Characterizing the Role of Homeostatic Plasticity in Central Pattern Generators

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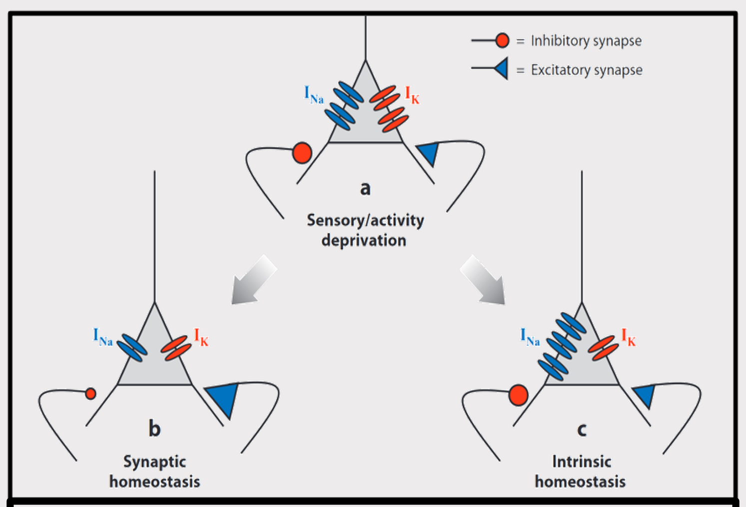
WHAT IS HOMEOSTATIC PLASTICITY (HP)?

- Grants robustness to perturbation
- Neurons regulate their excitability to maintain target activity level
- Tune strength of their incoming synapses and ionic conductances
  - Multiple molecular mechanisms, from receptor localization to gene expression



Adapted from Turrigiano, 2011 (Fig. 1)

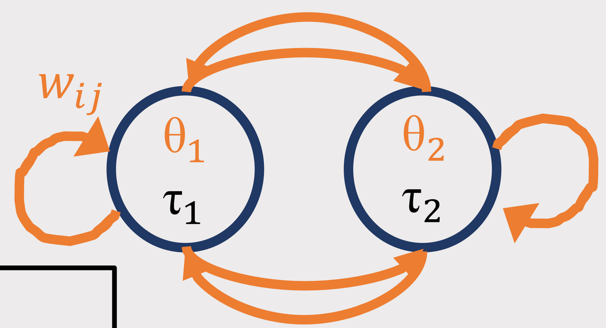
OBJECTIVES

- How does HP affect circuits as they behave normally?
- Does its effect depend on the features of HP (i.e. its timescale)?
- Does its role change in more complex behaviors?

MODEL

Continuous-Time-Recurrent NN

$$\tau_i \dot{y}_i = -y_i + \sum_{j=1}^{n} w_{ji}\sigma(y_j - \theta_j)$$

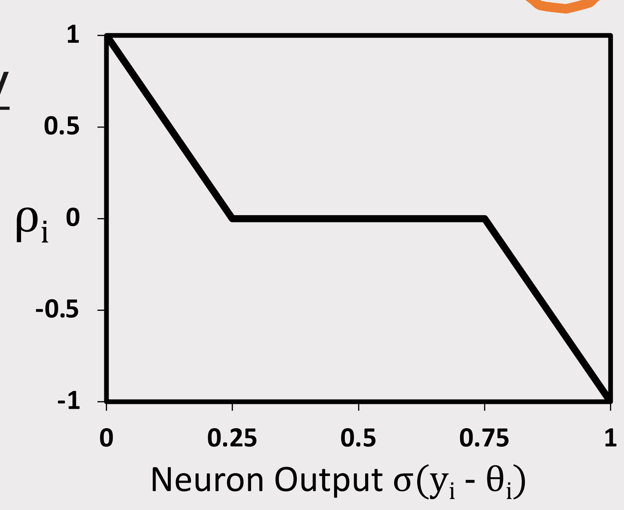


Homeostatic Plasticity

$$\tau_w \dot{w}_{ji} = \rho_i |w_{ji}|$$

$$\tau_\theta \dot{\theta}_i = \rho_i$$

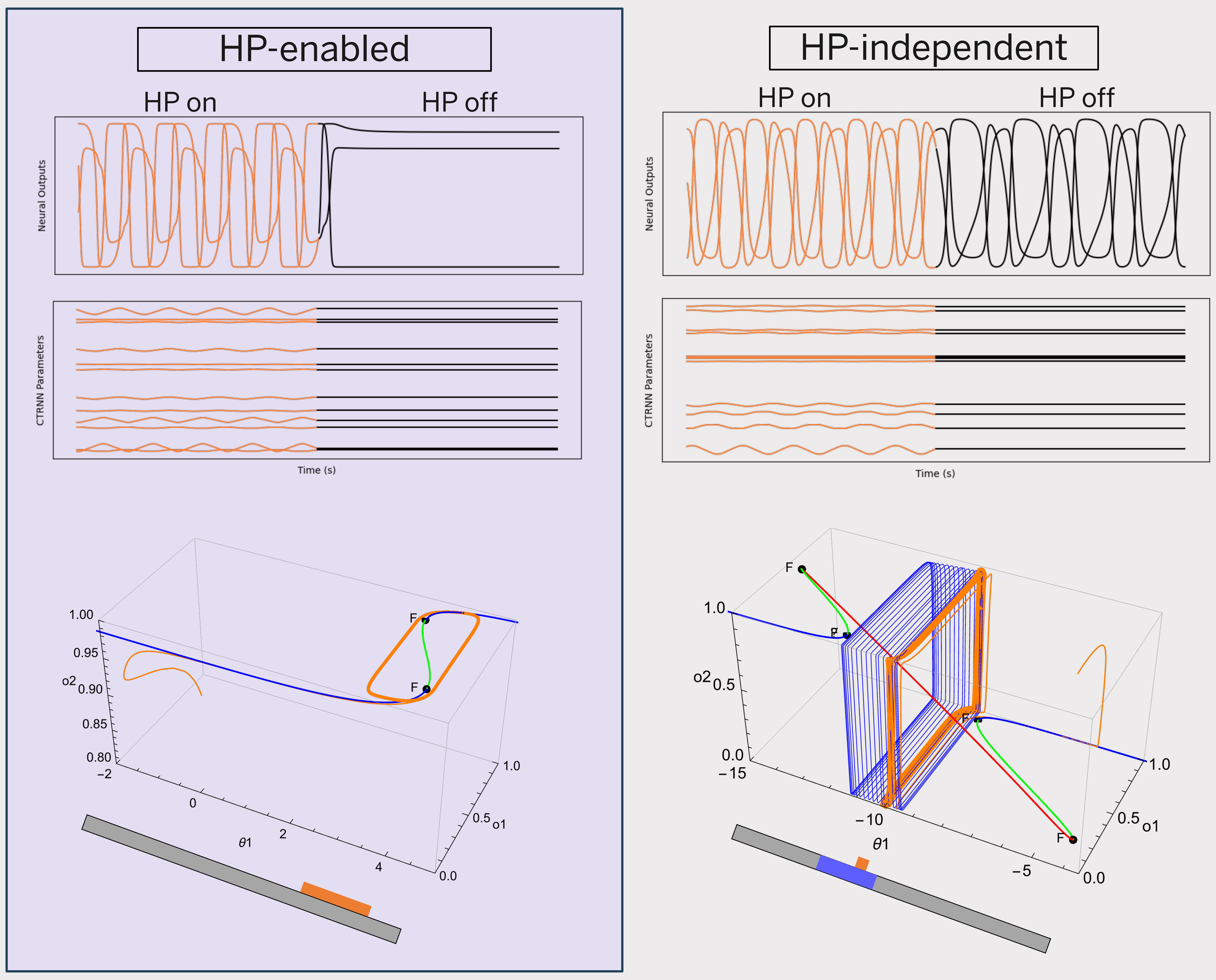
(Model based on Williams et al., 2005)



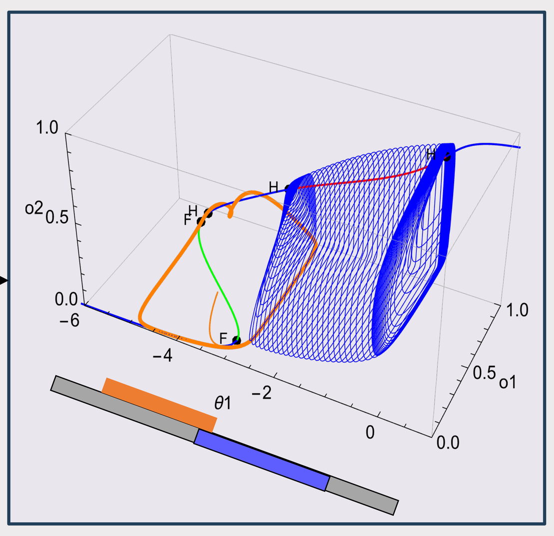
HP COMMONLY ENABLES OSCILLATIONS

Generate oscillators then turn HP off → oscillations may stop

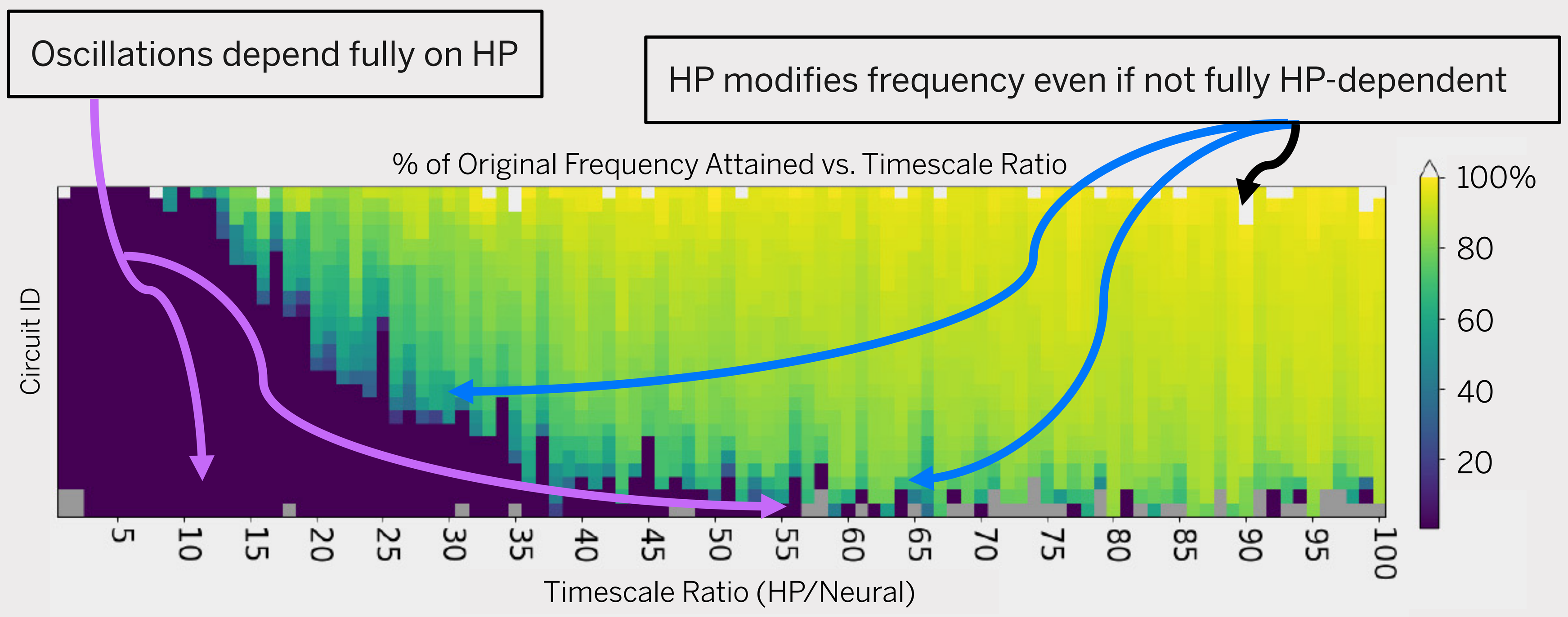
☆ **Oscillations in neural states and parameters can be produced by the action of HP**



Depends on when HP turns off—effectively HP-enabled



HP-ENABLED OSC. OCCURS DESPITE TIMESCALE SEPARATION



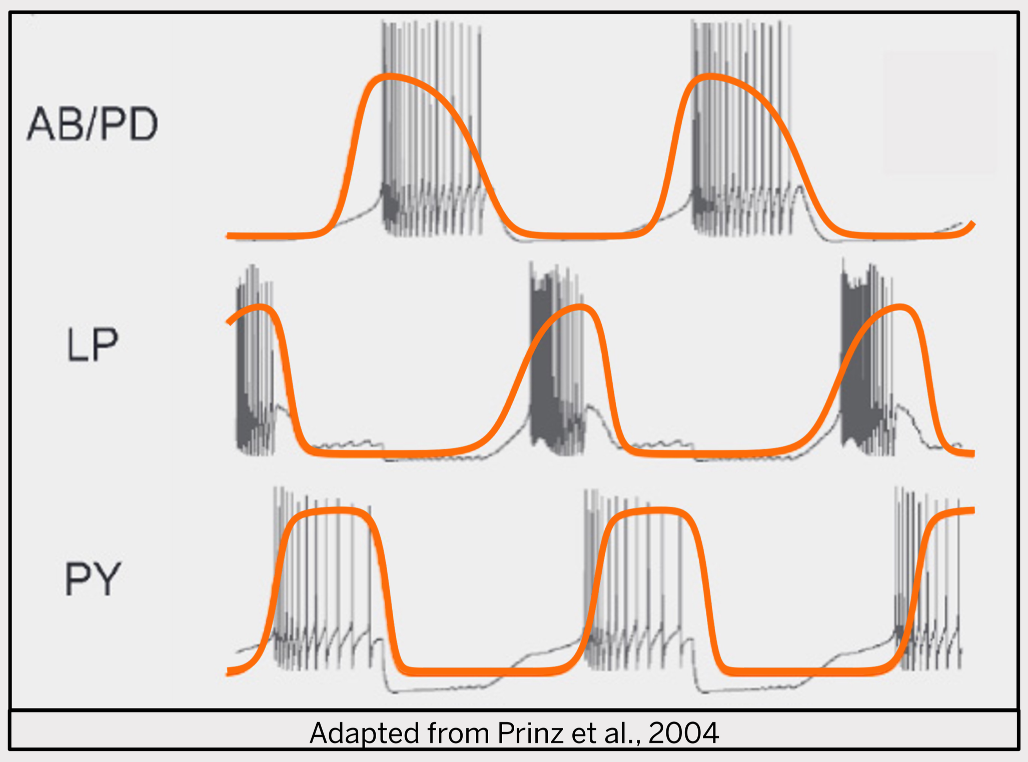
- Oscillatory behaviors and HP's molecular mechanisms occur on many different timescales.
- HP can enable and modify oscillations even when it is ~100x slower than neurons

HP-ENABLED OSCILLATORS ON A PYLORIC RHYTHM TASK

What about a more complicated behavior?

Out of 20 homeostatic circuits evolved to match the pyloric pattern,

- 13: neurons stopped oscillating without HP
- 0: ordering criteria break down without HP
- 6: still pyloric with worse timing/duty cycle
- 1: still pyloric with better timing/duty cycle



Adapted from Prinz et al., 2004

- HP-enabled limit cycles can meet complex criteria
- Non-homeostatic limit cycles may heavily influence their shape

CONCLUSIONS

- **HP plays modifying and constitutive roles in central pattern generation**
- Increases dimensionality of the dynamical system
- This may occur despite timescale separation

Homeo "stasis" is a *dynamic* process and plays a role in *dynamic* behavior

KEY REFERENCES

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