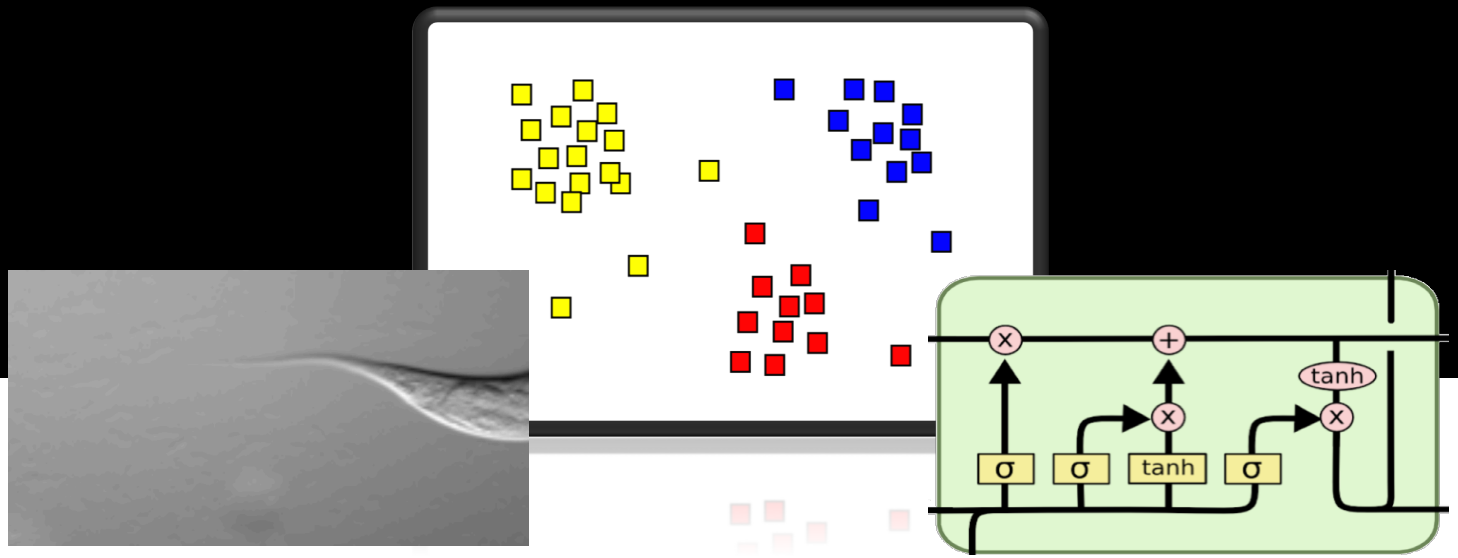
Connectomics + Dynamics = Nervous System -> Behavior



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Outline

1. Static Connectome
2. Dynamic Connectome
3. Functional Connectome
4. Connectome -> Behavior

Introduction-Outline

1. Static Connectome

What is the **connectome**? How to analyze the **connectome**?

2. Dynamic Connectome

What the connectome is **good for**? How to **model dynamics**?

3. Functional Connectome

What is **function ?** **How to infer functional pathways in** the connectome?

4. Connectome -> Behavior

How does the connectome **dictate** behavior?

Outline

1. Static Connectome

What is the **connectome**? How to analyze the **connectome**?

2. Dynamic Connectome

What the connectome is **good for**? How to **model** dynamics?

3. Functional Connectome

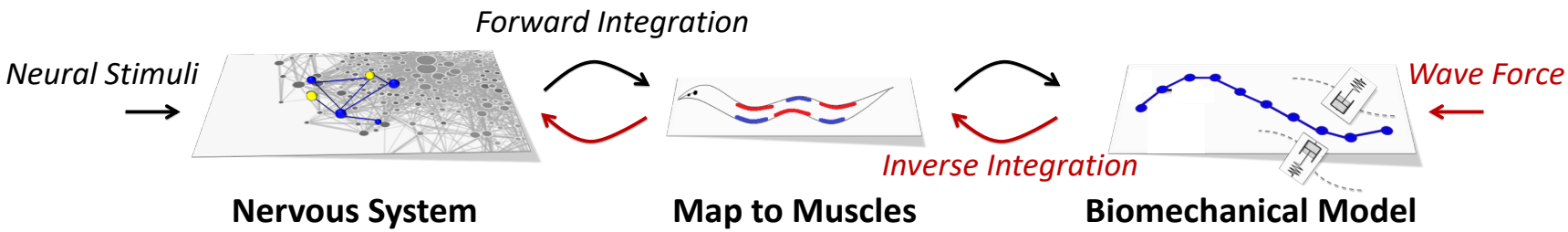
How to **define** function? **Functional pathways in** the connectome?

4. Connectome -> Behavior

How does the connectome **dictate** behavior?

Q. How does the connectome **dictate** behavior?

Add More Layers – Bio-Mechanics

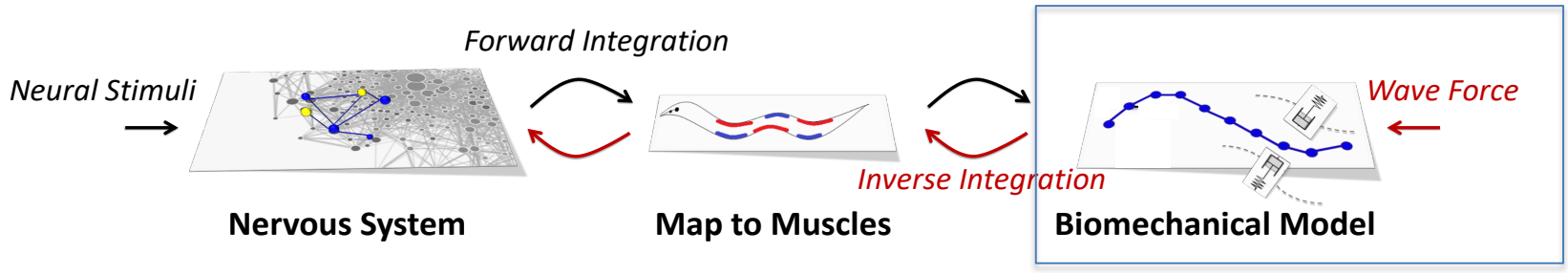


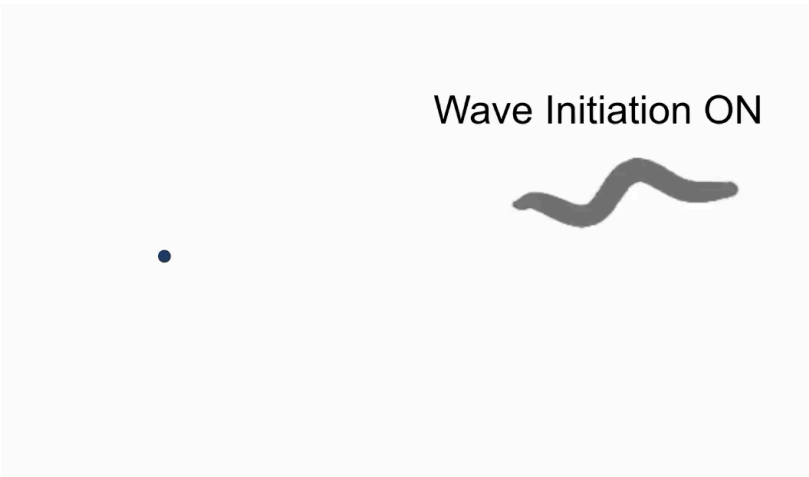
Whole Integration of Biomechanics and Neural Dynamics

https://shlizee.github.io/CelegansWholeIntegration/

Kim, Santos, Alkema ,Shlizerman, *bioRxiv , in review* 2019

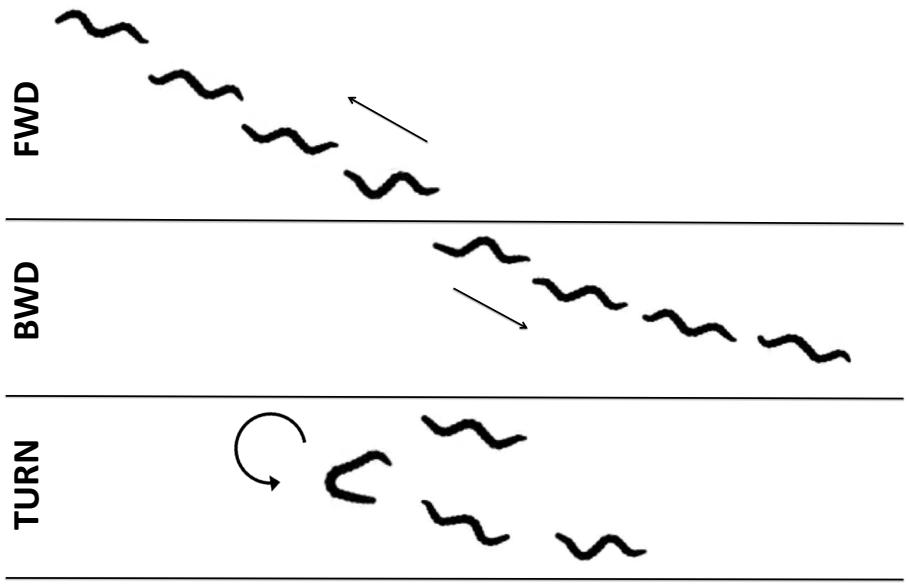
Whole Body Model Locomotion – Wave Force

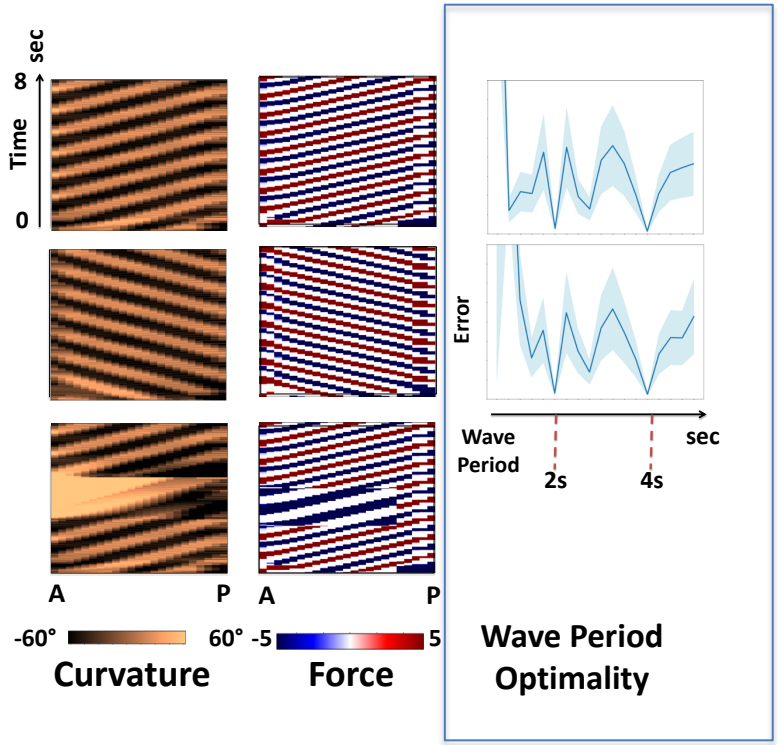




Wave Force Forward and Backward Locomotion

Are these movements simple responses?

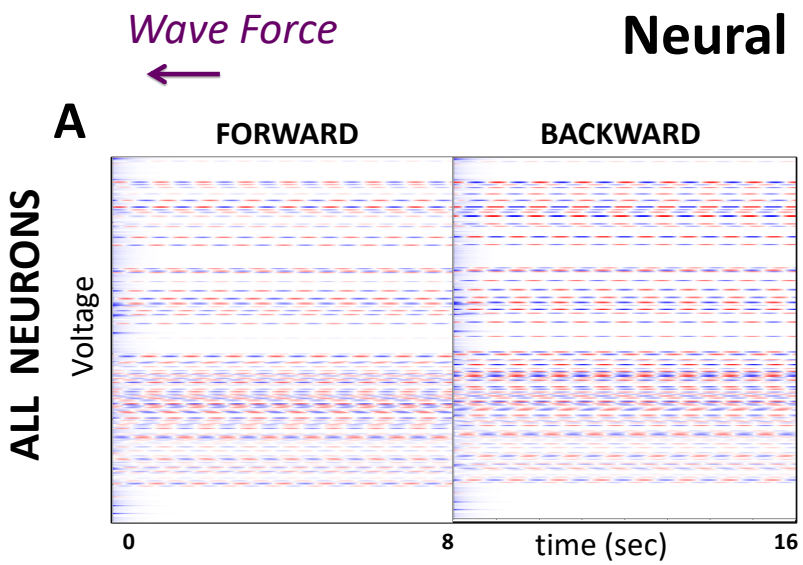


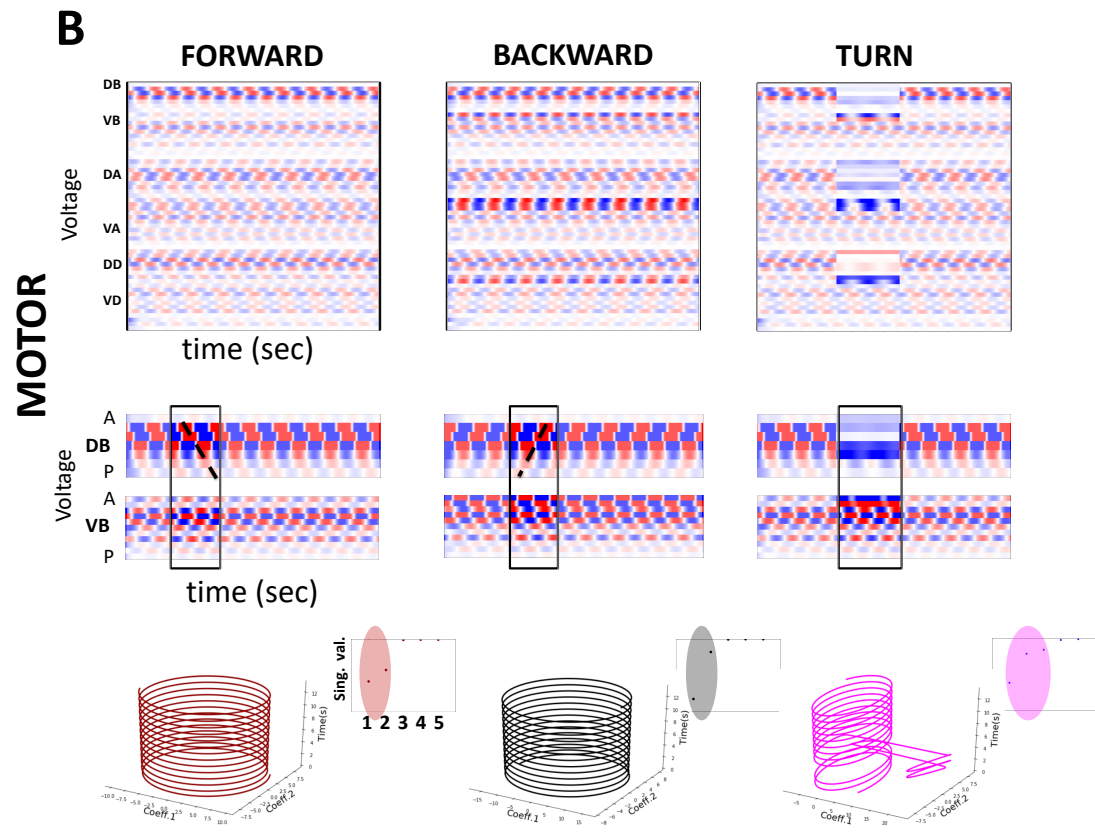


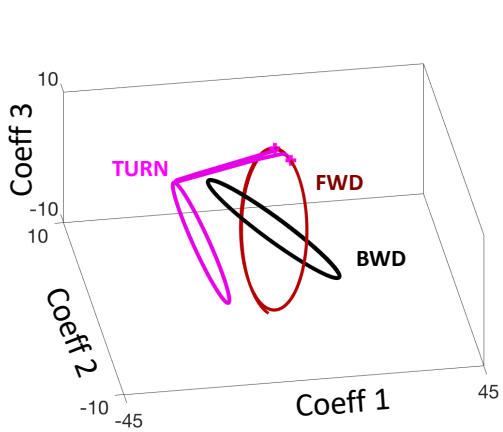
Nonlinear Response!

Underlying Neural Dynamics

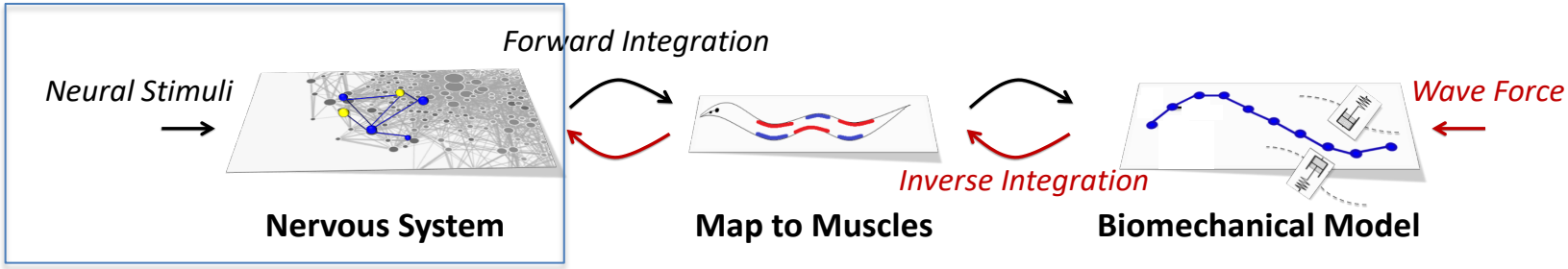
Neural Dynamics Induced By External Force





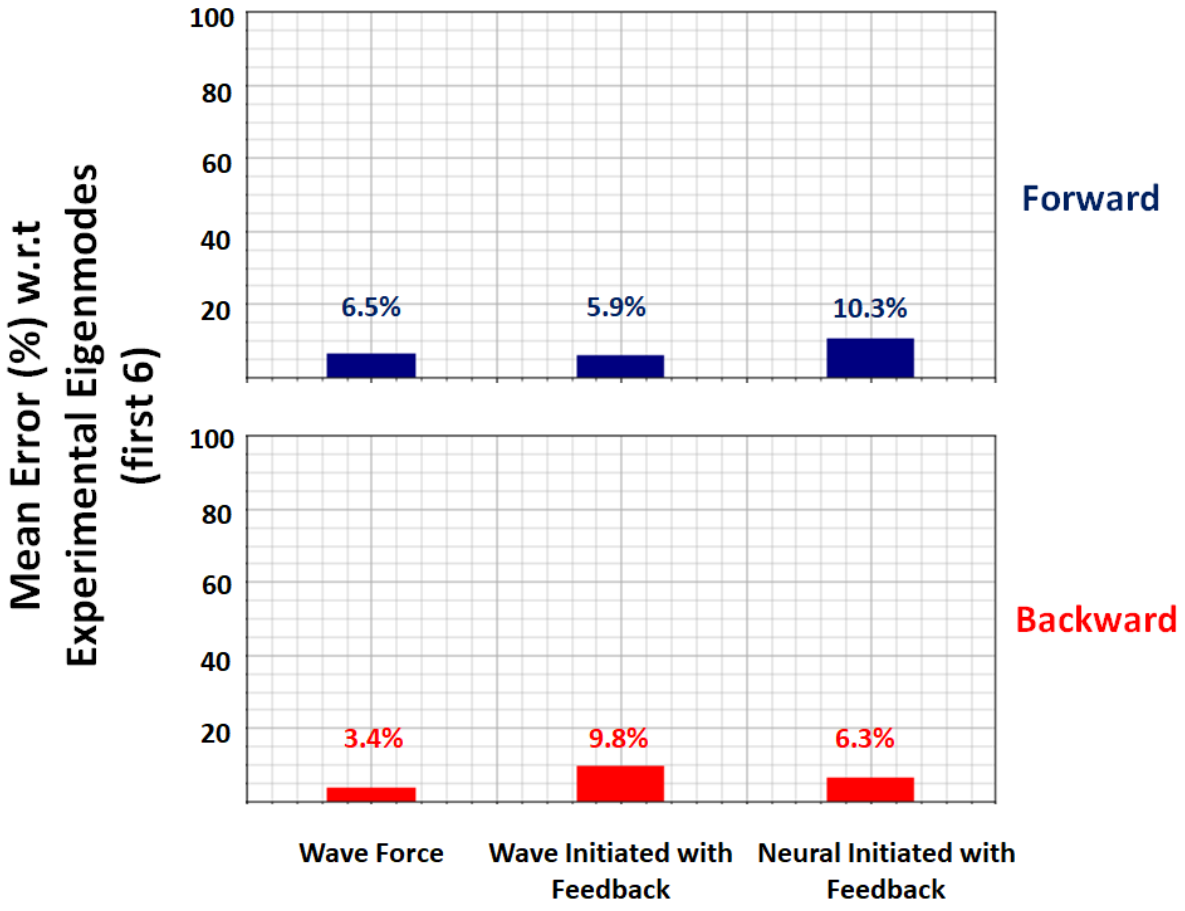


Whole Body Model Locomotion –Neural Stim



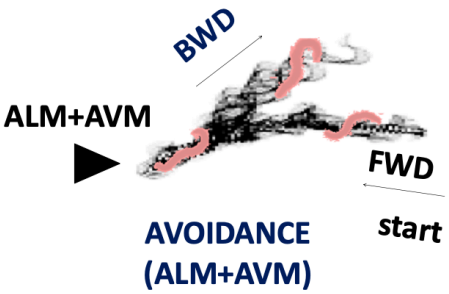
Neural Stimulus Initiated Forward and Backward Locomotion

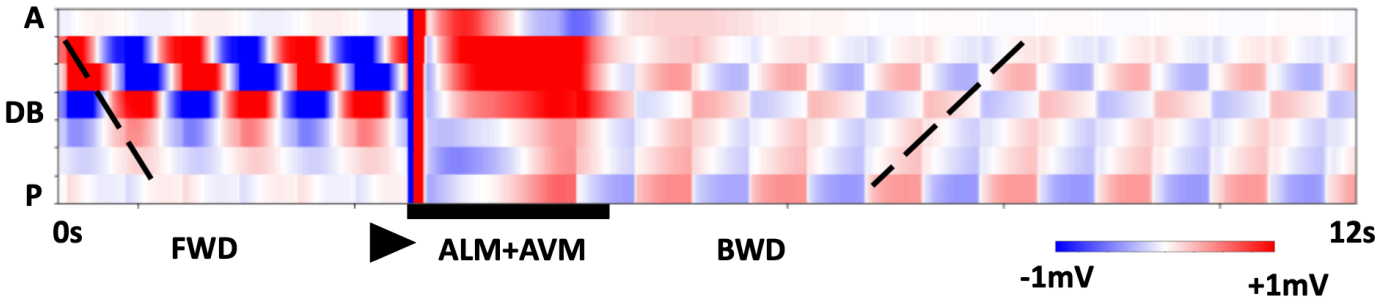
Are these movements typical?



Comparison with Eigenworms

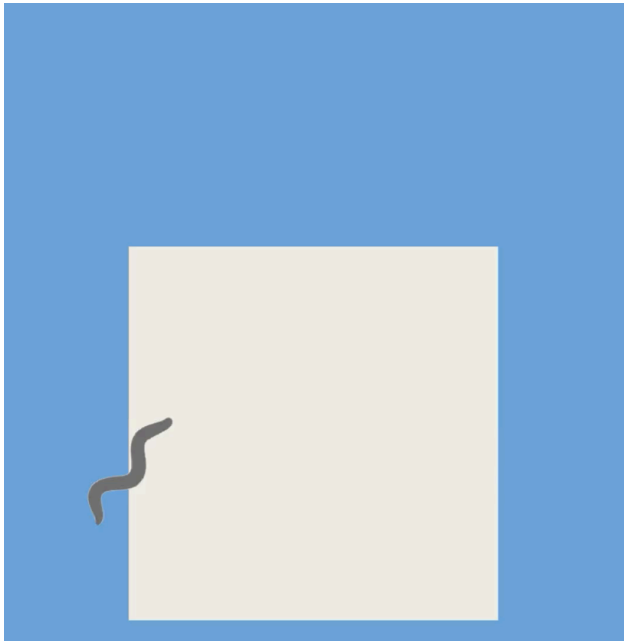
Neural Impulses during locomotion

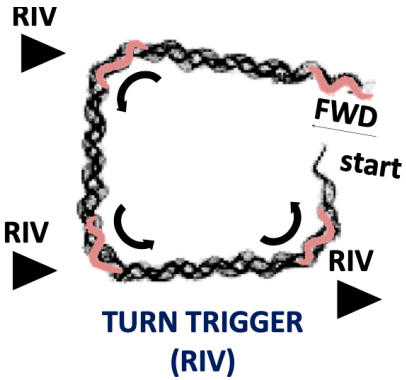


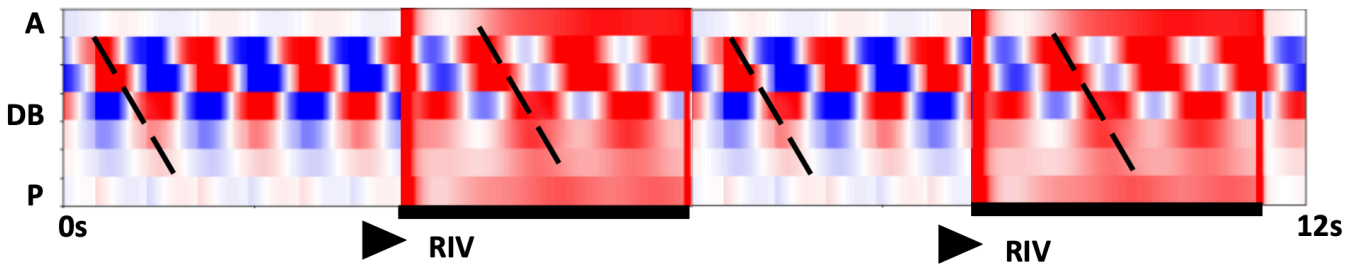


Avoidance

Neural Impulses during locomotion

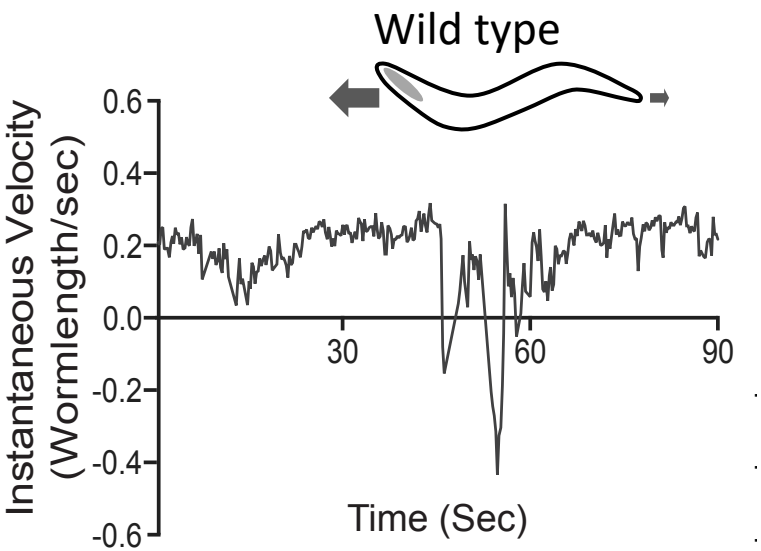


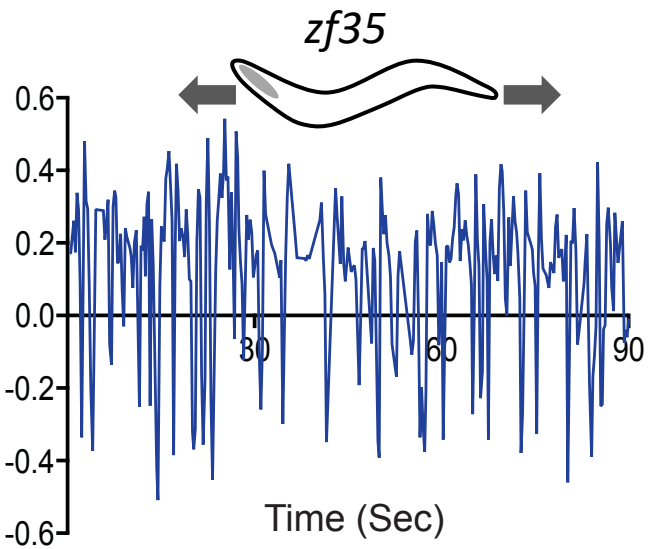




“A worm in a box”

Neural impulses during locomotion

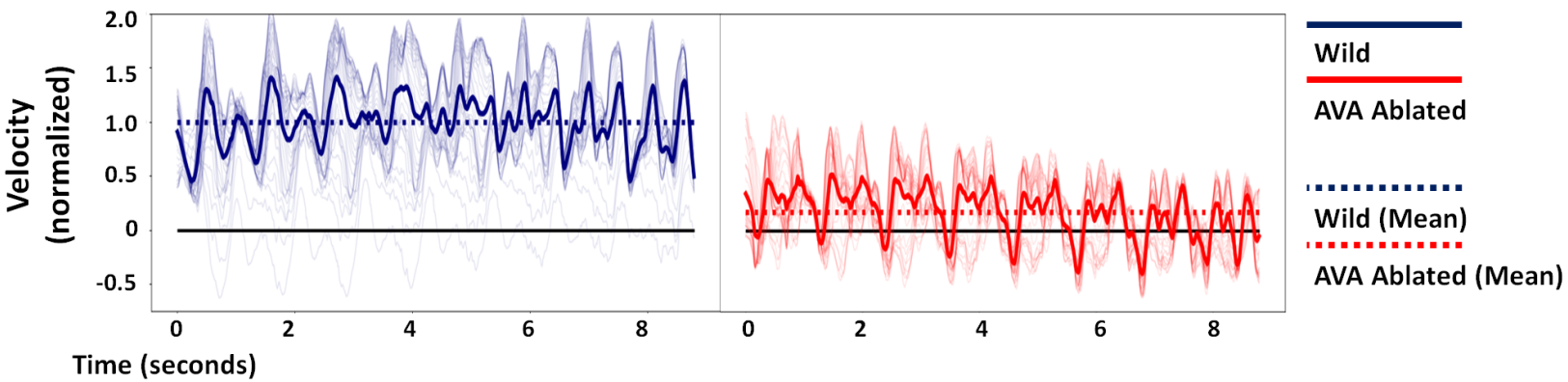




Excitation-Inhibition Balance

Huang et al., Elife 2019

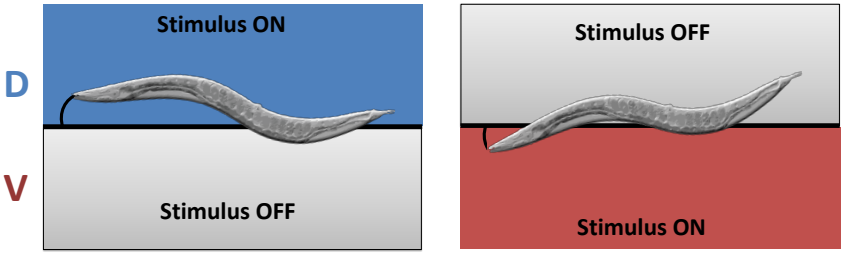
Neural impulses during locomotion



Excitation-Inhibition Balance

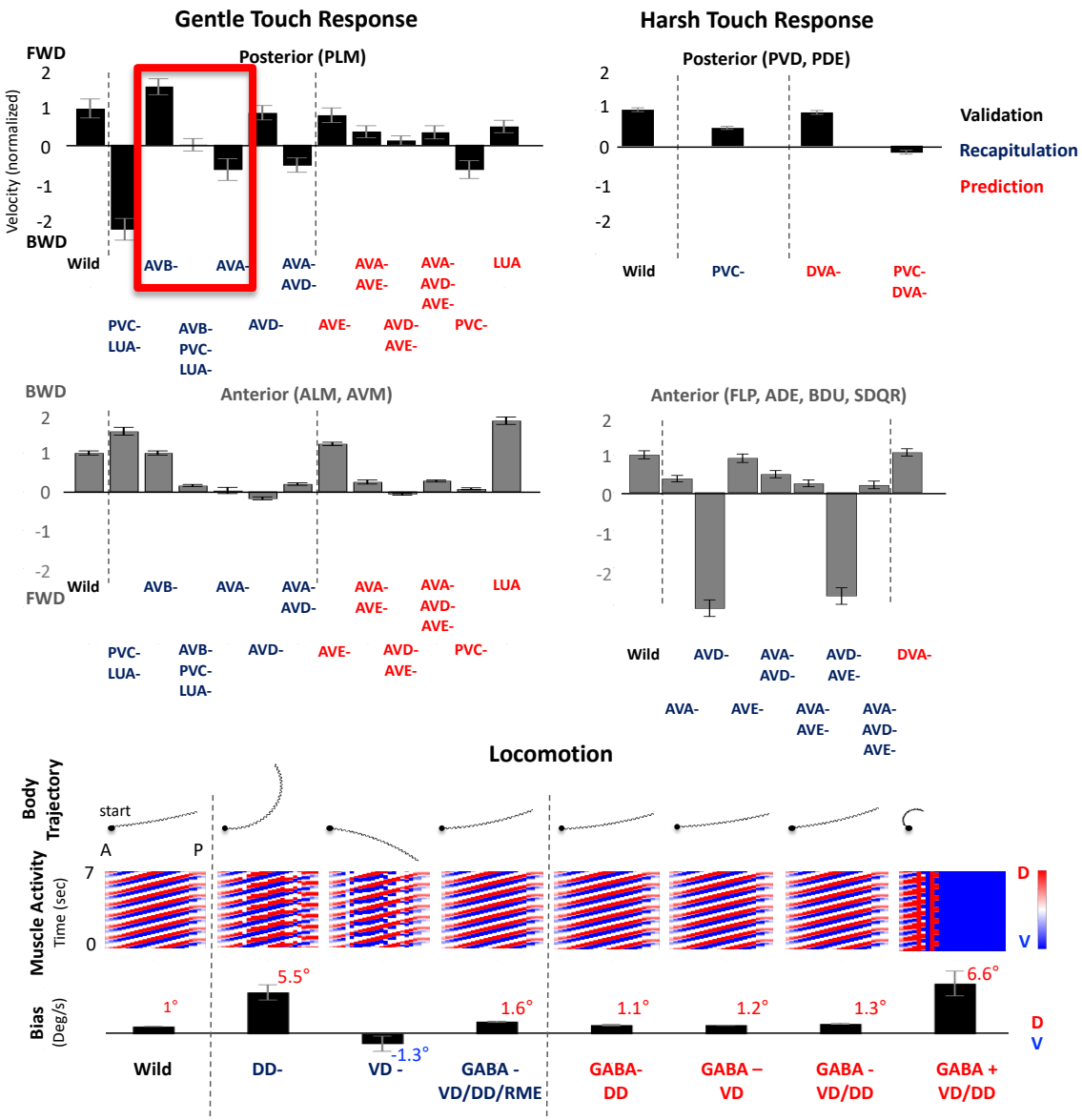
Neural Impulses during Locomotion

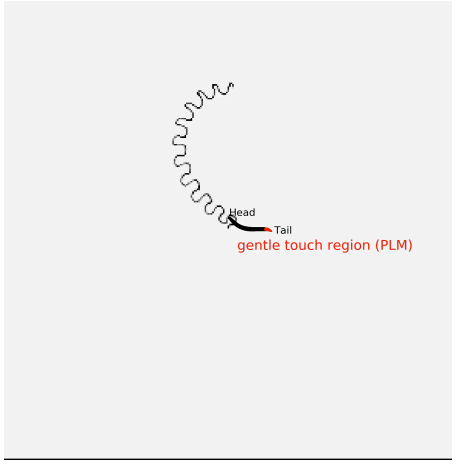
Asymmetric Stimulus



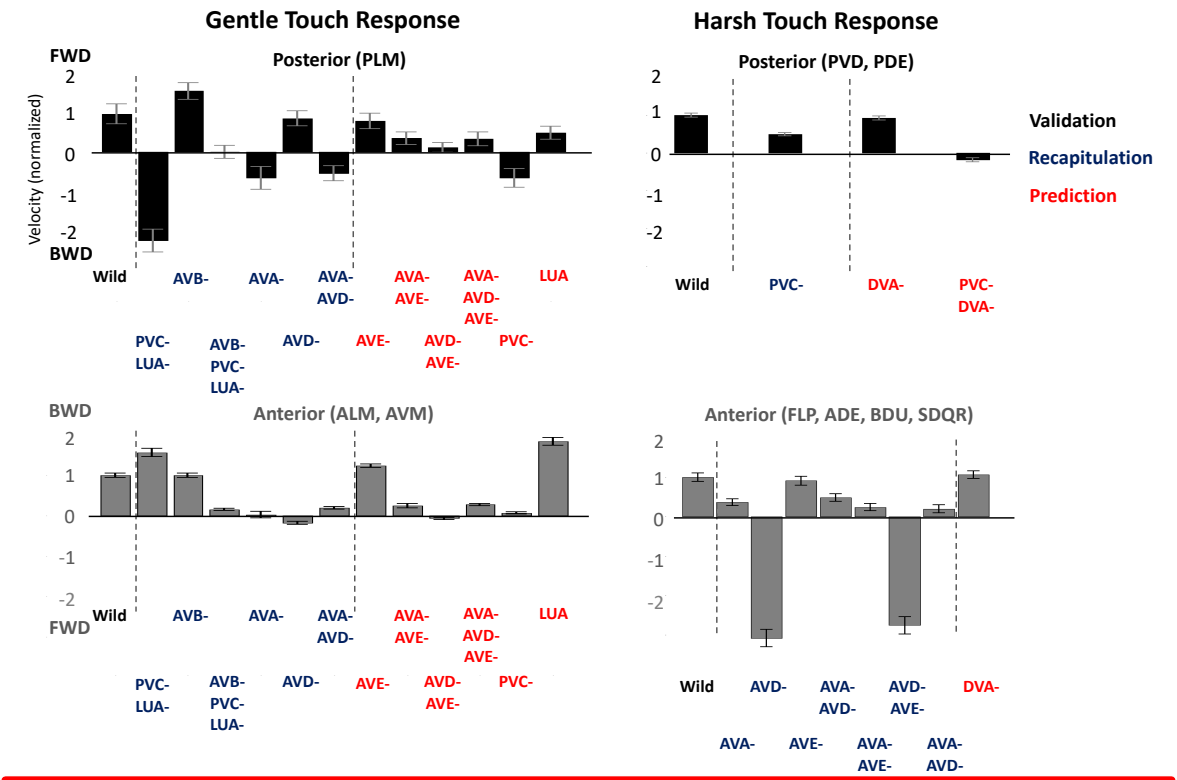
Posture related stimulus

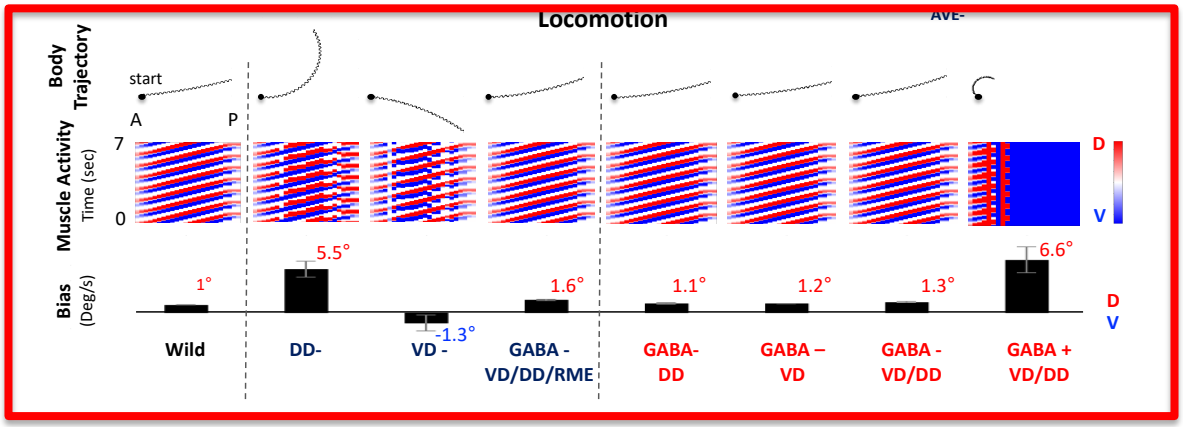
Ablation (Back to Connectomics)



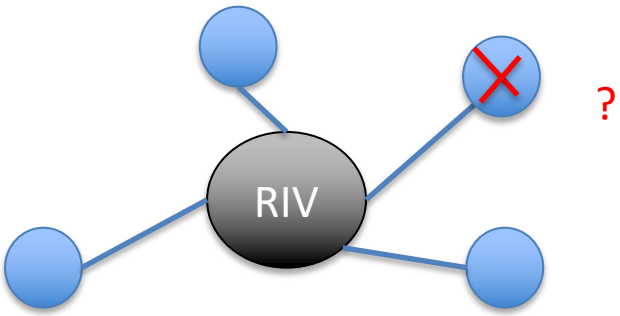


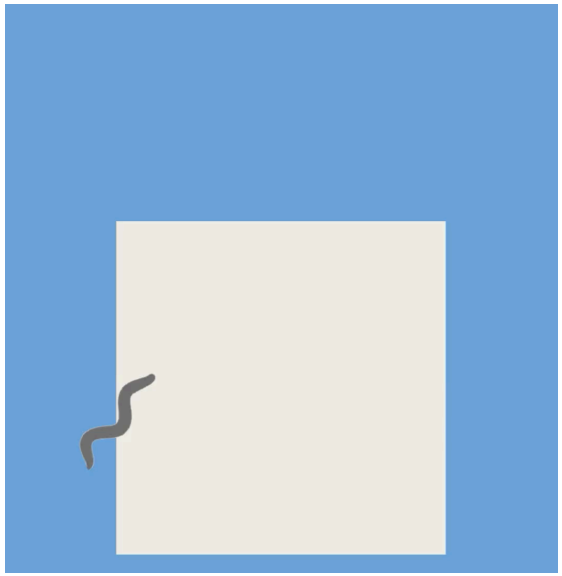
Ablation of groups of neurons

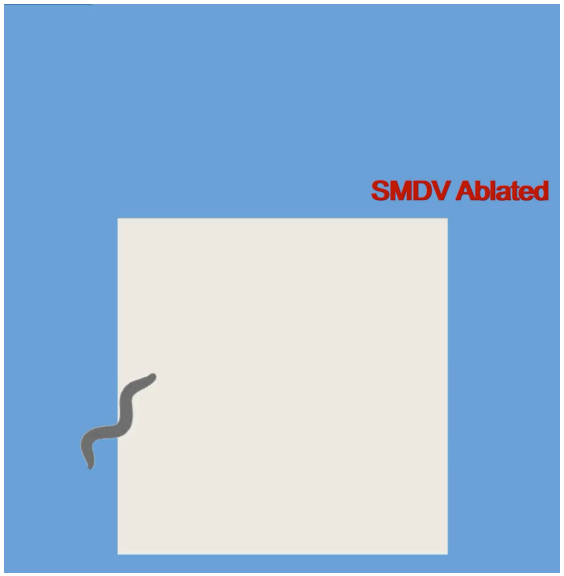




Ablation Search (Back to Connectomics)

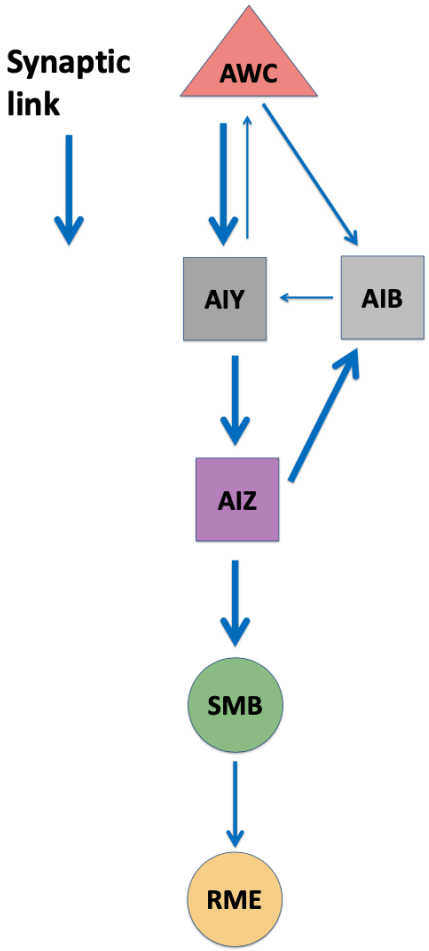




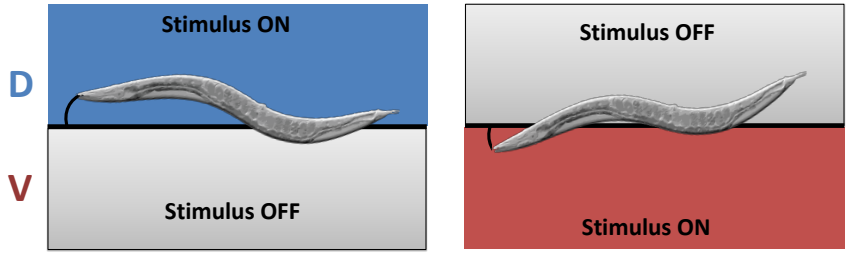


Behavioral Circuits

Olfactory Circuit

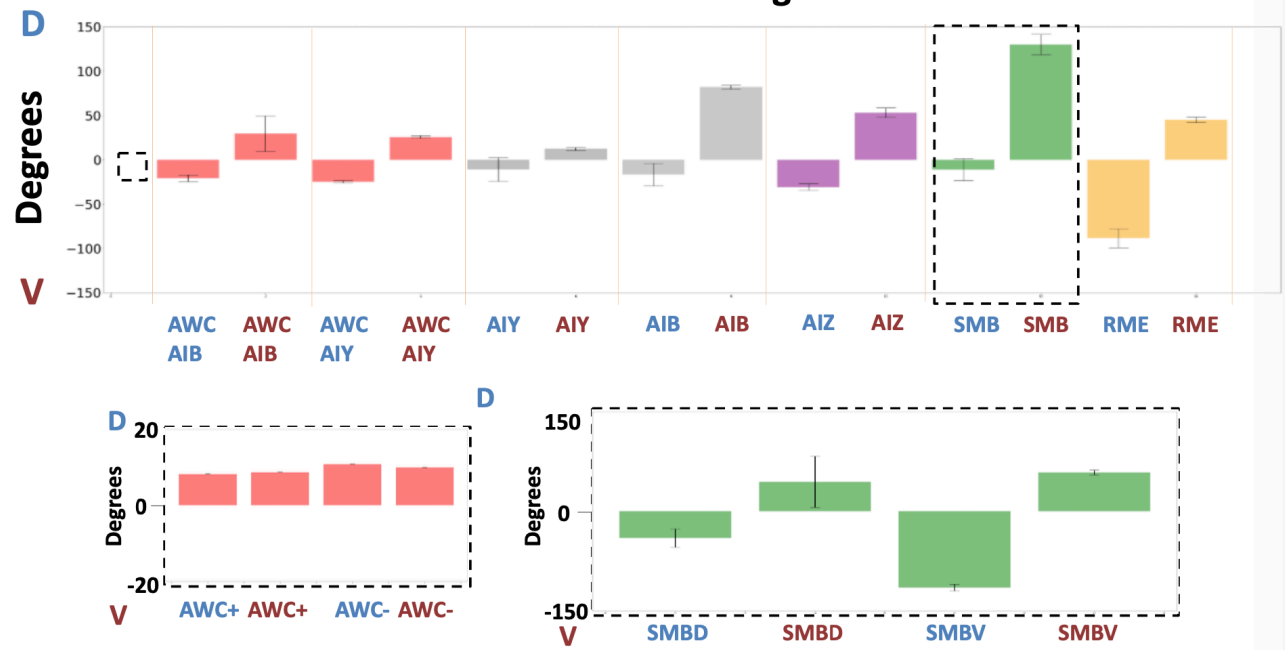


Asymmetric Stimulus



C

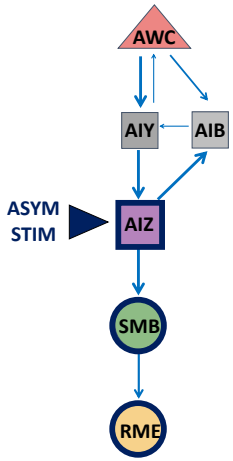
Head Offset Angle



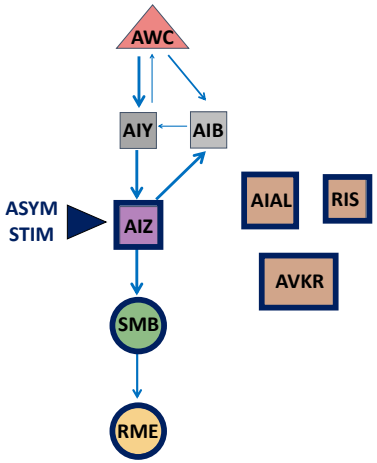
Stimulation Flow

A

AIZ Stimulus



Ablated	Turn Angle (V)	Turn Angle (D)
-	53º	-31º
AWC	52º	-30º
AIY	52º	-28º
AIB	45º	-26º
AIZR	**40º**	**-13º**
AIZL	**36º**	**39º**
SMB	**57º**	**-10º**
RME	**48º**	**-3º**



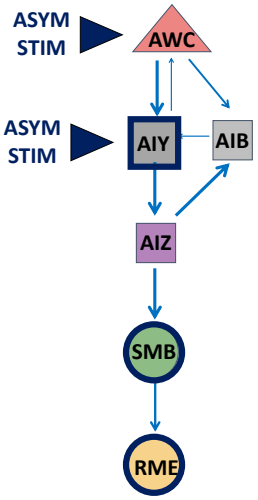
From ALL interneurons

AIAL	**32º**	**2º**
RIS	**56º**	**-41º**
AVKR	**57º**	**-20º**

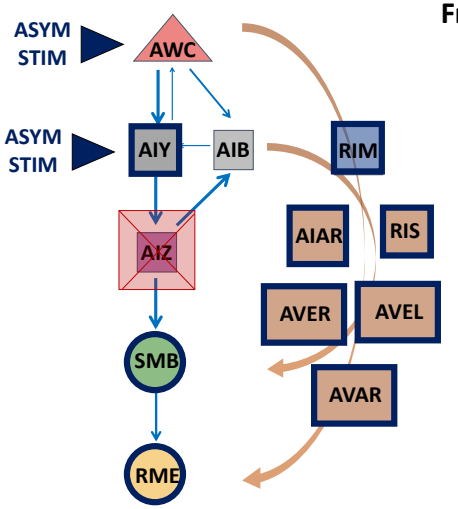
Conditional Ablation (Stimulation Flow)

B

AWC+AIY Stimulus



Ablated	Turn Angle (V)	Turn Angle (D)
-	26º	-25º
AWC	16º	-31º
AIYR	**9º**	**2º**
AIYL	**3º**	**26º**
AIB	19º	-32º
AIZ	24º	-25º
SMB	**13º**	**-2º**
RME	**50º**	**15º**



From ALL interneurons | AIZ Ablated

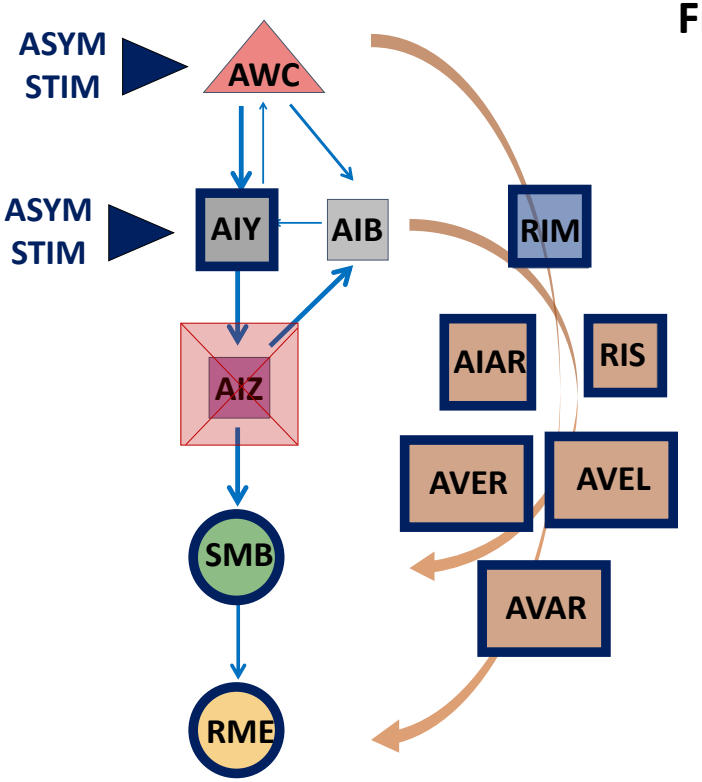
AVAR	**-7º**	**-28º**
AVEL	**26º**	**1º**
AVER	**63º**	**-1º**
AIAR	**23º**	**-12º**
RIS	**40º**	**-42º**

From ALL neighbors | AIZ Ablated

RIML	**20º**	**1º**
RIMR	**3º**	**-7º**

Ablation Survey

Inference of behavioral circuits



From ALL interneurons | AIZ Ablated

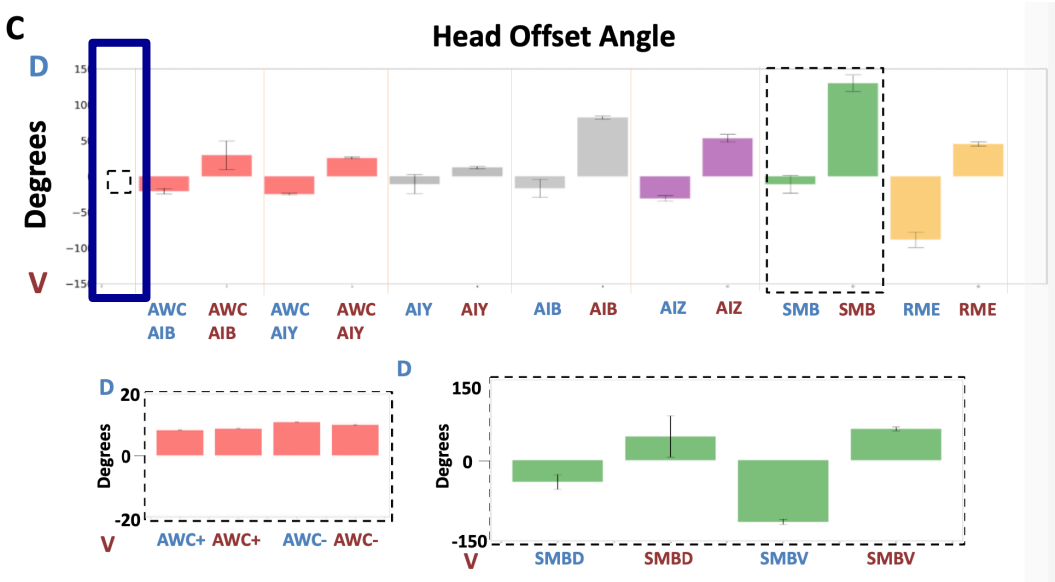
AVAR	-7º	-28º
AVEL	26º	1º
AVER	63º	-1º
AIAR	23º	-12º
RIS	40º	-42º

From ALL neighbors | AIZ Ablated

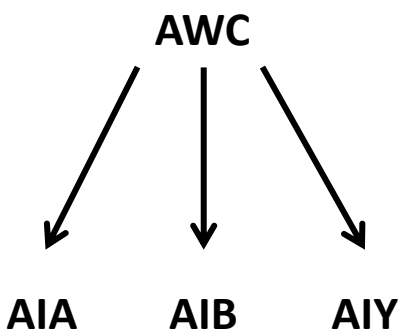
RIML	20º	1º
RIMR	3º	-7º

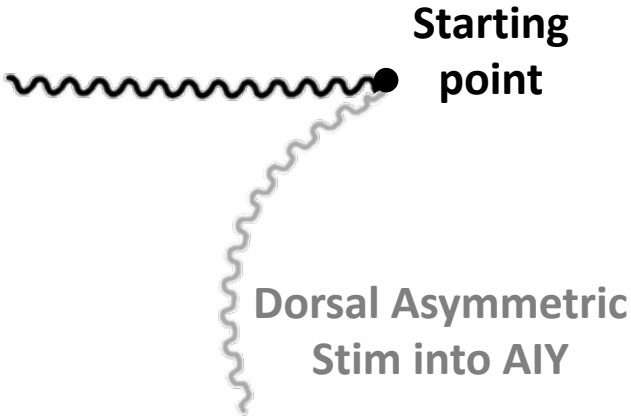
Is the model accurate enough?

- **Search for model failures in prediction**

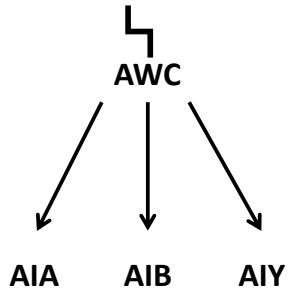
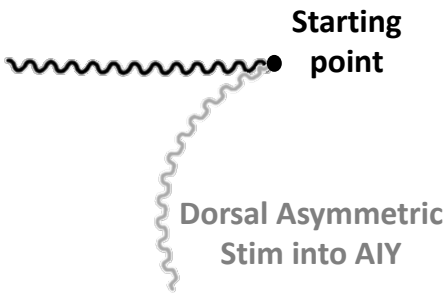
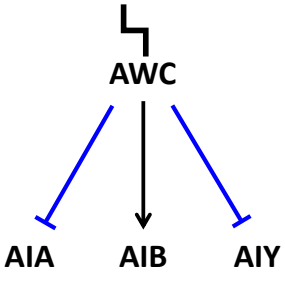
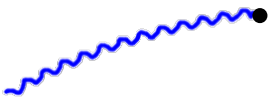


Base





Model Refinement

Configuration	Connectome	Movement Trajectory (Dorsal Asymmetric Stim into AWC)
Base		
GluCl (AWC → AIA, AIY)		

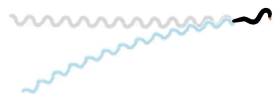
Dorsal asymmetrical stimuli (AWC)
with GLUCL (AWC -> AIY, AIA)
Negative Neuropeptides into AIY, AIA

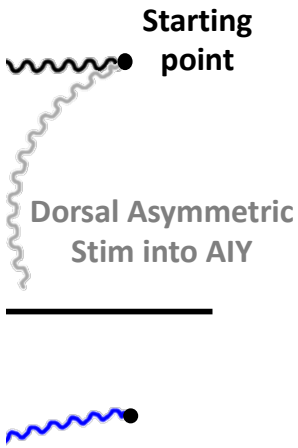
Model Refinement

Configuration **Connectome** **Movement Trajectory**

(Dorsal Asymmetric Stim into AWC)

Dorsal asymmetrical stimuli (AWC)
with GLUCL (AWC -> AIY, AIA)
Negative Neuropeptides into AIY, AIA

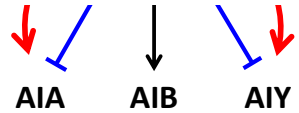




(AWC

Neu

(AWC → AIA, AIY)



Spontaneous Behavior/Stochastic behavior

“Can of worms”

Stochastic Behavioral Circuits