



Electromagnetic Brain Mapping Physiology of source signals

Sylvain Baillet

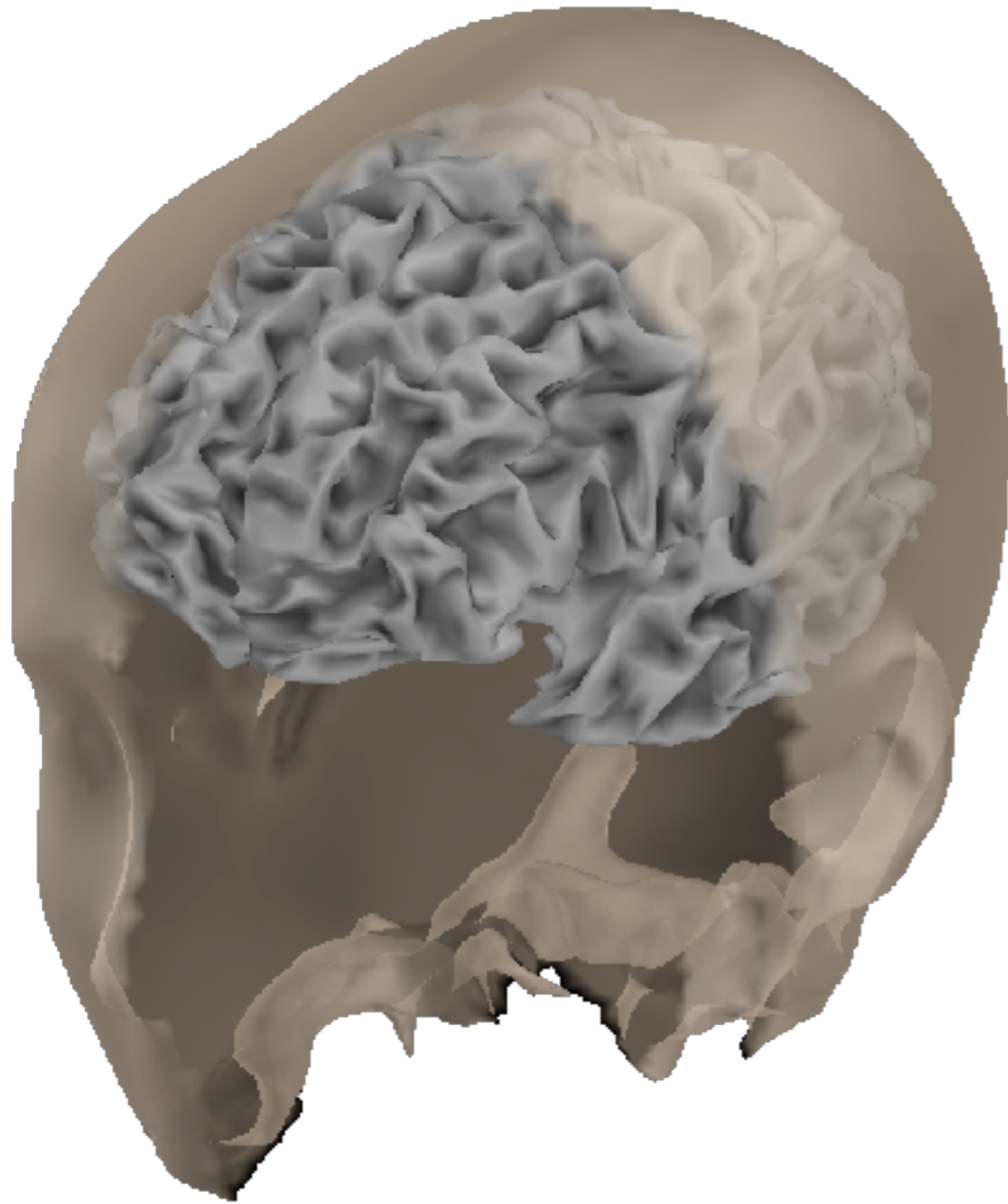
McConnell Brain Imaging Centre
Montreal Neurological Institute
McGill University

[\[sylvain.baillet@mcgill.ca\]](mailto:sylvain.baillet@mcgill.ca)

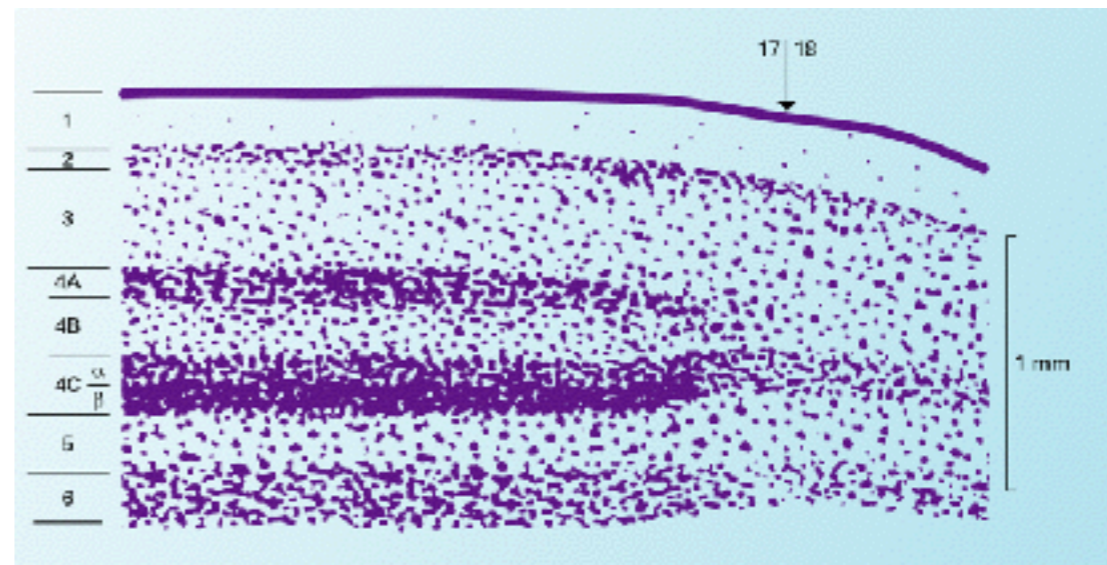
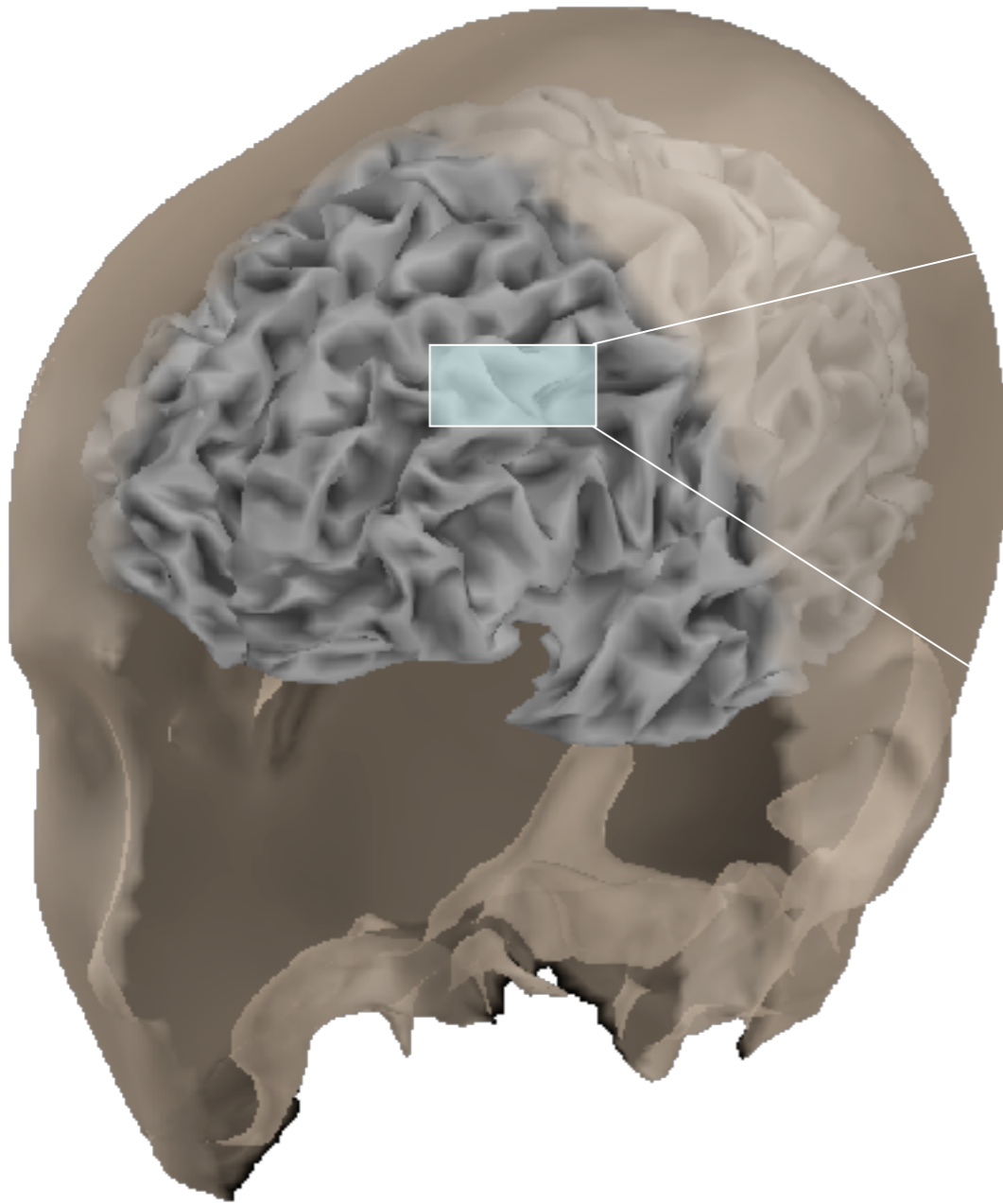


Google it! 'MEG MNI'

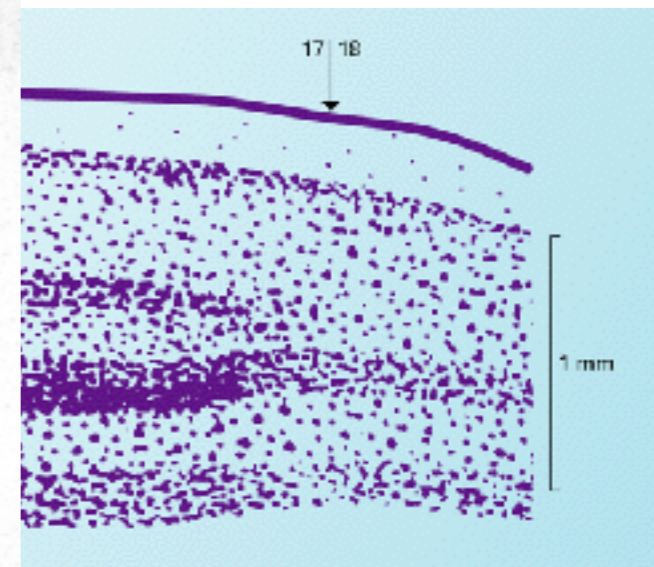
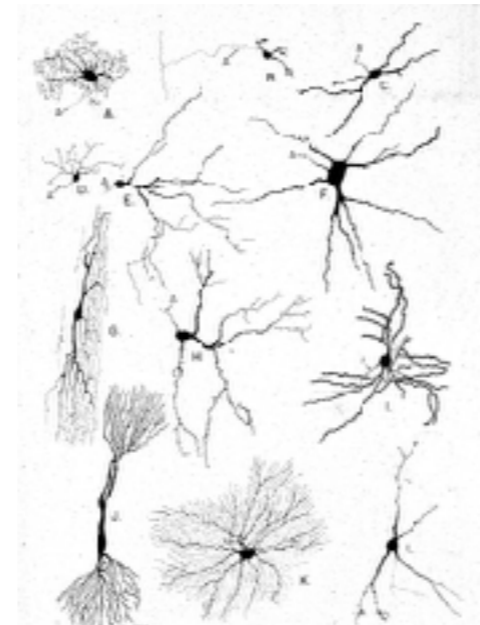
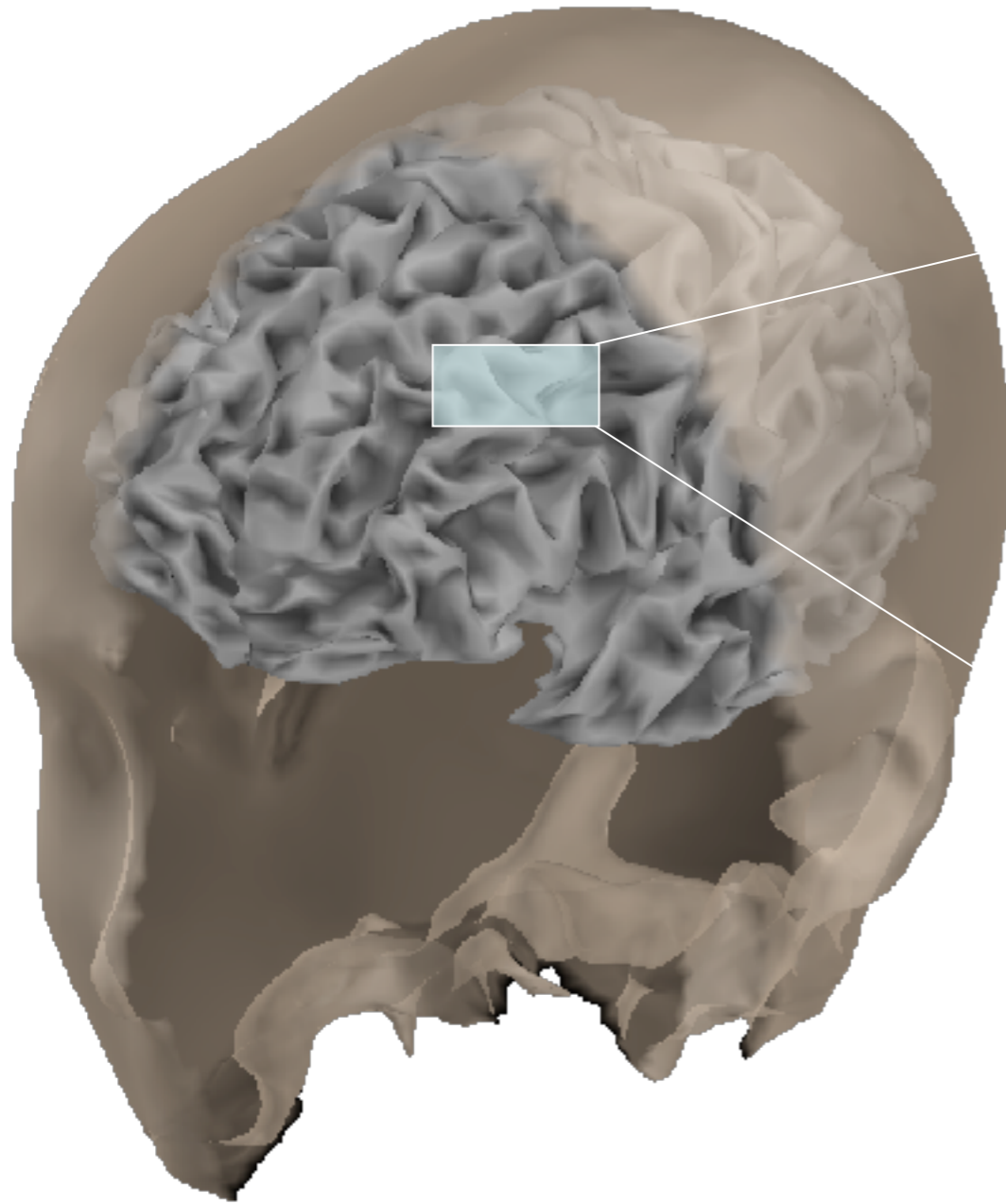
The neural cell as elementary building block



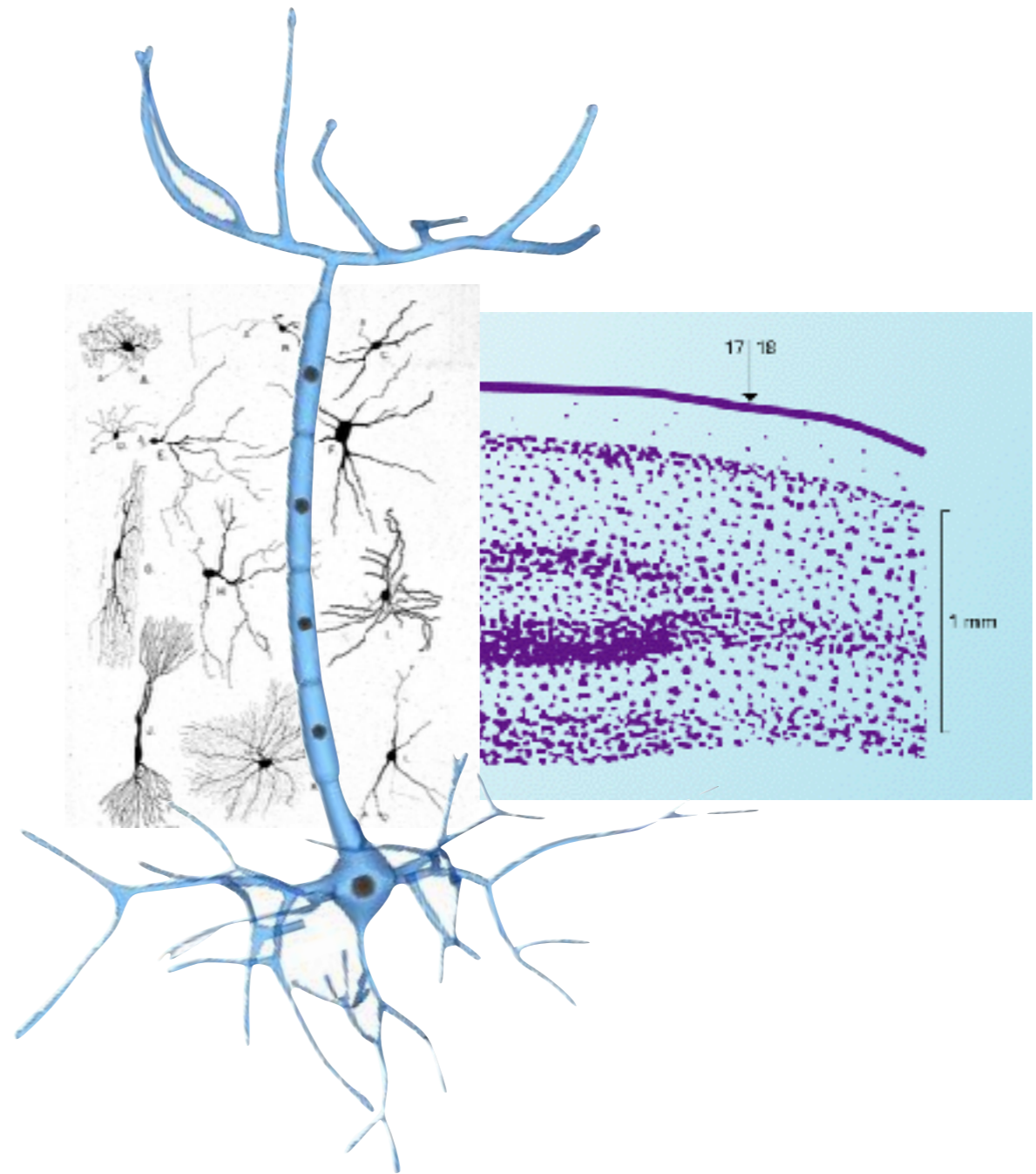
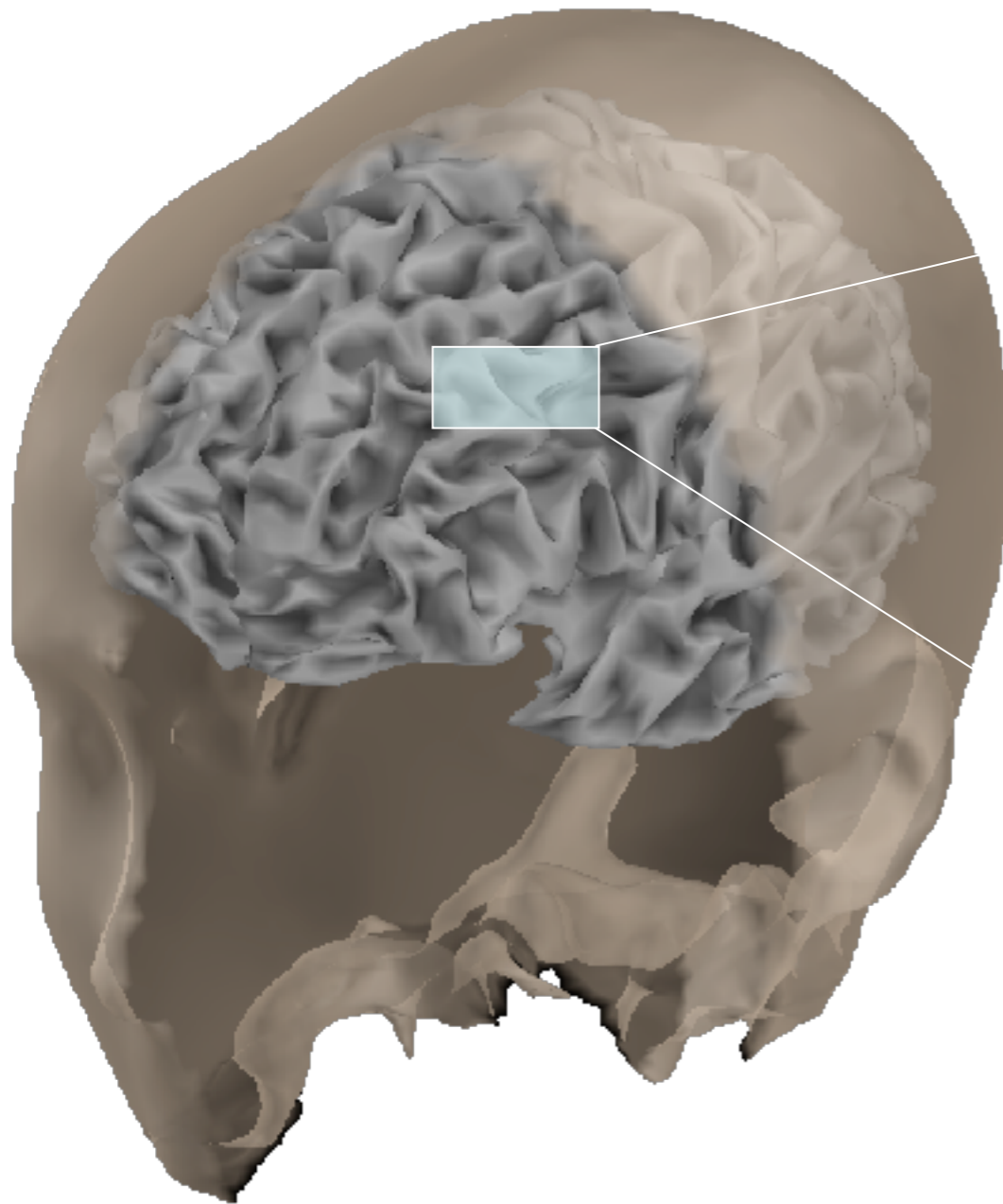
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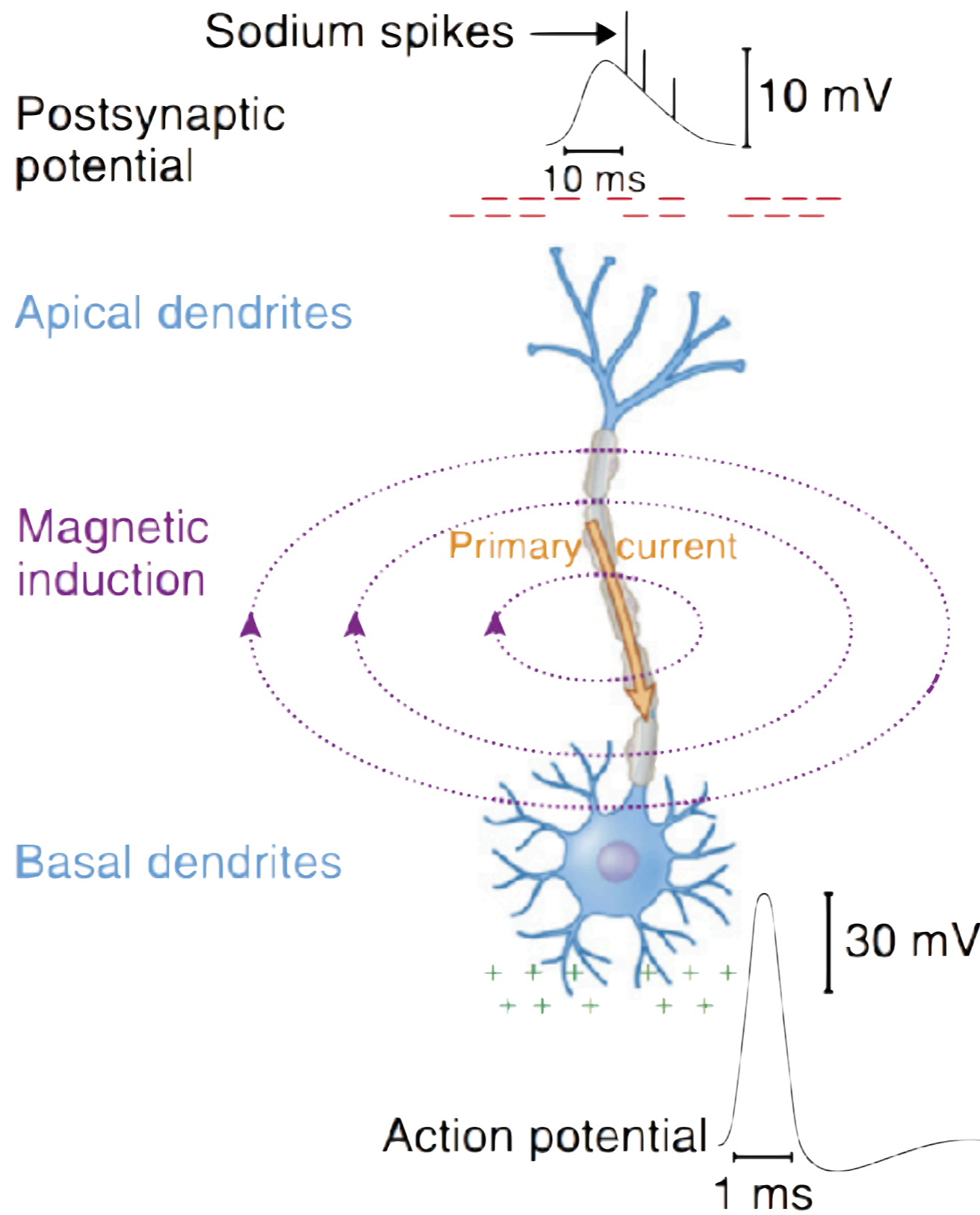
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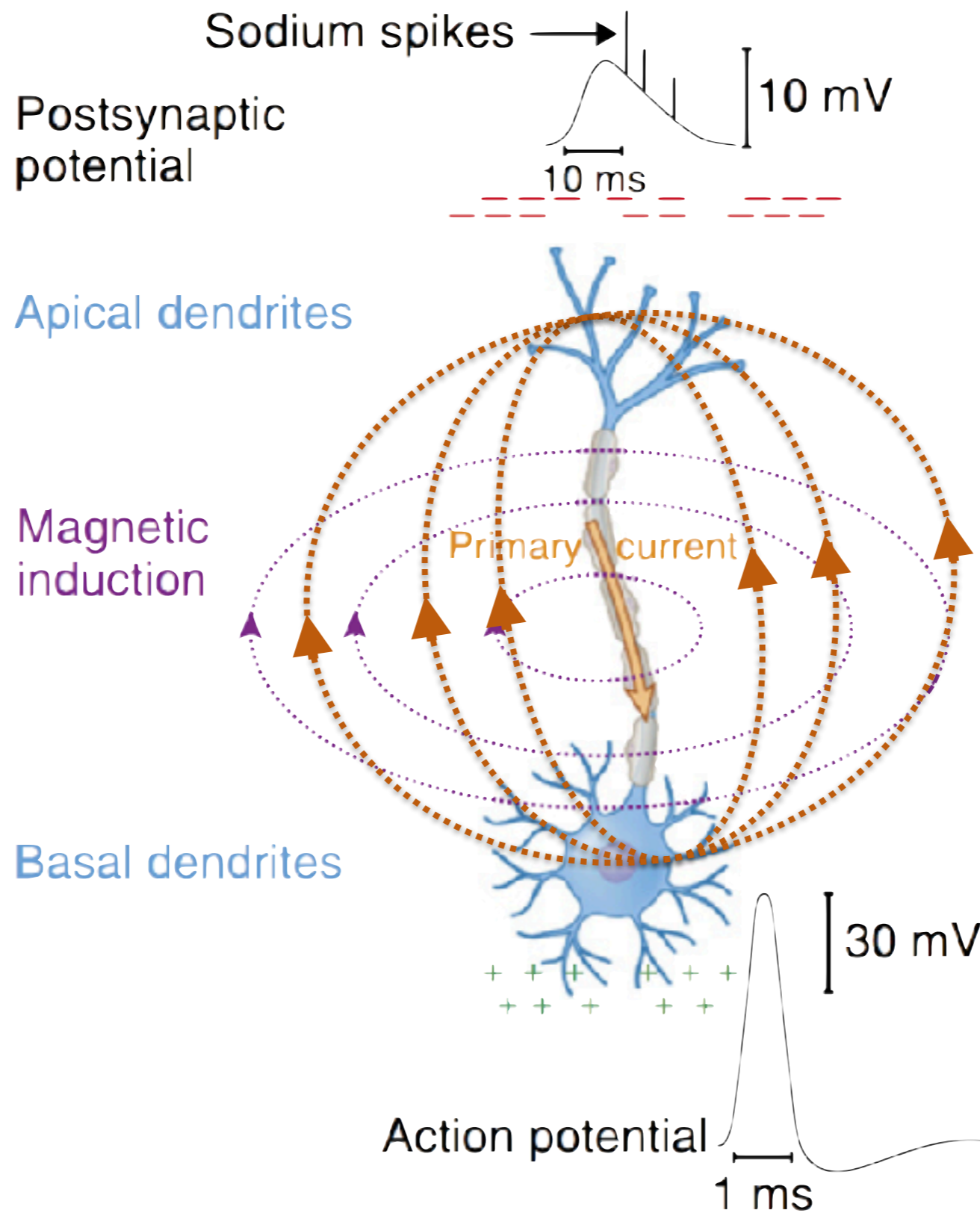


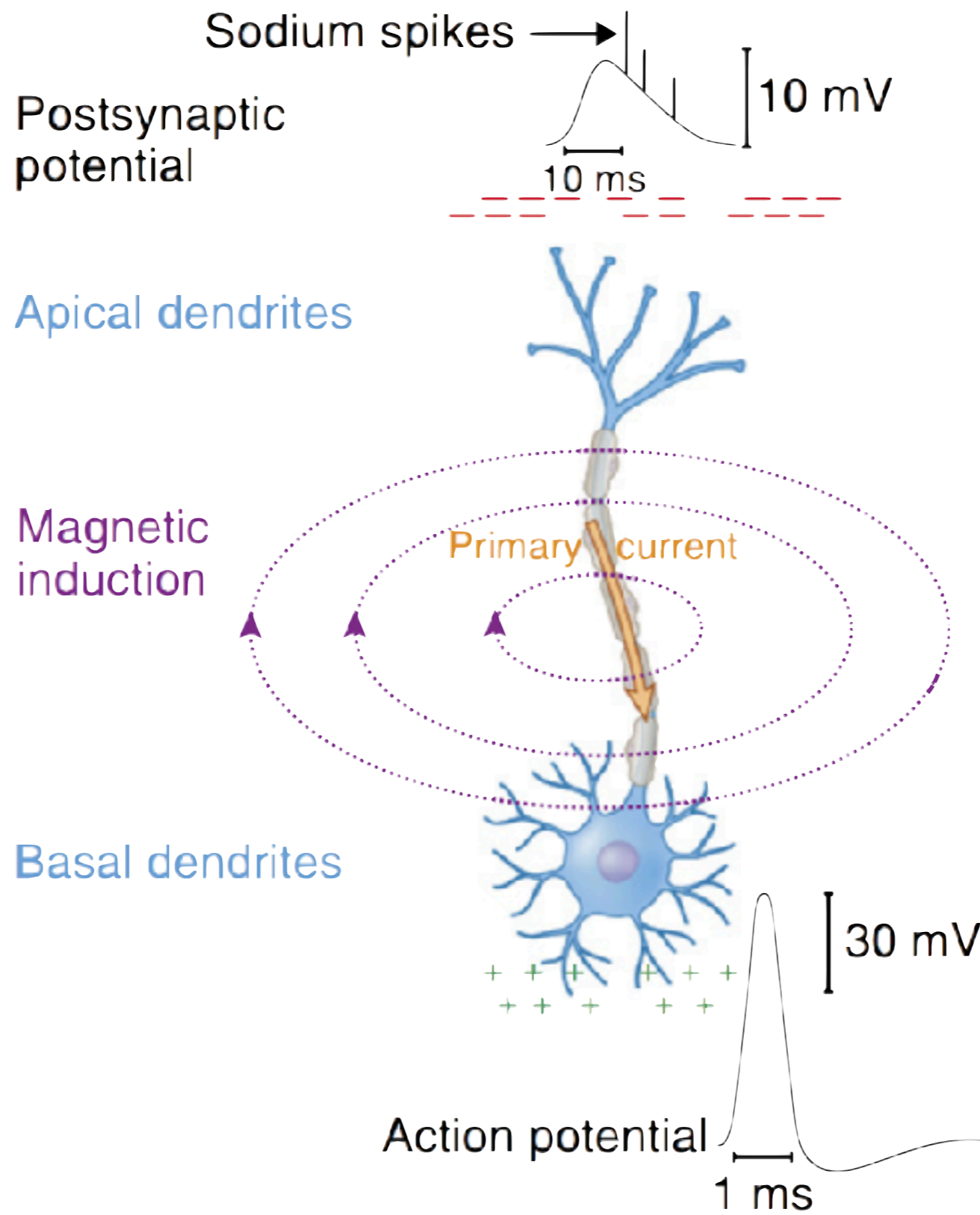
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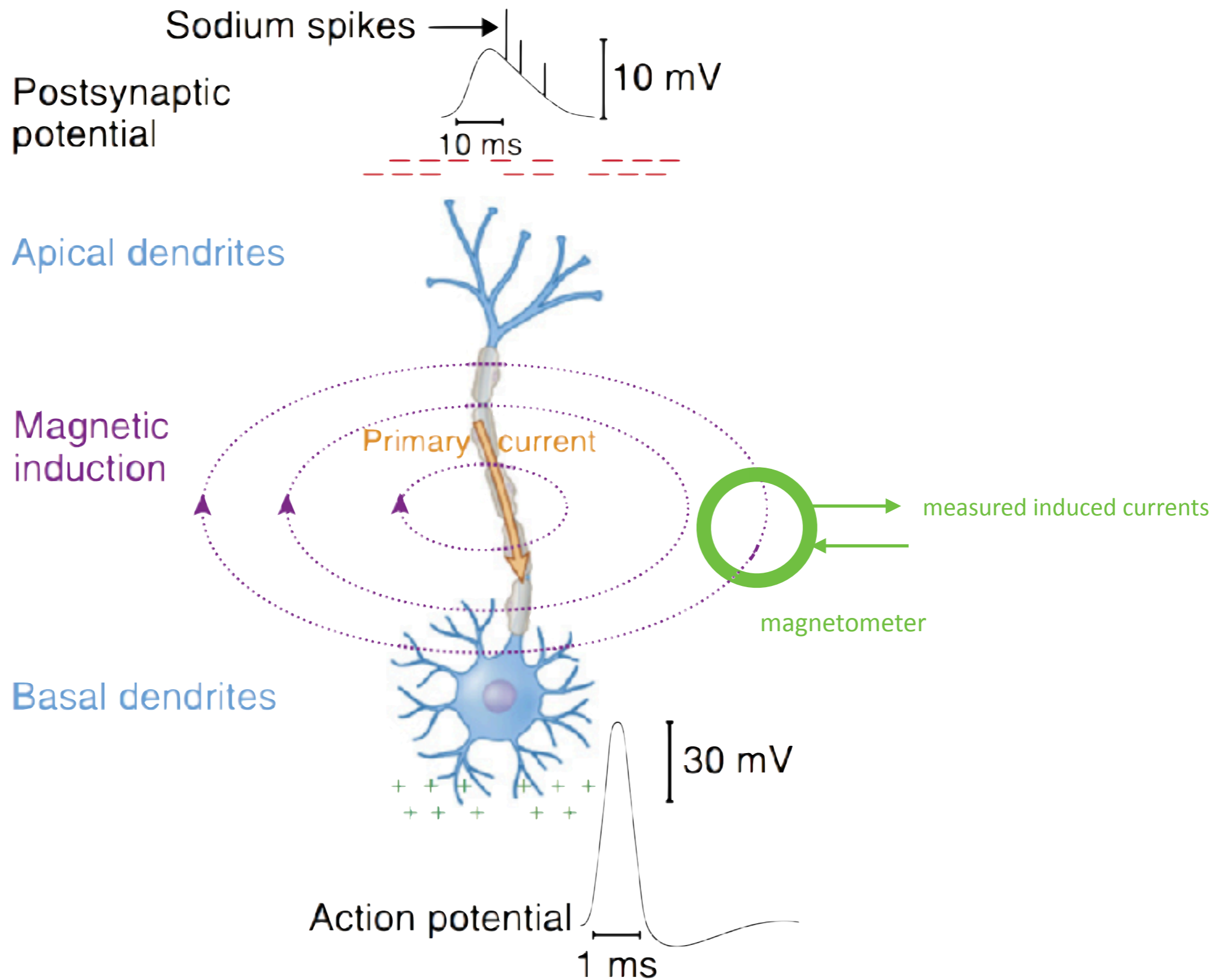


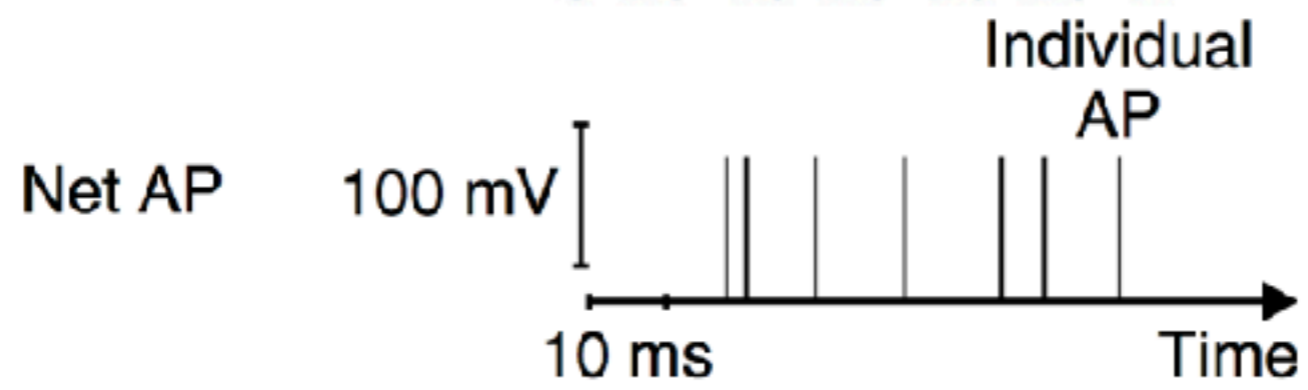
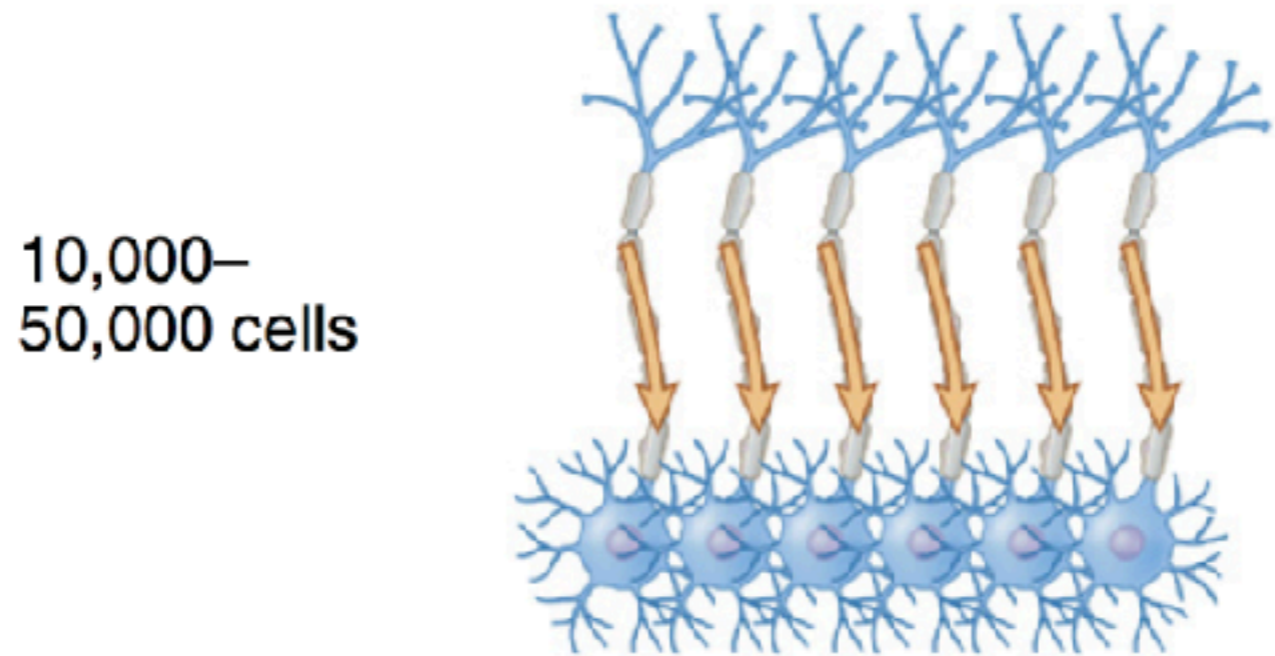
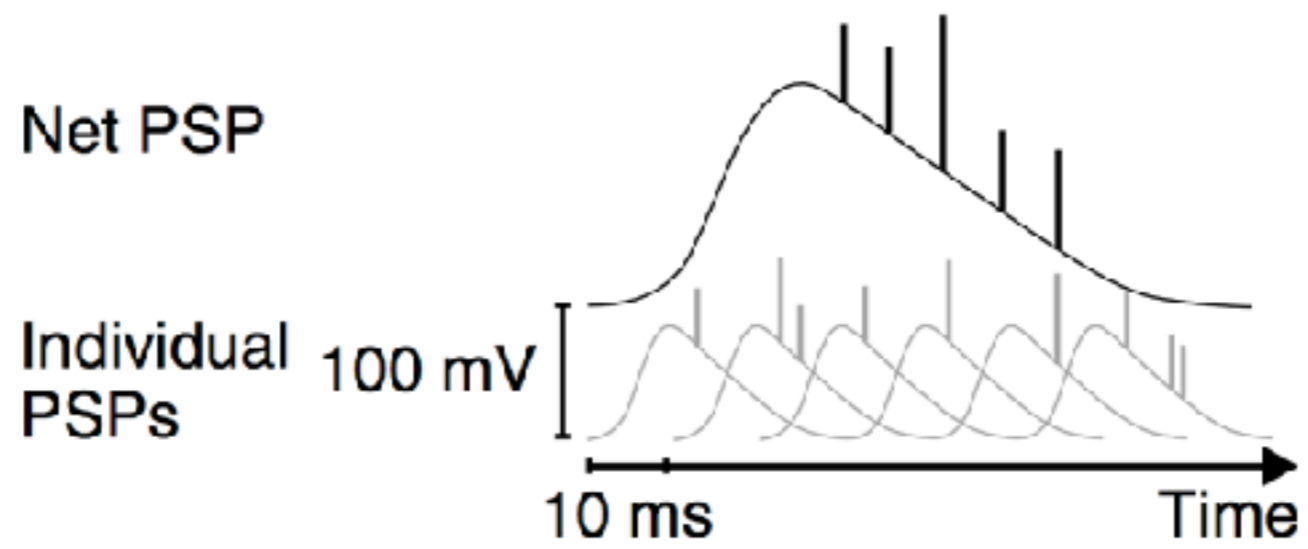
pyramidal cell as canonical source element

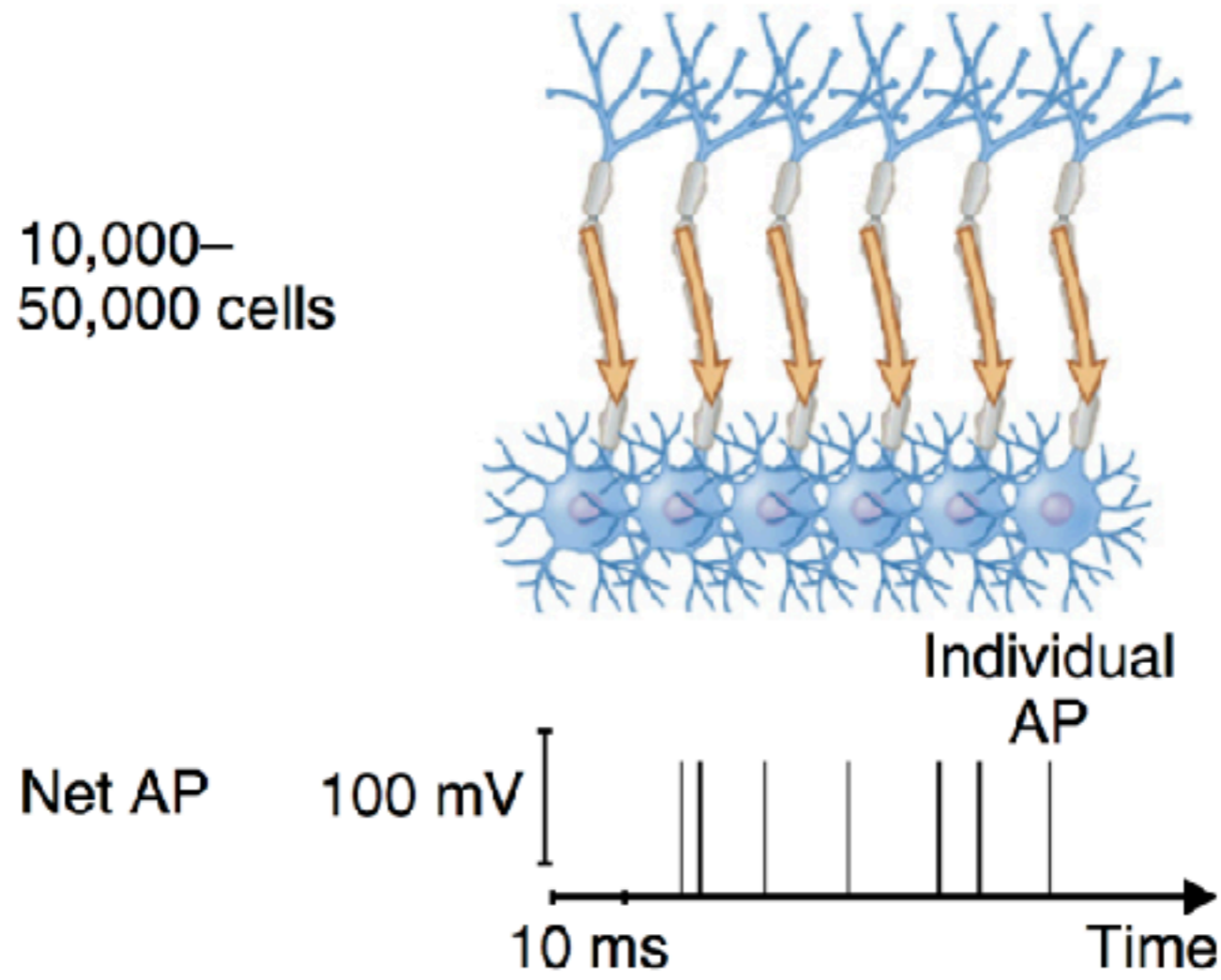
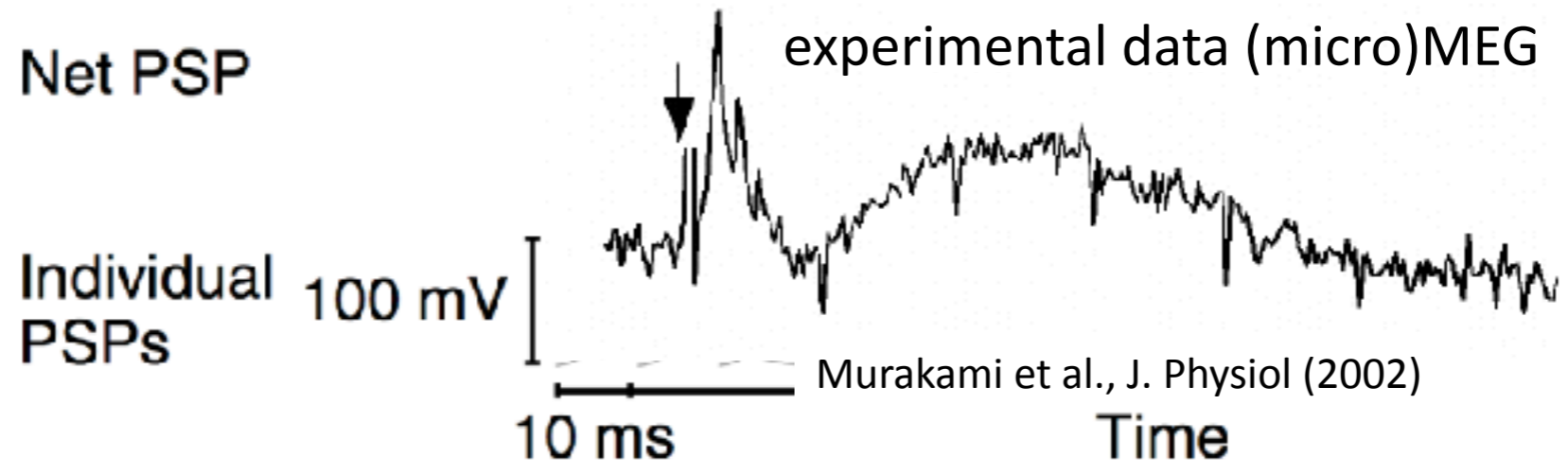


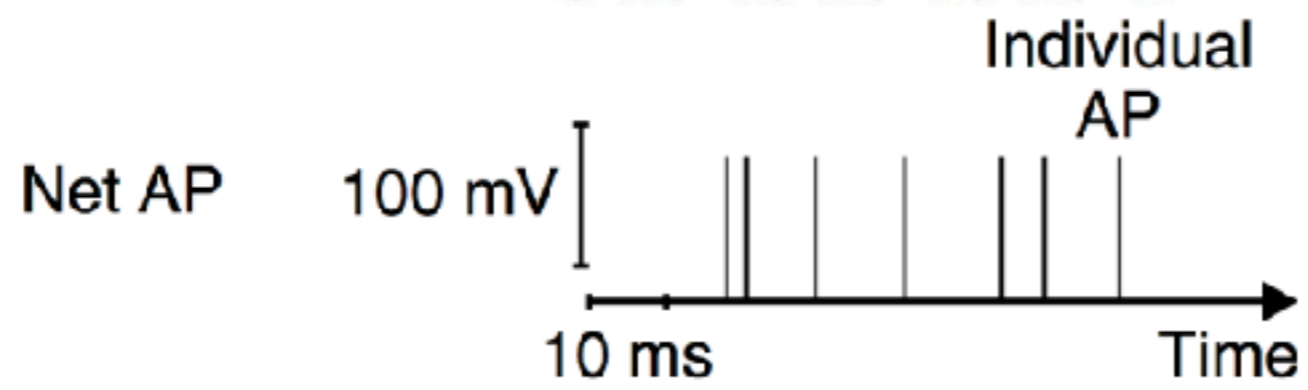
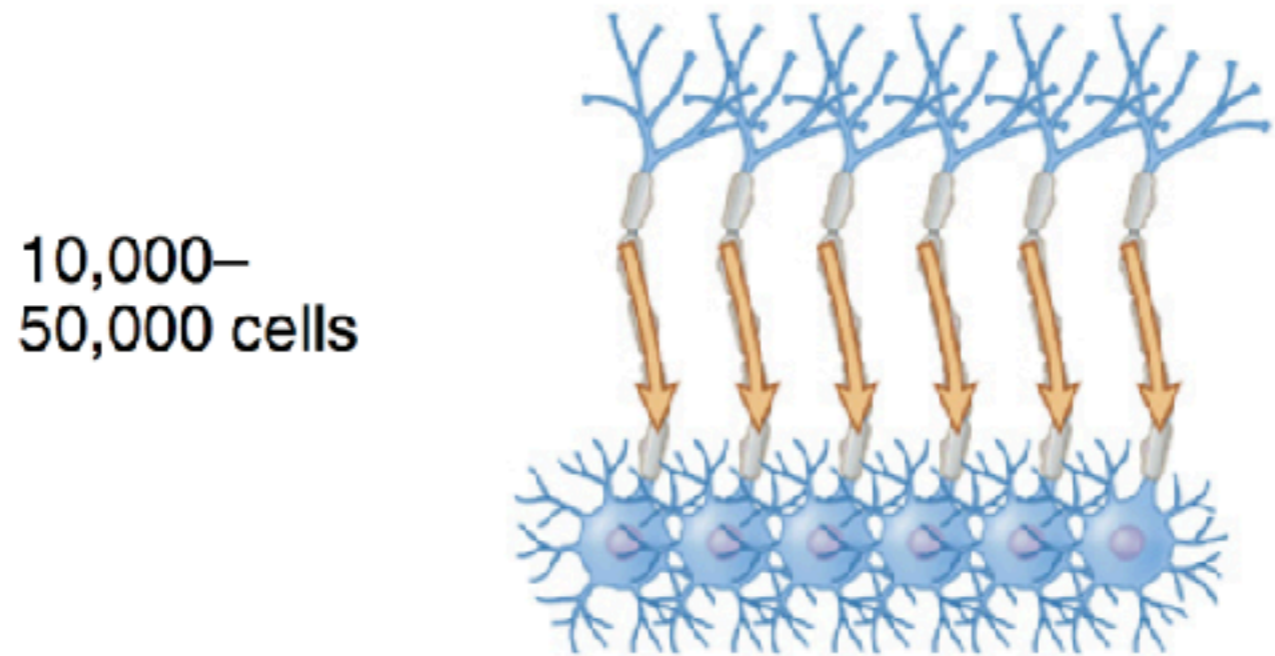
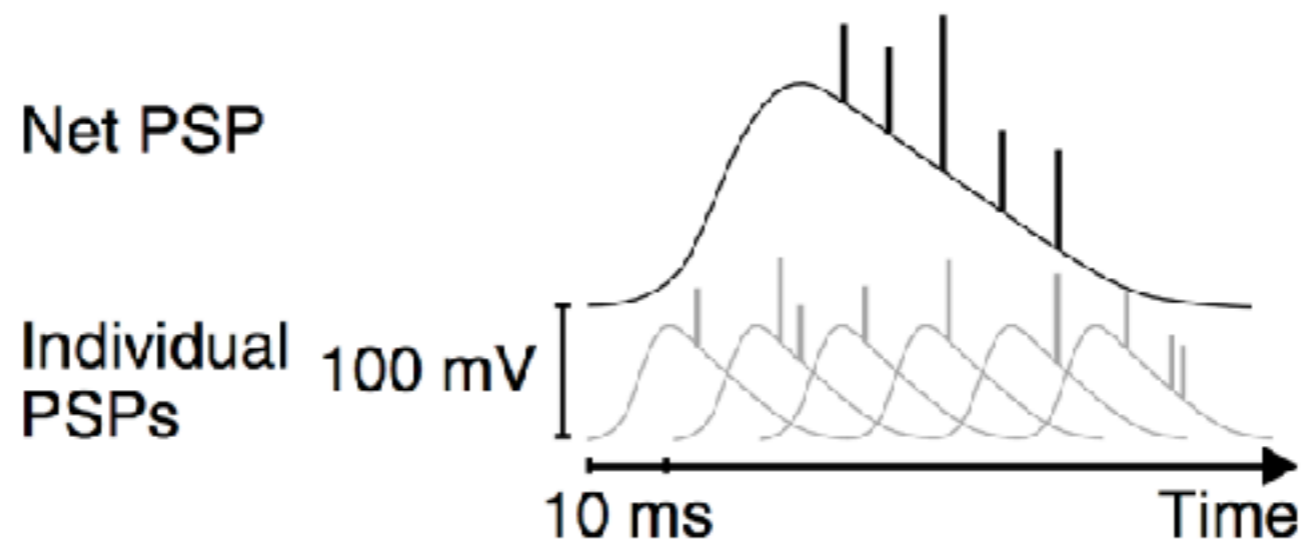




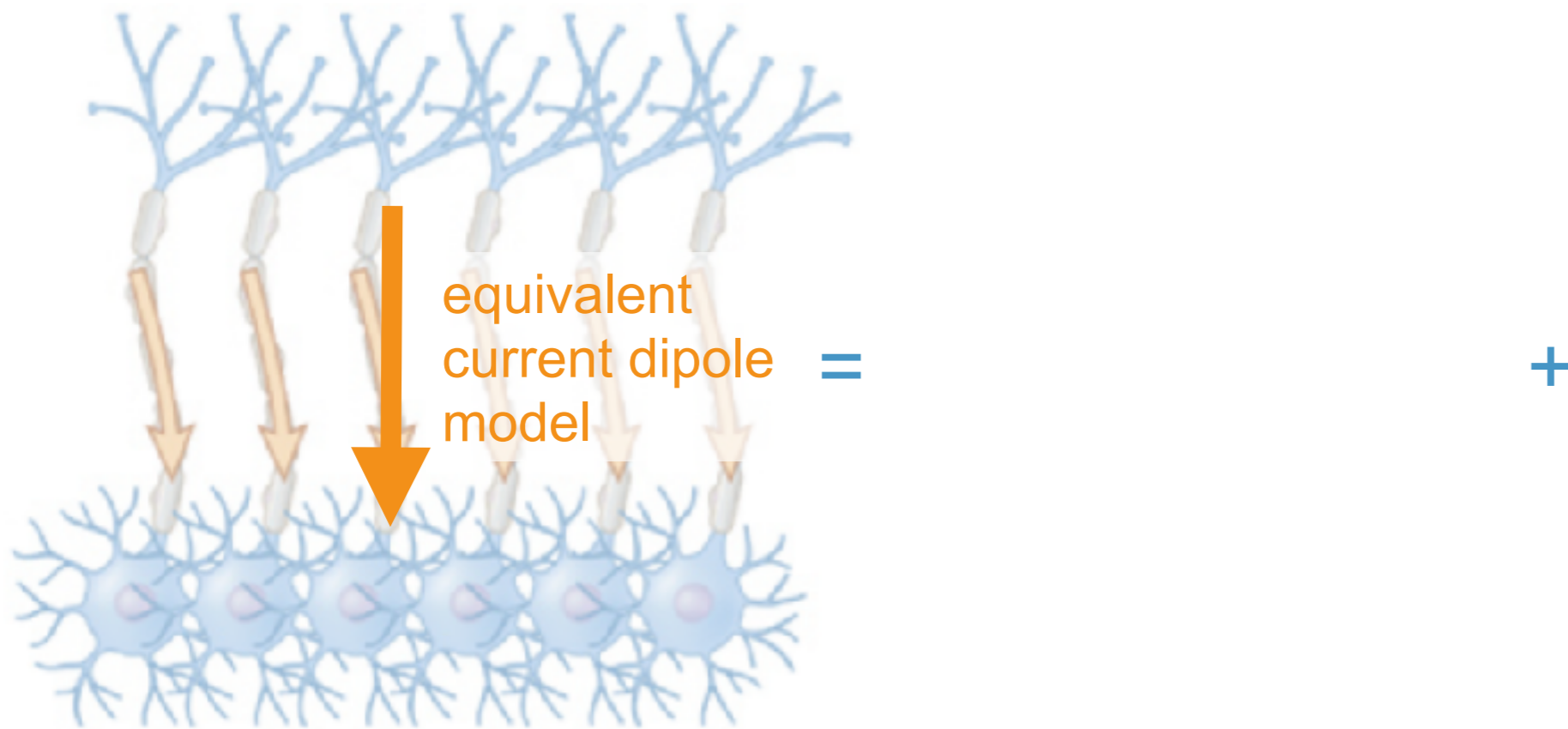




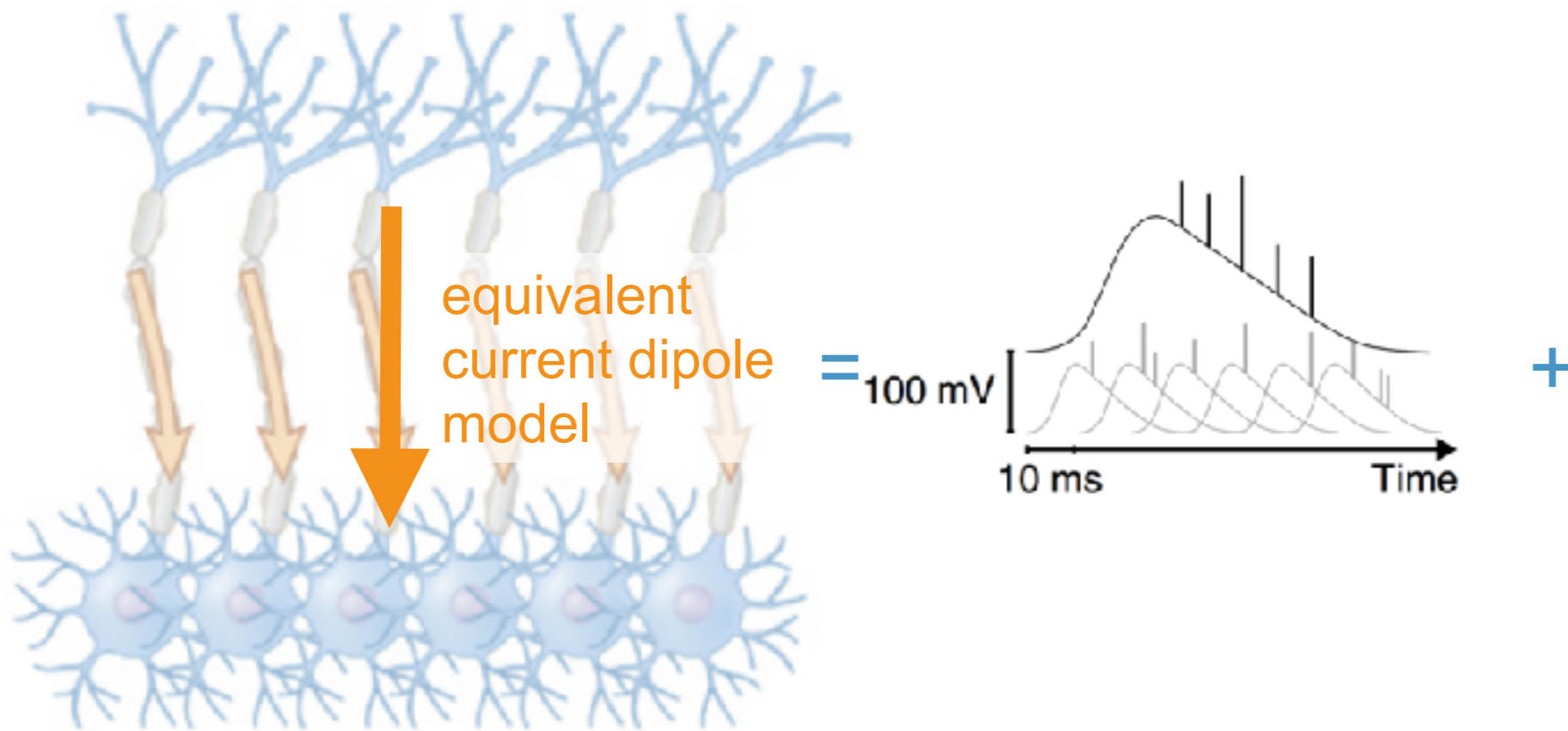




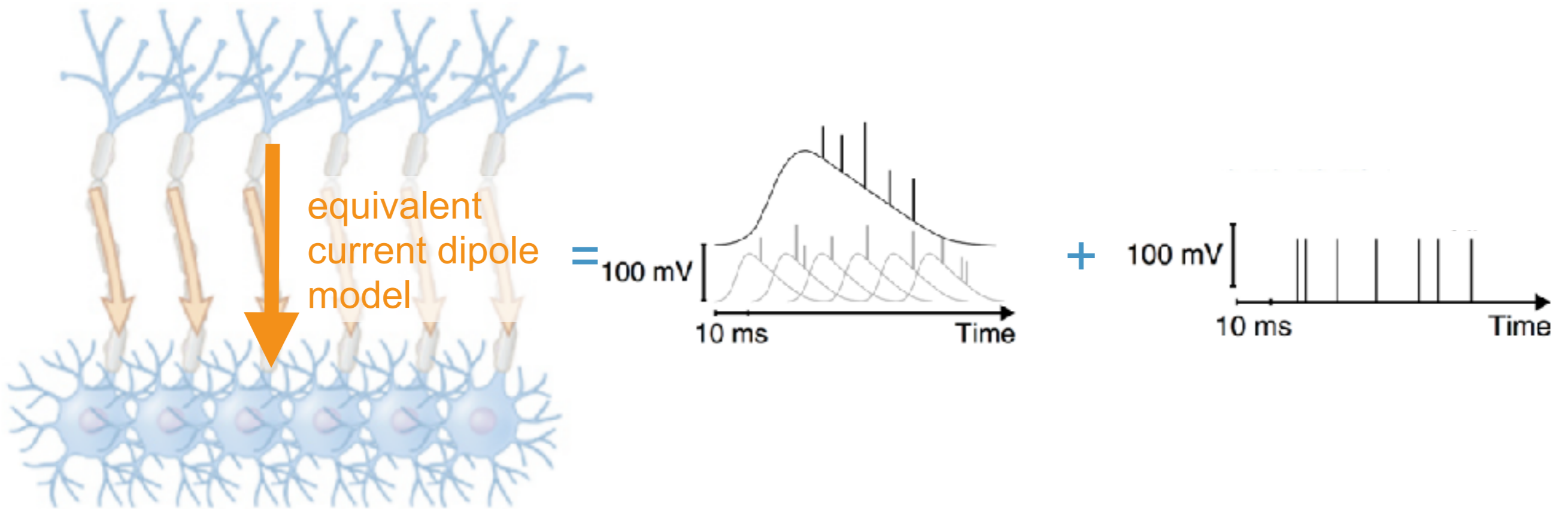
The equivalent current dipole
=
current source model of PSP's and AP's



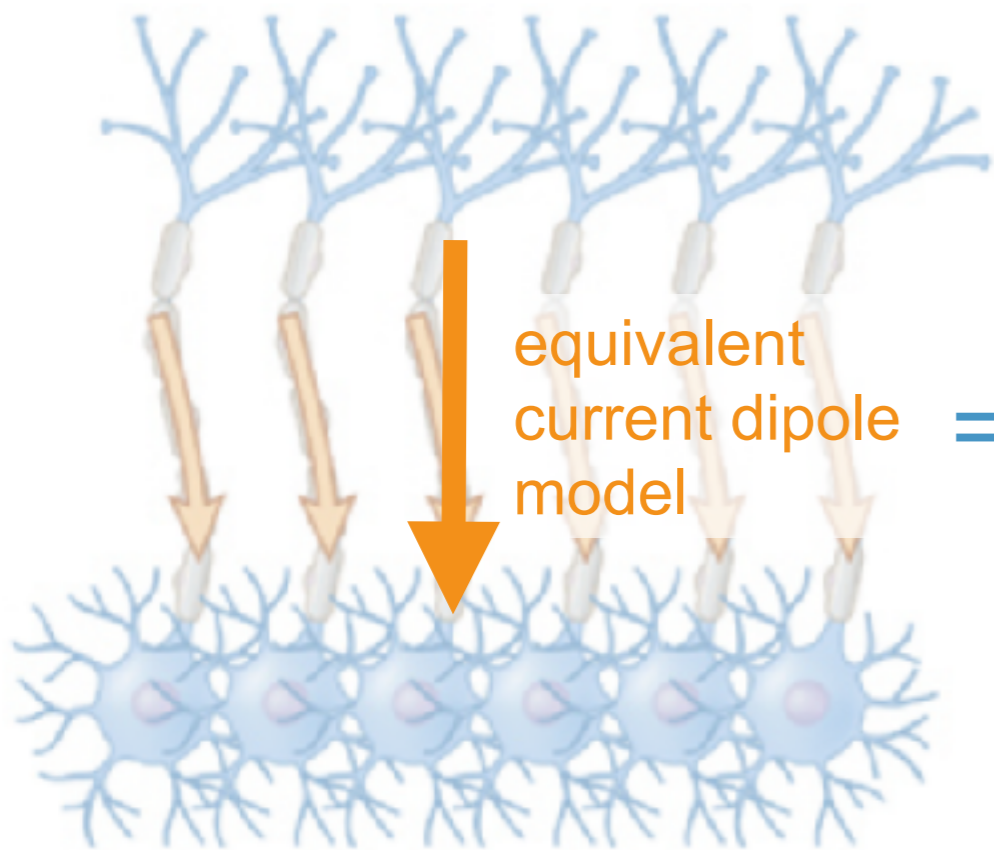
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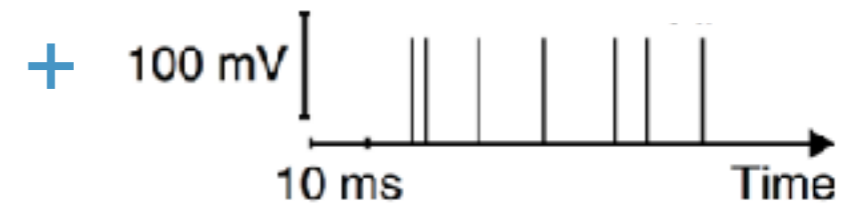
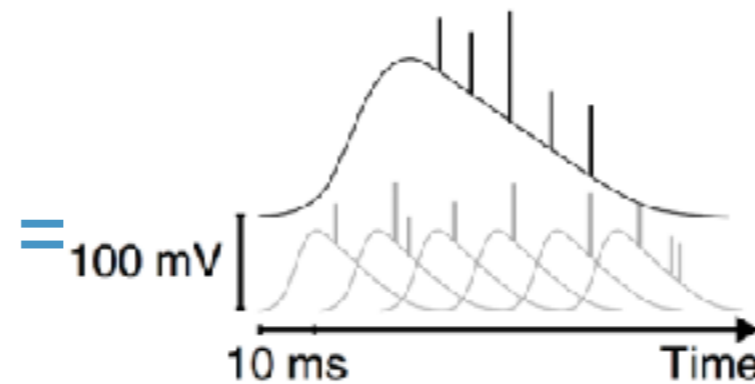
The equivalent current dipole = current source model of PSP's and AP's



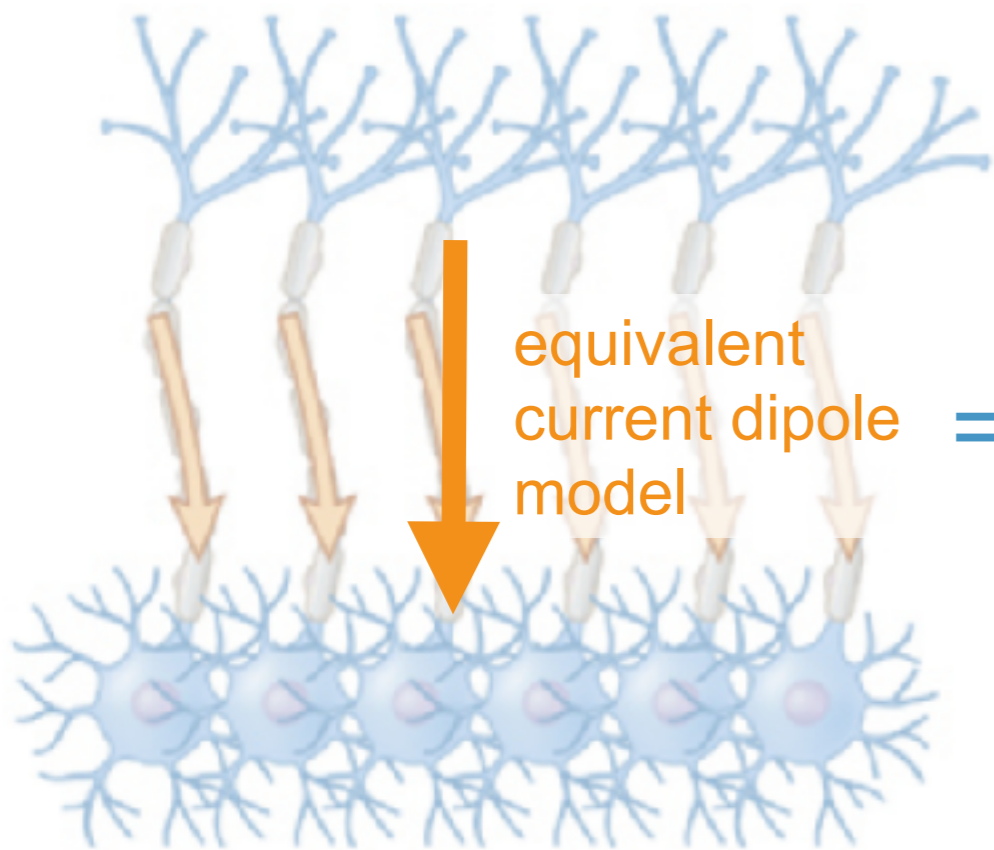
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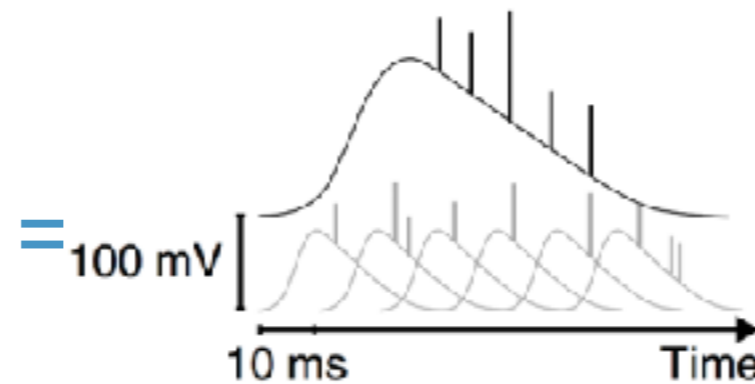
overlap of multiple PSPs
yields stronger contribution
to MEG/EEG signalling



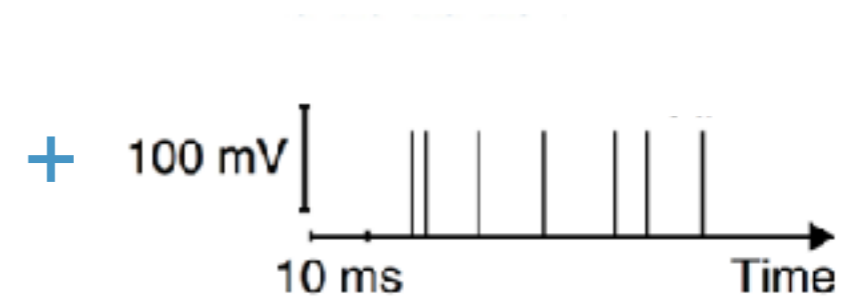
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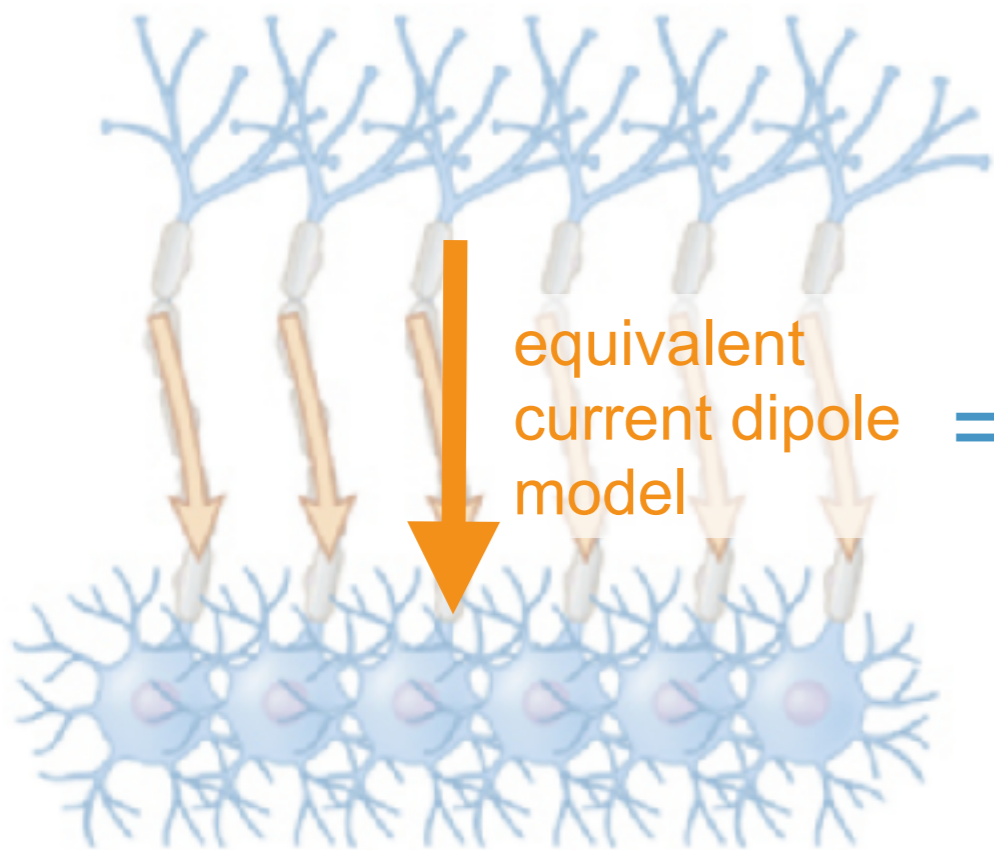
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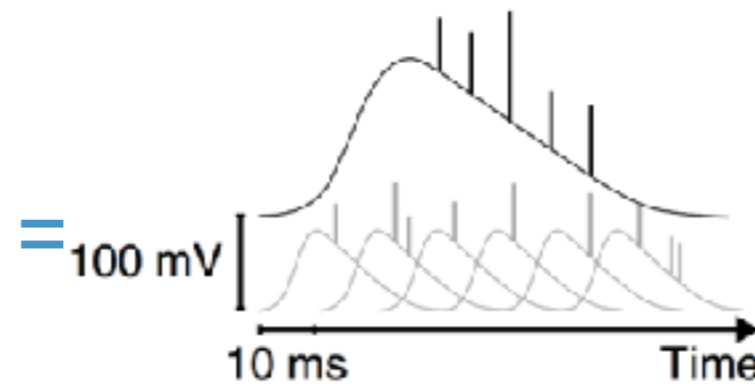
stronger individual currents
but
poorer temporal overlap of AP's



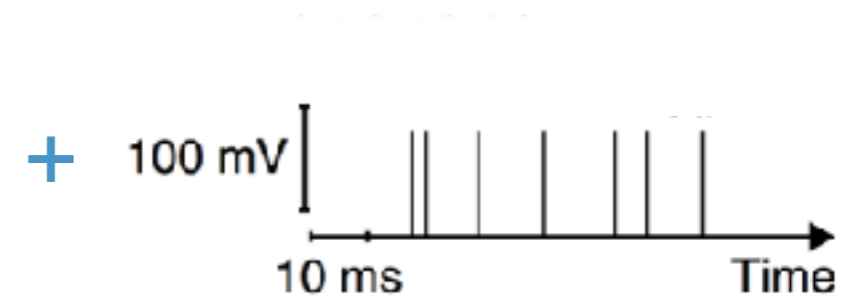
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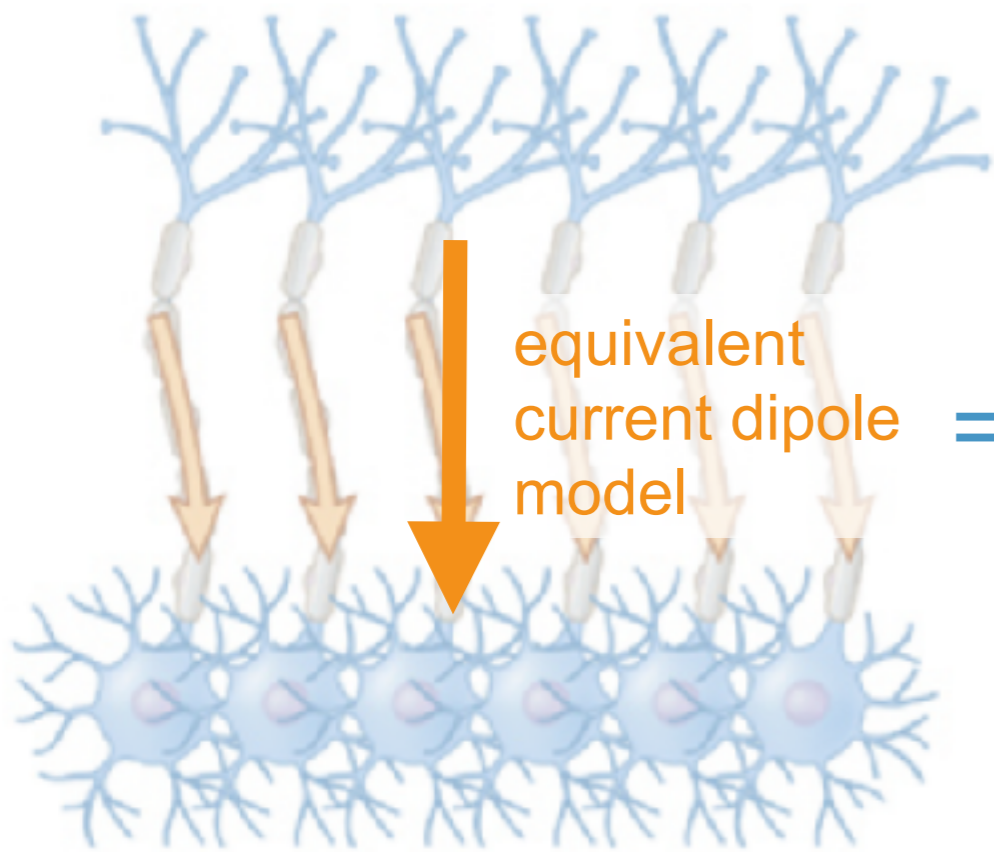


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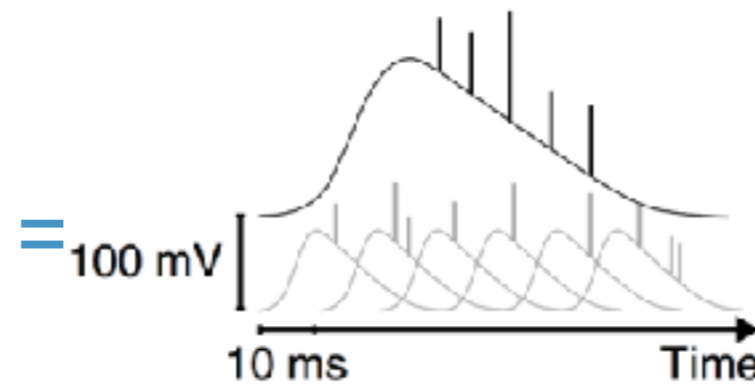
> 50,000 cells

The equivalent current dipole = current source model of PSP's and AP's



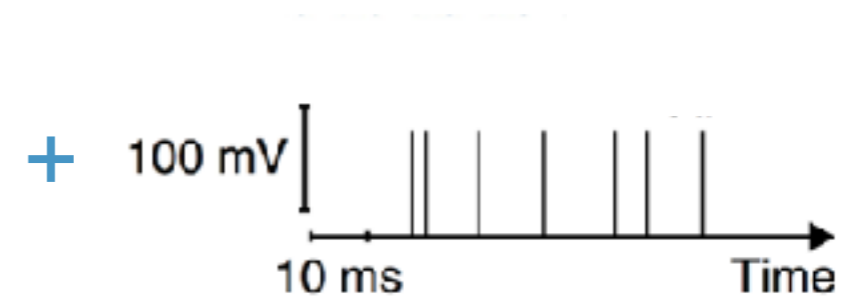
equivalent
current dipole
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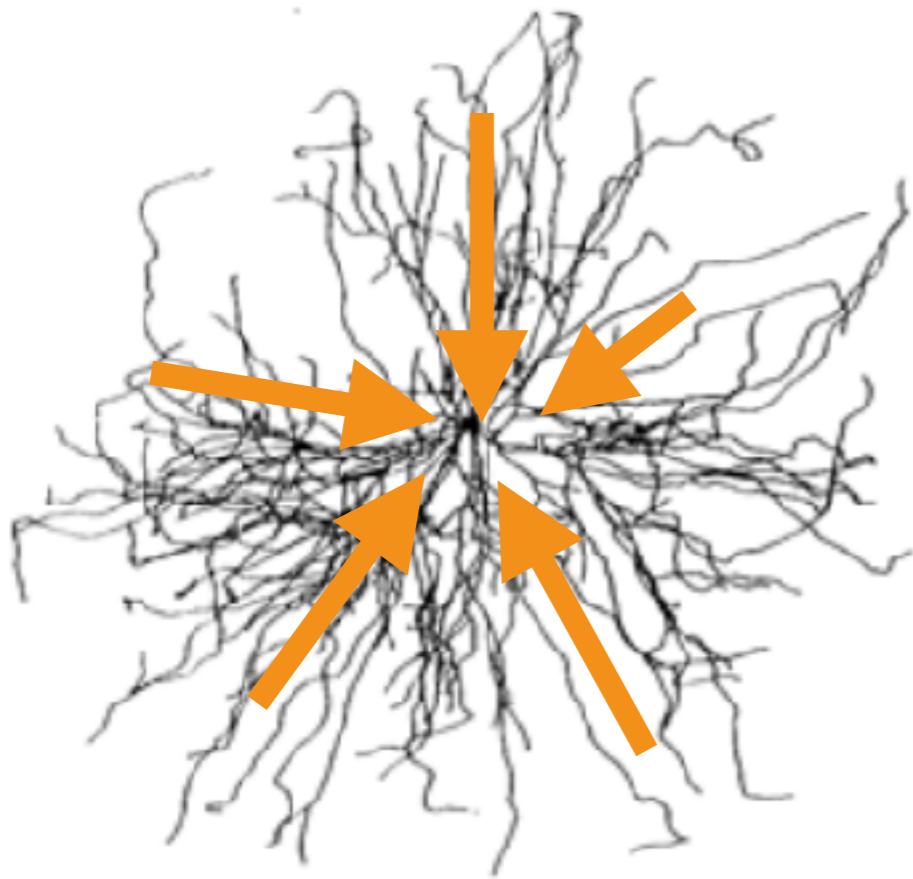
stronger individual currents
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> 10,000 cells

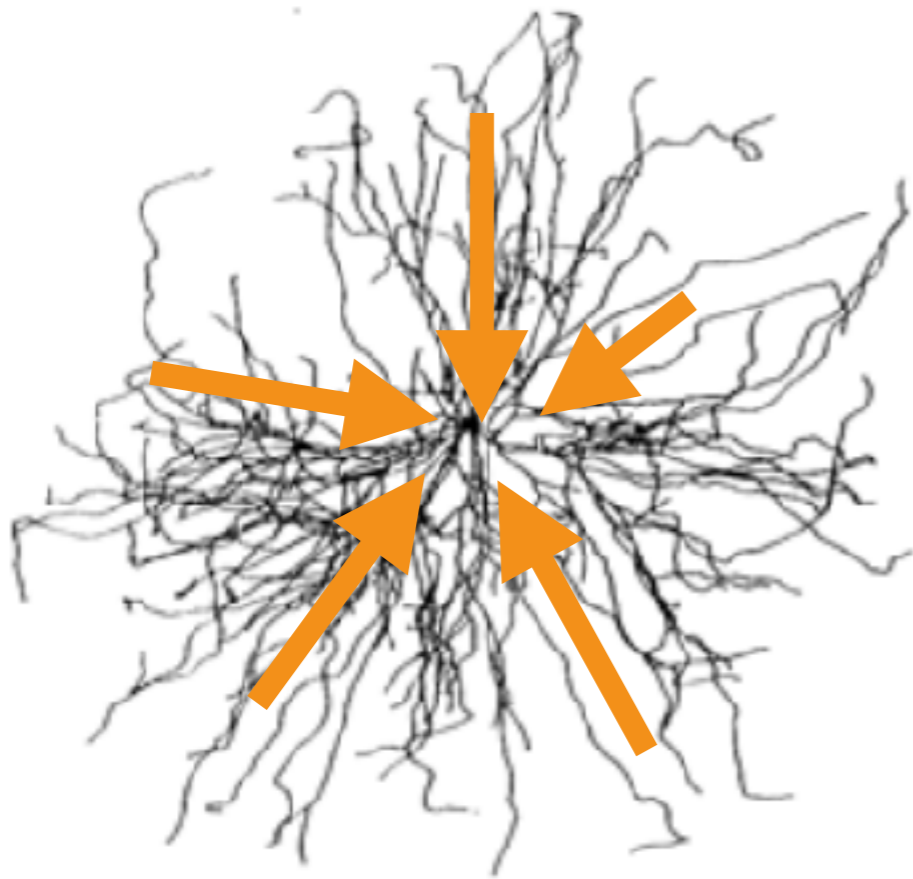
influence of cell morphology on signal strength

radial cell morphology



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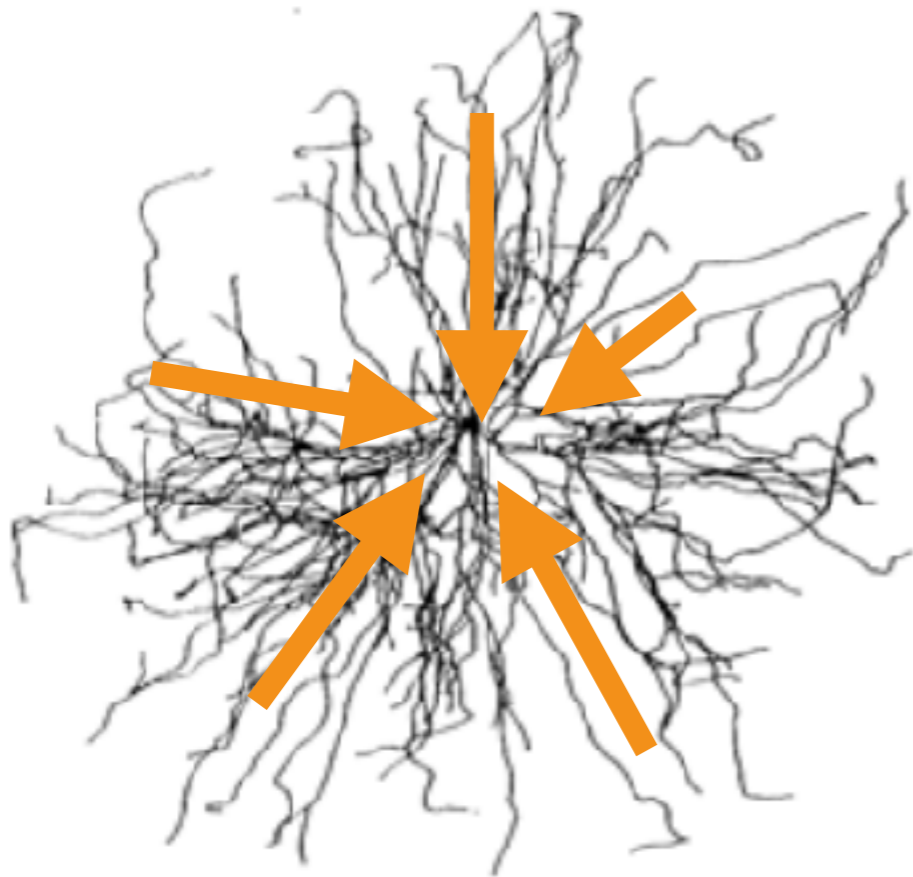


net current dipole



influence of cell morphology on signal strength

radial cell morphology

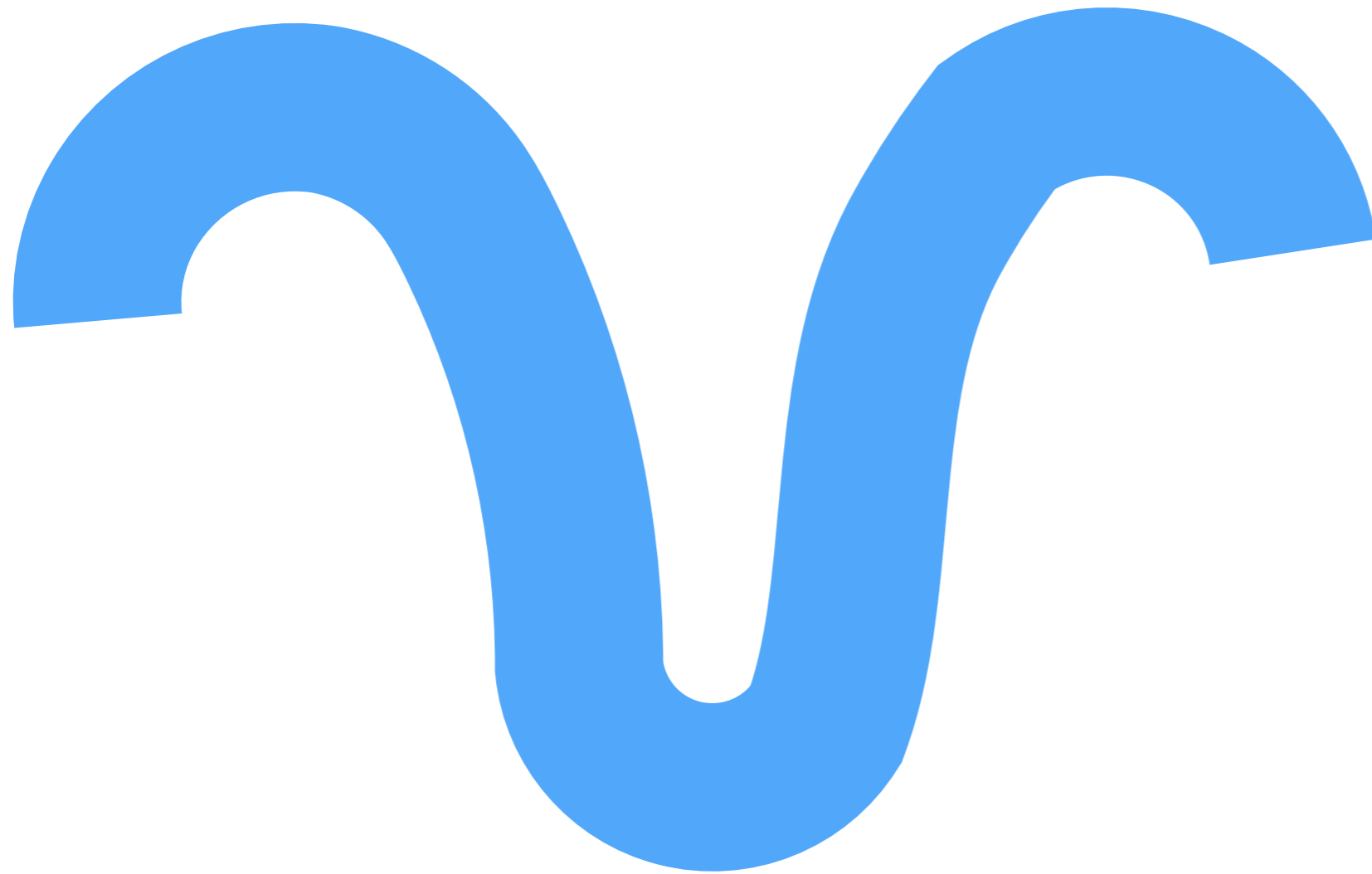


weaker net currents than
from elongated cell morphology

net current dipole

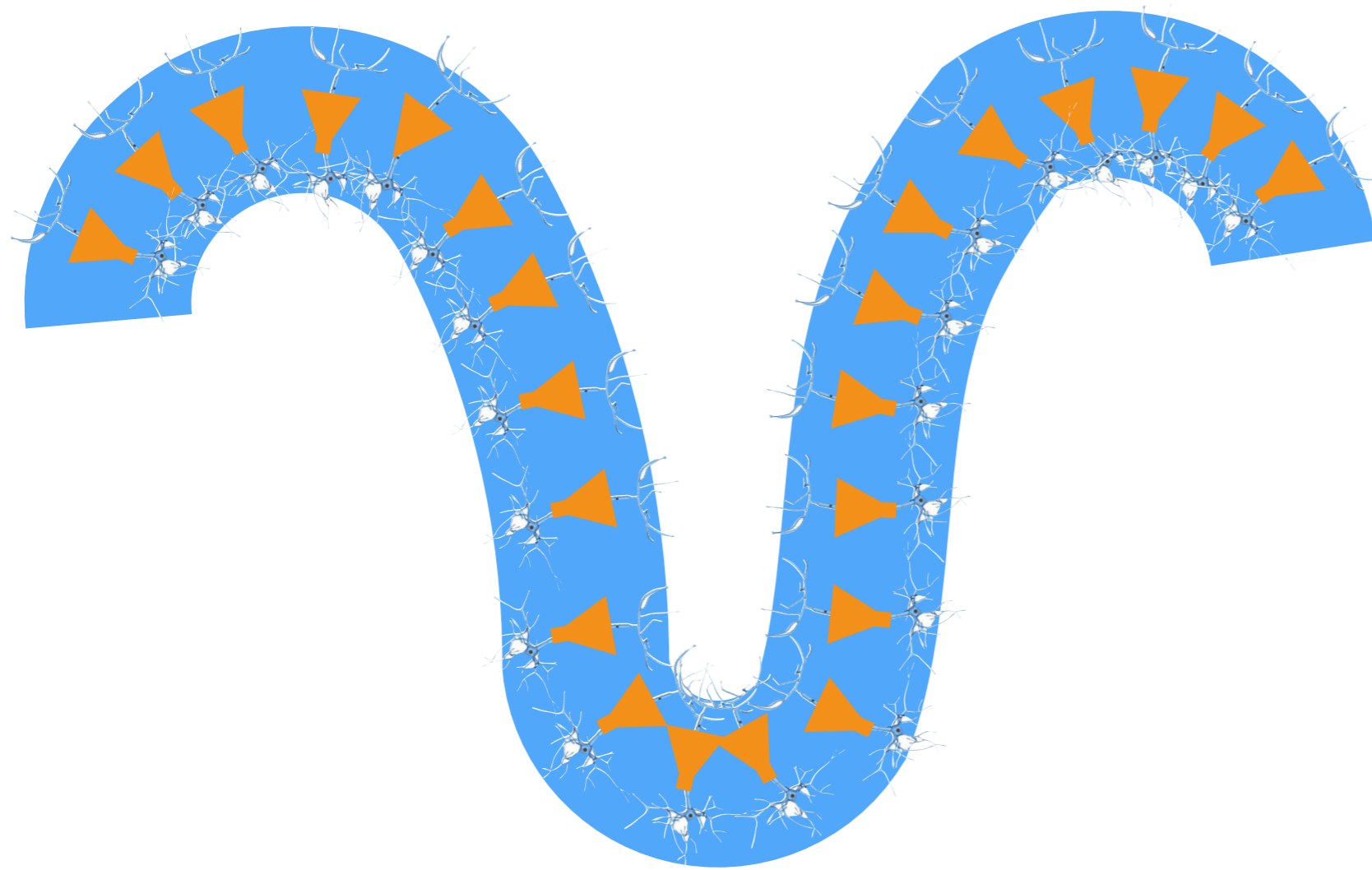


mesoscopic distribution of currents



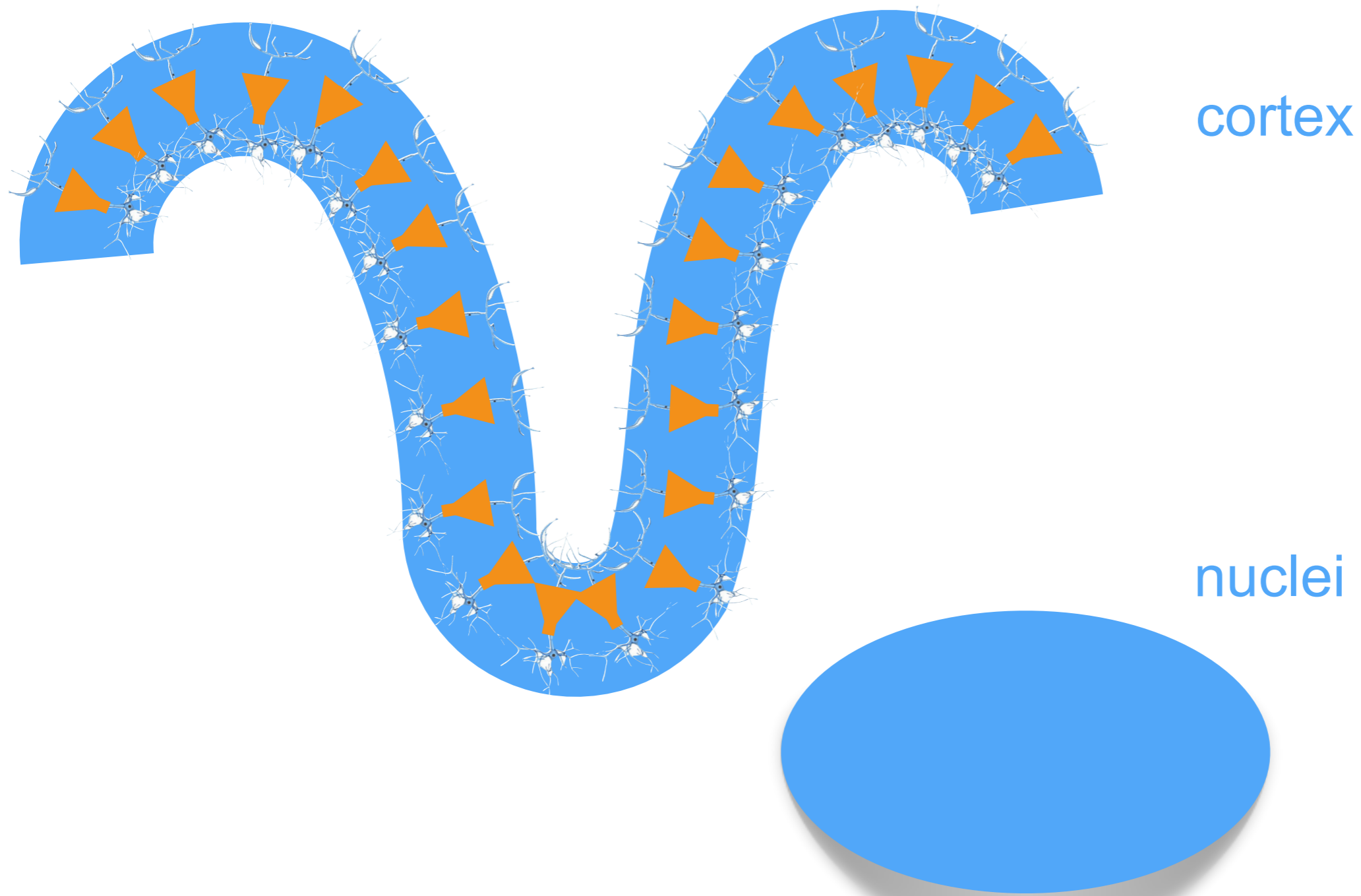
cortex

mesoscopic distribution of currents

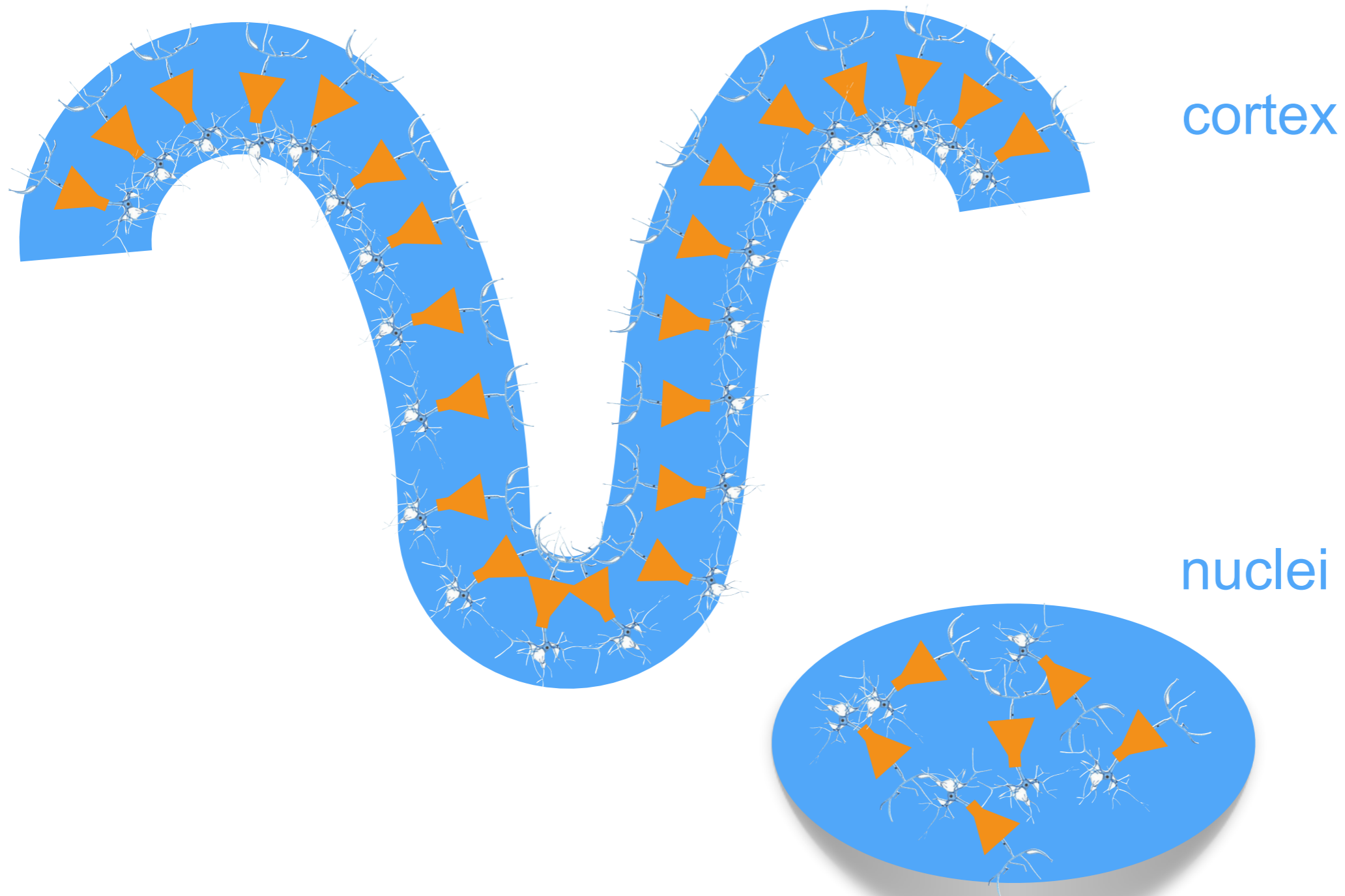


cortex

mesoscopic distribution of currents

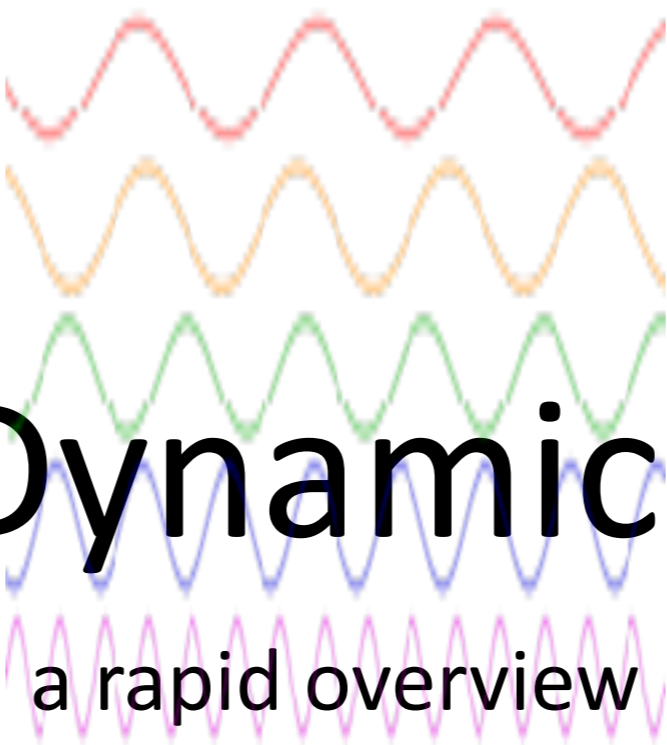


mesoscopic distribution of currents



Dynamics

a rapid overview



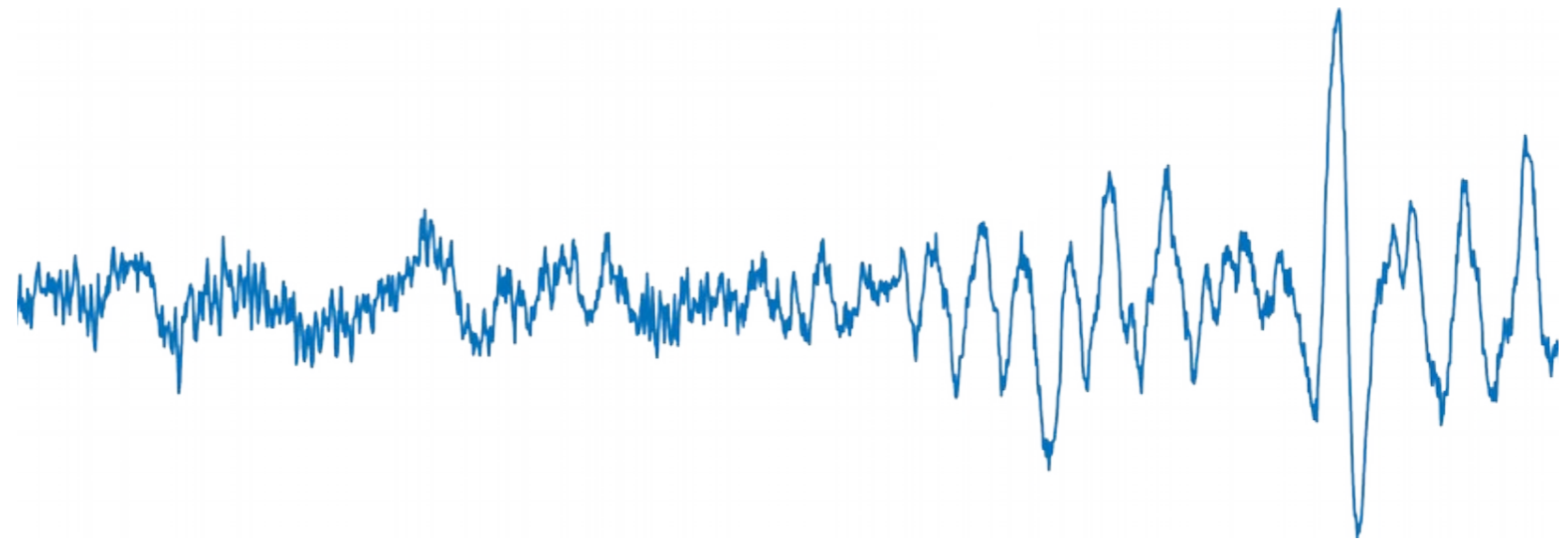
Dynamics

a rapid overview

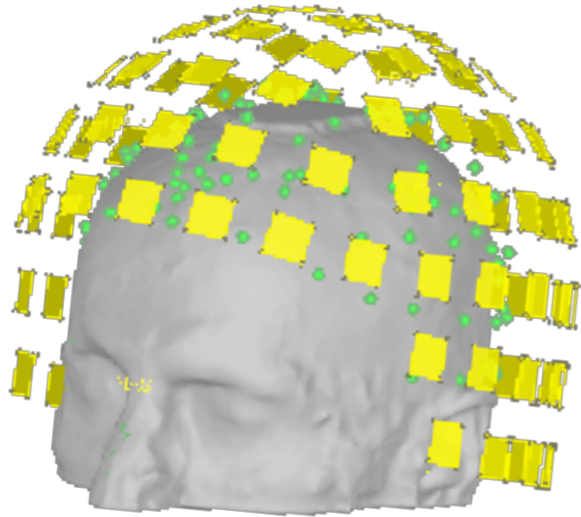
Signal extraction: several options

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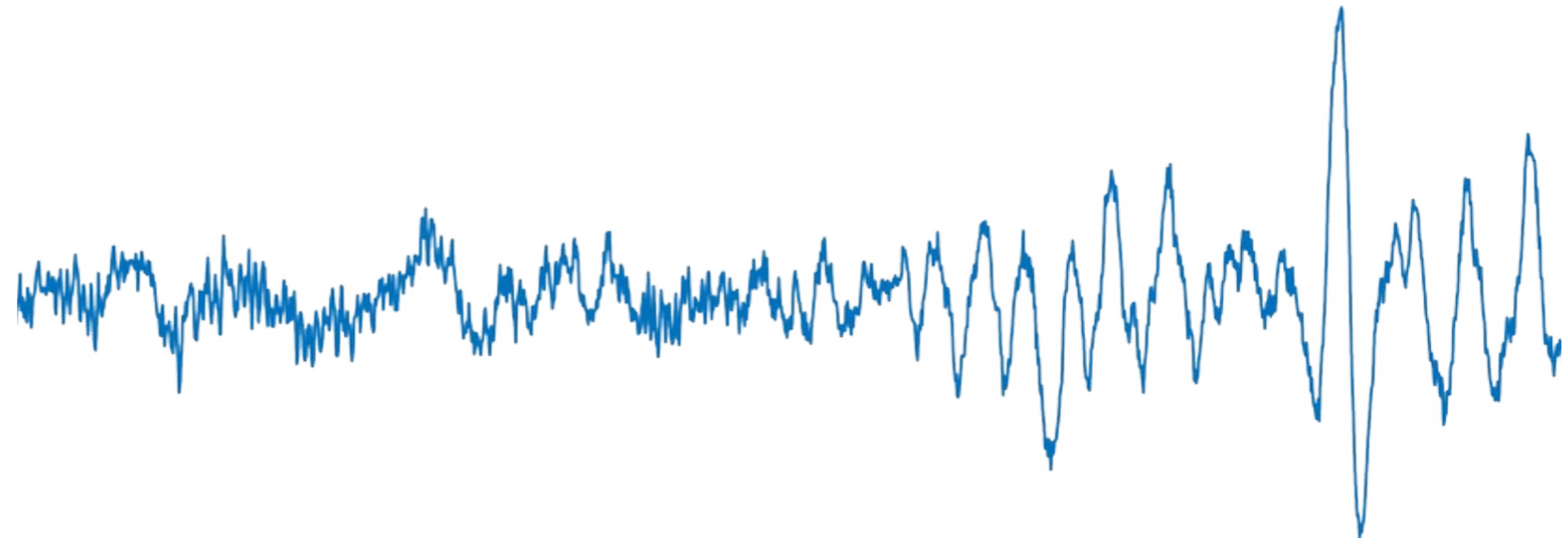
LFP
EEG sensor/source
MEG sensor/source



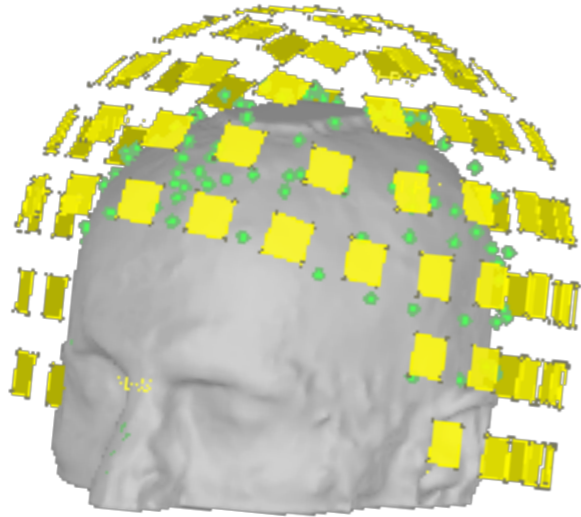
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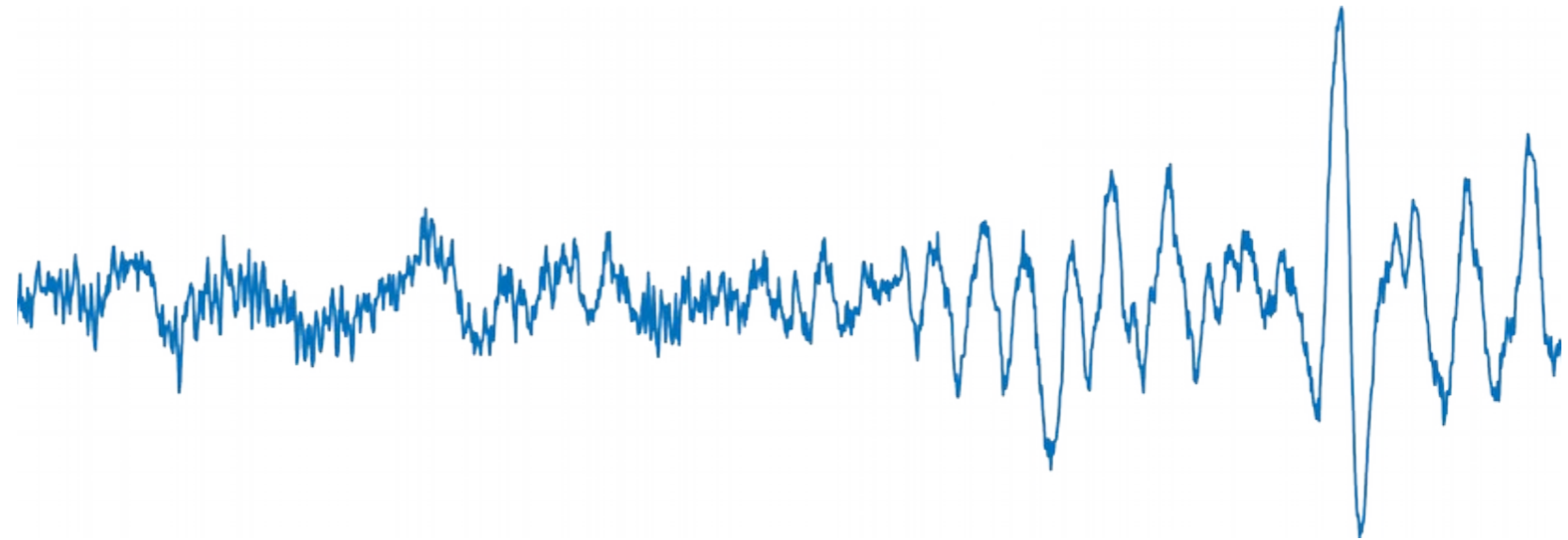
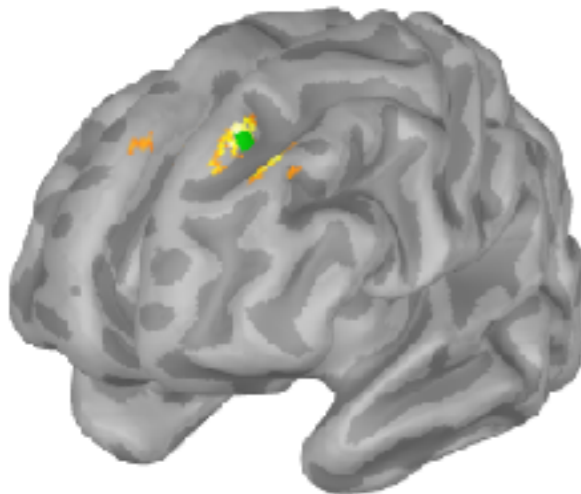
LFP
EEG sensor/source
MEG sensor/source



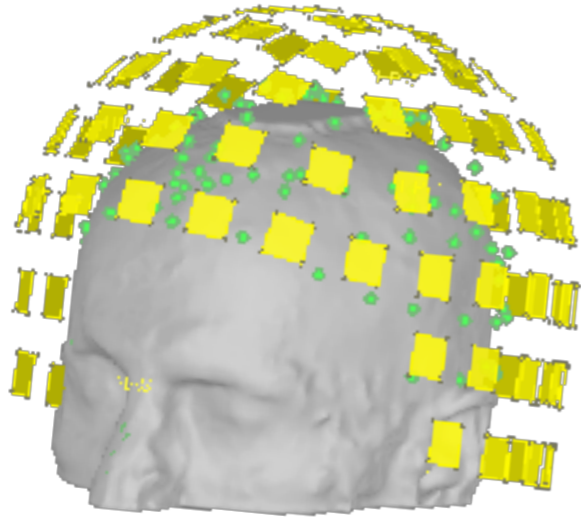
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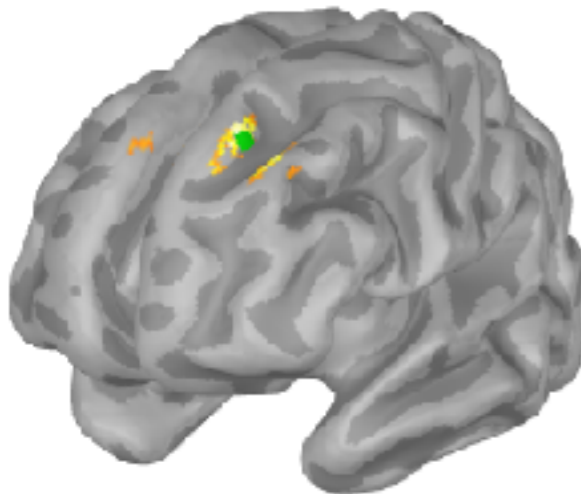
LFP
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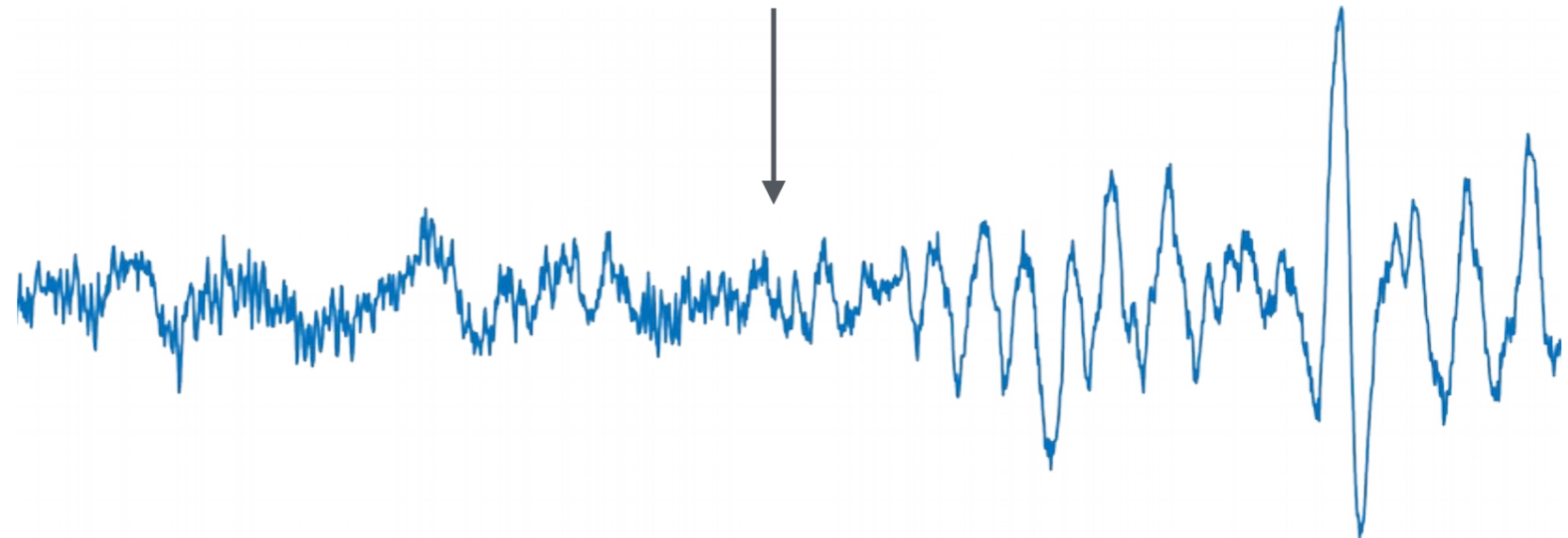
Signal extraction: several options



LFP
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MEG sensor/source

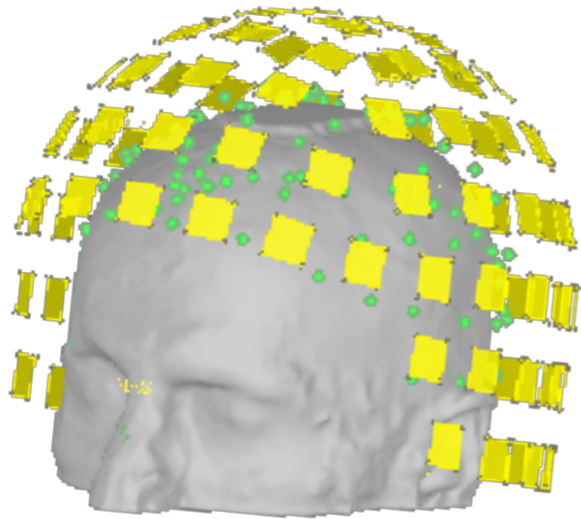


Stimulus / behavioral
event

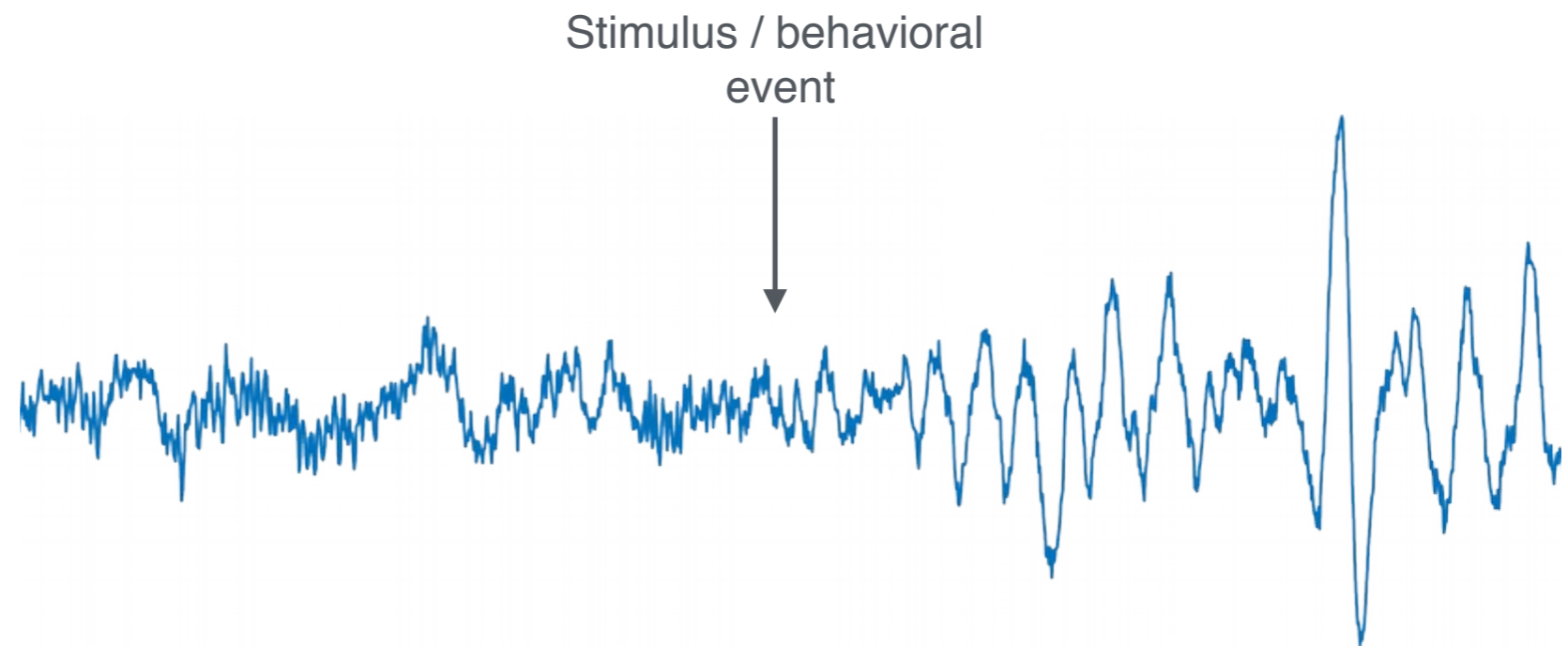
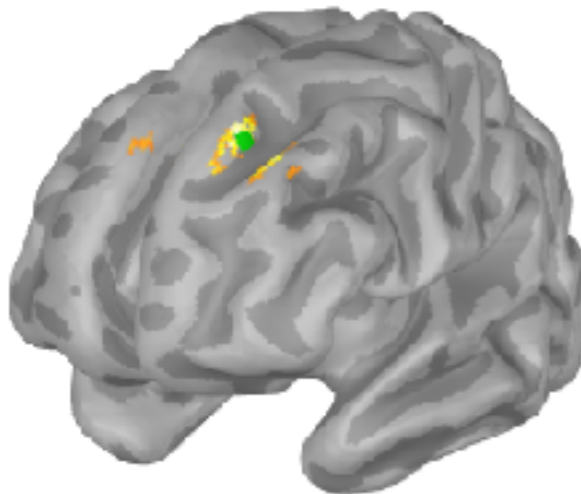


Signal extraction: several options

“Average” representations

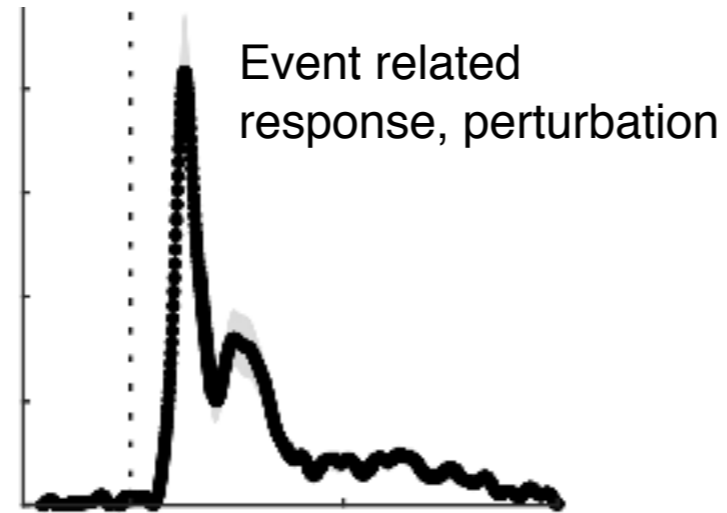
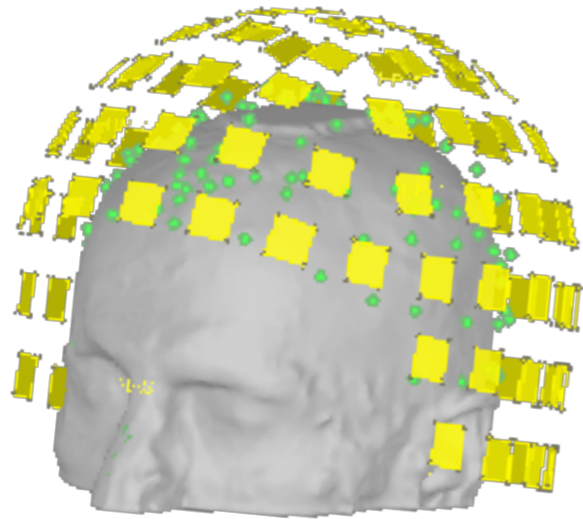


LFP
EEG sensor/source
MEG sensor/source



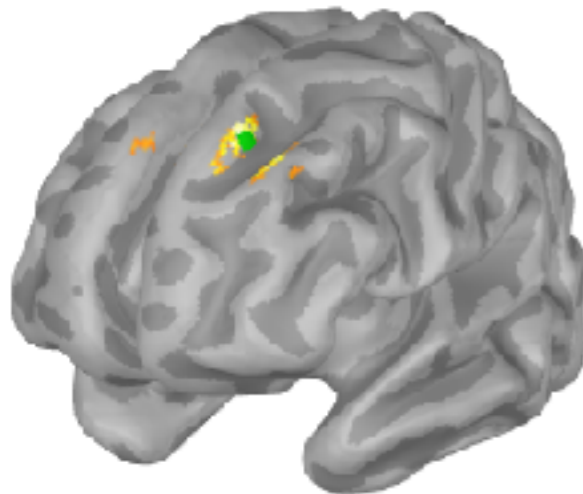
Signal extraction: several options

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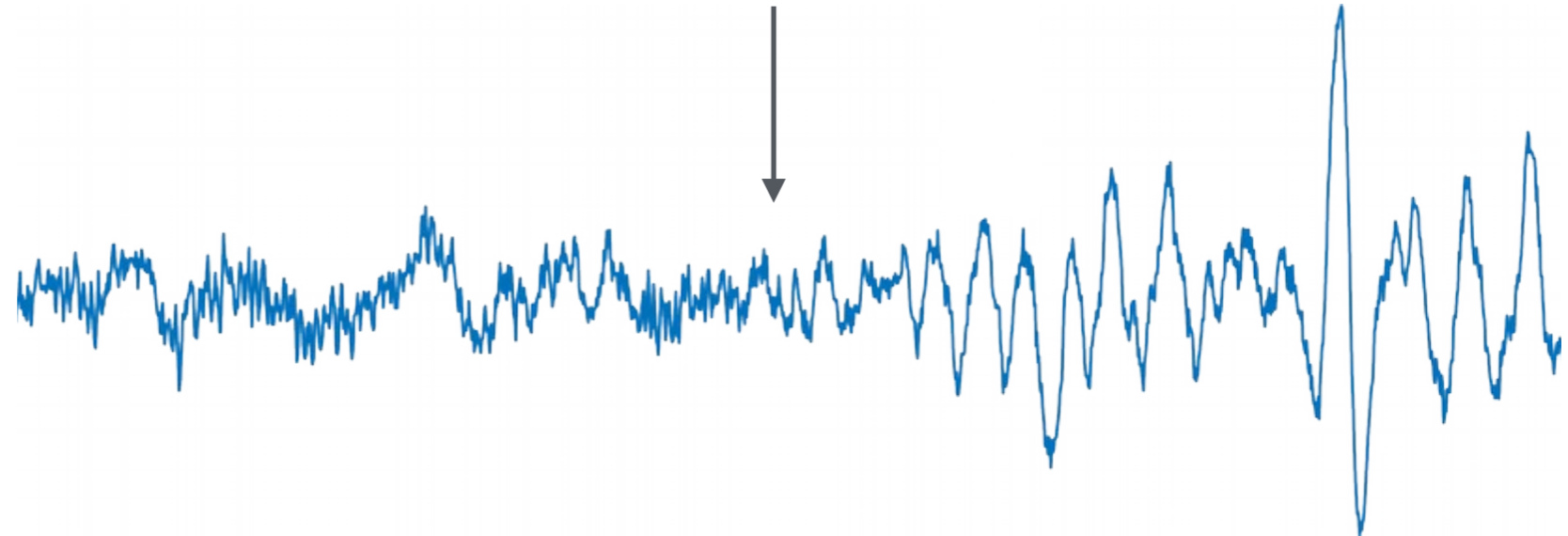


Event related
response, perturbation

LFP
EEG sensor/source
MEG sensor/source

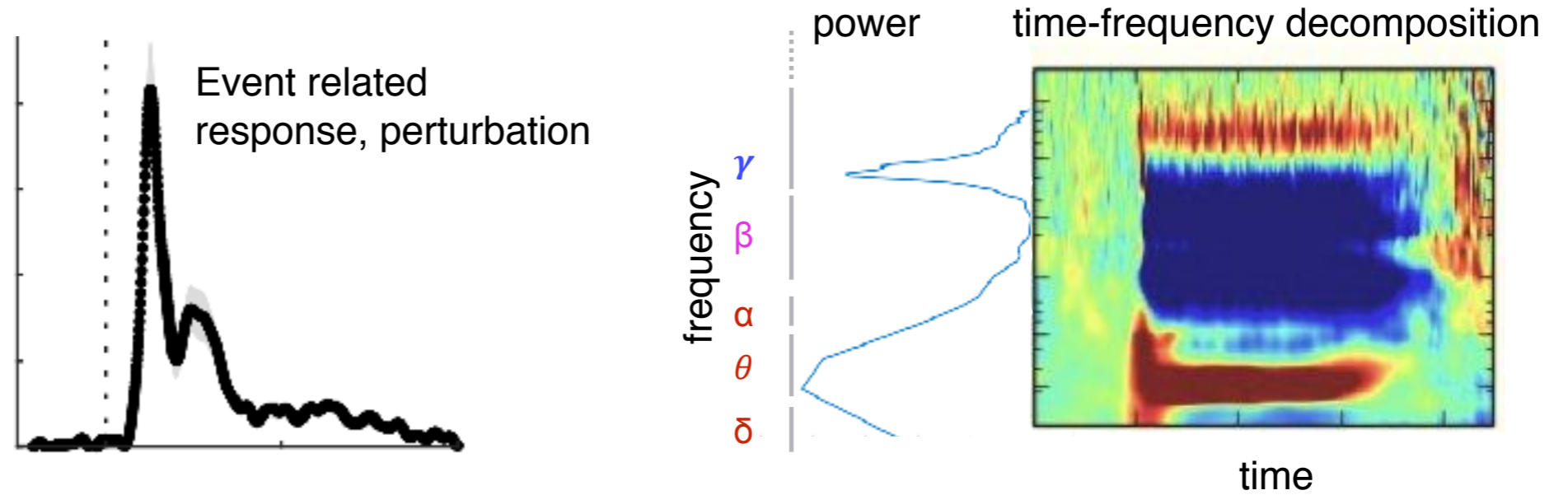
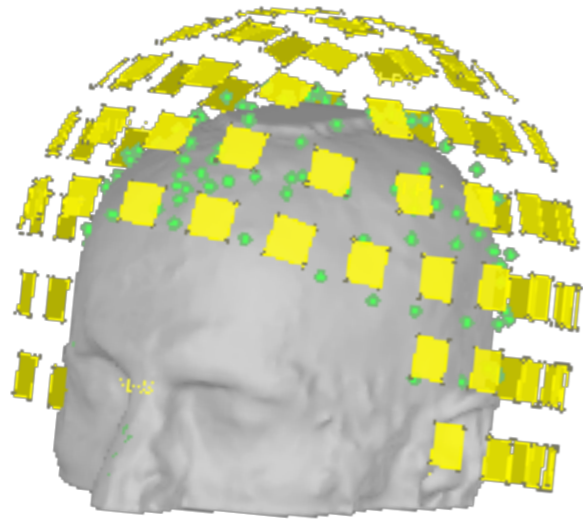


Stimulus / behavioral
event

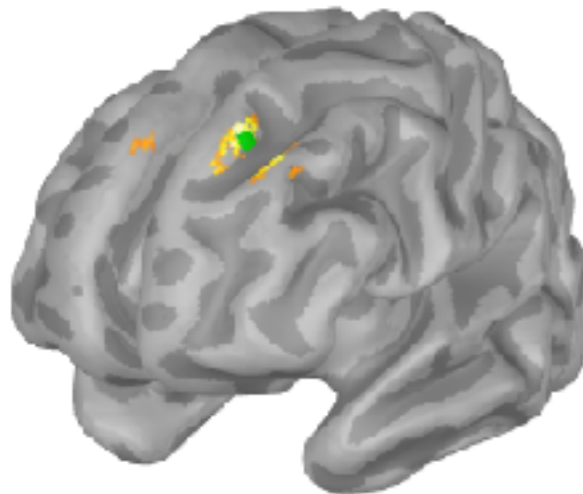


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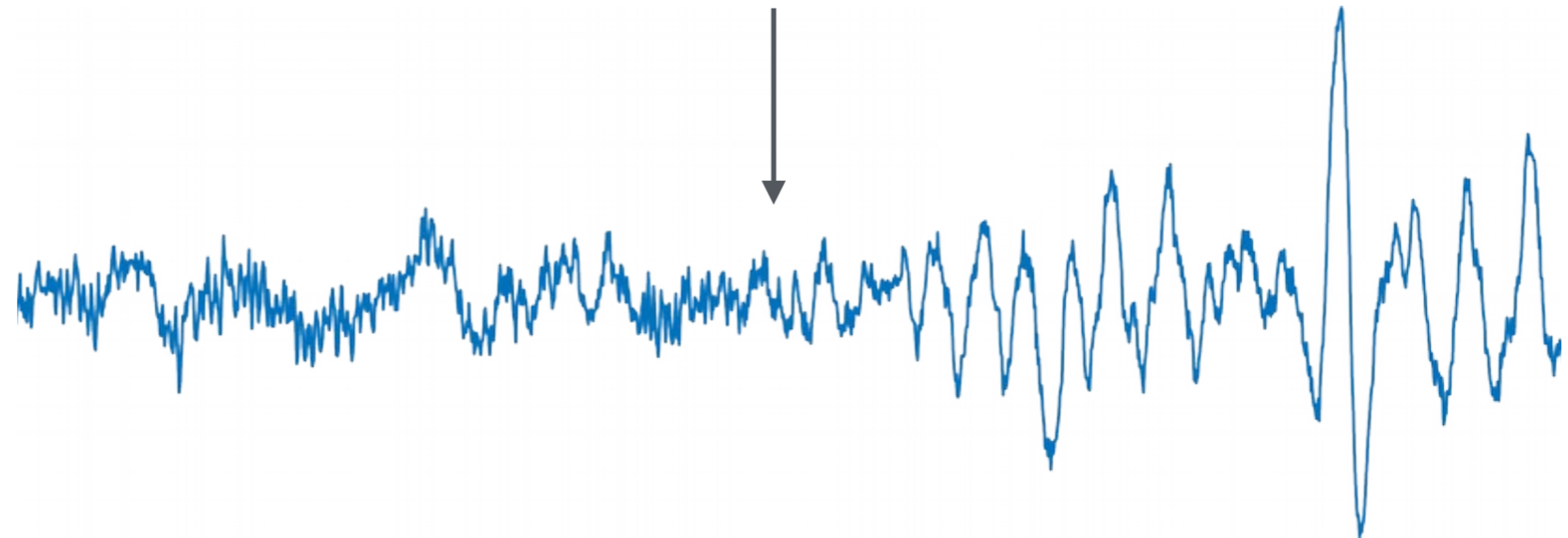
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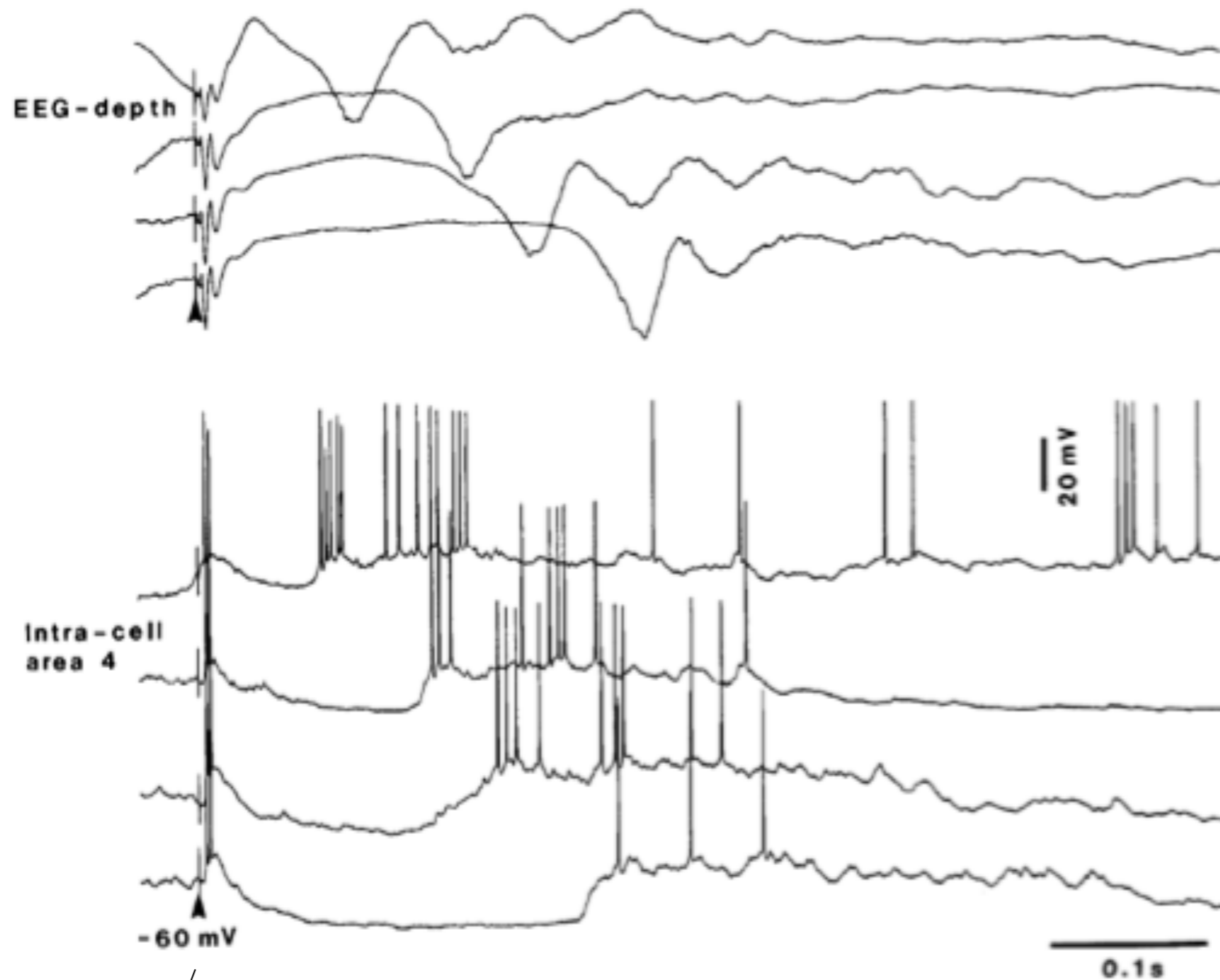
LFP
EEG sensor/source
MEG sensor/source



Stimulus / behavioral event



Temporal jitter of unitary and ensemble responses

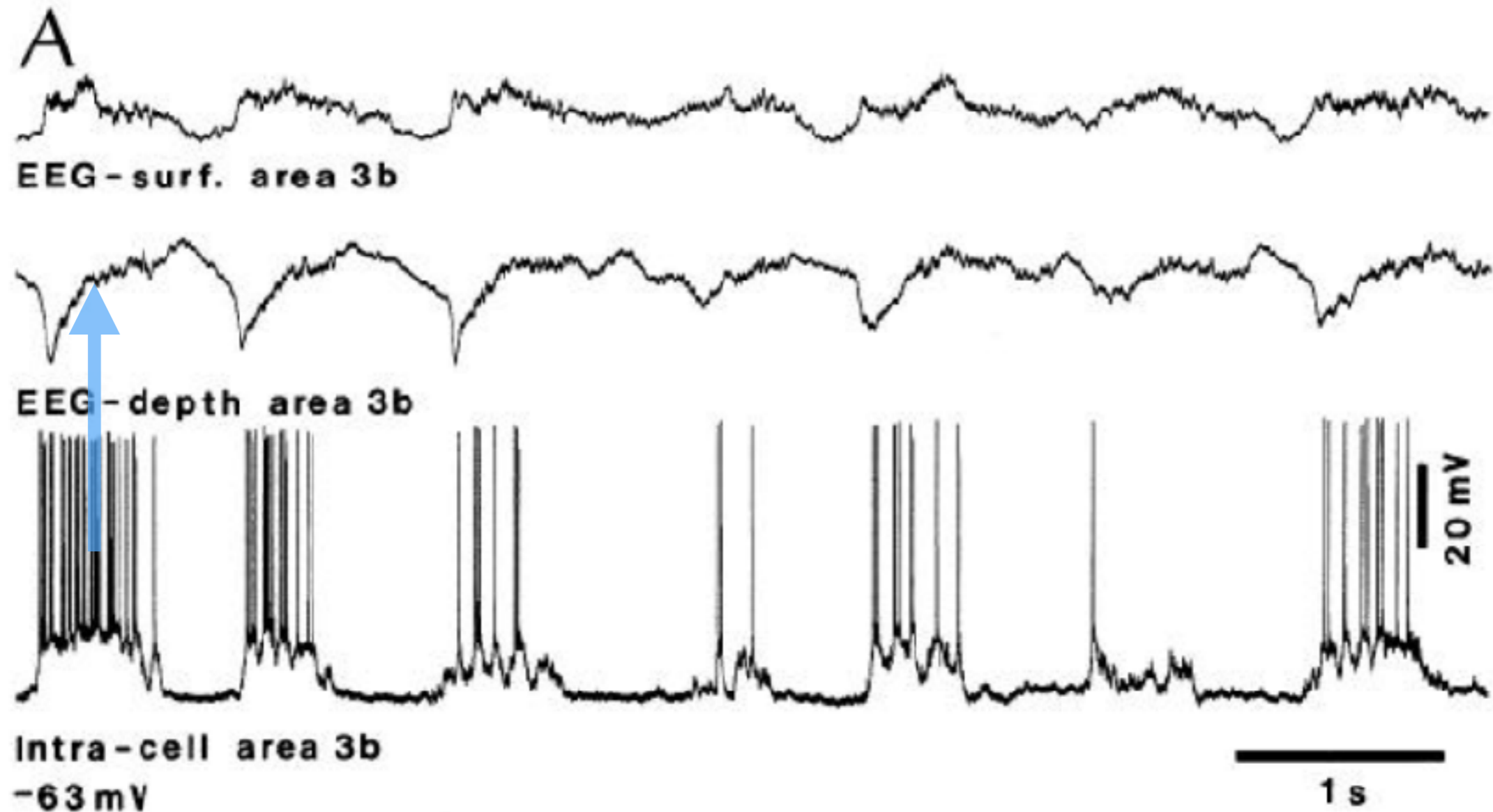


Thalamic stimulation

Cortical response

Contreras & Steriade, J. Neurophys. (1996)

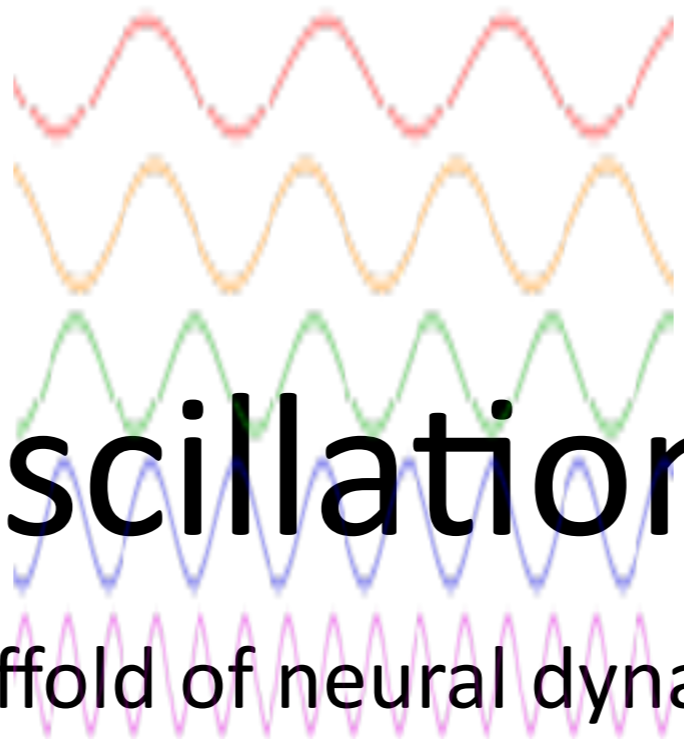
Evidence of low-to-high frequency coupling of neural oscillations: single cells & assemblies



Contreras & Steriade, J. Neurosci. (1995)

Oscillations

a scaffold of neural dynamics



Oscillations

a scaffold of neural dynamics

State-dependent expressions of neural oscillations

State-dependent expressions of neural oscillations

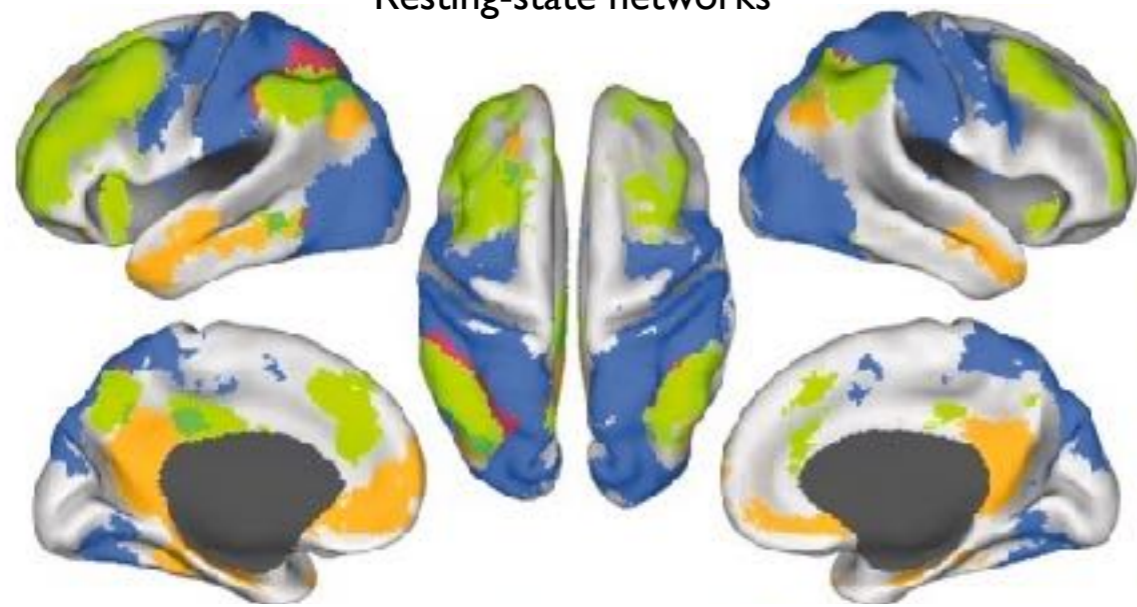
Consider the “resting-state” as a case example

State-dependent expressions of neural oscillations

Consider the “resting-state” as a case example

fMRI - BOLD

Resting-state networks



Buckner et al. *Ann NY Acad. Sci.* (2008)

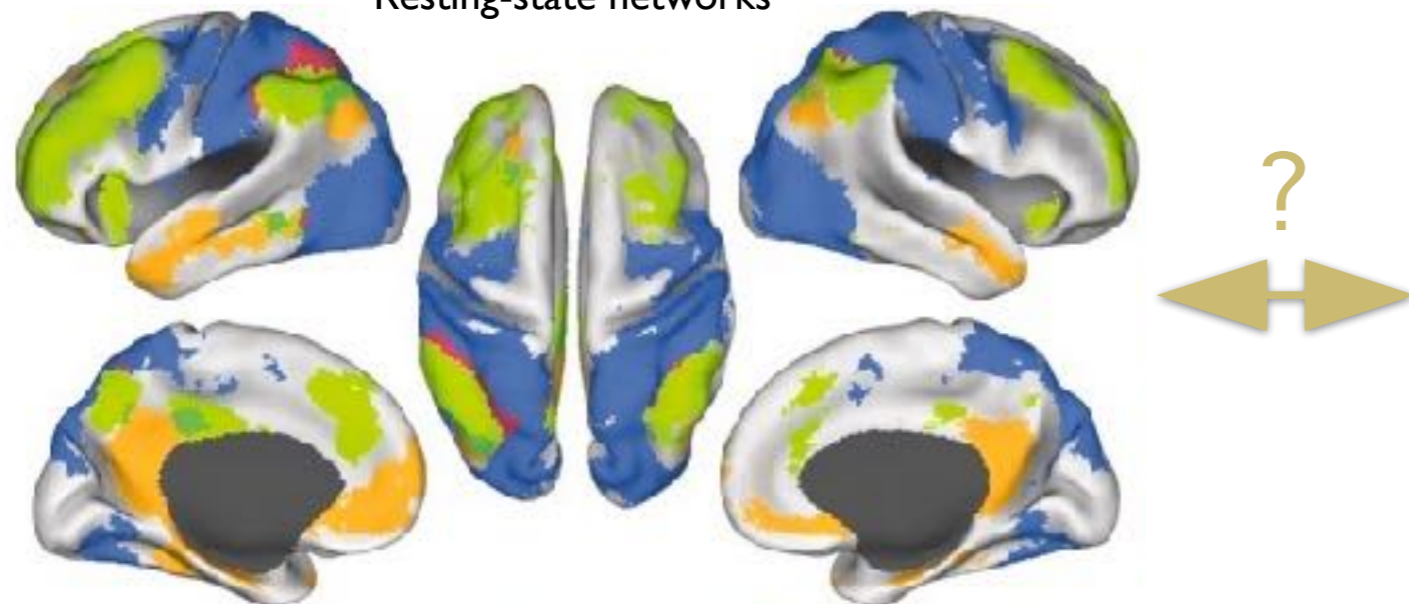
Carhart-Harris & Friston, *Brain* (2010)

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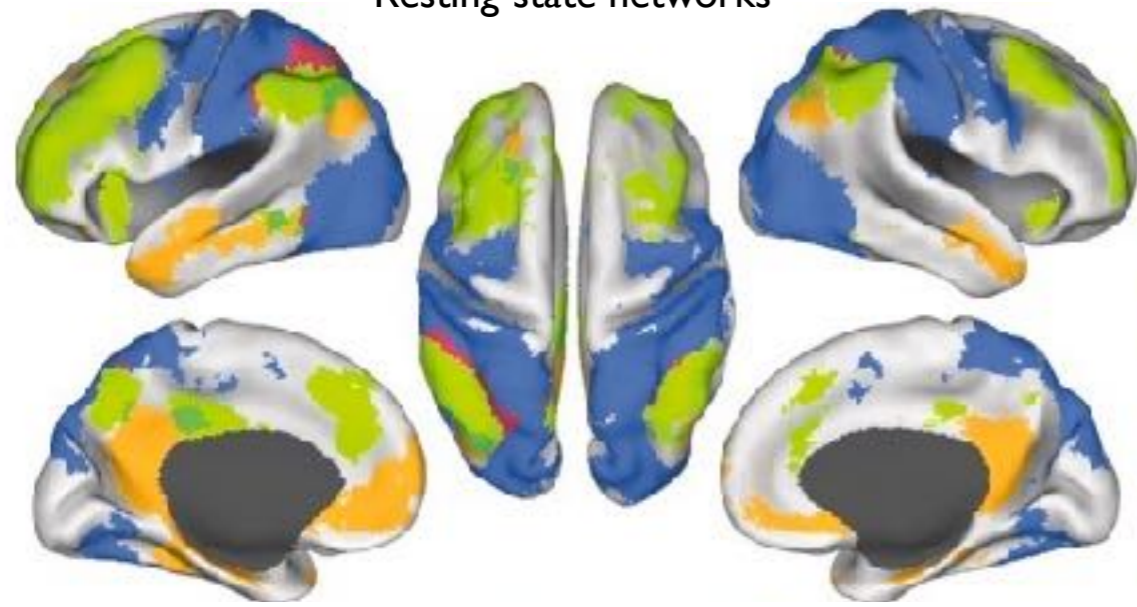
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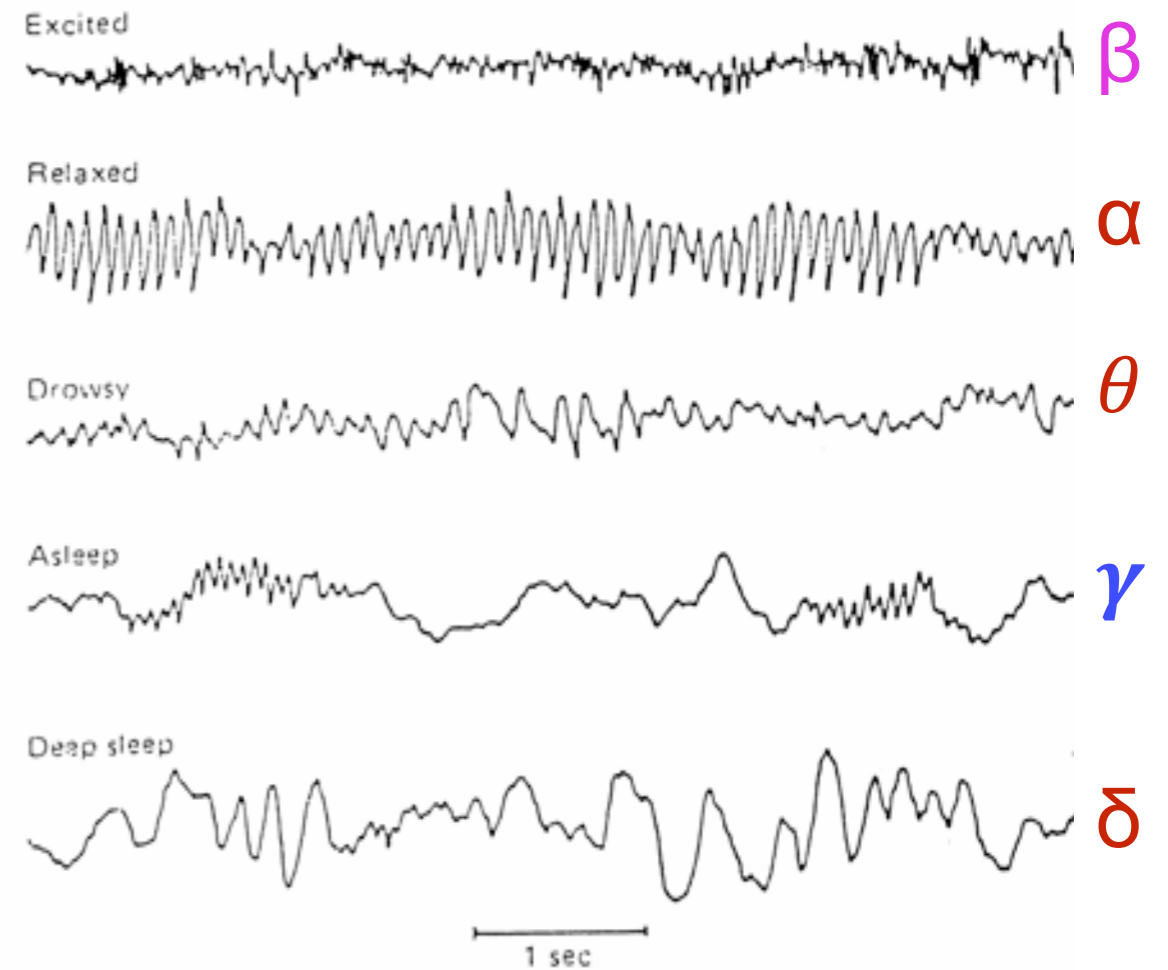
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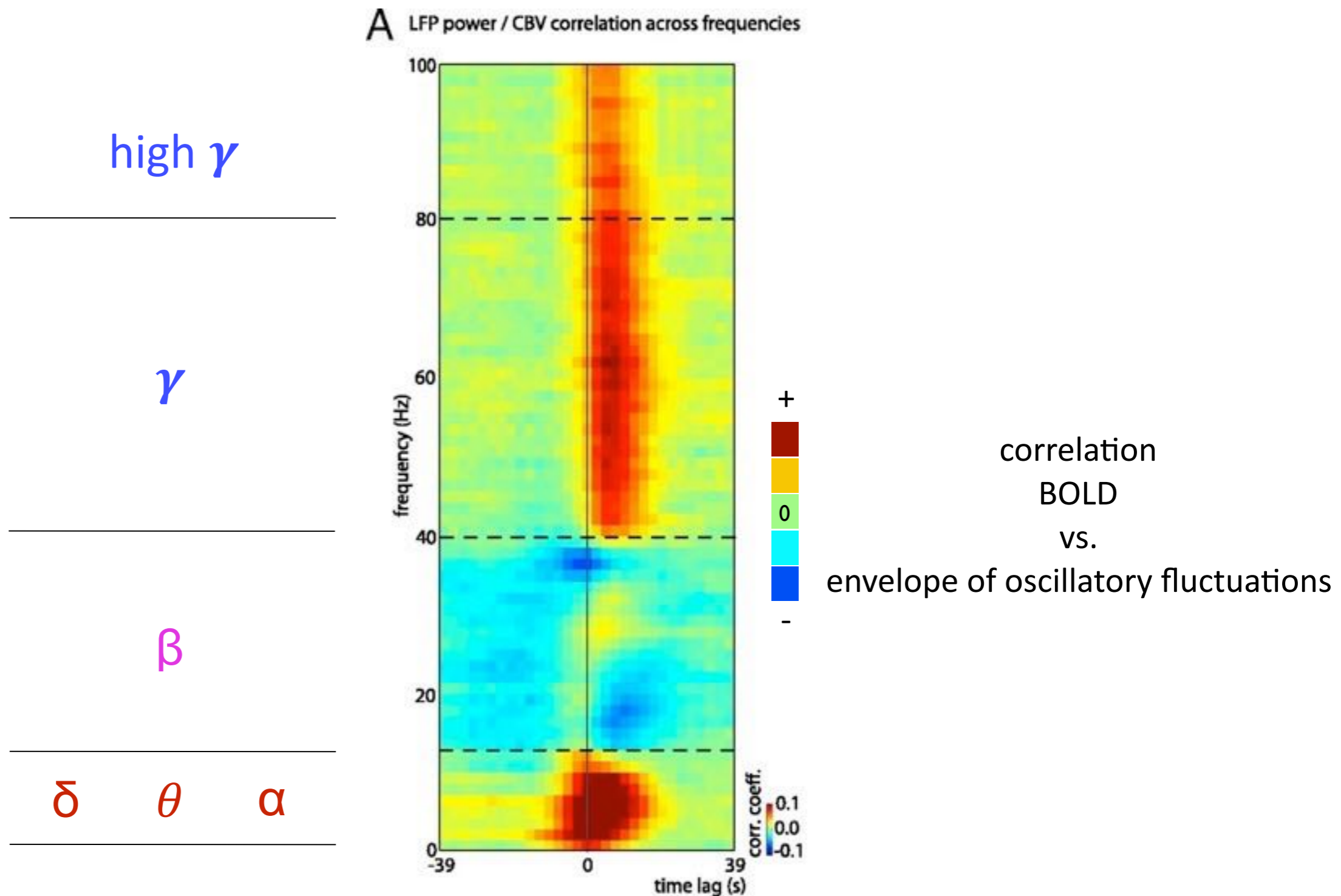


electrophysiology



Buckner et al. *Ann NY Acad. Sci.* (2008)
Carhart-Harris & Friston, *Brain* (2010)

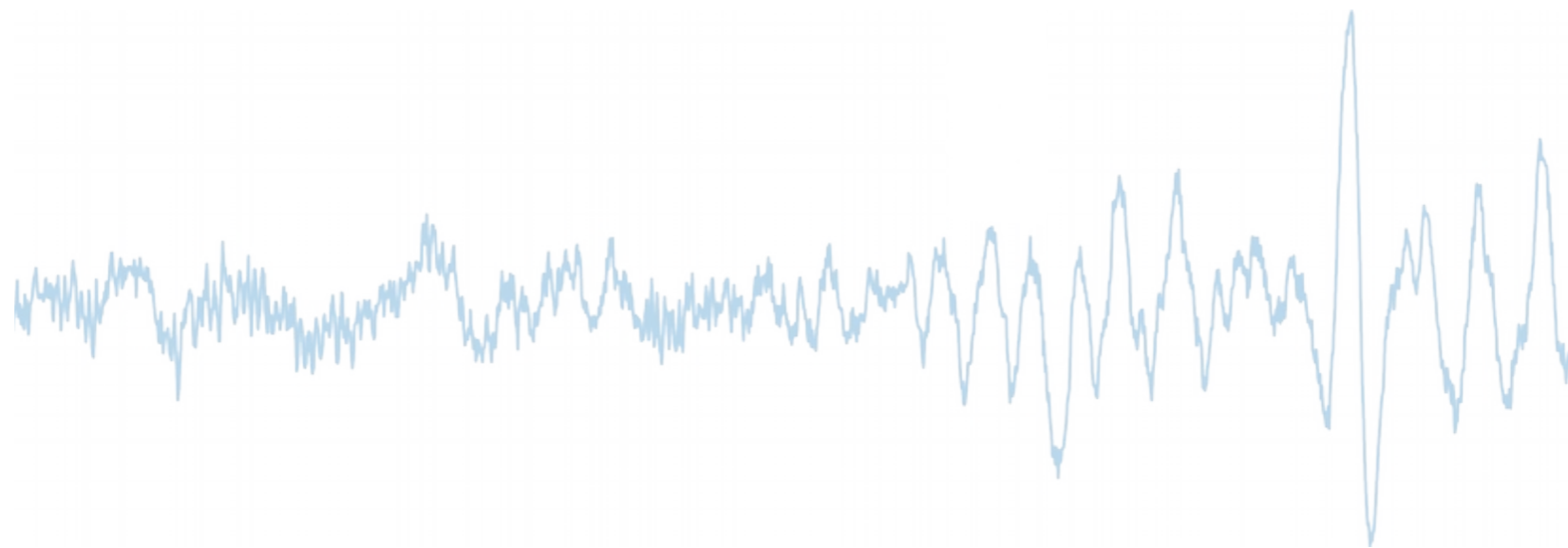
Correlation between ongoing brain rhythms and BOLD



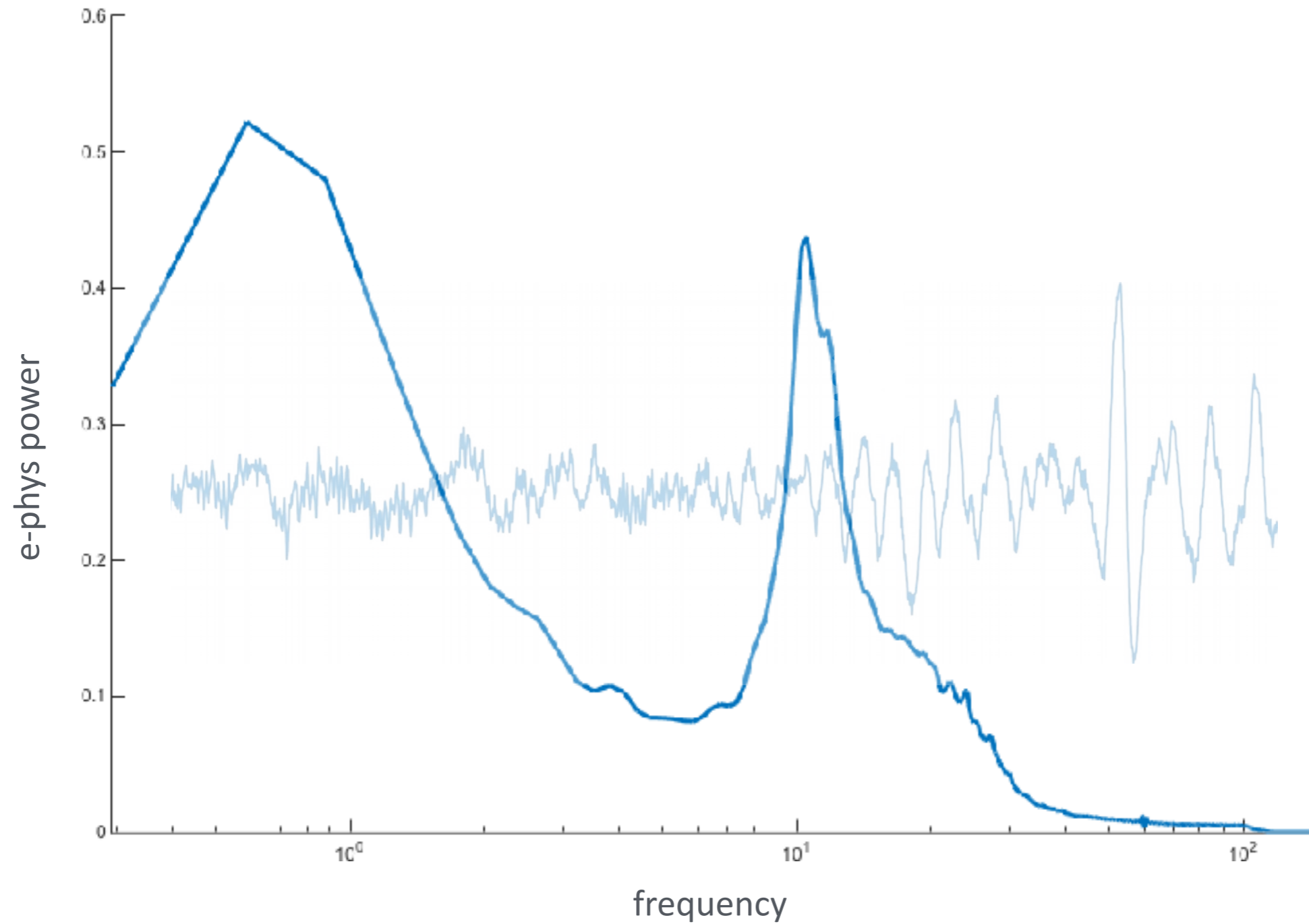
Schölvinck et al. *PNAS* (2010)
see also Logothetis et al., *Nature* (2001)

Interdependencies in the polyrhythmic activity of the brain?

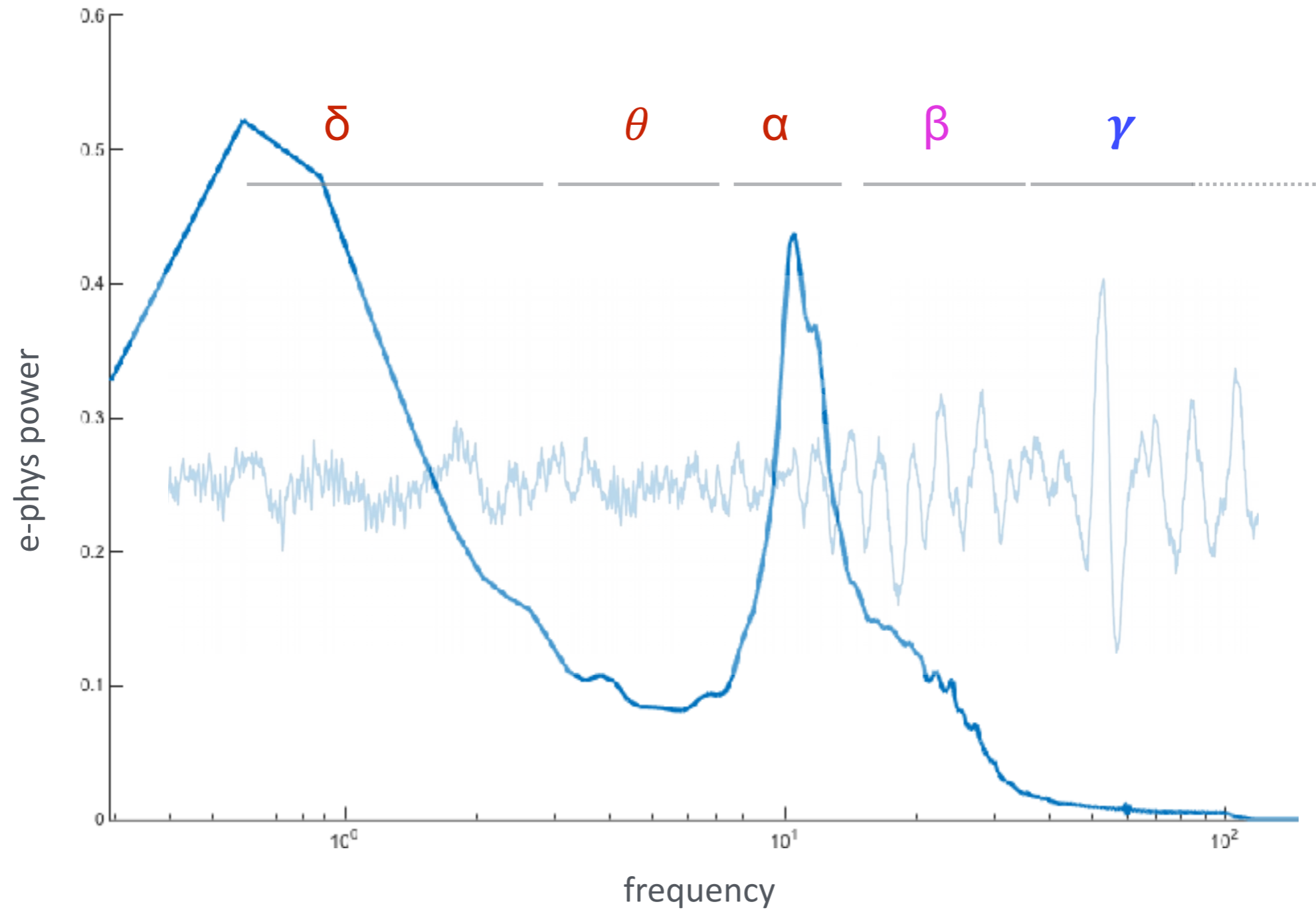
Interdependencies in the polyrhythmic activity of the brain?



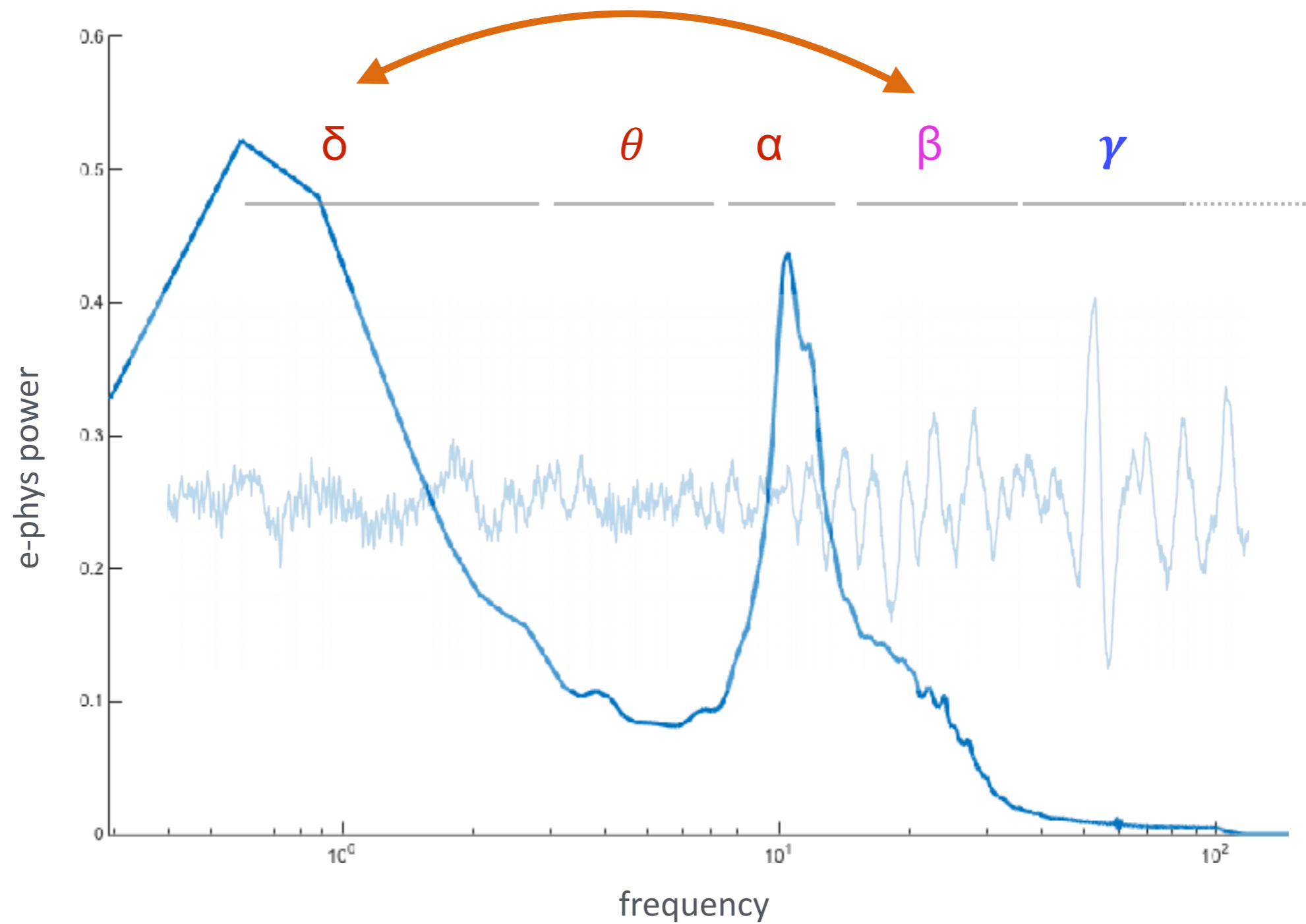
Interdependencies in the polyrhythmic activity of the brain?



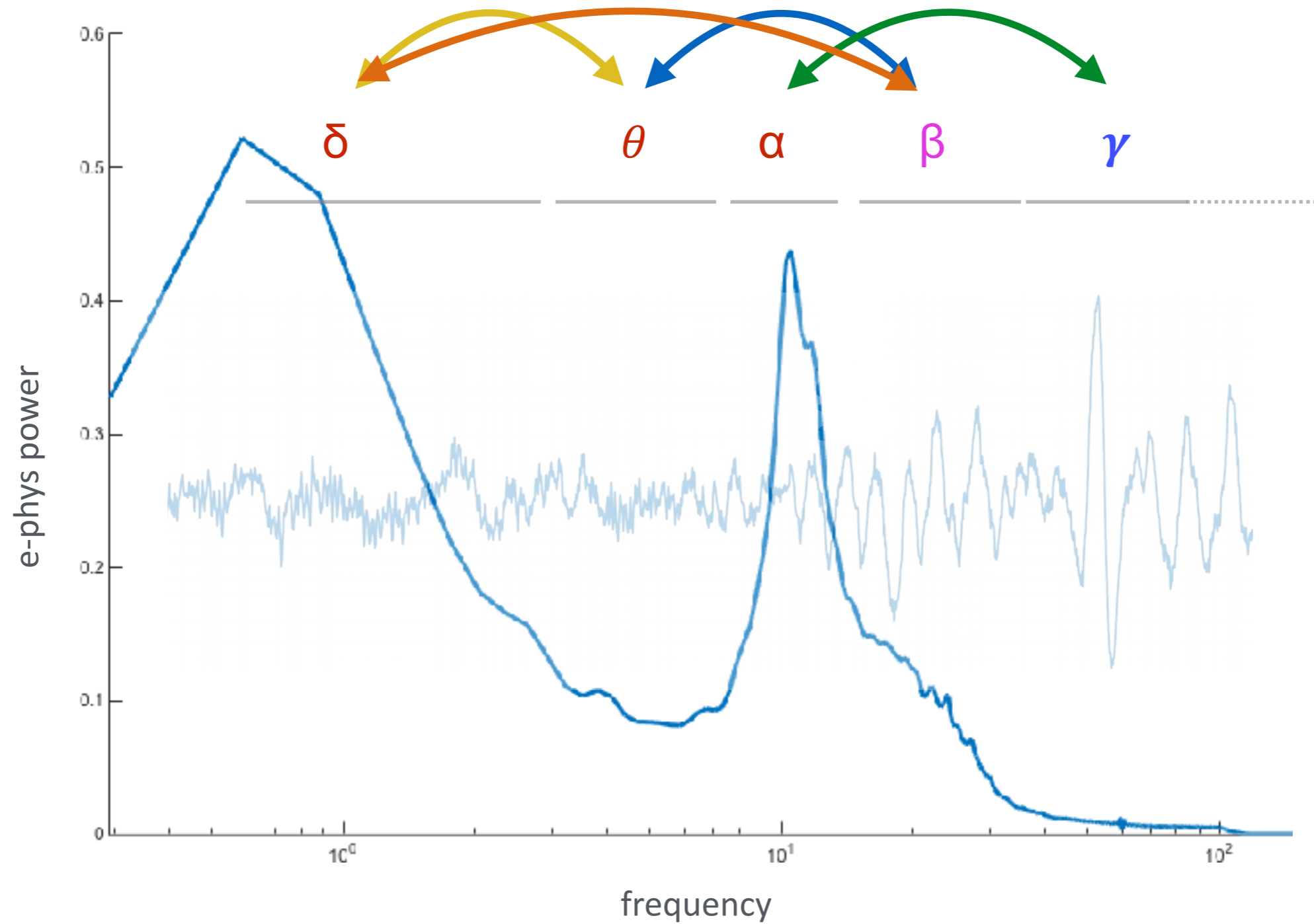
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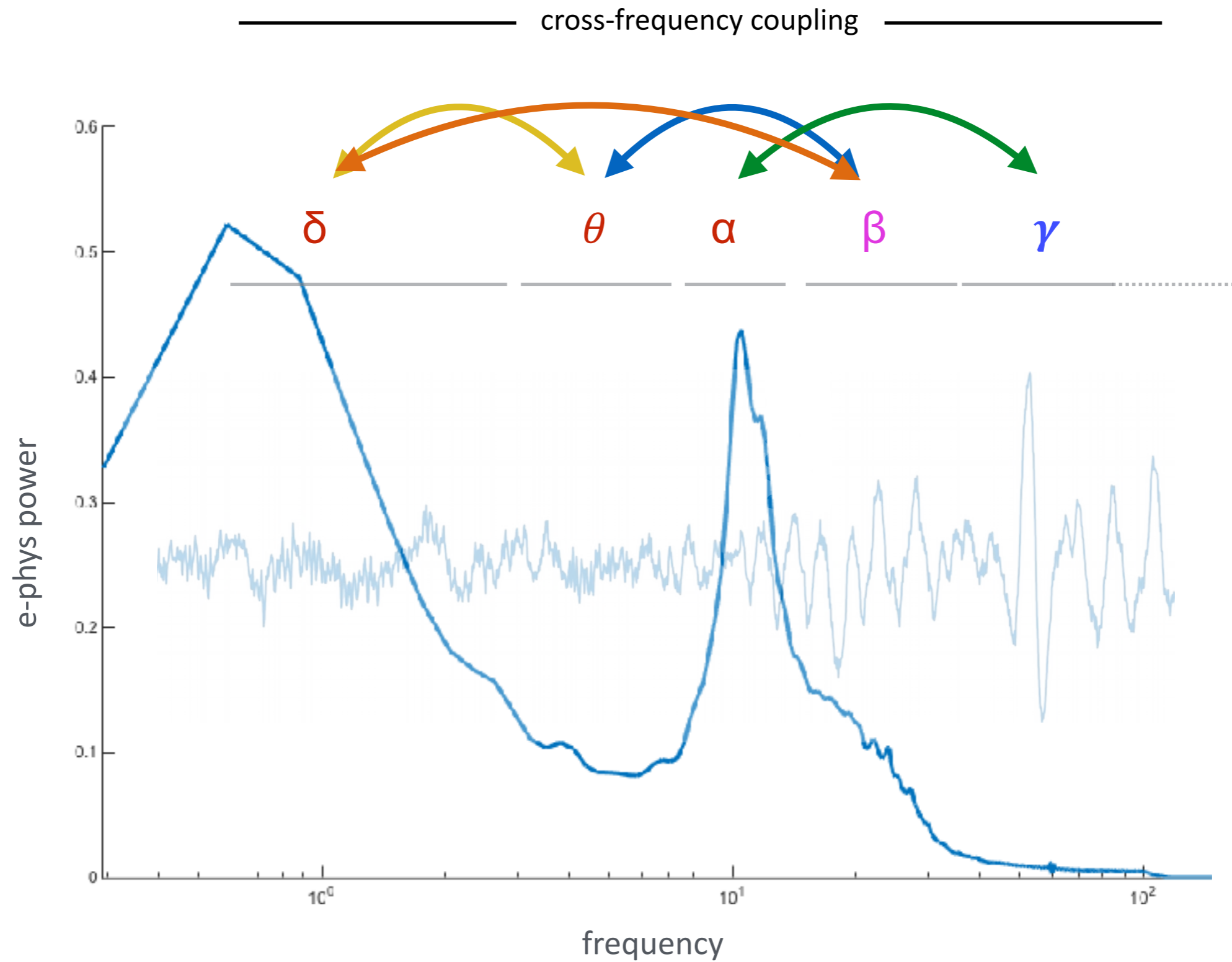
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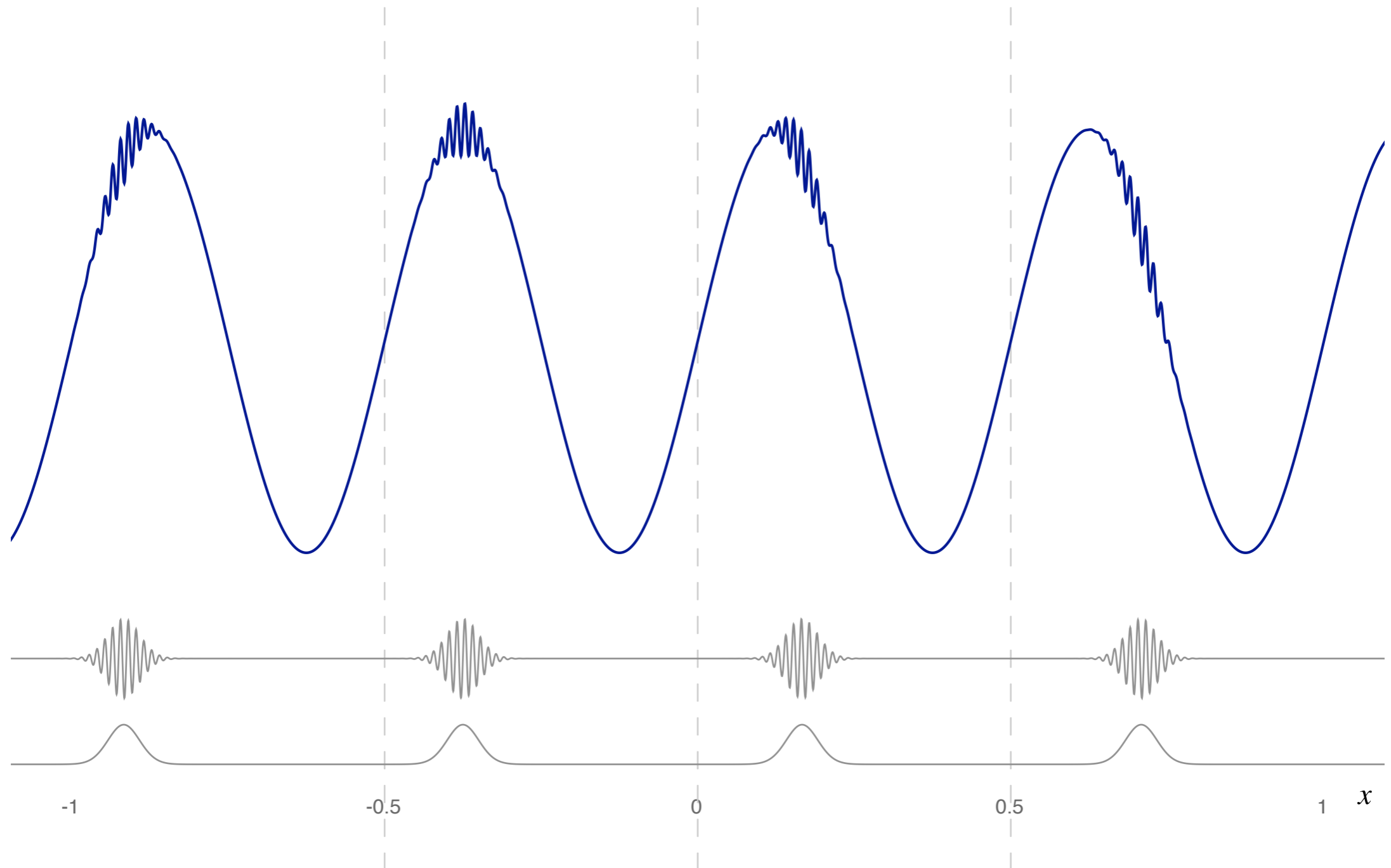
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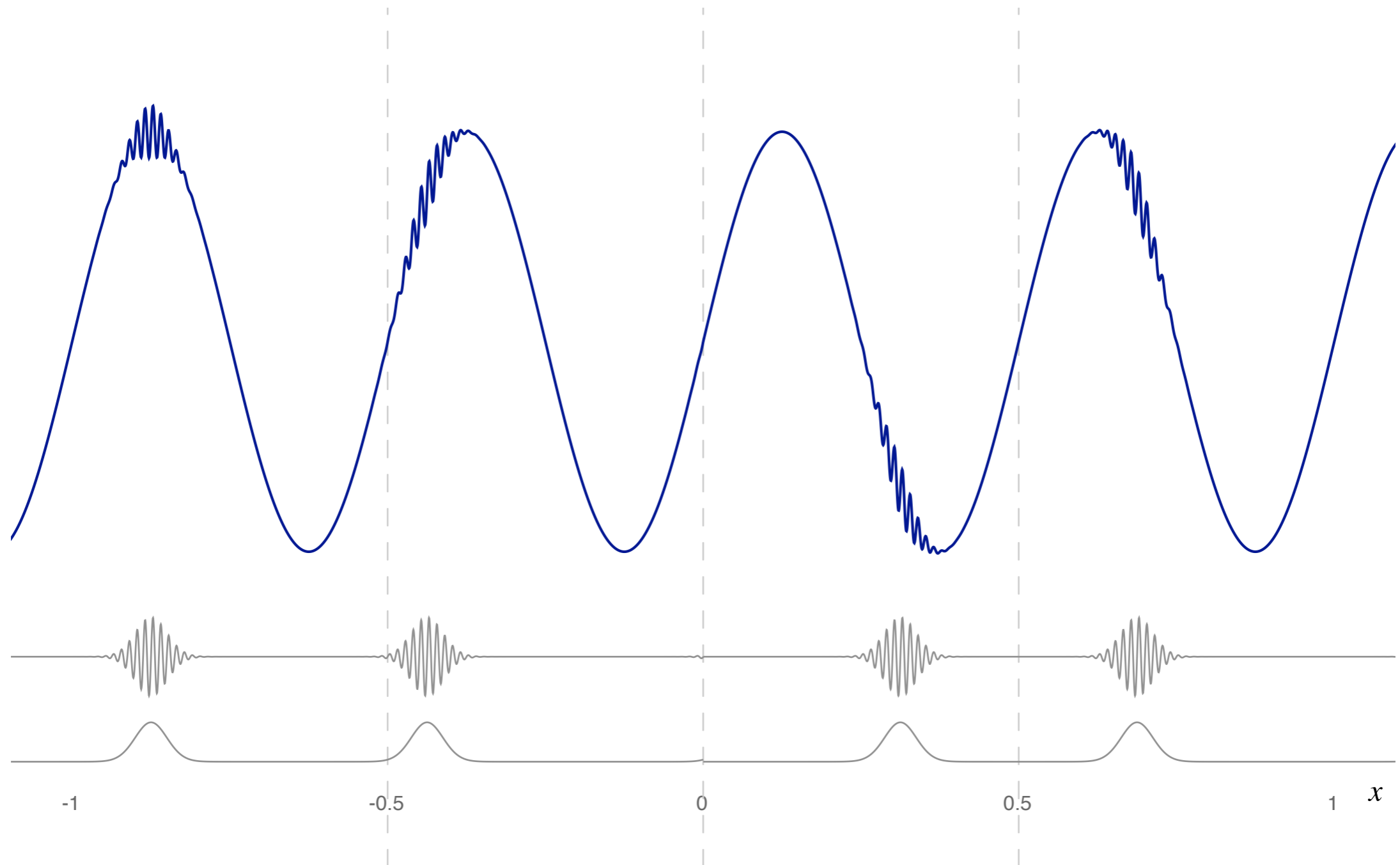
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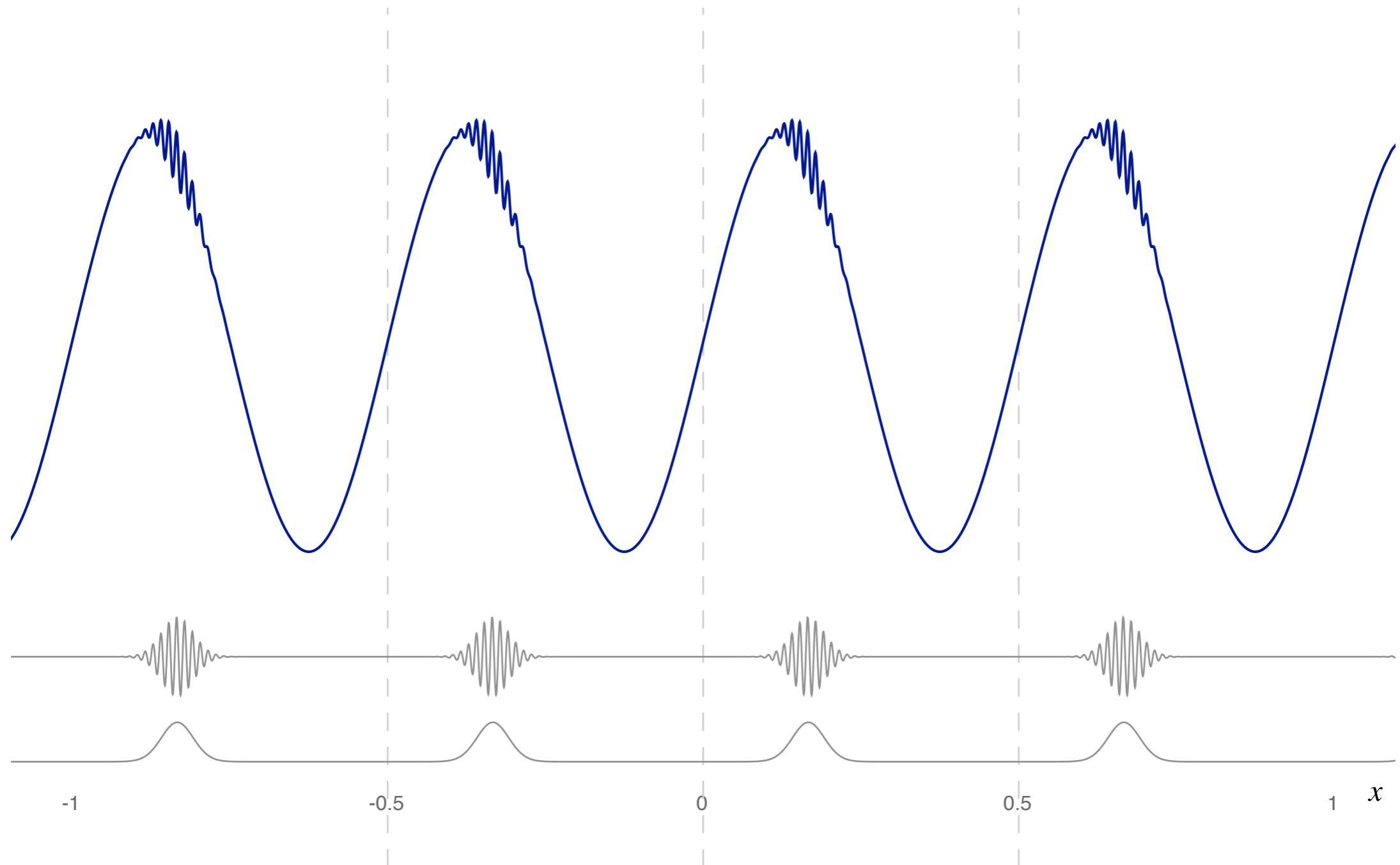
Cross-frequency phase-amplitude coupling (PAC)



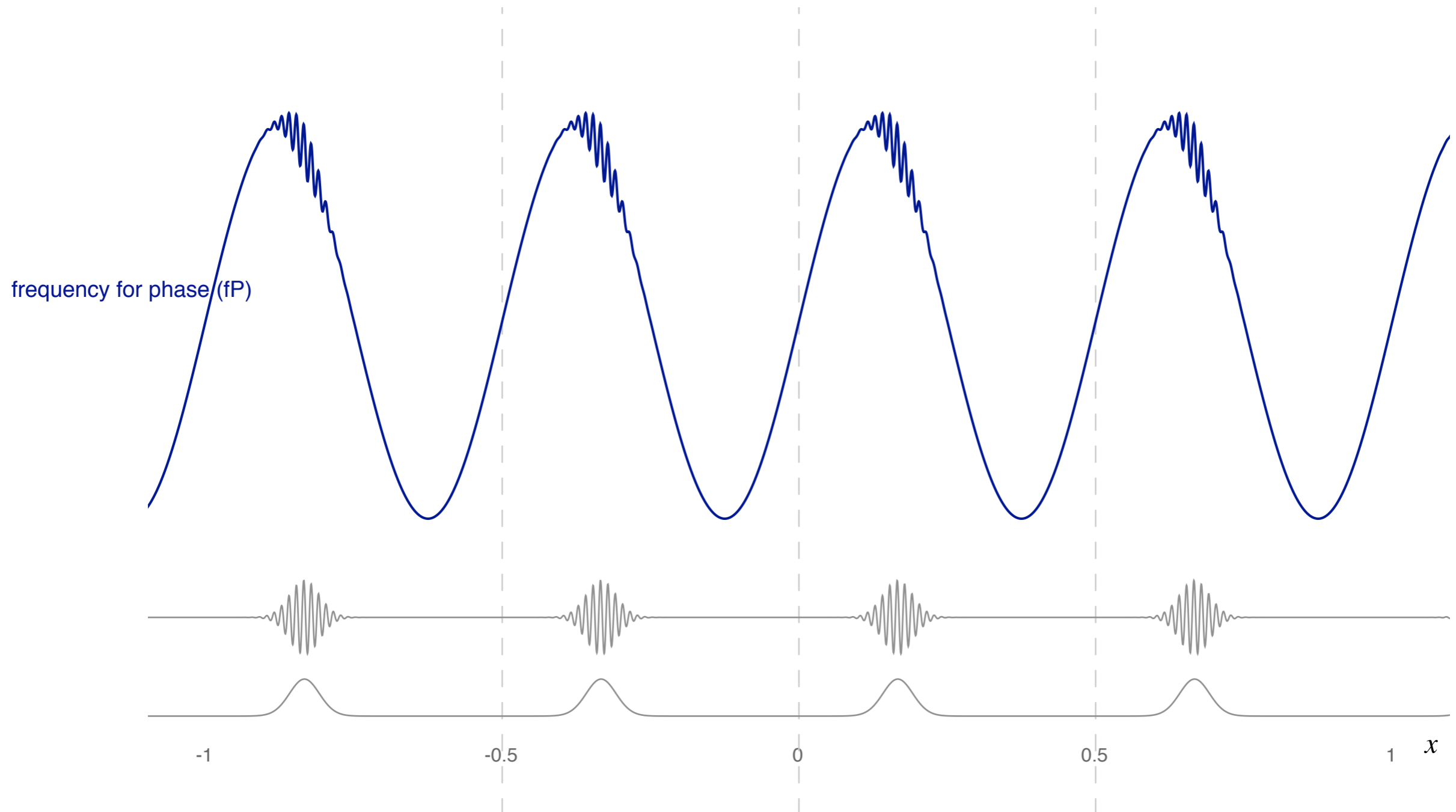
Cross-frequency phase-amplitude coupling (PAC)



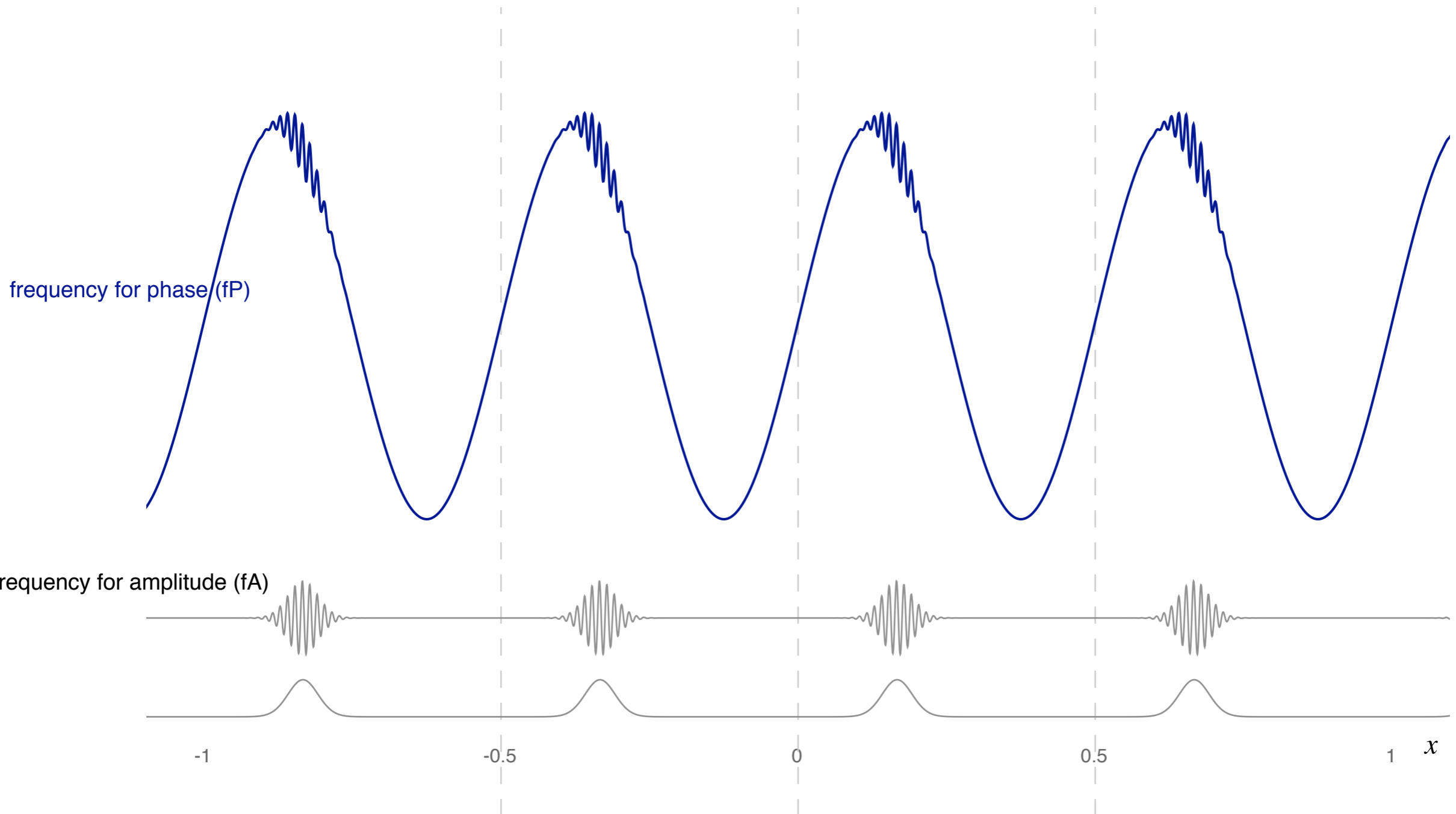
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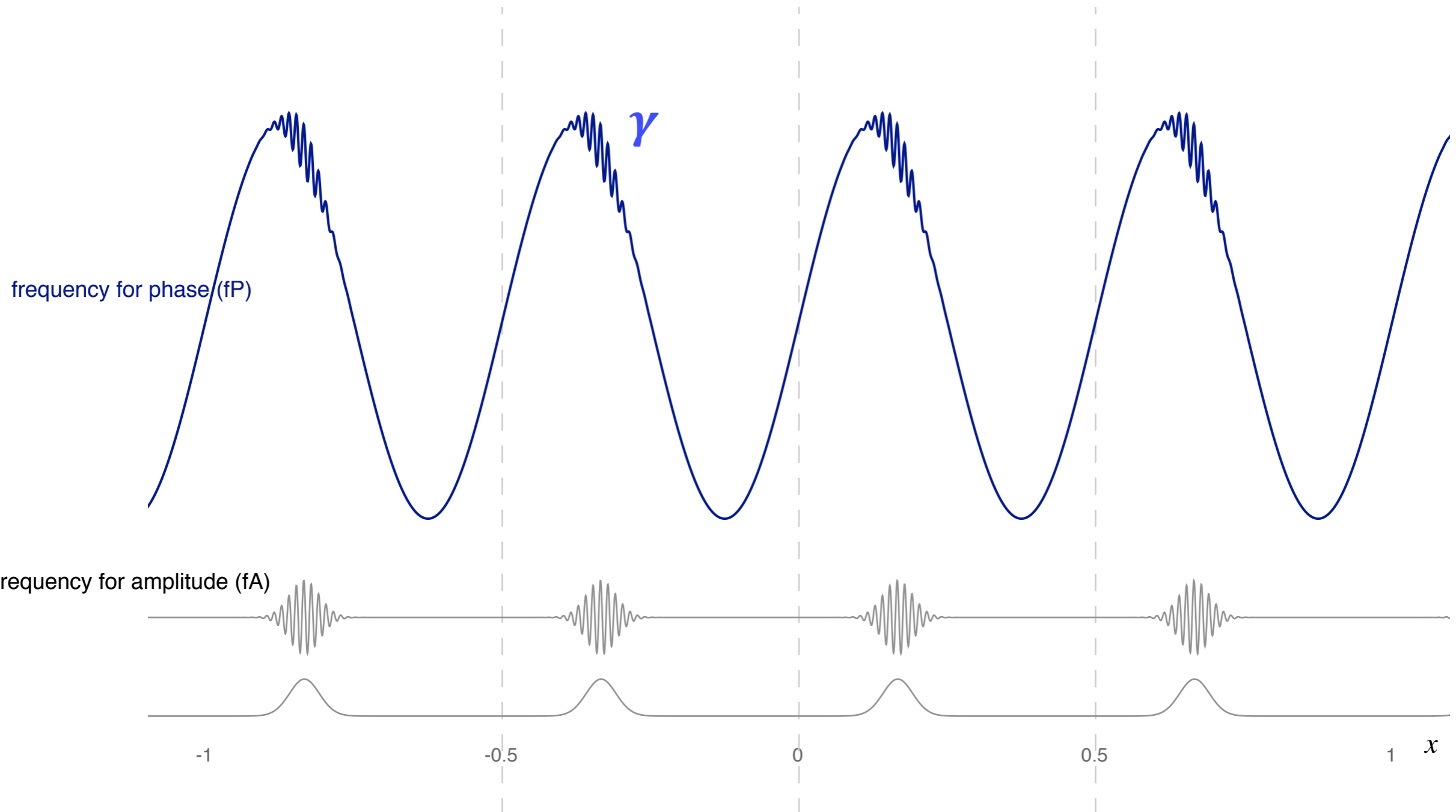
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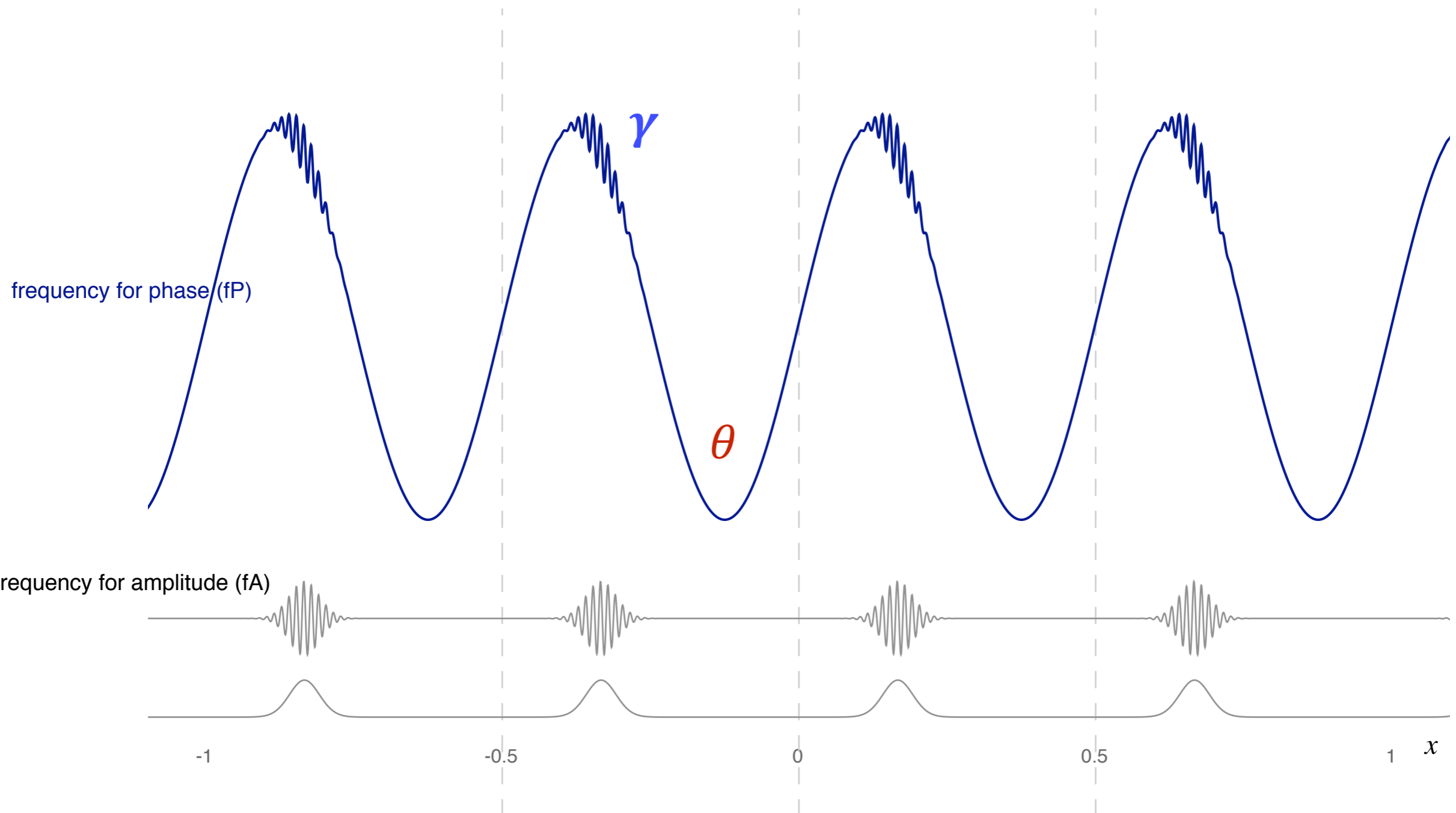
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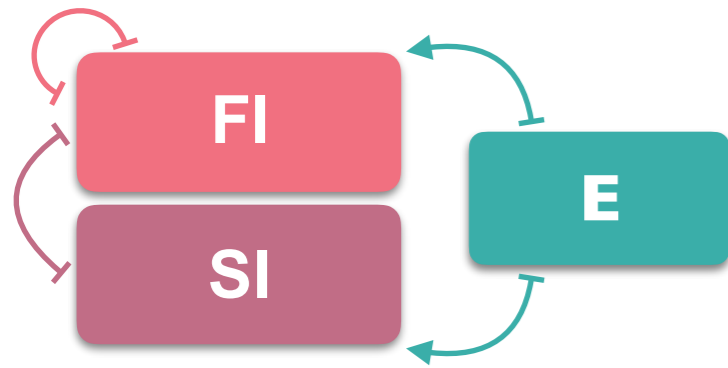
Cross-frequency phase-amplitude coupling (PAC)



Cross-frequency phase-amplitude coupling (PAC): A generic mechanism regulating local brain dynamics?

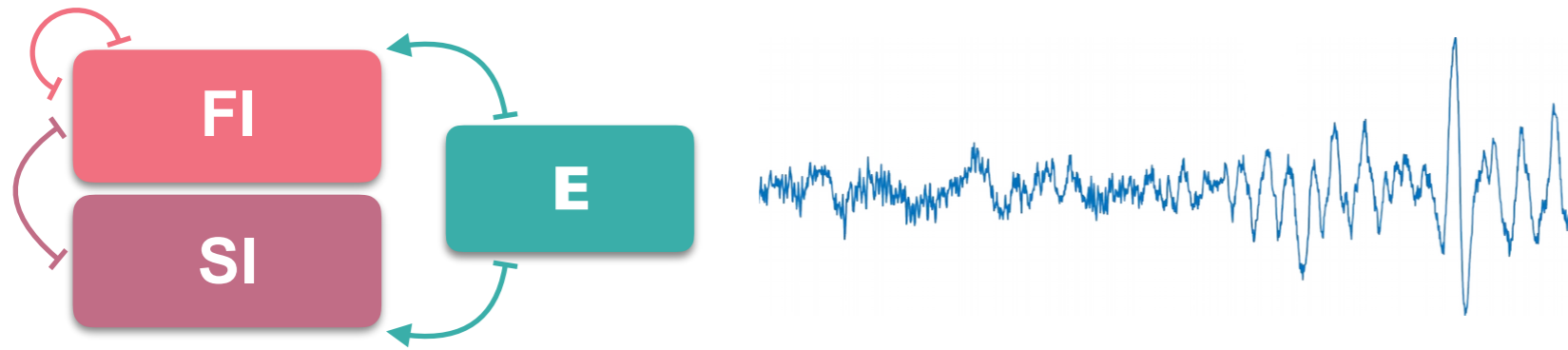
Cross-frequency phase-amplitude coupling (PAC): A generic mechanism regulating local brain dynamics?

neural cell assembly



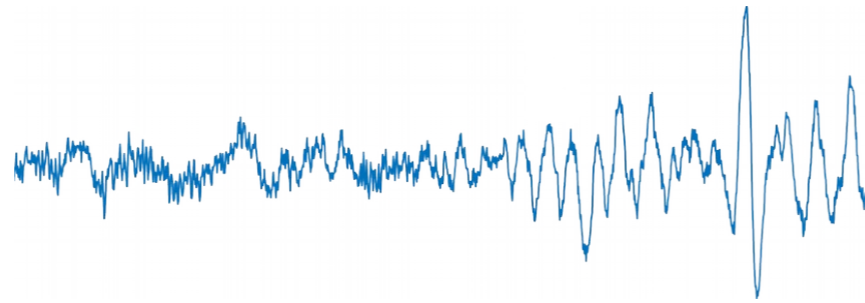
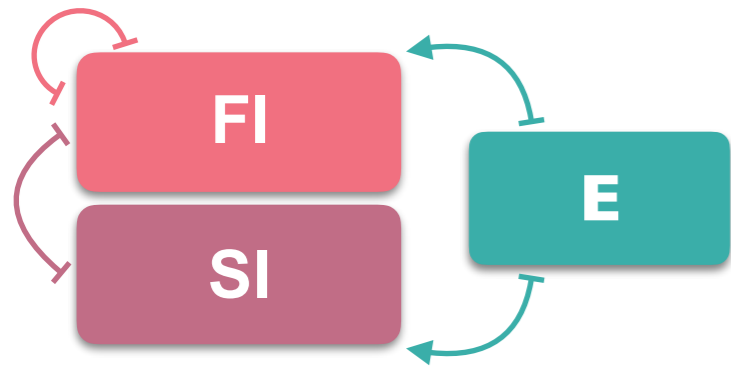
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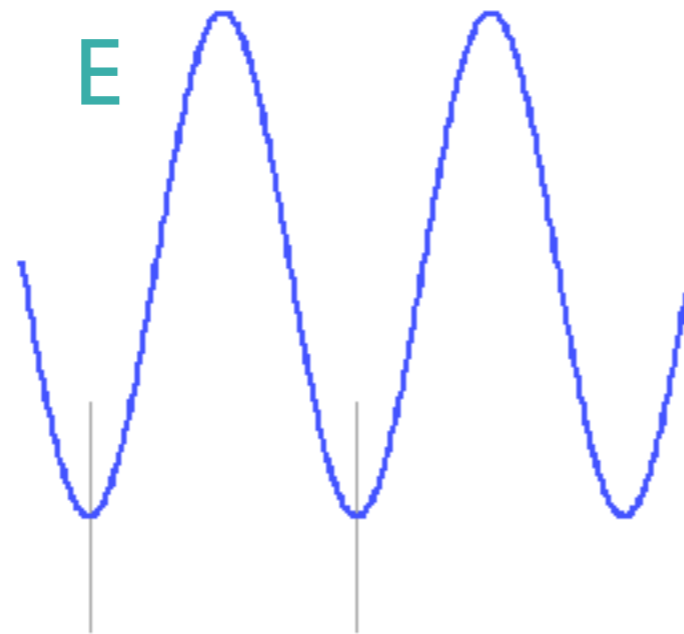


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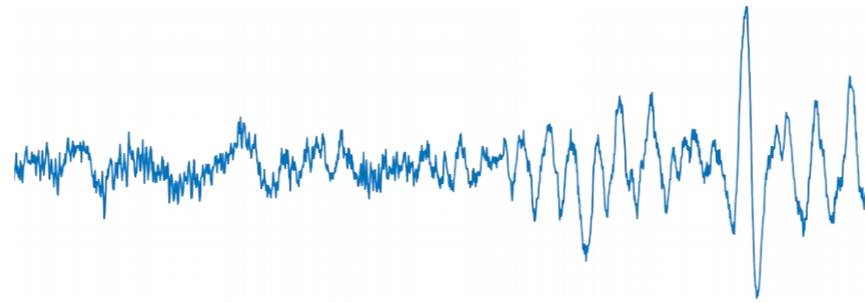
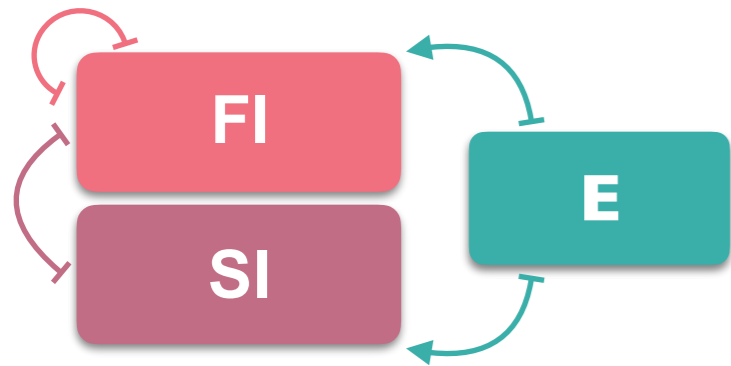
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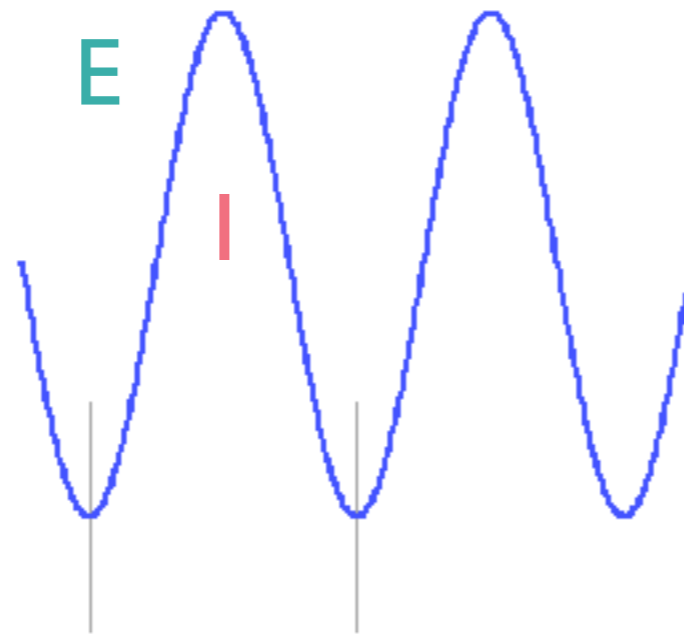
Buszaki & Wang
Ann Rev Neurosc (2012)

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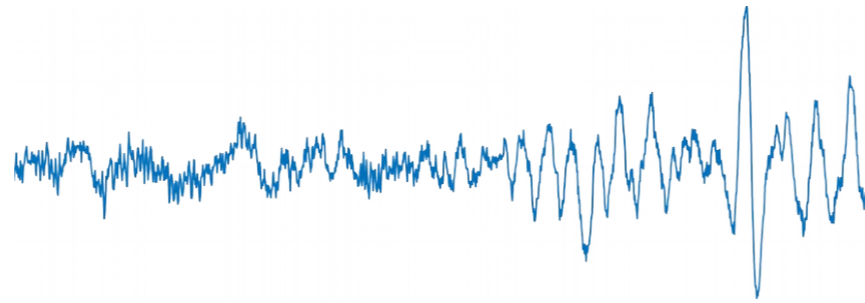
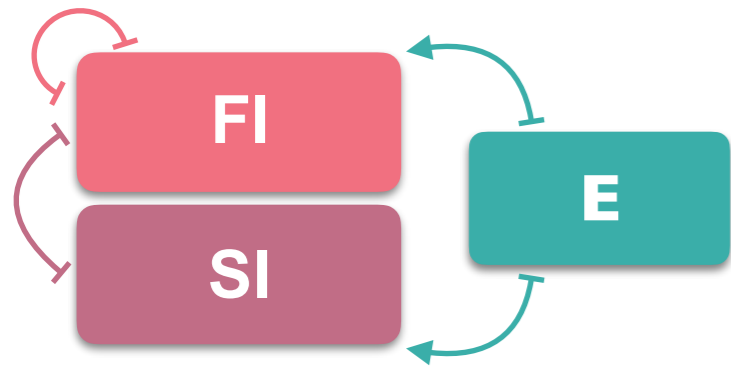
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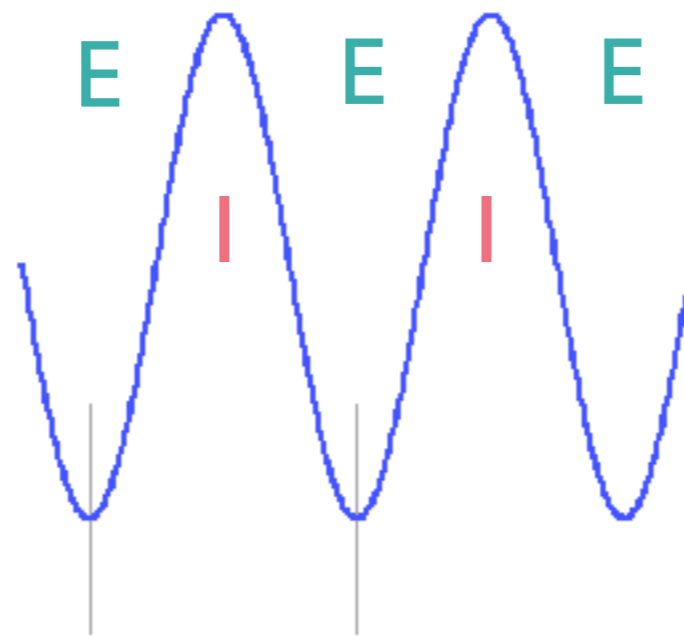
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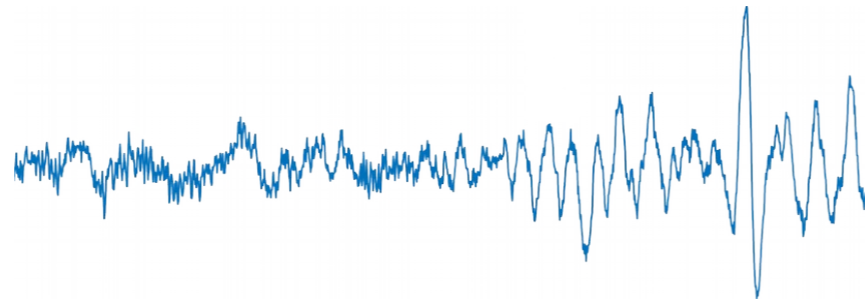
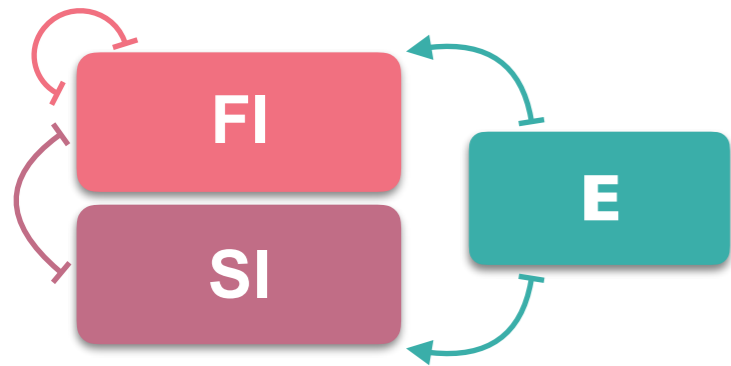
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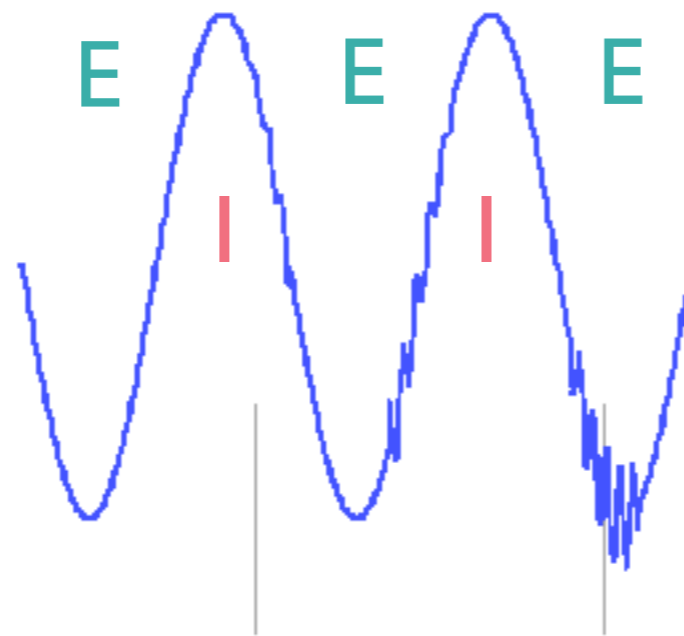
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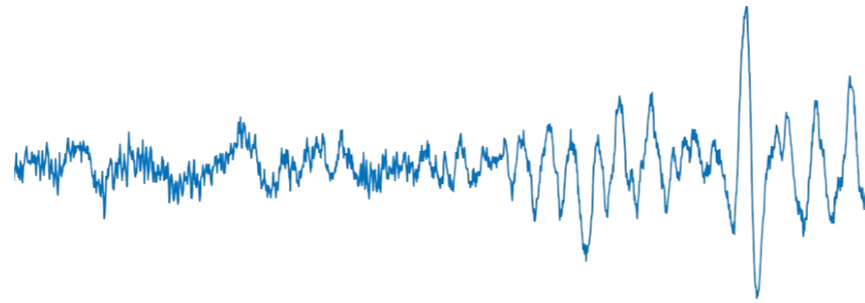
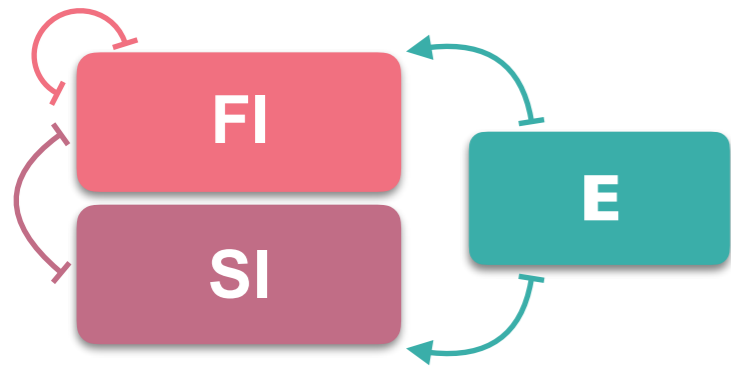
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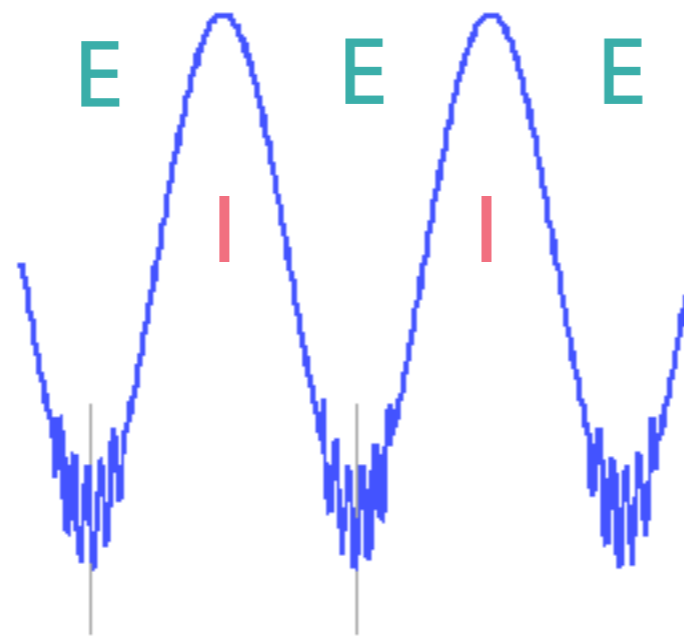
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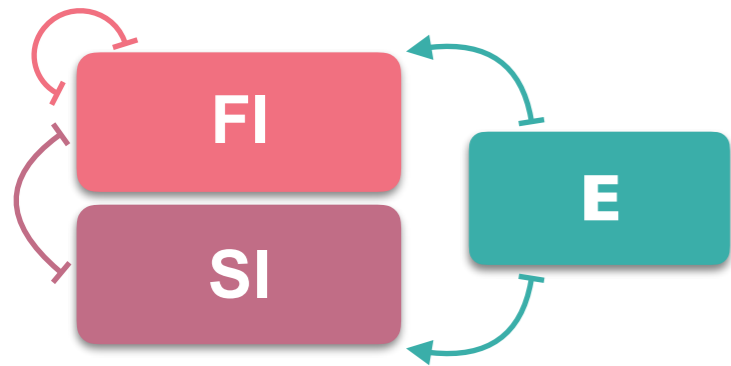
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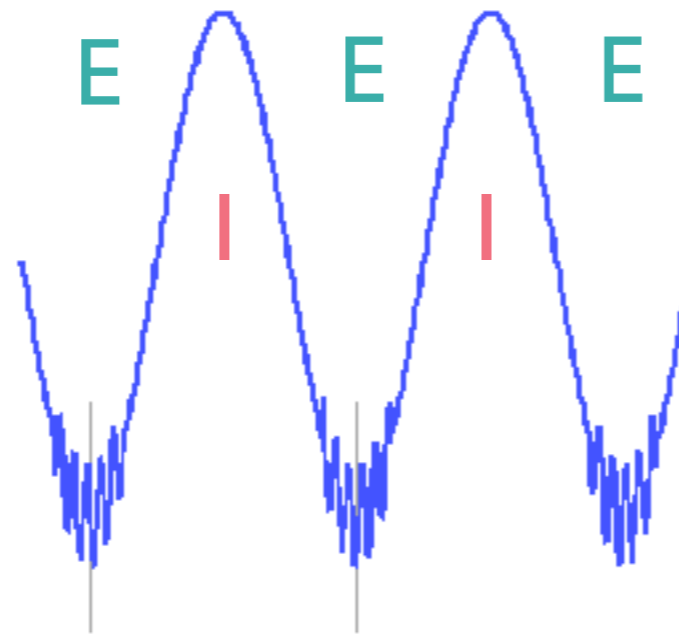
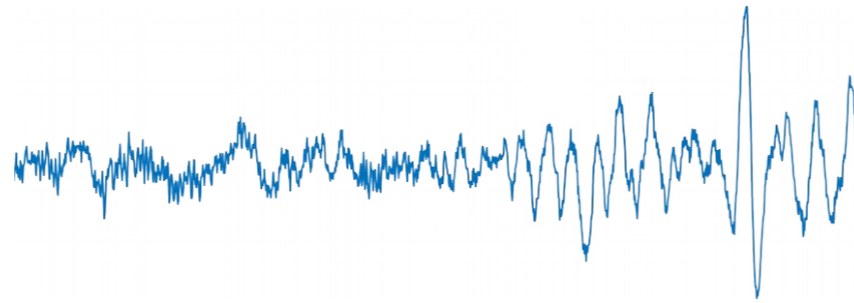
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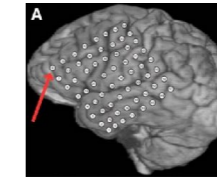
neural cell assembly



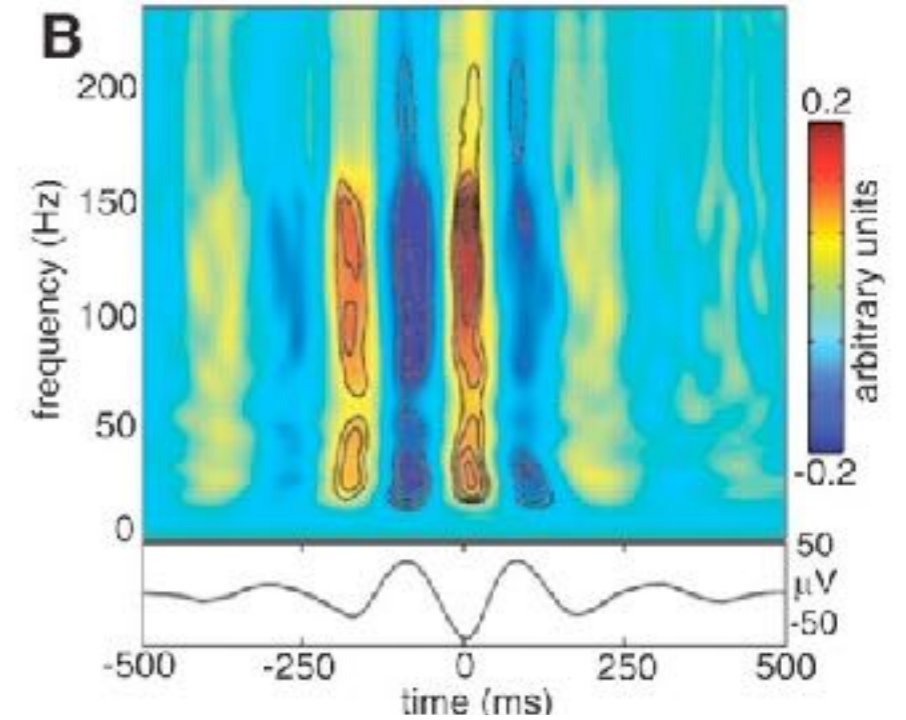
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Ann Rev Neurosc (2012)

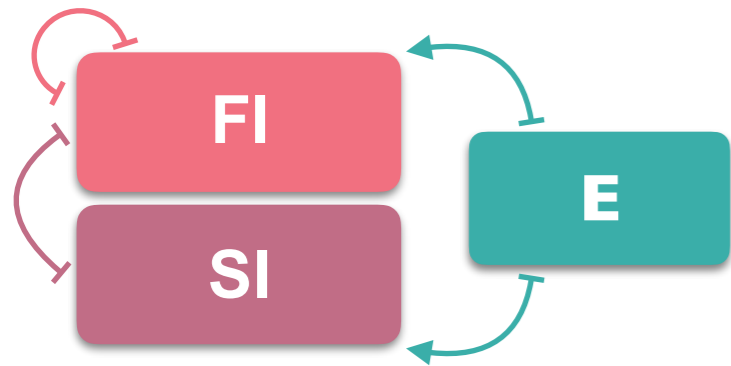


Human LFP
Canolty et al. *Science* (2006)

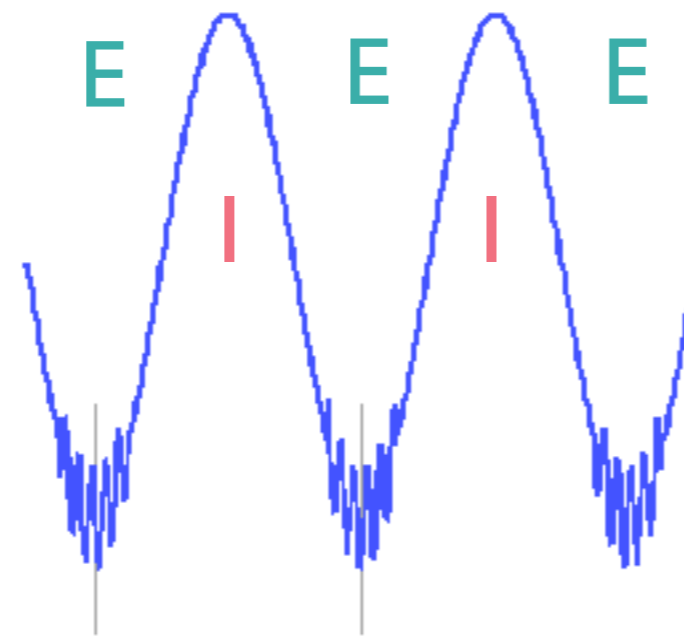
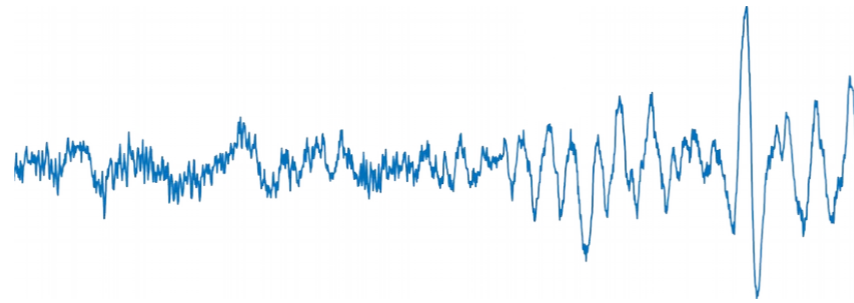


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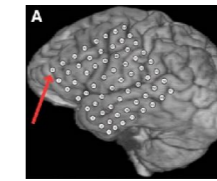
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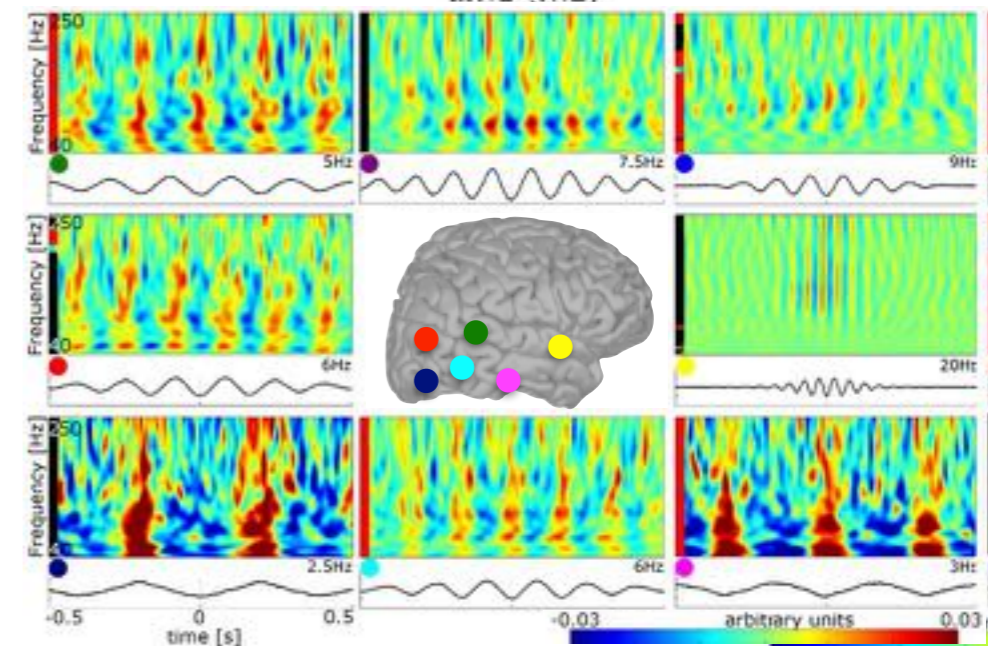
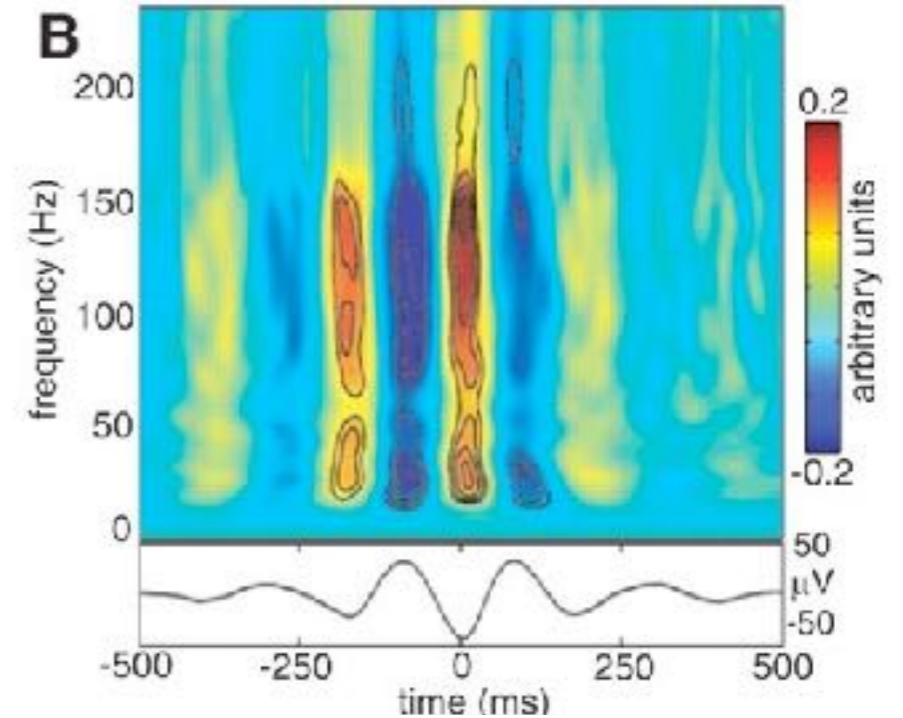
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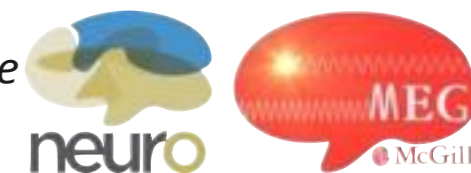
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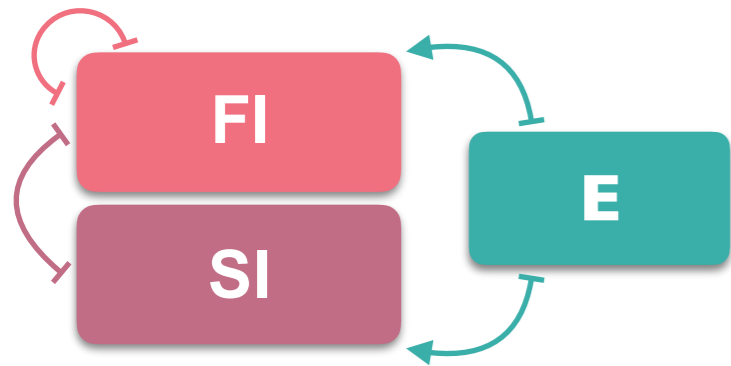


MEG
Florin & Baillet *NeuroImage*
(2015)

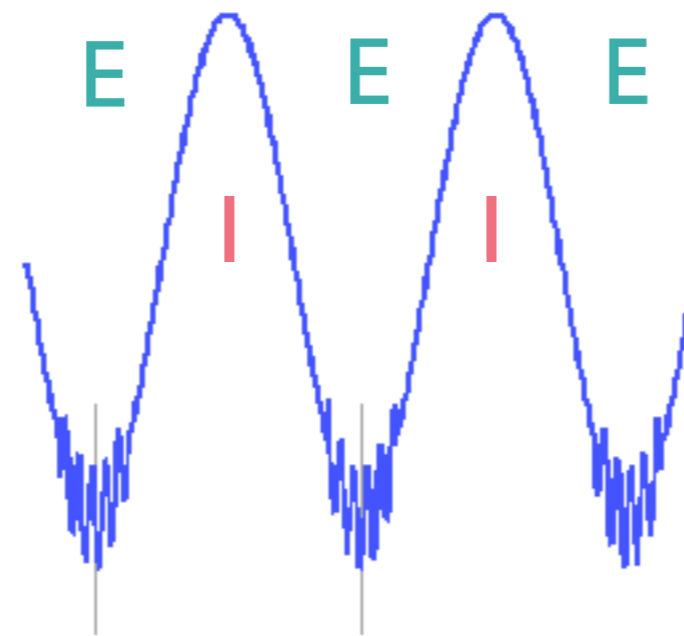
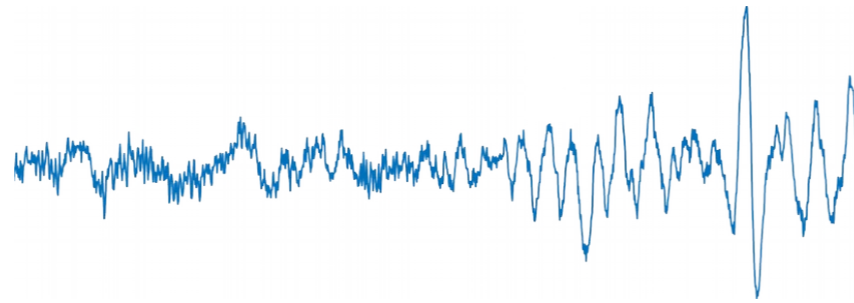


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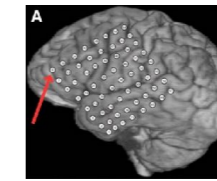
neural cell assembly



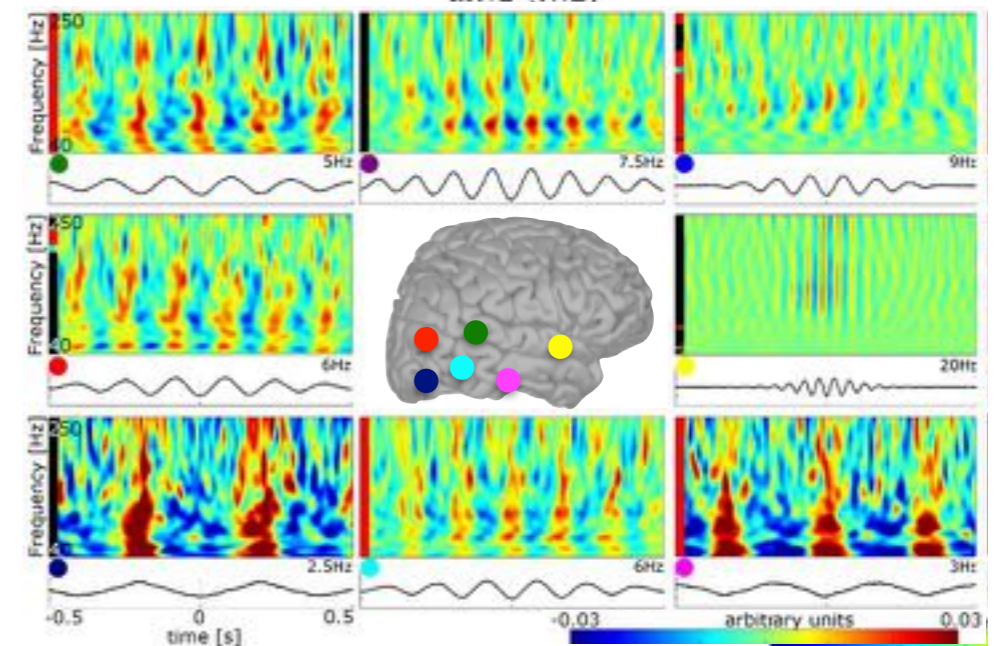
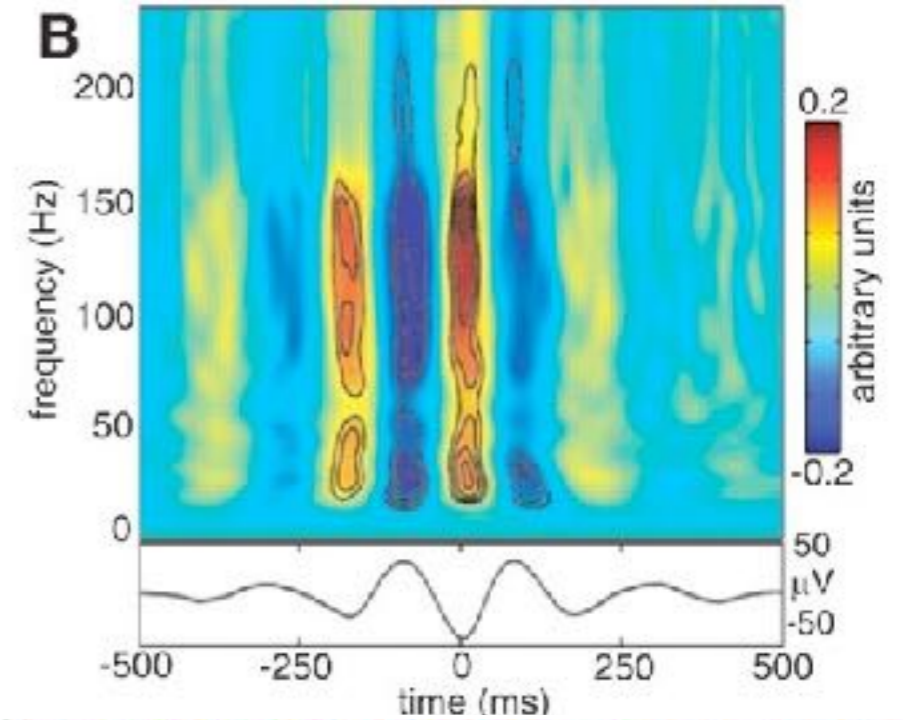
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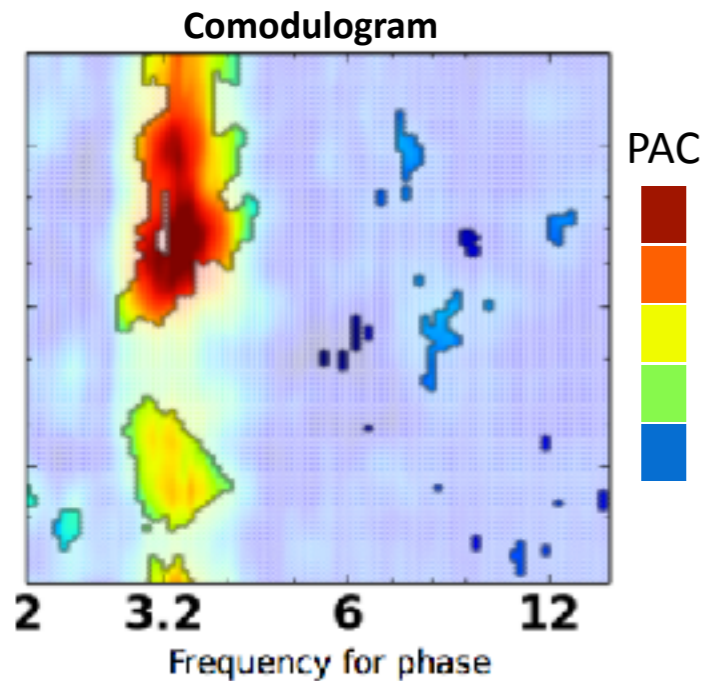
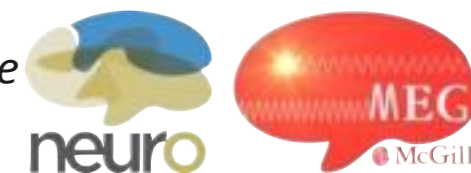
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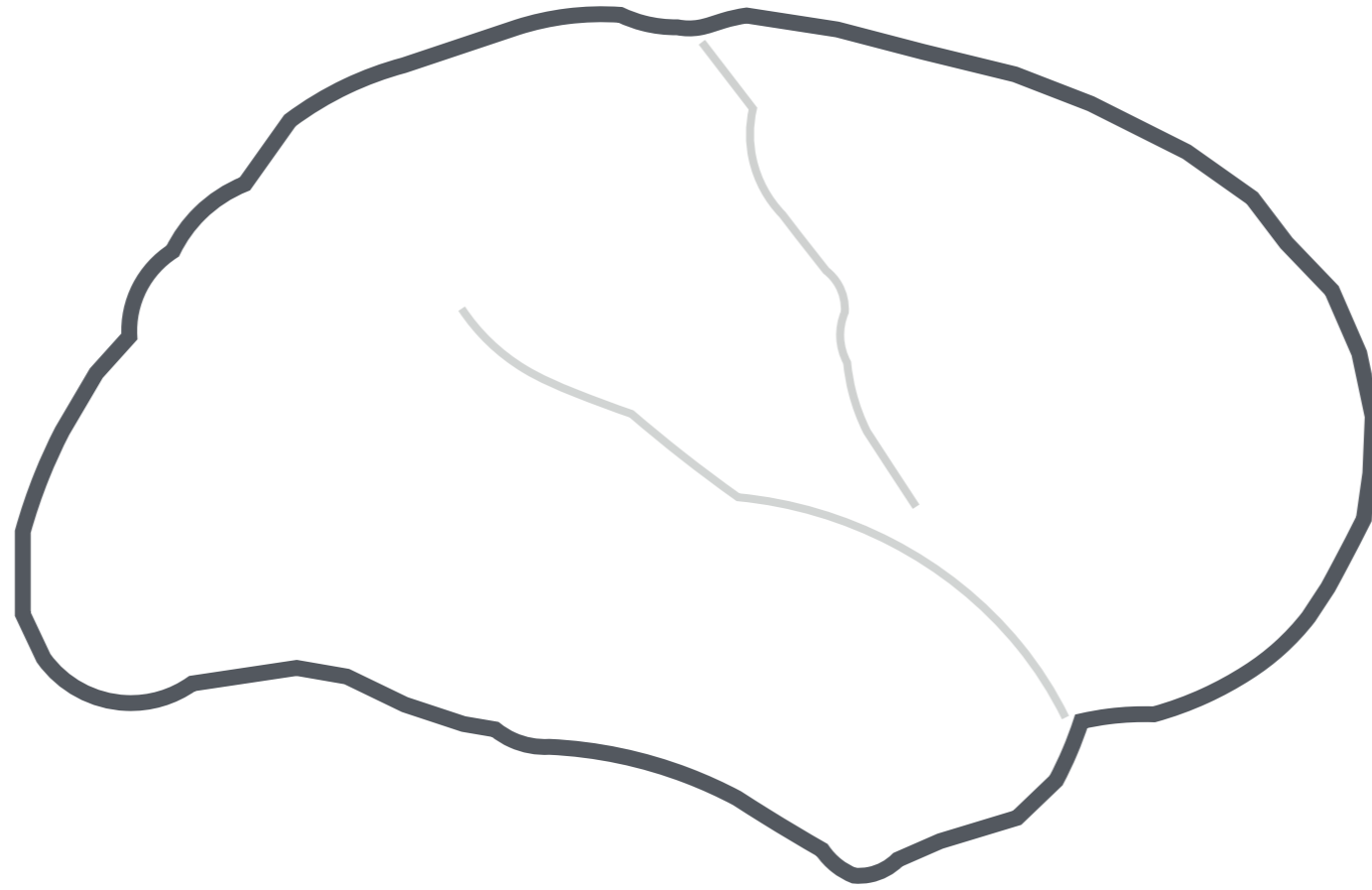
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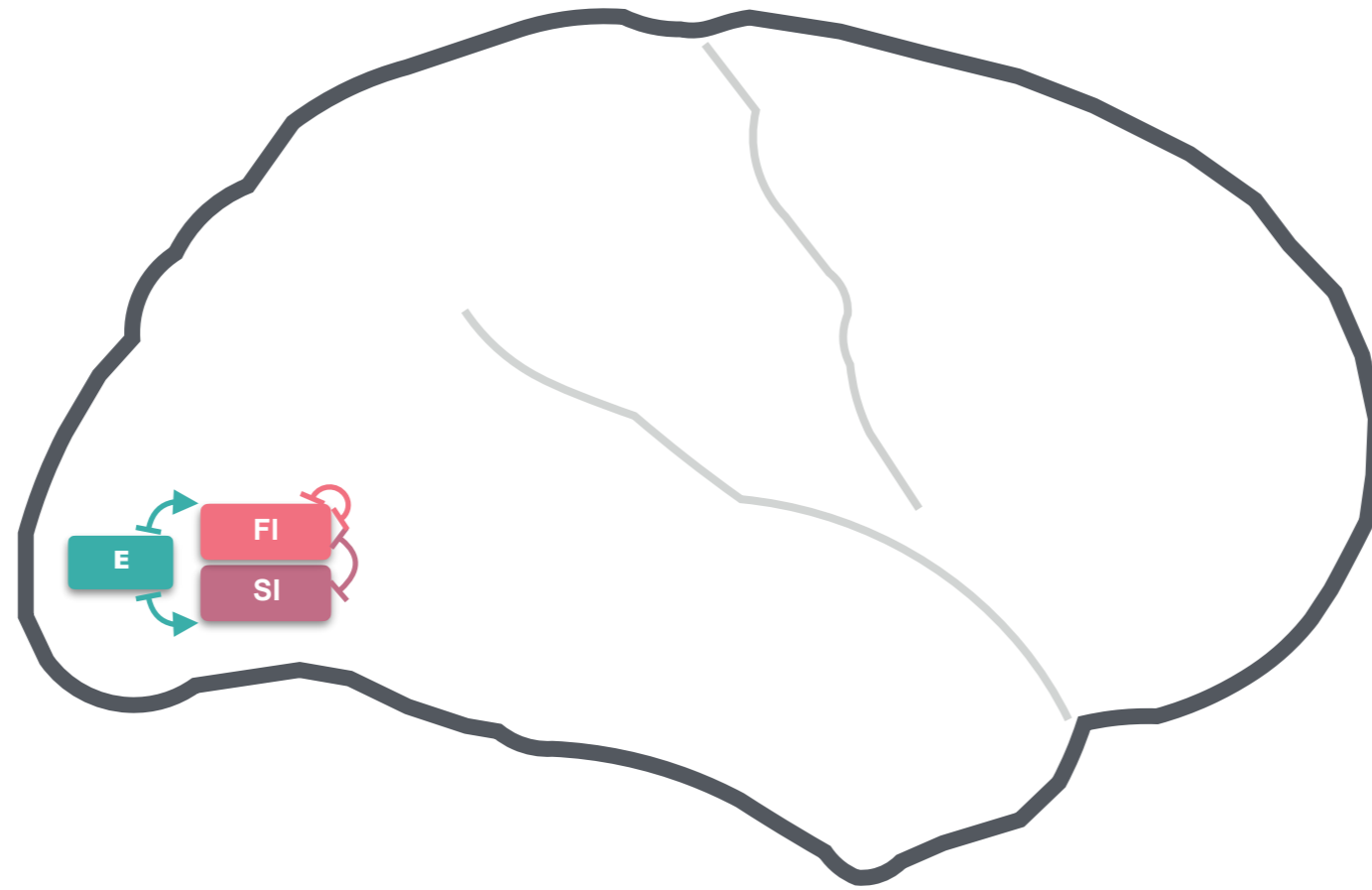
Baillet, *Nature Neuroscience* (2017)

Cross-frequency coupling:
a generic mechanism regulating long-range brain dynamics?

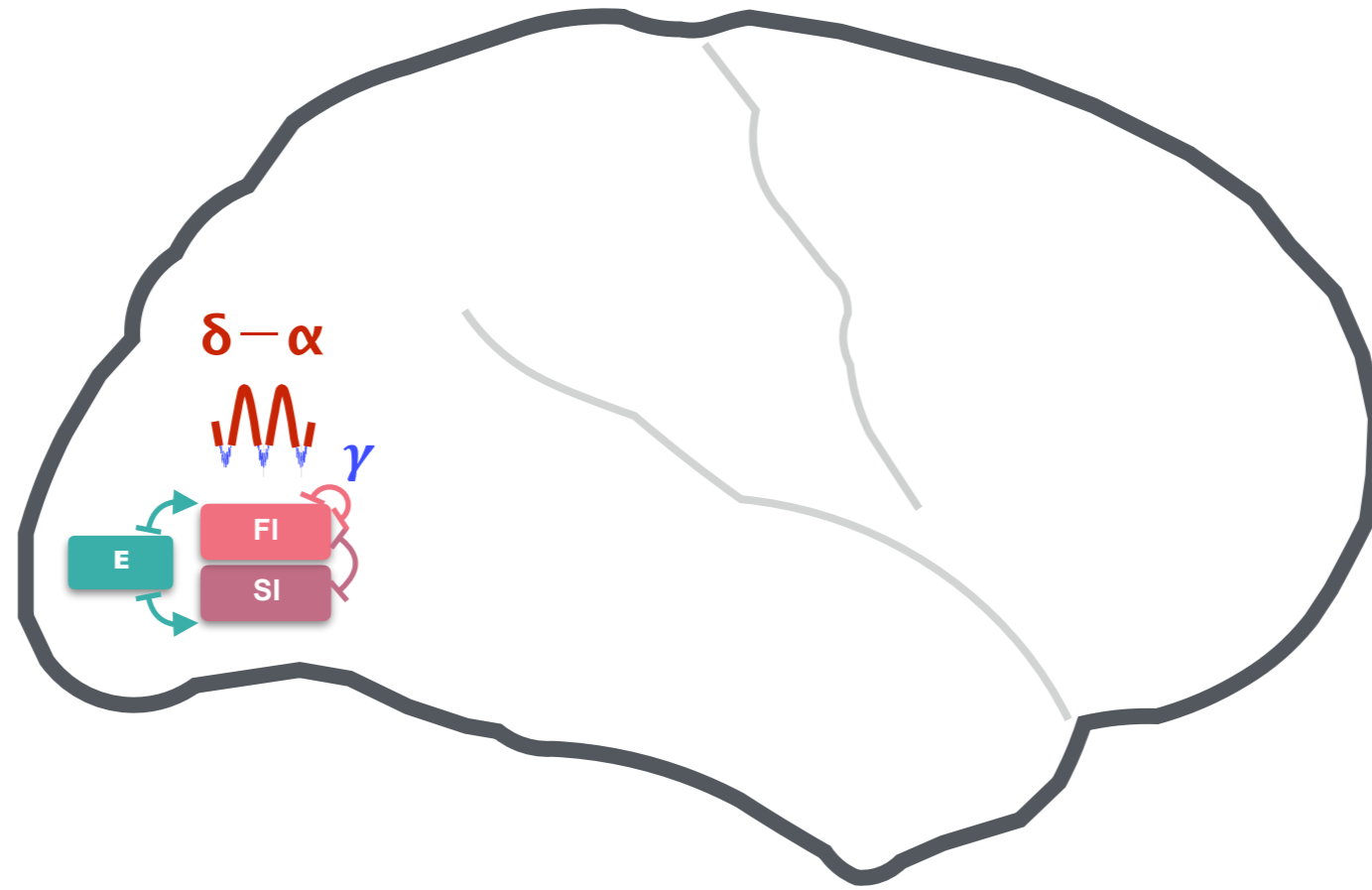
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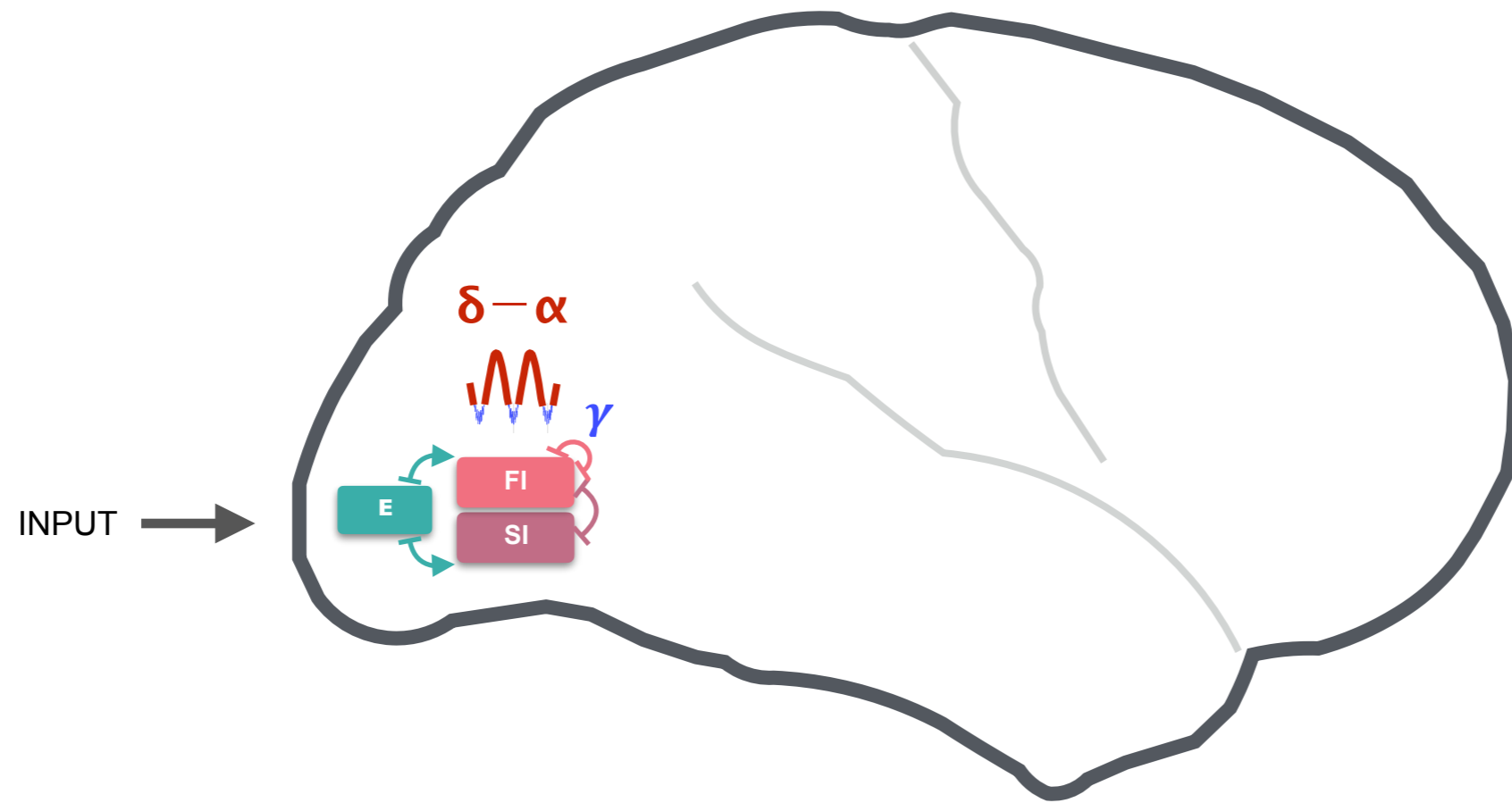
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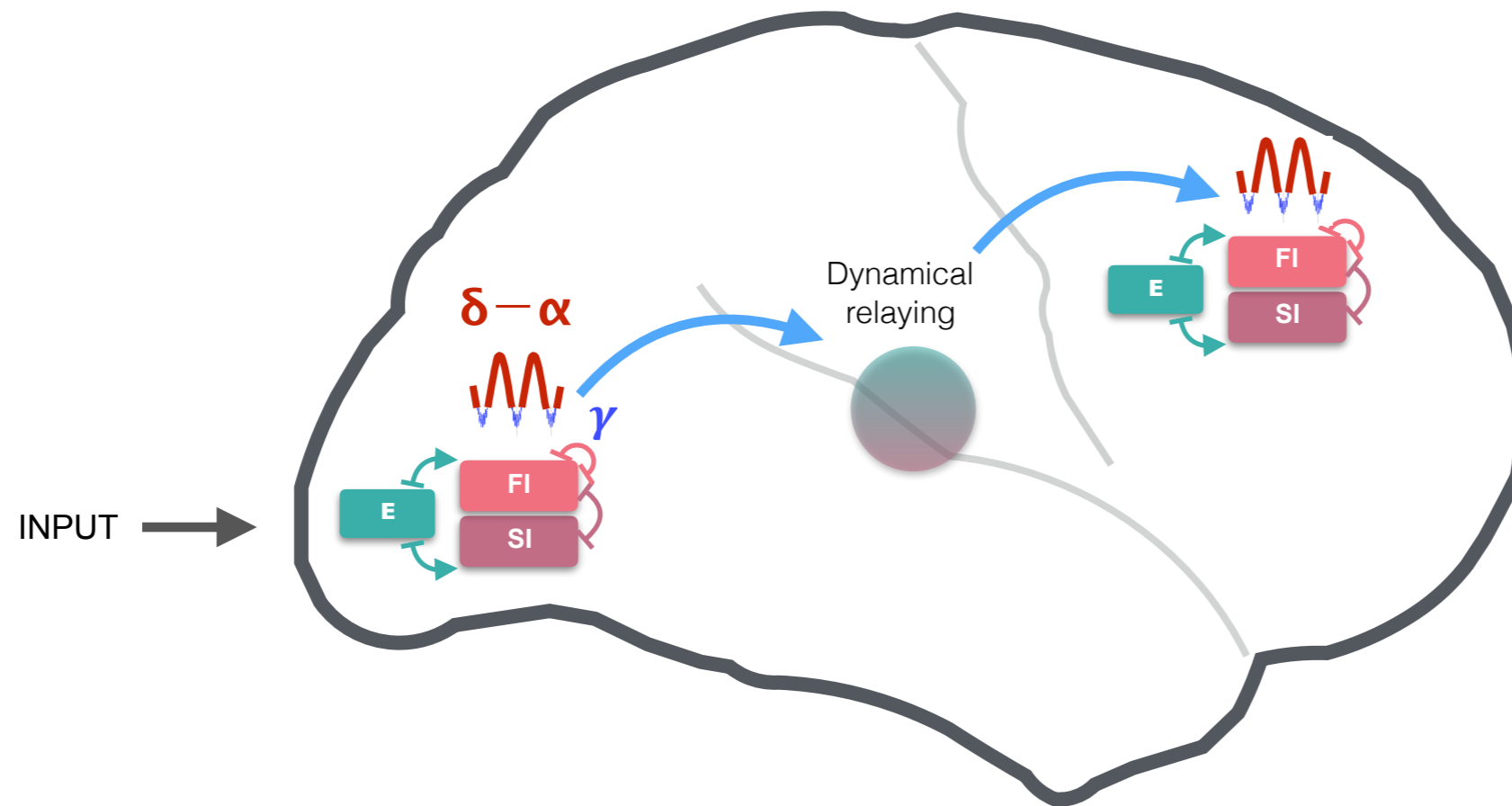
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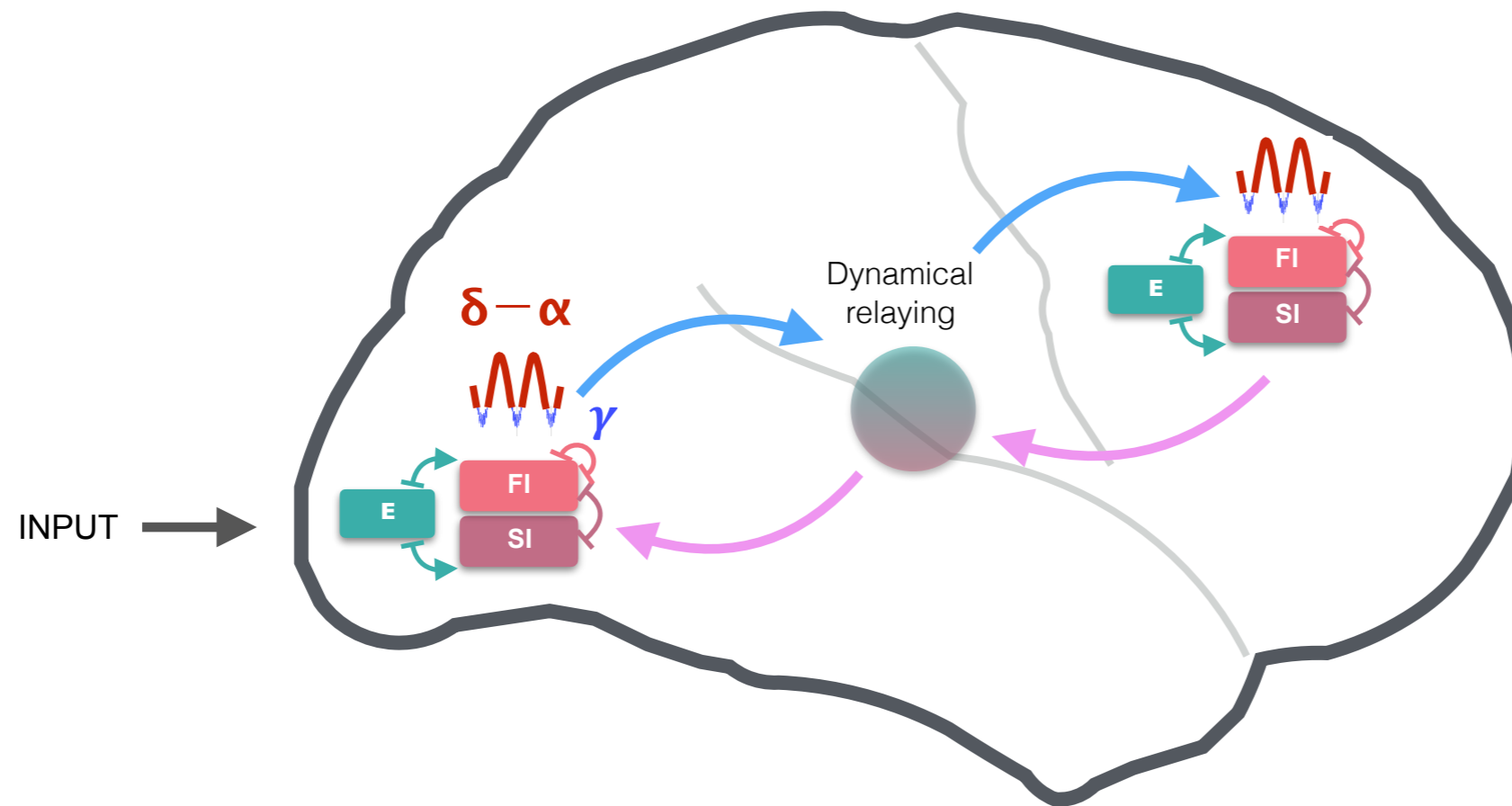
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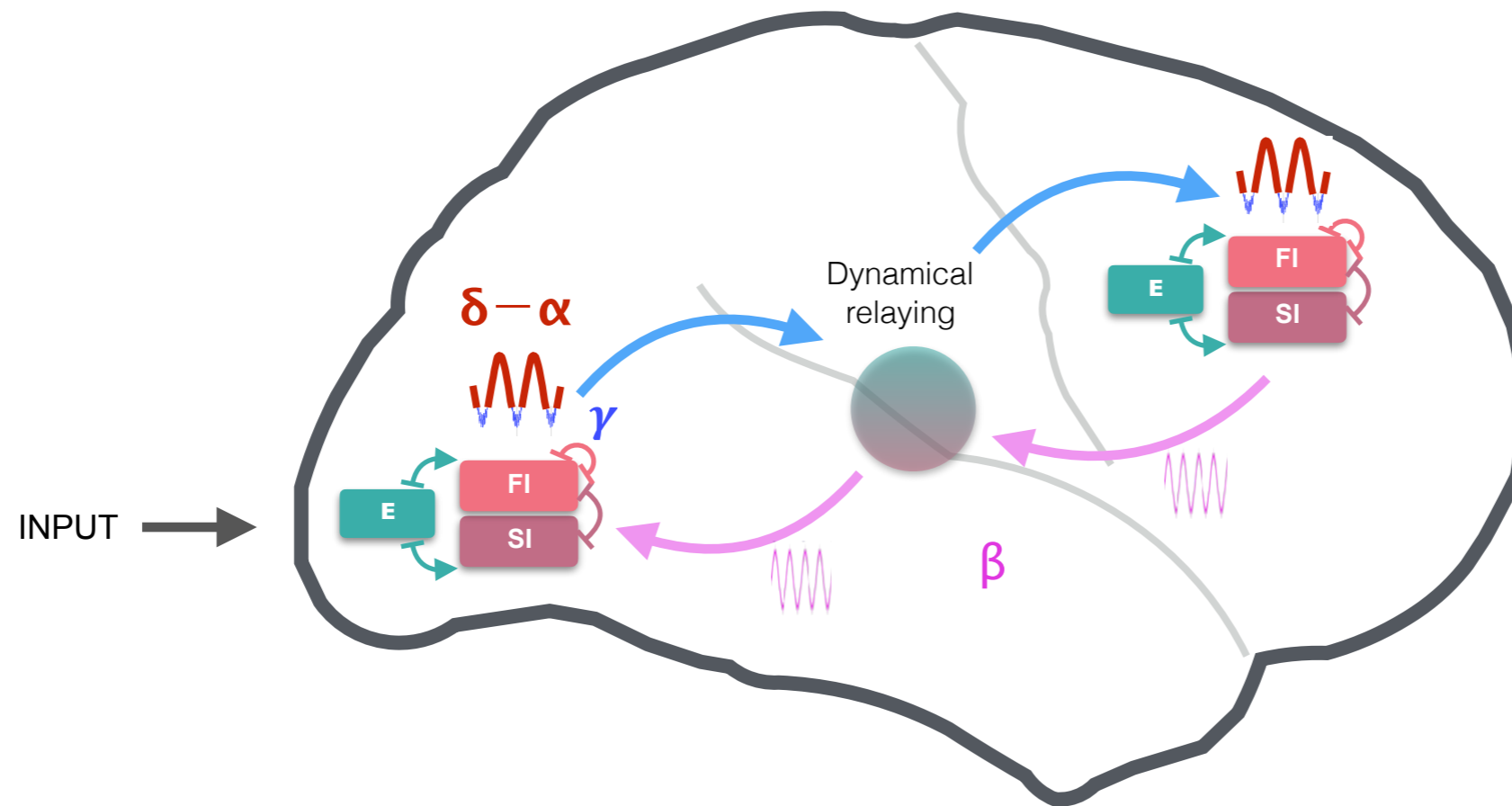
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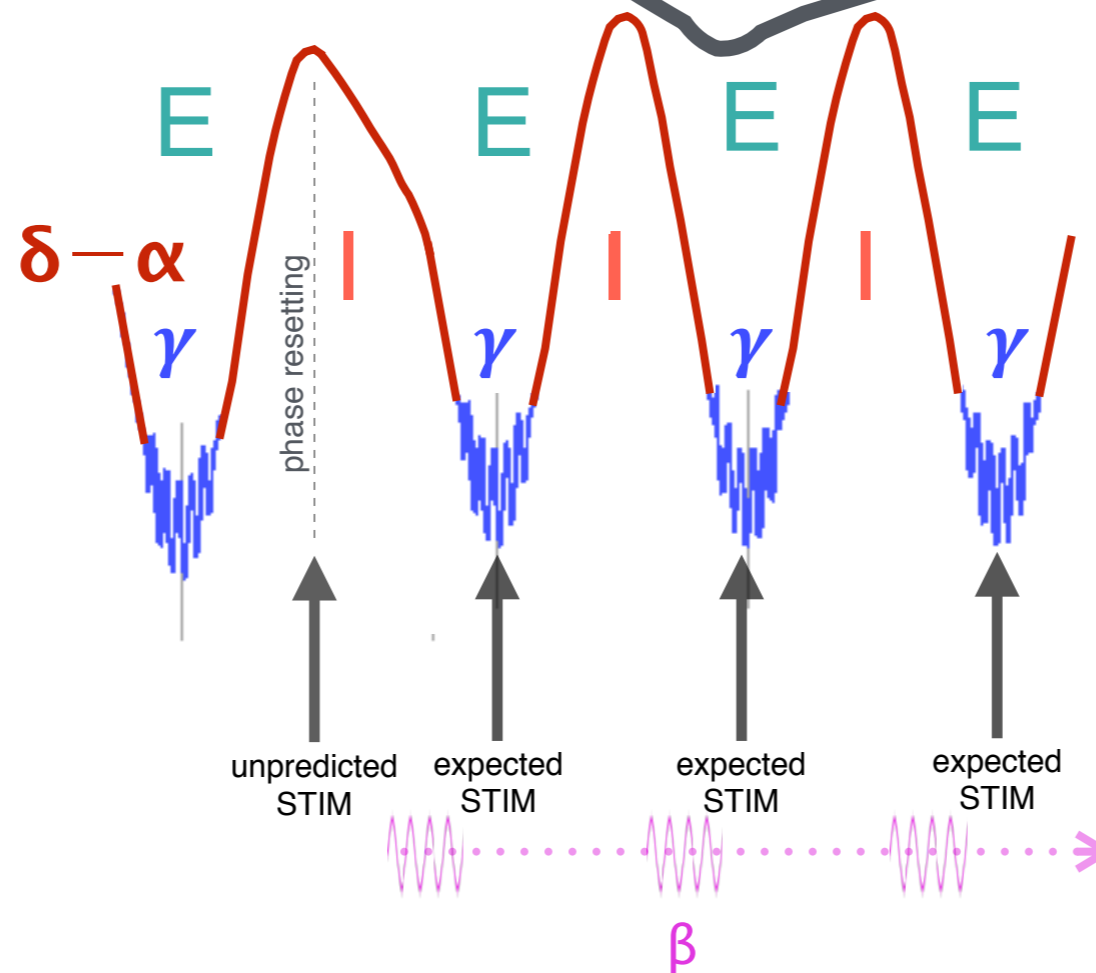
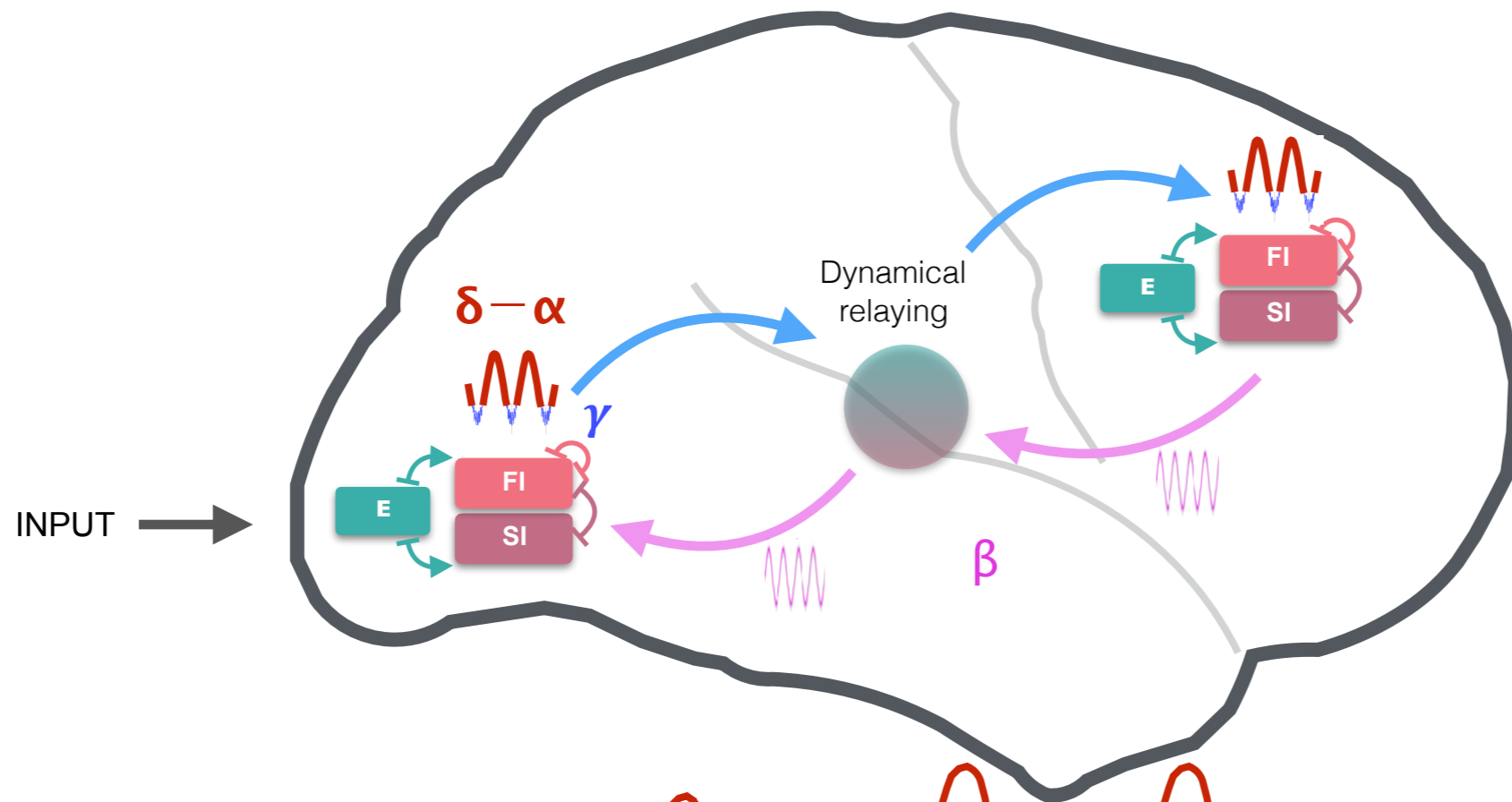
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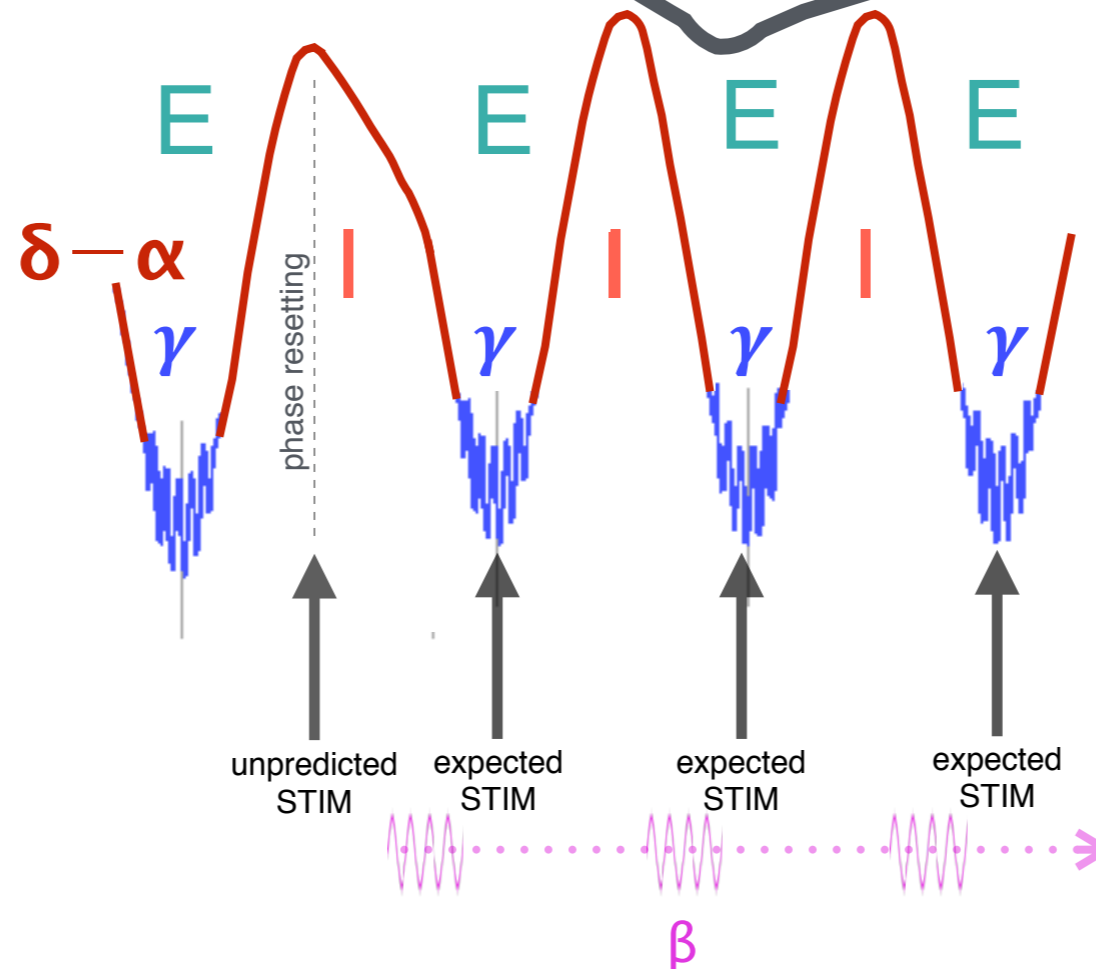
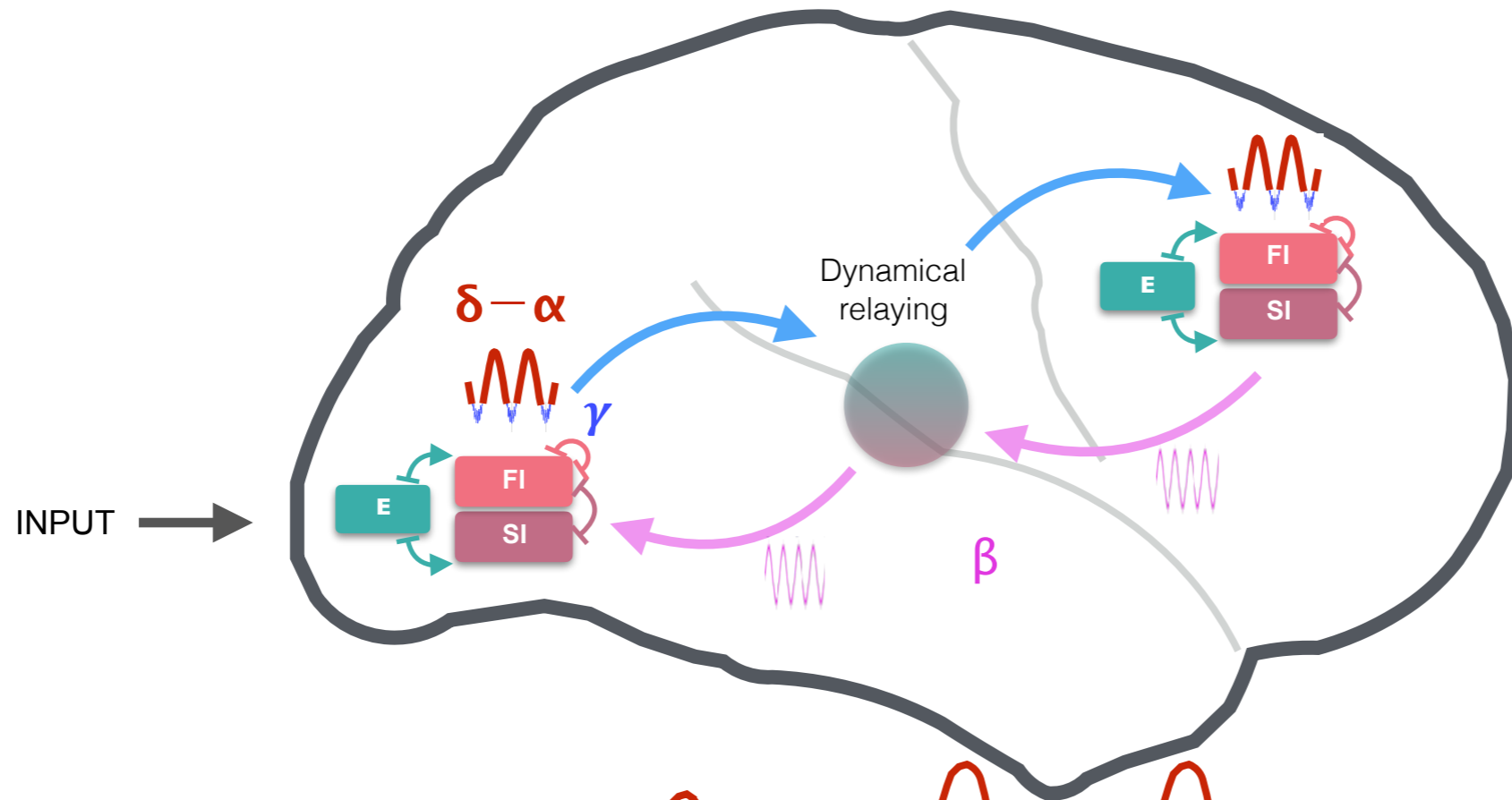
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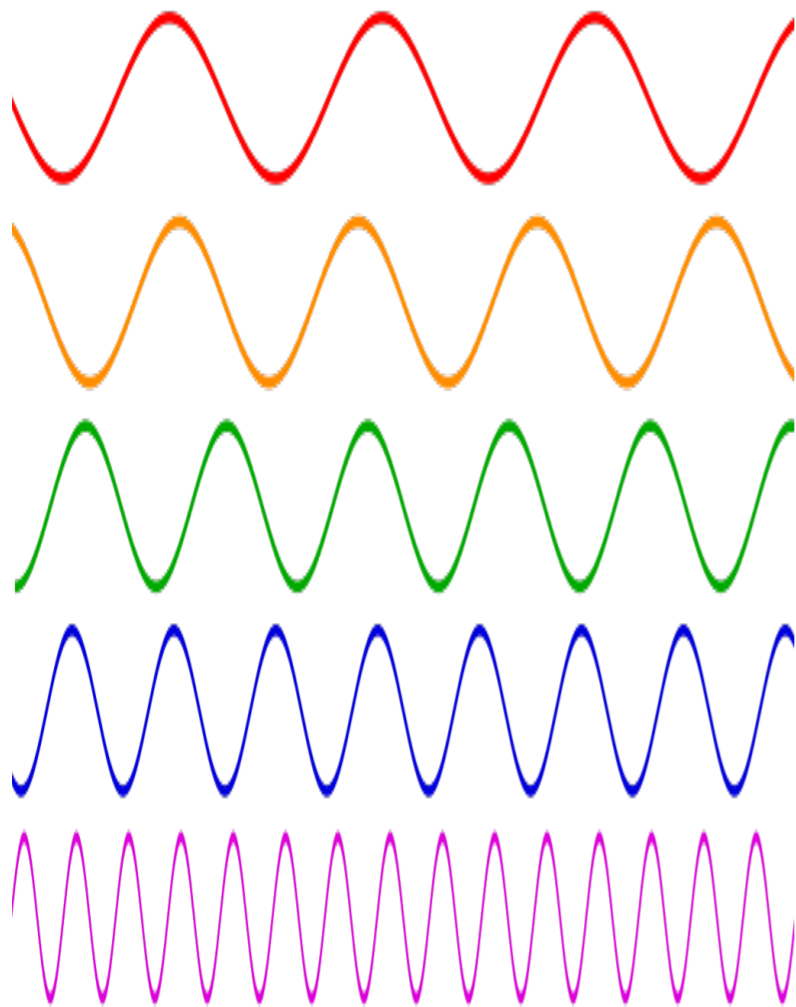
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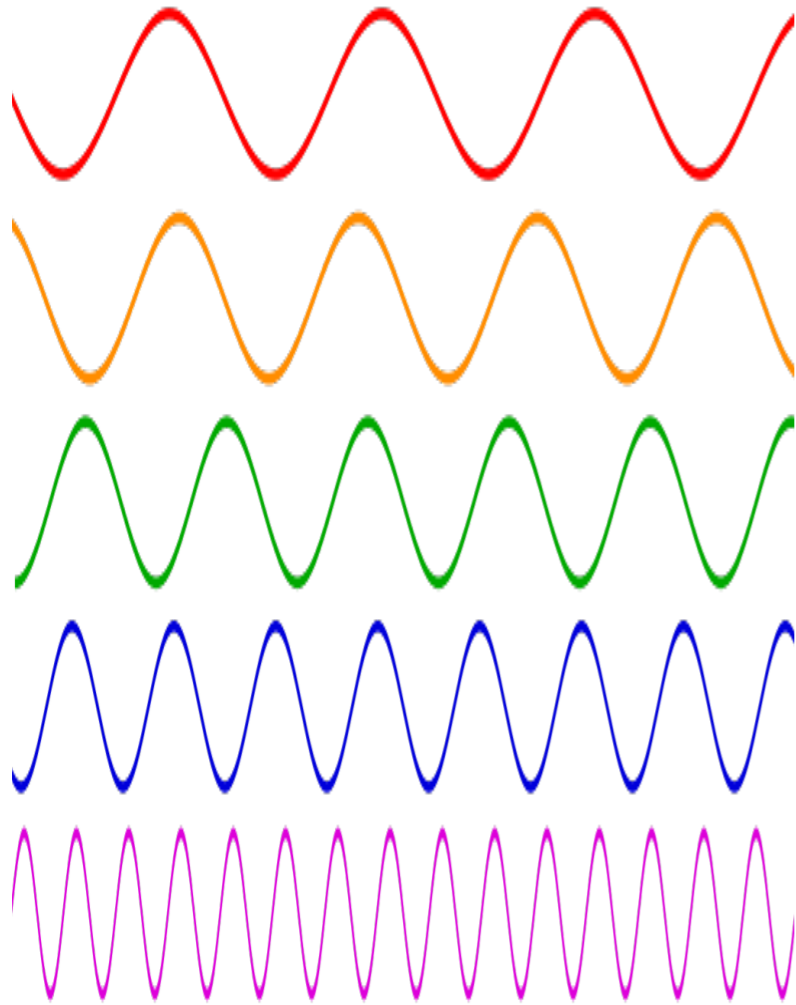
A **testable**
holistic model of
interdependent,
polyrhythmic
neural activity

Wrap-up: distinct roles for distinct frequencies

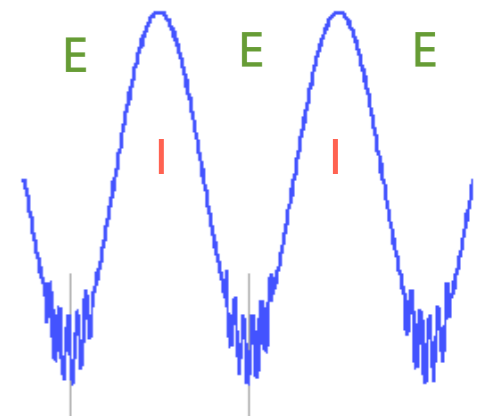
Wrap-up: distinct roles for distinct frequencies



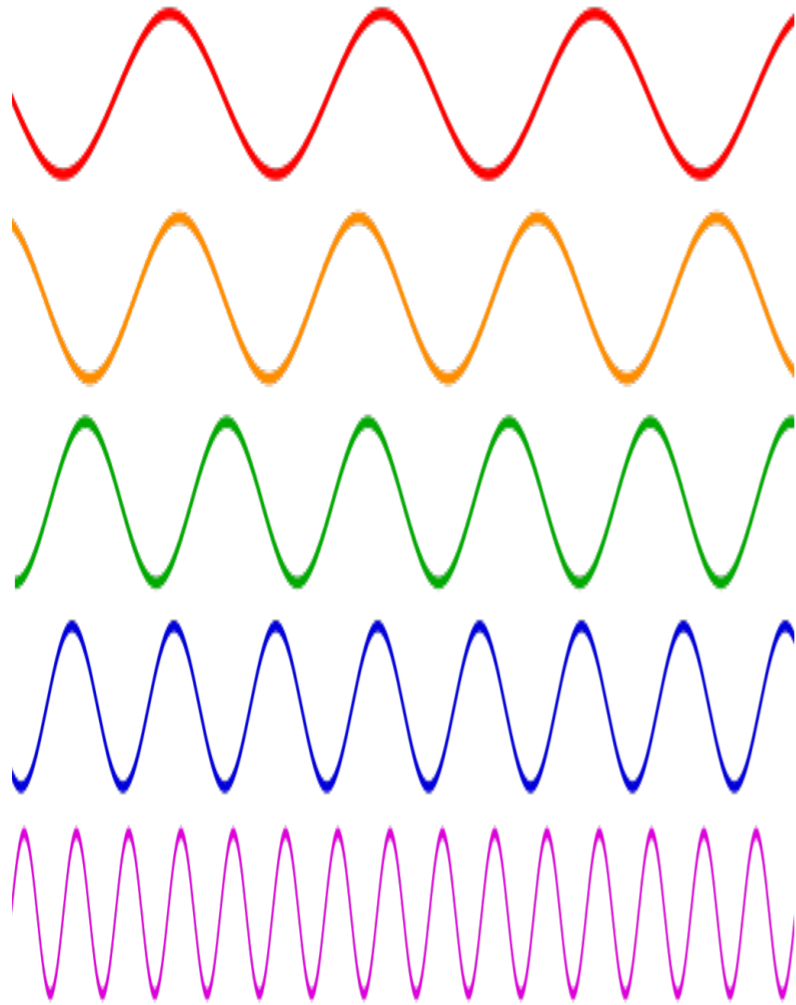
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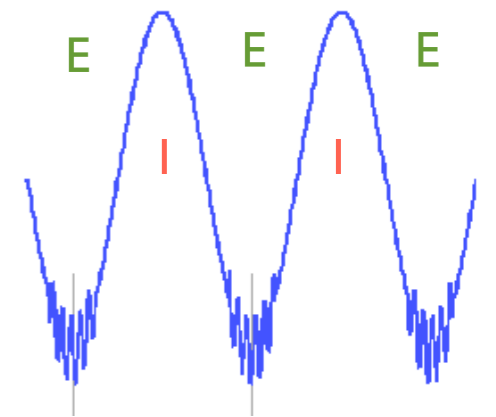
$\delta - \alpha$: cycles of regional excitability



Wrap-up: distinct roles for distinct frequencies

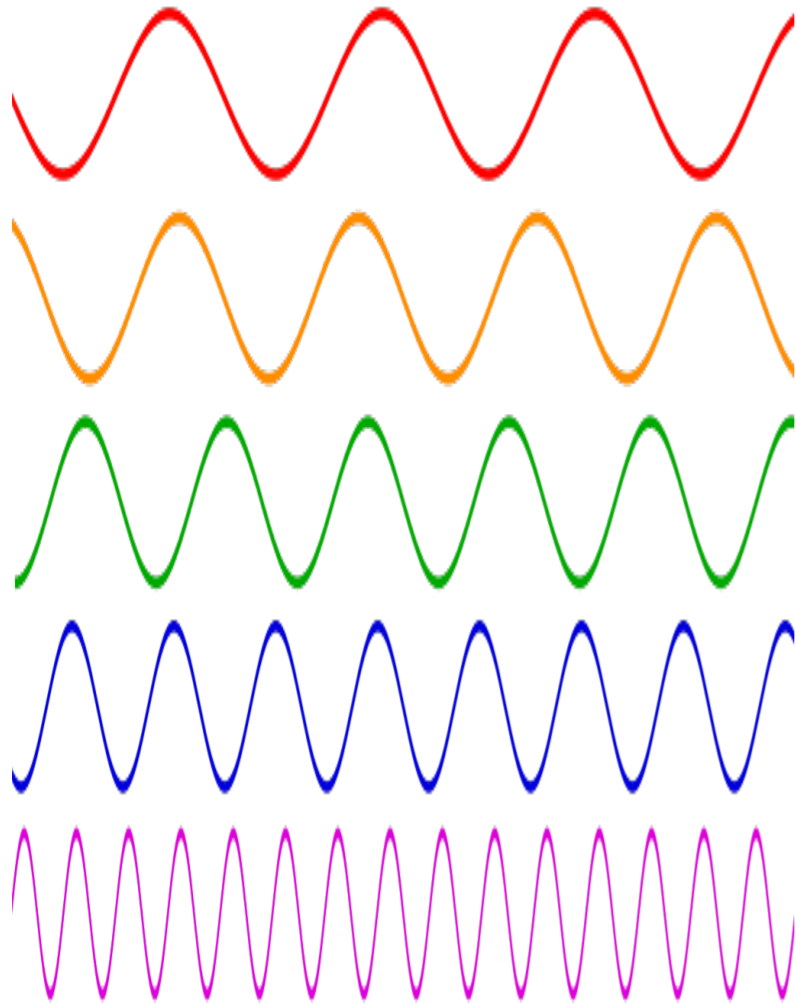


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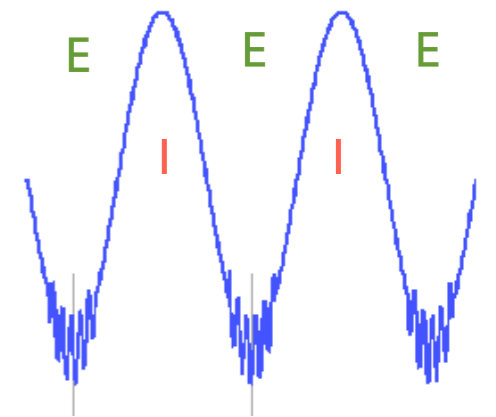


β : bursts as expressions of top-down modulations

Wrap-up: distinct roles for distinct frequencies



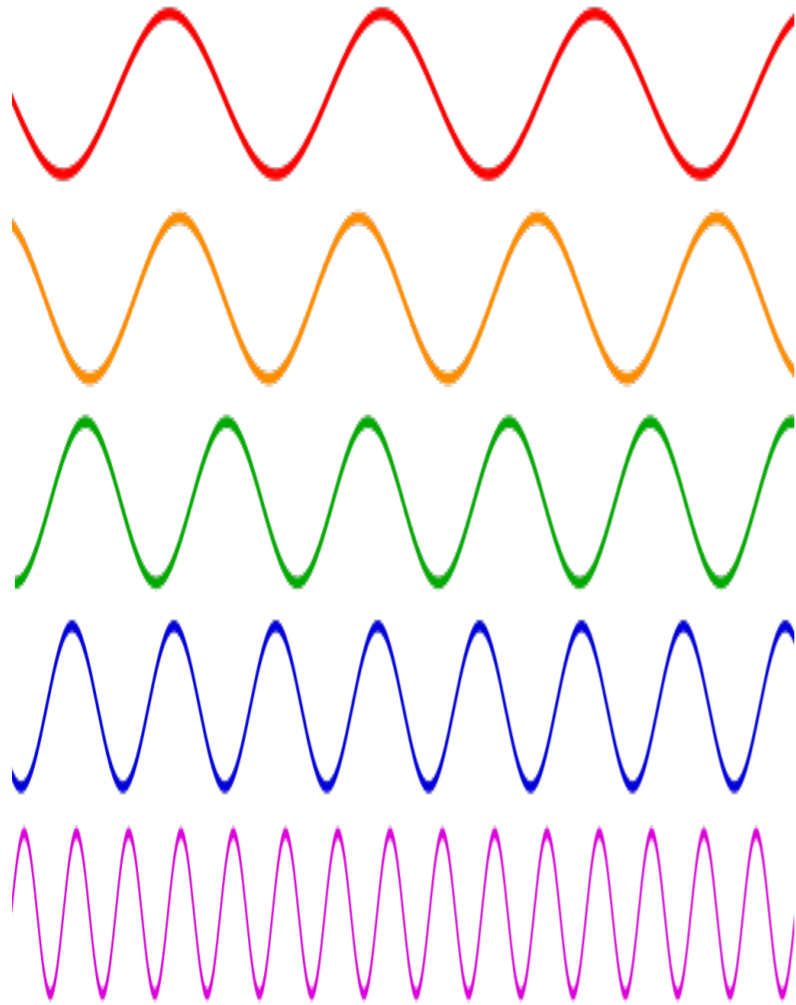
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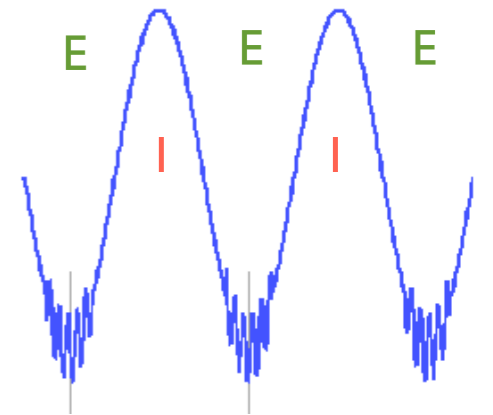
β : bursts as expressions of top-down modulations

γ : bursts nested in slower rhythms, bottom-up signaling

Wrap-up: distinct roles for distinct frequencies



$\delta - \alpha$: cycles of regional excitability



β : bursts as expressions of top-down modulations

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higher γ : PSP/AP spiking ?

Review

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- Dynamics
 - ⦿ event-related responses as resetting of ongoing activity
 - ⦿ distinct roles of typical frequency bands: net excitation, bottom-up vs top-down signaling, etc
 - ⦿ a topic of intense research