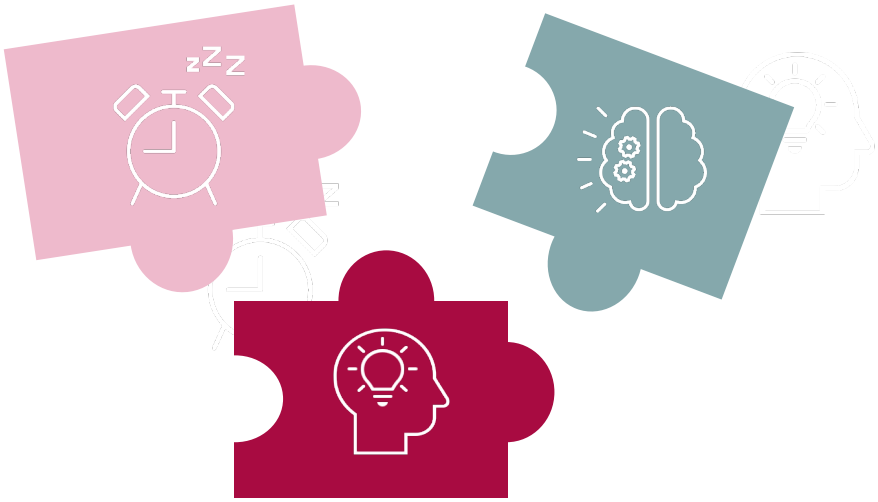
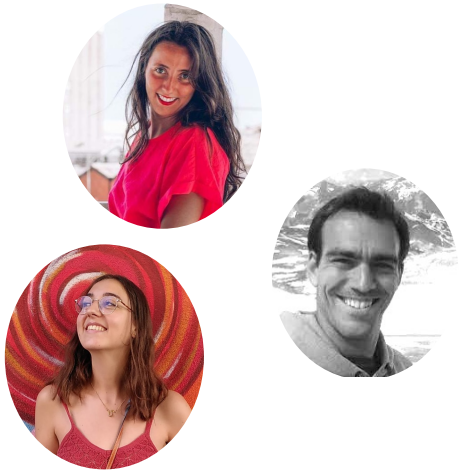
Effect of switches in brain states on calcium-based plasticity rules: a computational study for sleep-dependent memory consolidation

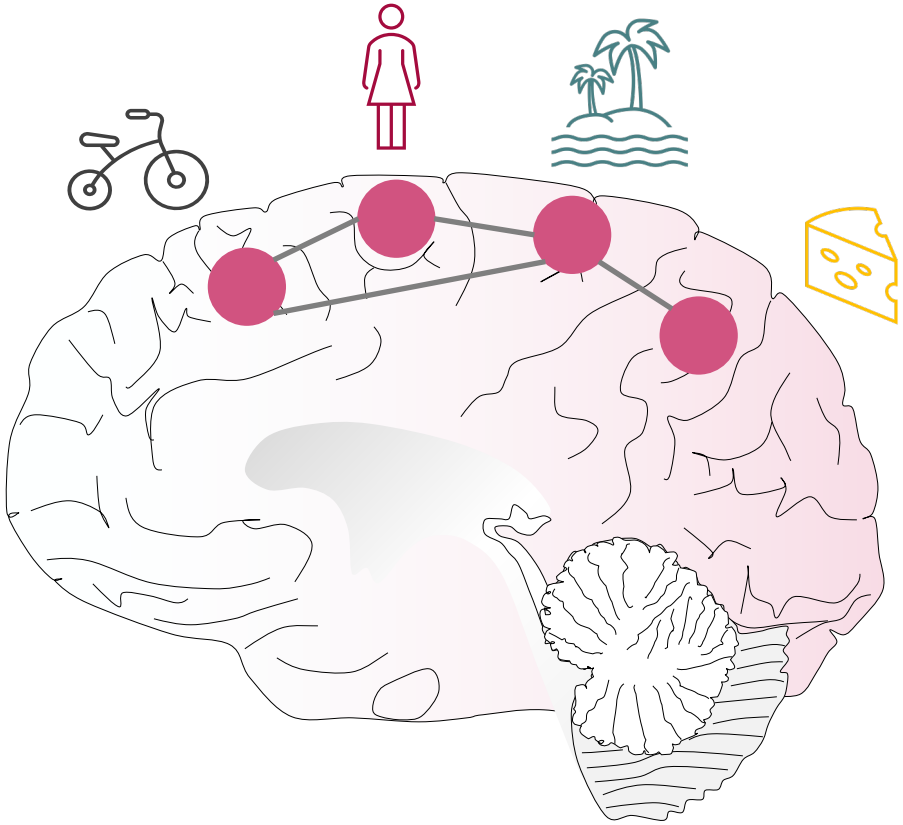
Kathleen Jacquerie, Caroline Minne and Guillaume Drion

Department of Electrical Engineering and Computer Science,
University of Liege, Belgium

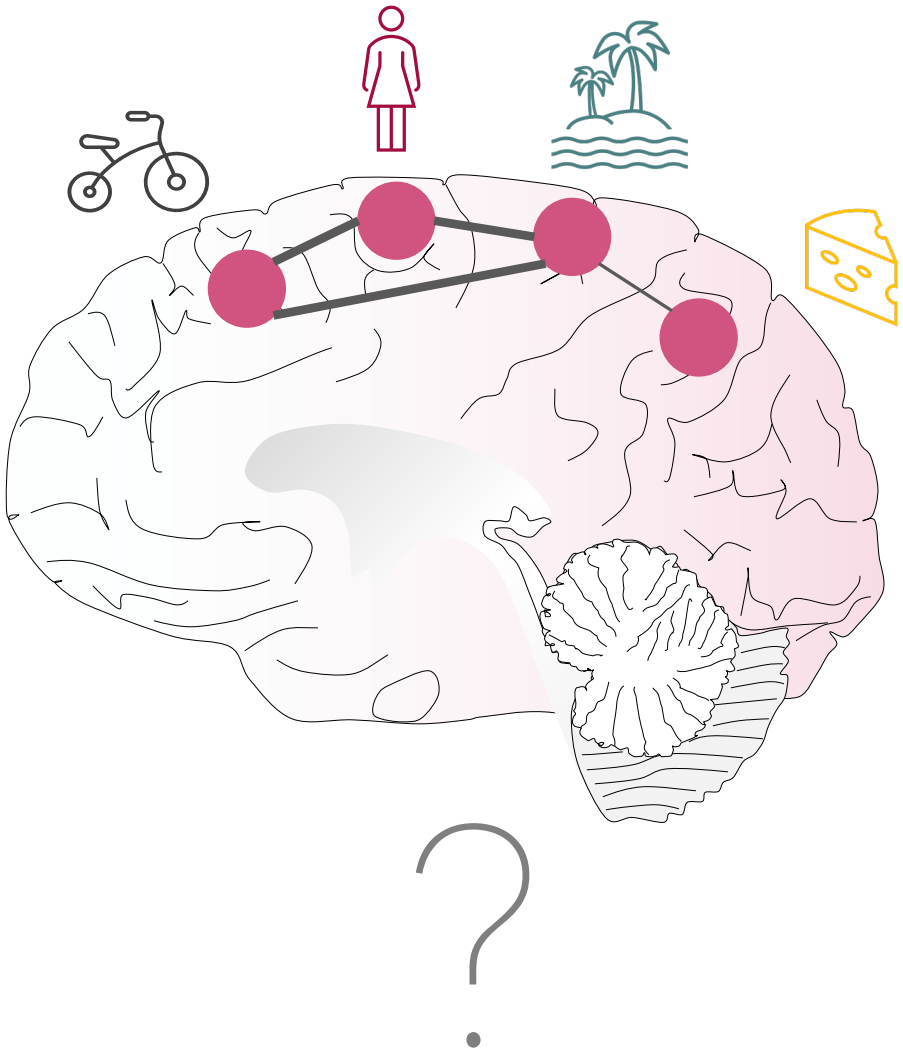




kathleen.jacquerie@uliege.be



Adapted from [Feld,2020]
Adapted from http://www.incertae-sedis.fr/gl/docu1173_03_circuits-recompense-encephale-humain.htm



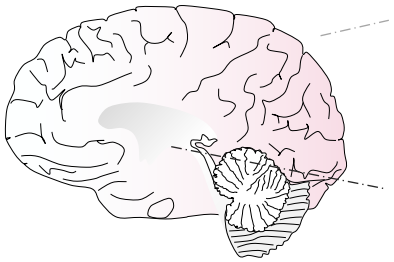
Switches in network rhythms during sleep and wakefulness

Synaptic plasticity: calcium-based rules

Model sleep-dependent memory consolidation

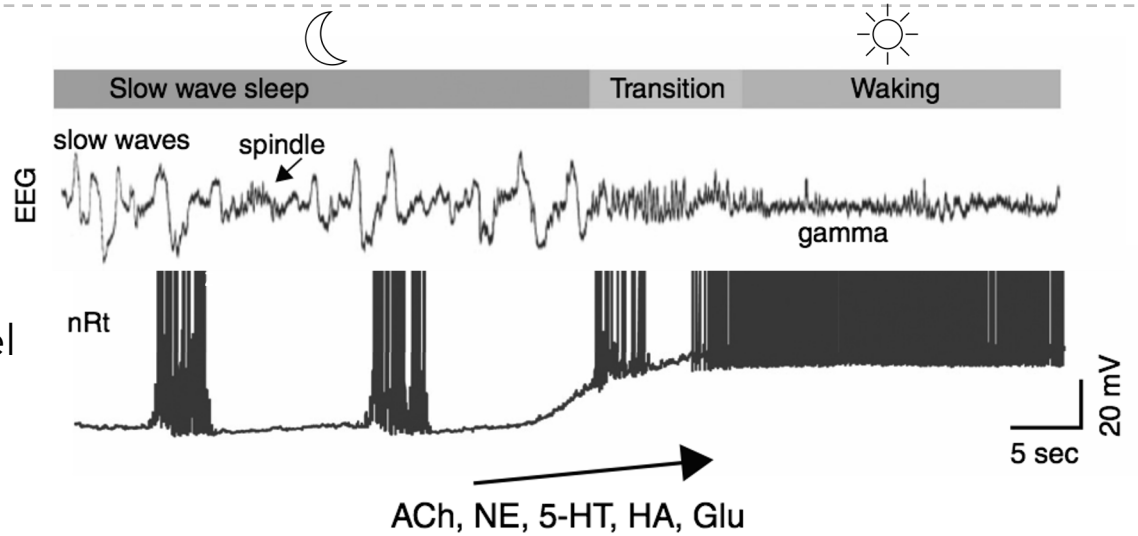
Network rhythms during sleep and wakefulness

Experiment



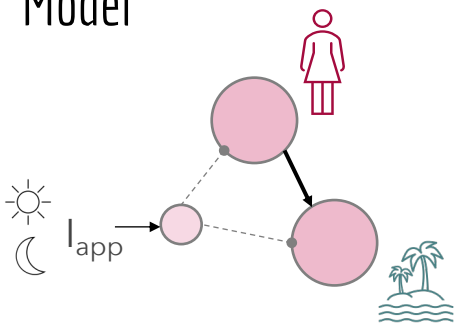
Brain level

Cellular level



Adapted from [Zagha and McCormick, 2014]

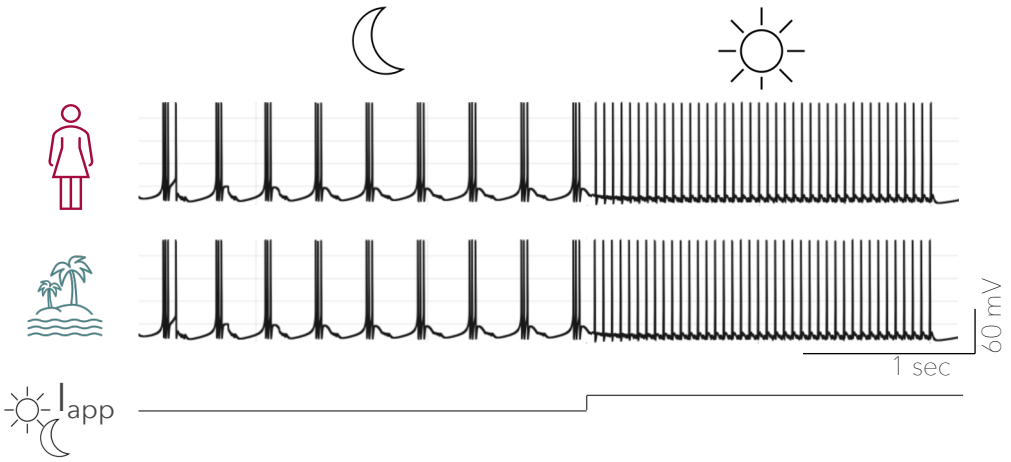
Model



Switch in firing activity from tonic to burst

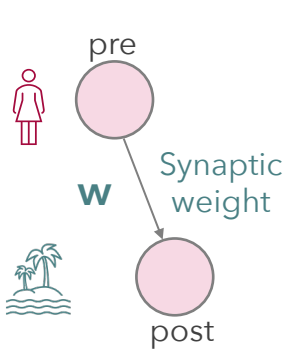
Conductance-based model

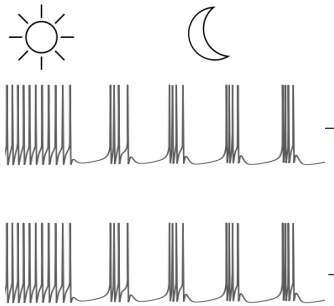
- ✓ Robust to neuromodulation
- ✓ Robust to plasticity



[Drion,2018; Jacquerie,2021]

Which synaptic plasticity rule is compatible with switches?

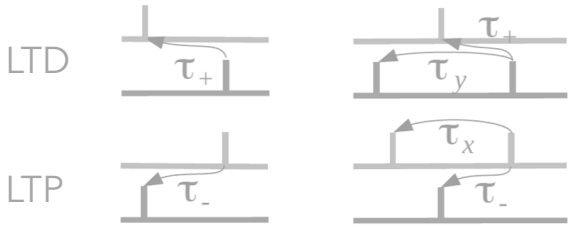




Plasticity rule

Synaptic change

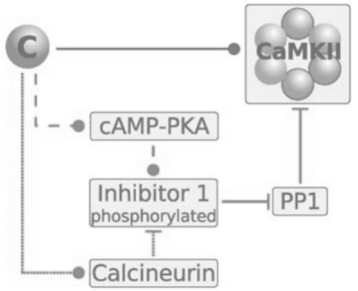
Phenomenological models



- Using pre- and post- spike time to compute Δw
- Can involve complex mathematical models

→ Spike-time dependent plasticity, triplet model, …

Biophysical models

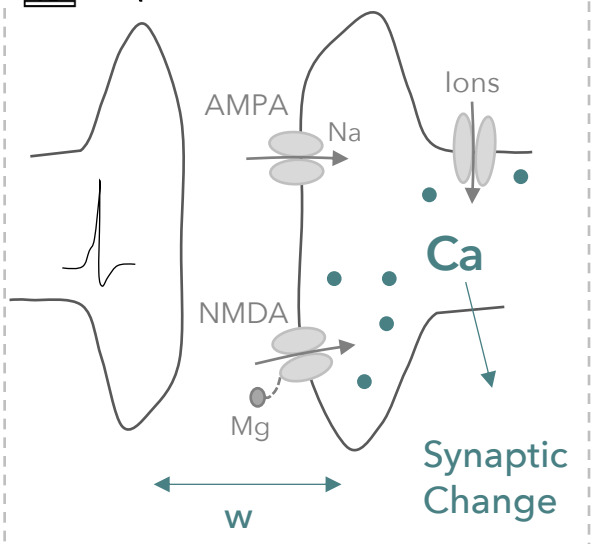


- Model the biological machinery
- Degree of biological details can vary

Adapter from [Graupner,2015]

Calcium-dependent plasticity rules

Experiment



Model

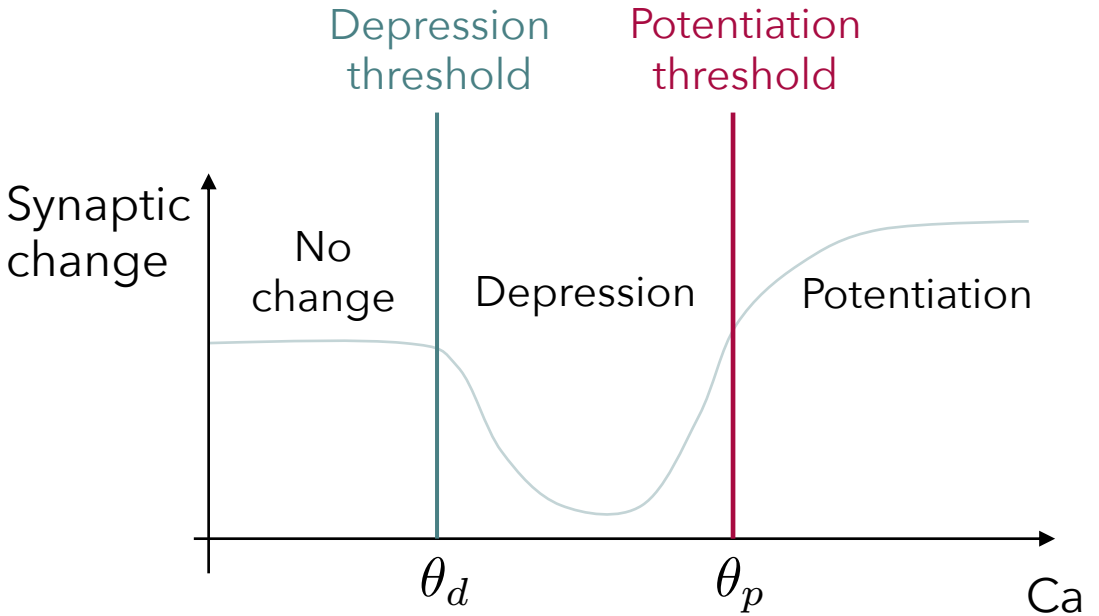
[Graupner, 2016; Deperrois, 2020]

$$\tau_w \dot{w} = \gamma_p(1-w)\Theta(Ca-\theta_p) - \gamma_d w \Theta(Ca-\theta_d)$$

[Shouval, 2002]

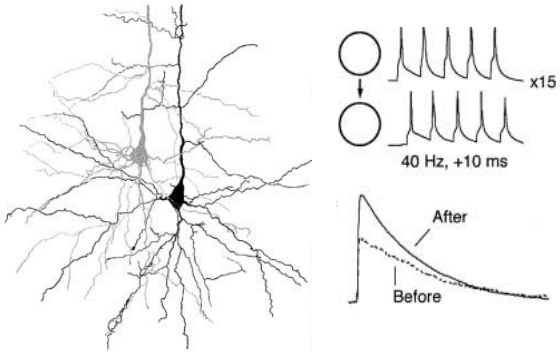
$$\tau_w(Ca)\dot{w} = \Omega(Ca) - w$$

Calcium influx governs the synaptic change



Validation on experimental data in wakefulness

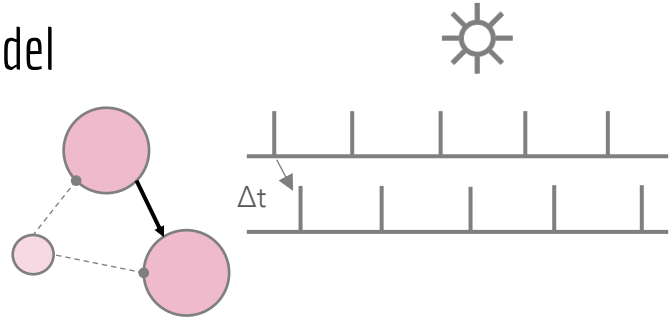
Experiment

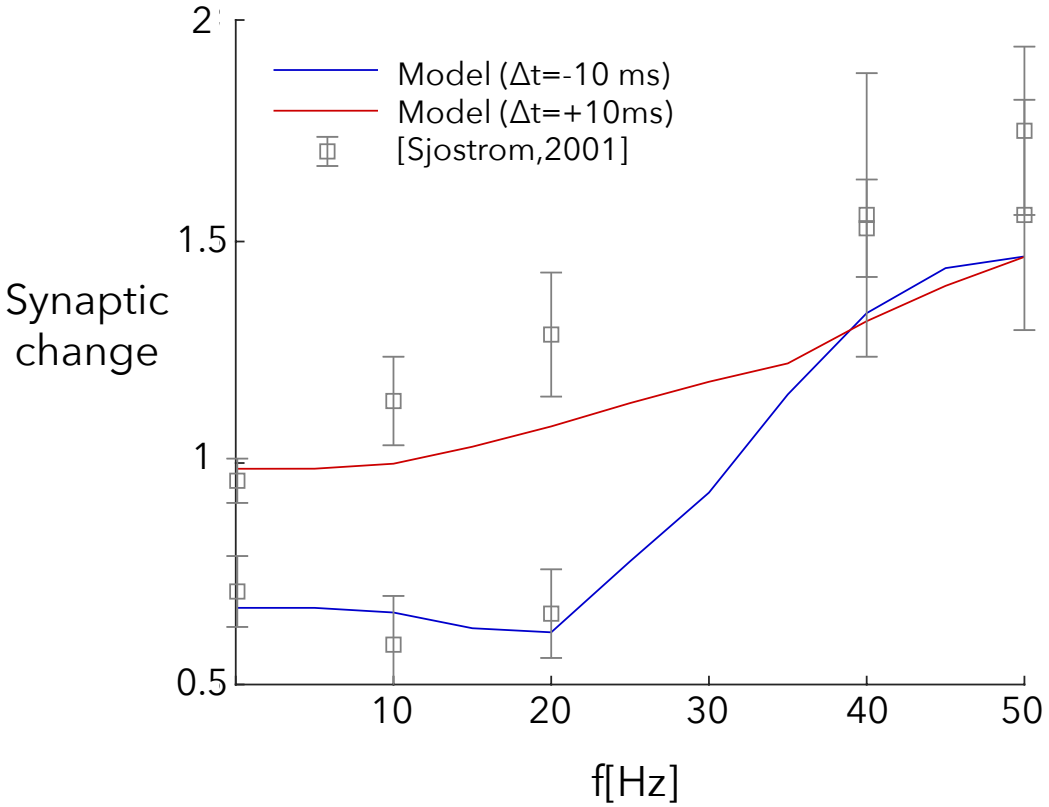


5 spikes pre-post
at a given frequency

[Sjostrom,2001; Graupner,2016]

Model





Conclusion

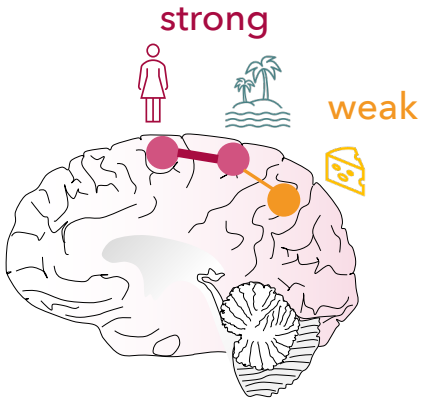
We reproduced the pairing protocol experiment with the 3 calcium-dependent rules in a robust conductance-based model

Fitting completed ✓

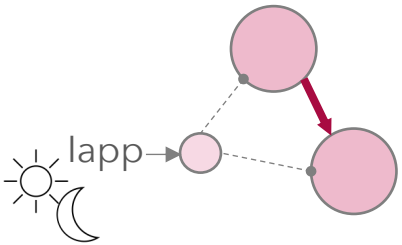
Calcium-based rules tested during sleep

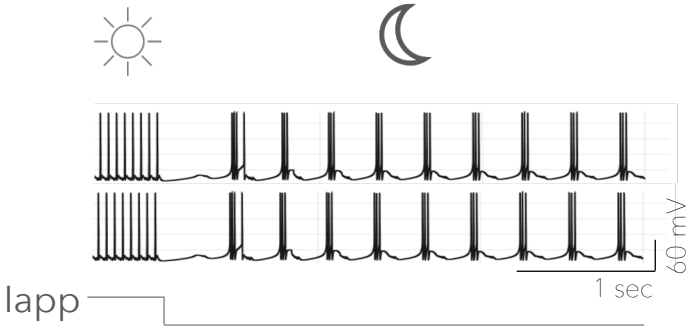
Experiment

How does connectivity strength change during sleep?

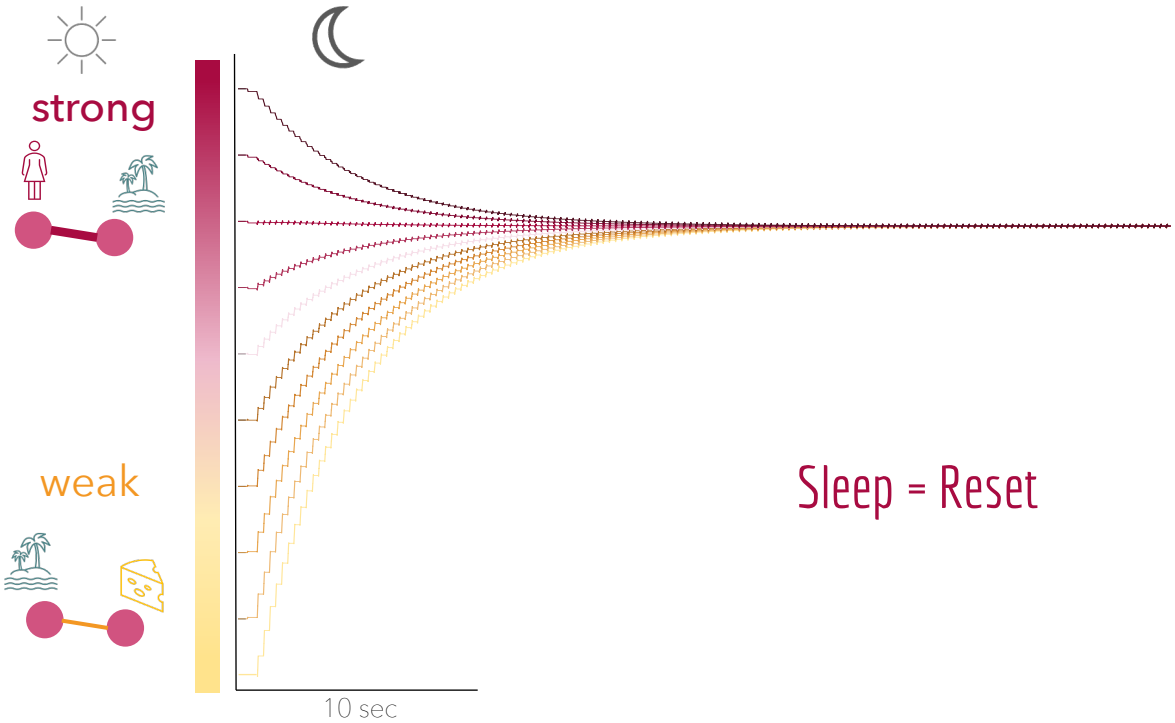


Model





Evolution of the connection strength during a sleep rhythm



Conclusion

Whatever we have learnt
the connection is restored
to a given value.

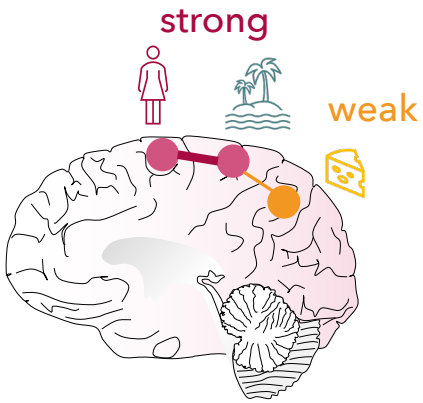
No learning,
nor consolidation,
nor down-selection is shown.

Sleep = Reset

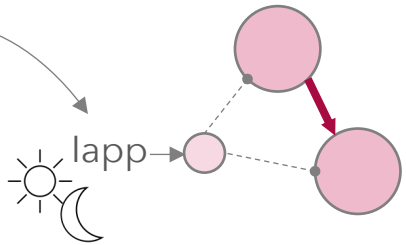
Calcium-based rules tested during sleep

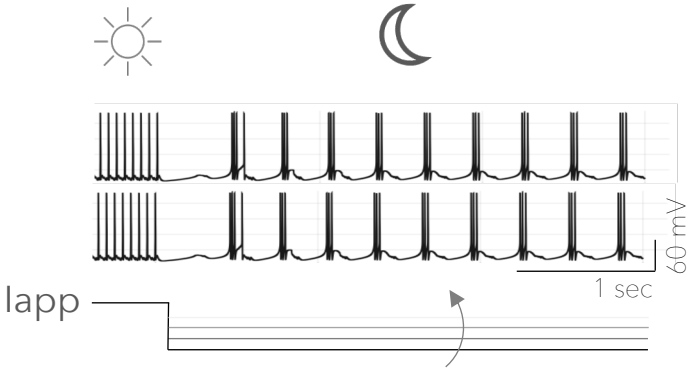
Experiment

Varying the bursting activity
(bursting freq., #spk/burst,…)

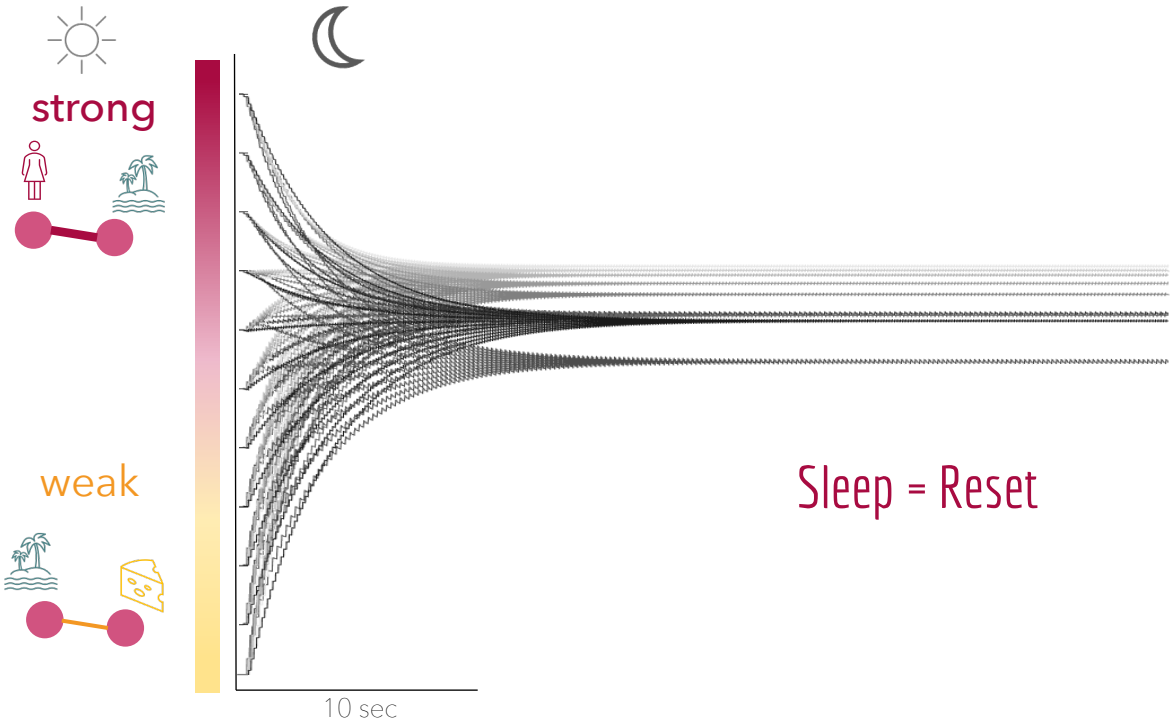


Model





Evolution of the connection strength during a sleep rhythm



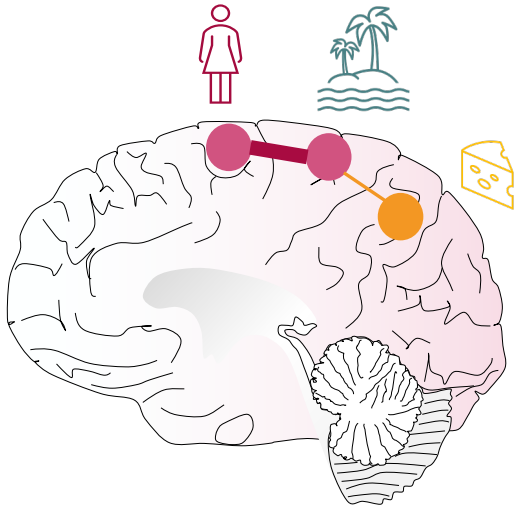
Conclusion

Changing the bursting rhythm does not affect the ability to consolidate

Sleep = Reset

Conclusions & Perspectives

- The classical calcium-dependent plasticity rules are not appropriate to study plasticity during bursting activity
- Same result is demonstrated with phenomenological models [Poster P113.07 from C.Minne]
- Next step: building a calcium-dependent rule **robust to neuromodulation**



kathleen.jacquerie@uliege.be