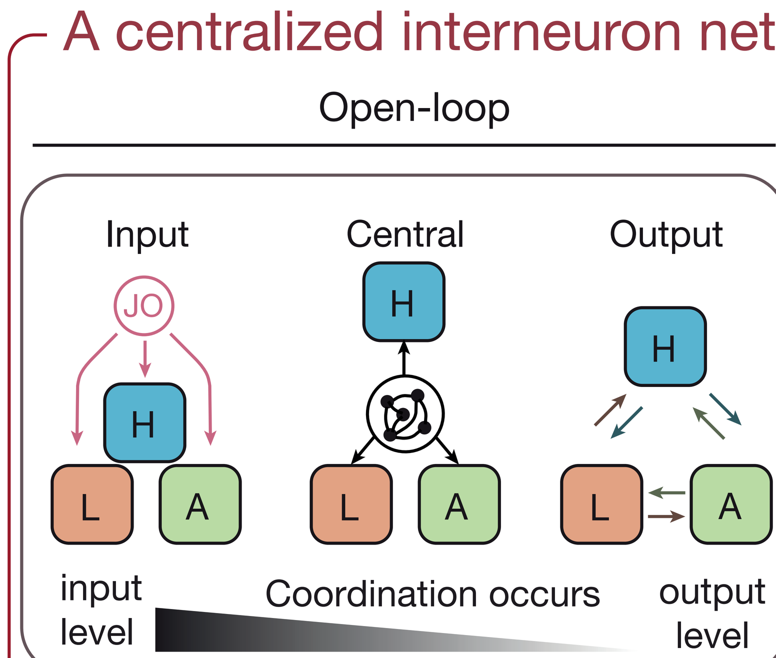
Sensory feedback cannot explain multi-body part coordination

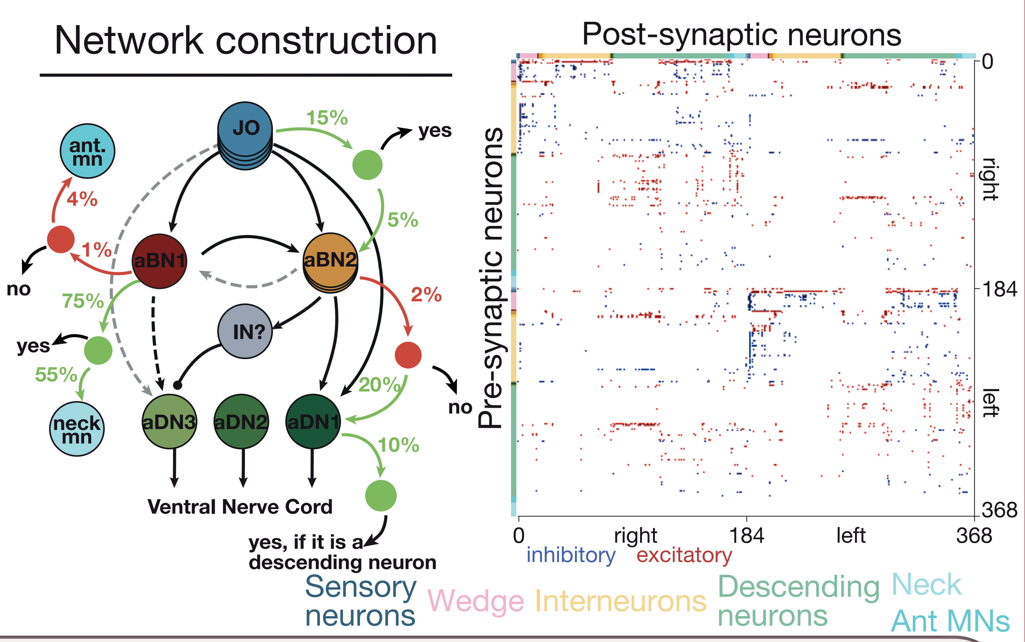


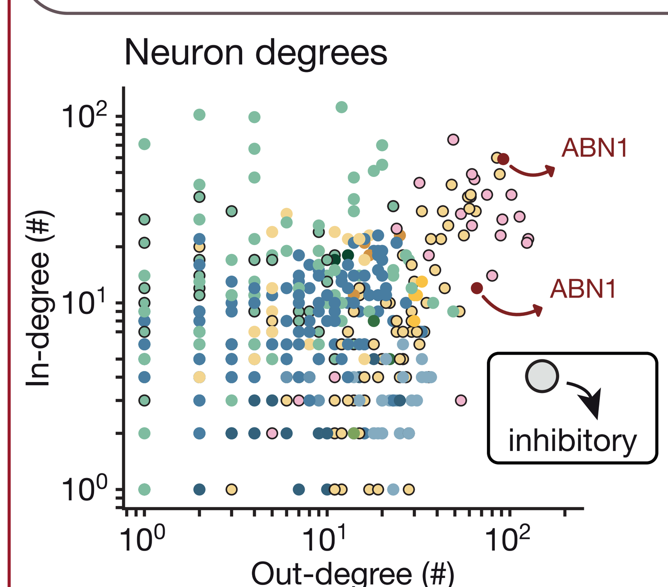


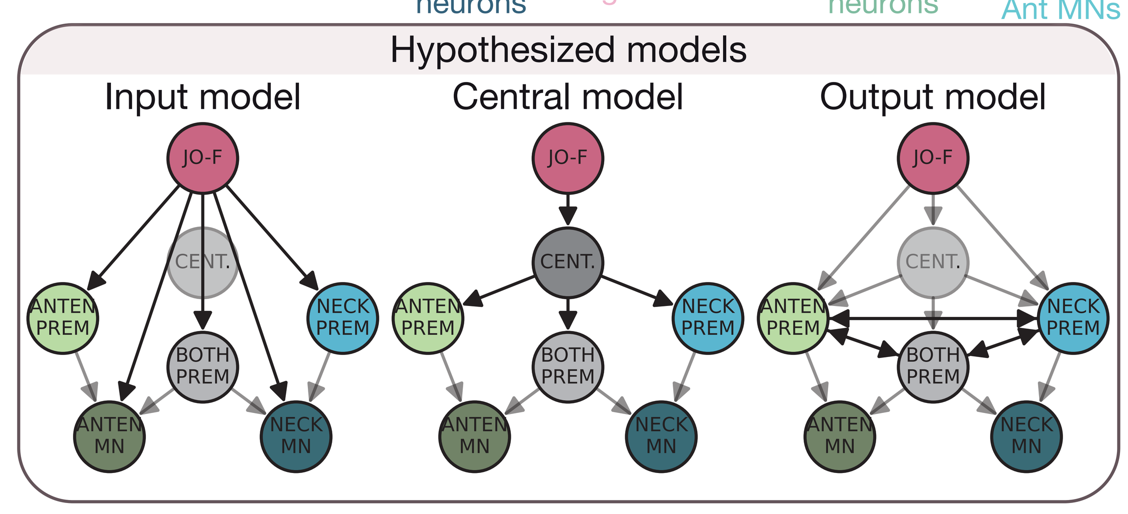
No sensory feedback perturbation could impede multi-body part coordination. Thus, an open-loop control mechanism is more likely to govern the movement.

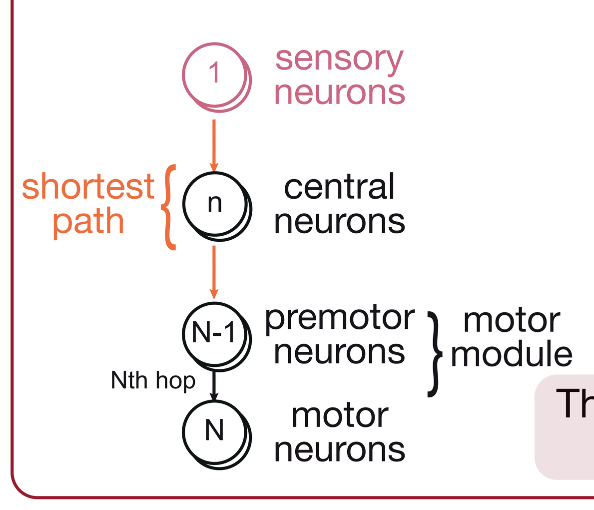
A centralized interneuron network links body-part motor networks

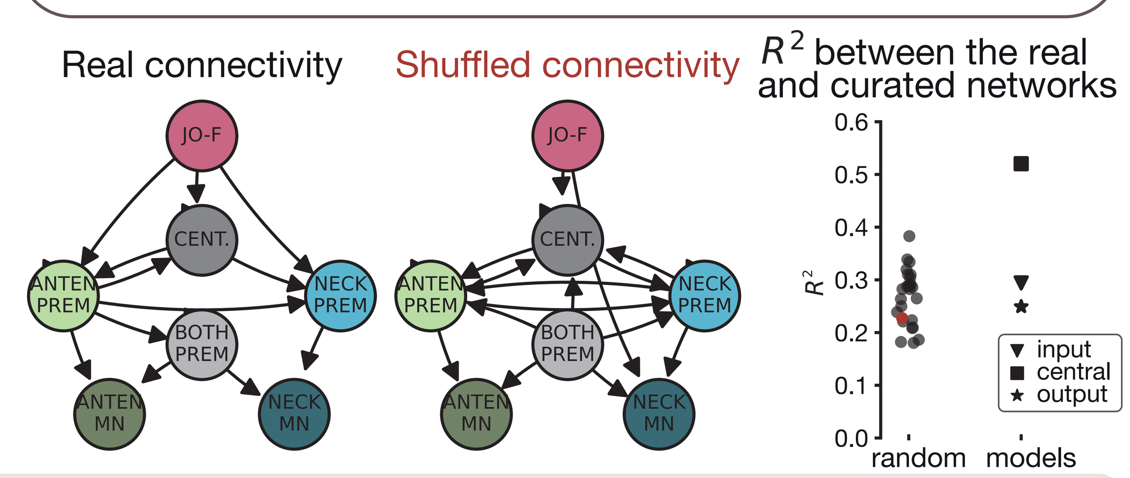






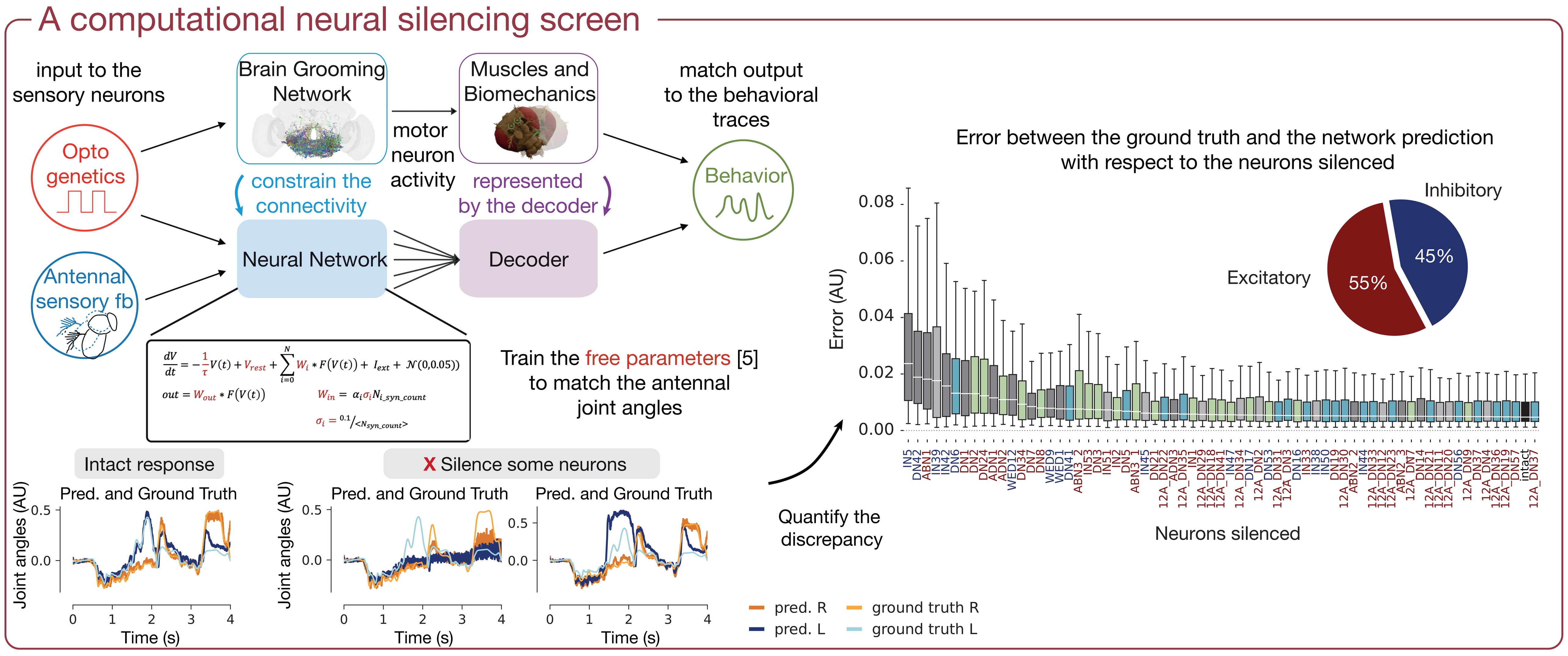






The real connectivity contains the motifs from each model to varying extents, with the 'central' model having the highest correlation.

A computational neural silencing screen



Outlook & future work

- Antennal grooming involves the coordinated movements of the antennae, head, and forelegs.
- Morphological perturbations of body-part movements during antennal grooming revealed that each body part can move independently of the other, suggesting an open-loop control mechanism.
- The grooming network derived from the brain connectome exhibits redundancy, supporting multiple open-loop models. Among these, the central model stands out.
- Our simulations, constrained by the connectome, indicate that the central inhibitory neurons play an important role in shaping the motor output.
- Future investigations will empirically validate the network predictions by selectively silencing neurons through genetic manipulation.

References

[1] Hampel et al., 2015. A neural command circuit for grooming movement control.
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