

Stochastic Synchrony: Emergence of Brain Rhythms from Noise

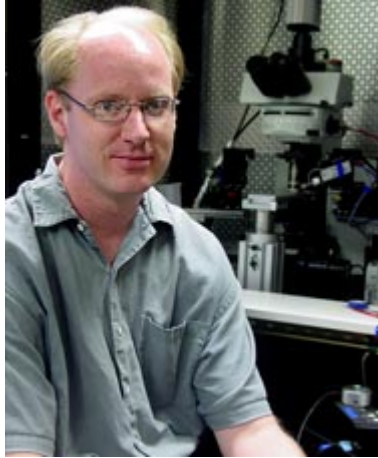
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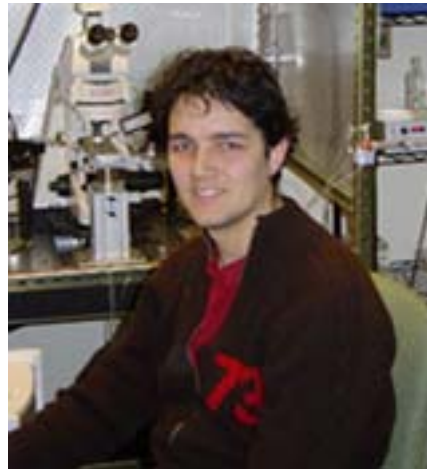
In collaboration with:



Nathan Urban

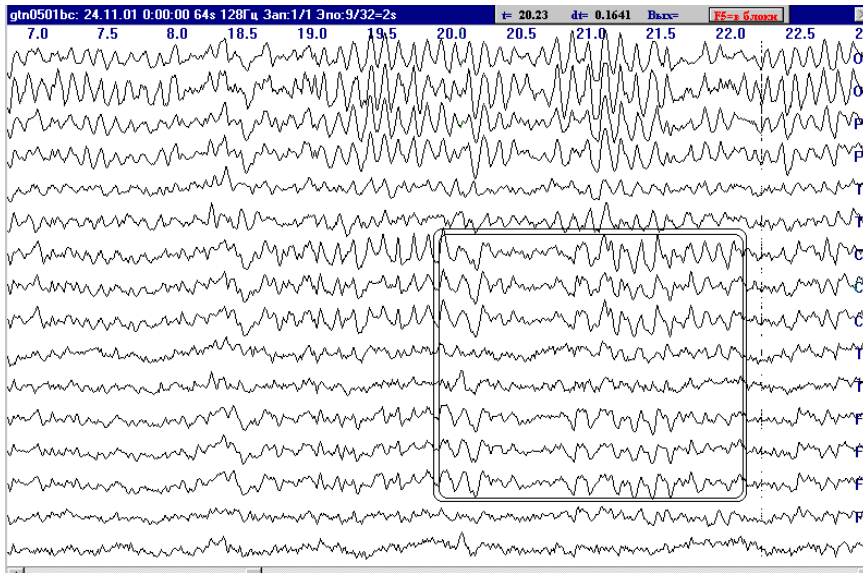
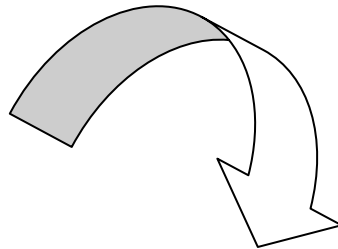
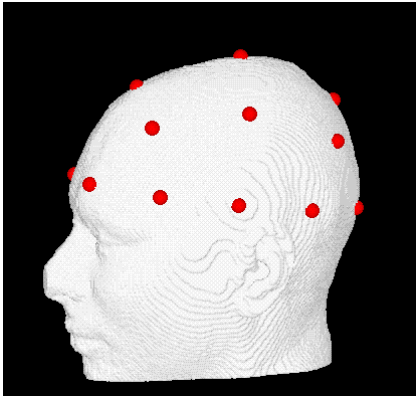


Bard Ermentrout

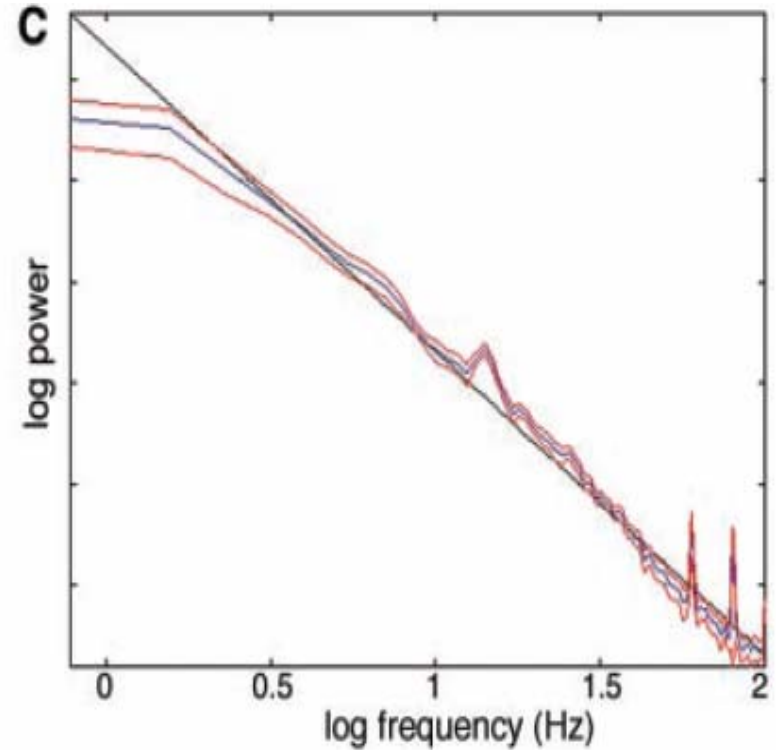


Nicolas Fourcaud-Trocmé

Brain rhythms



from Moscow University



Buzsaki & Draguhn (2004) Science

Brain rhythms: why we care

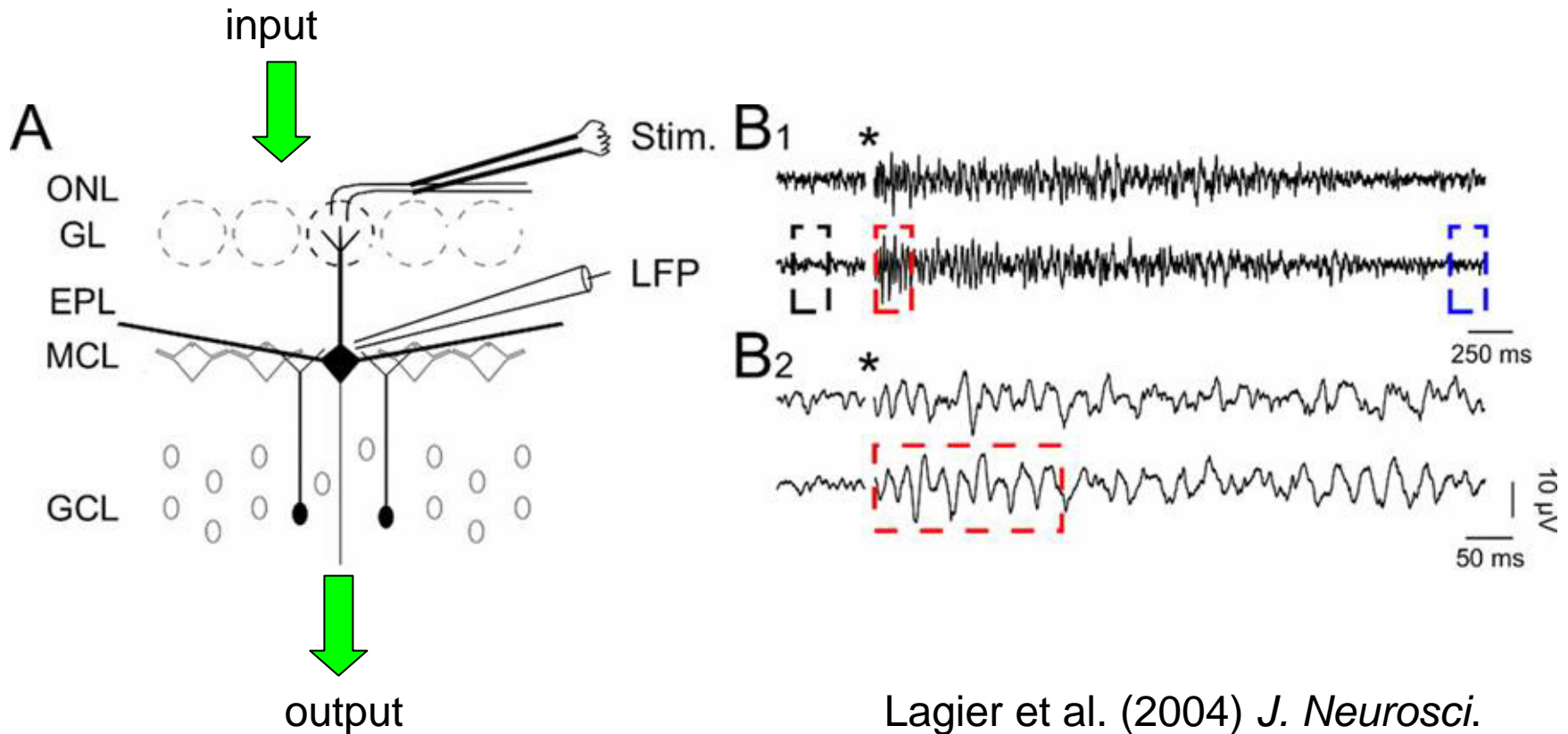
- Synchronous brain oscillations are thought to encode, route and process information in the brain
- Synchronous activity is important for cortical development and memory formation.
- Alterations of neuronal synchronization are associated with pathologies (e.g. epilepsy, Parkinson's disease, schizophrenia)

Precision versus Variability

- Synchronous activity requires precise entrainment: timing is everything!
- Yet, neurons display a lot of spontaneous activity and there is evidence of considerable spontaneous release

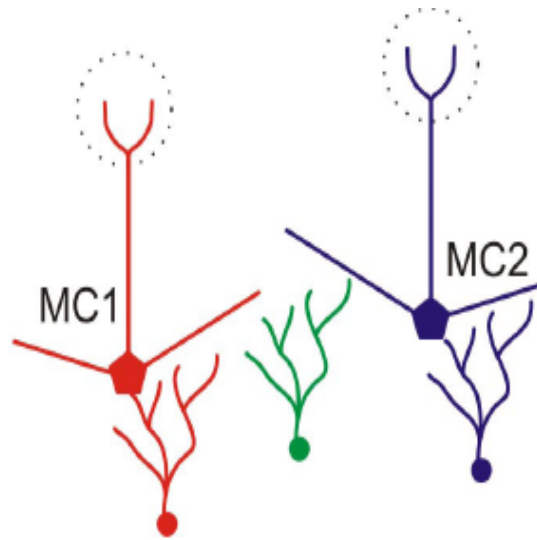
How can collective, temporal order emerge from randomness?

Neuronal Synchrony in the Olfactory System



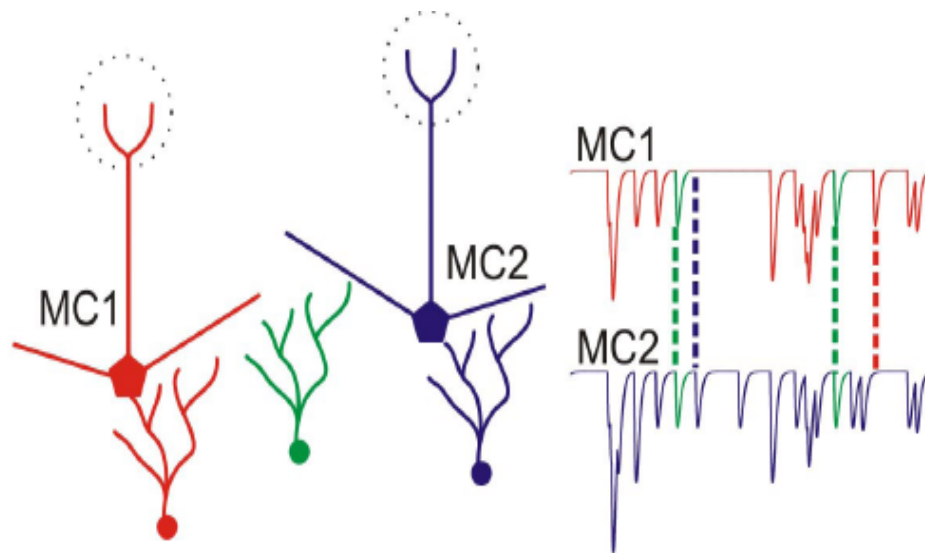
Lagier et al. (2004) *J. Neurosci.*

Network circuitry creates correlations of random synaptic events



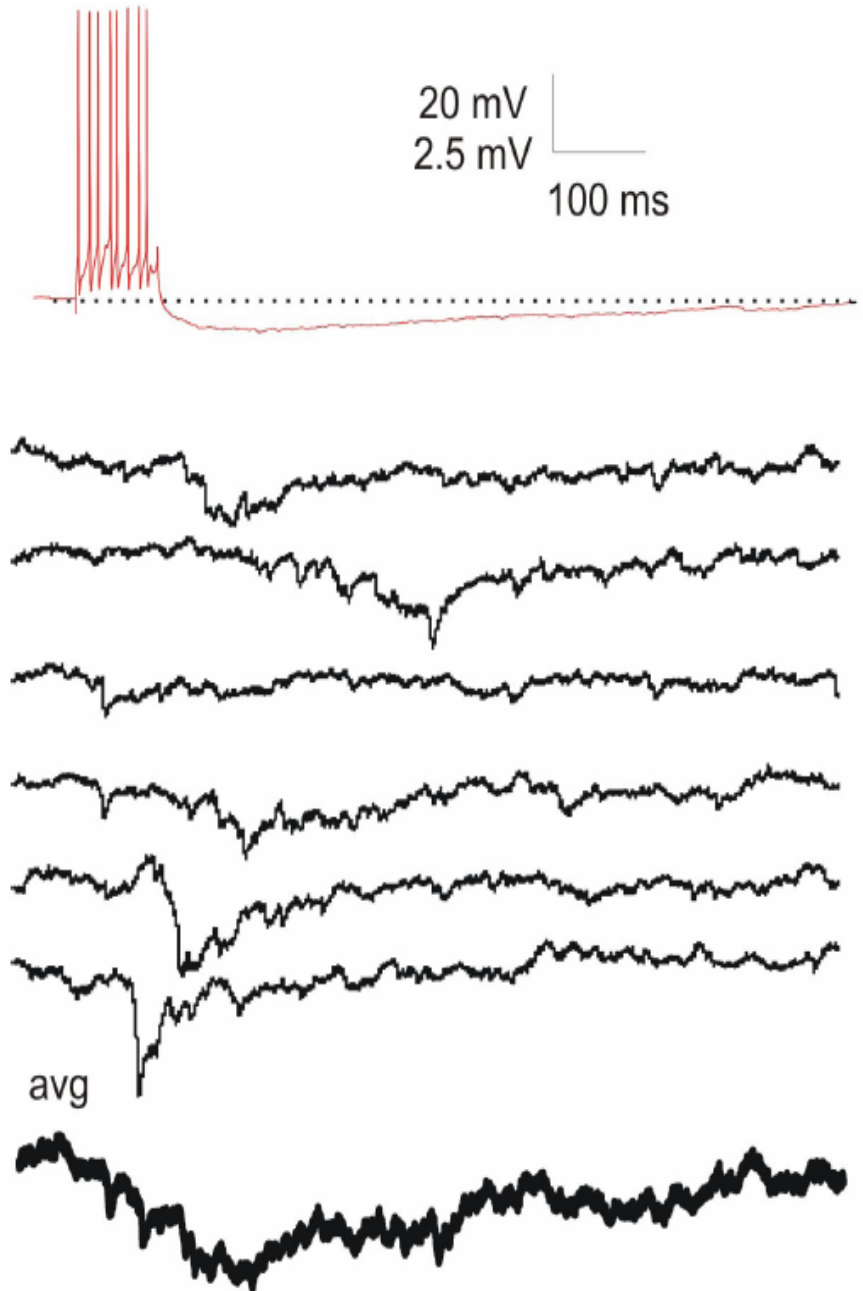
R.F.Galán et al. (2006) *J. Neurosci.*

Network circuitry creates correlations of random synaptic events



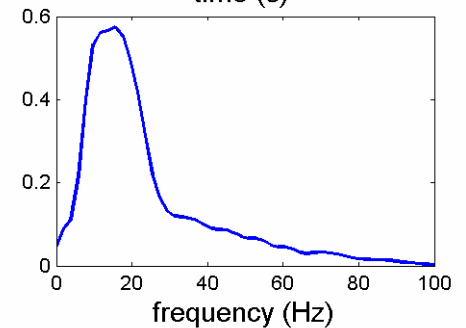
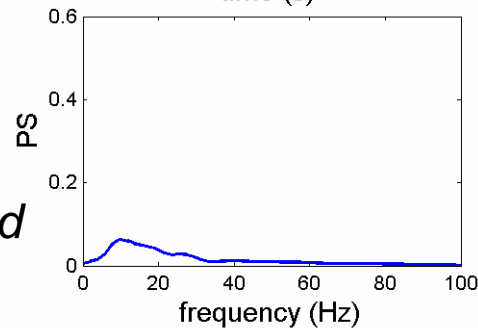
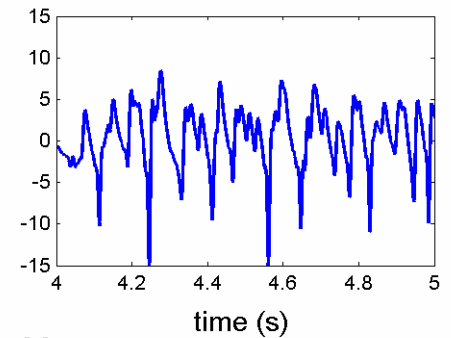
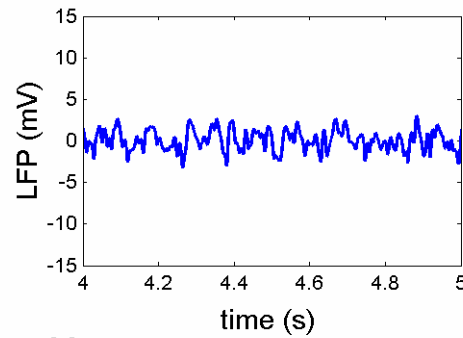
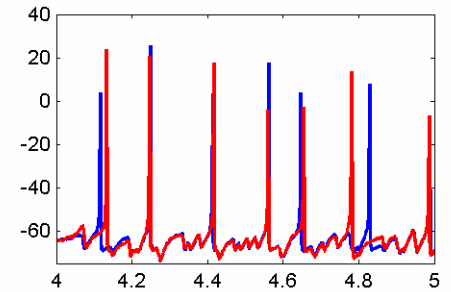
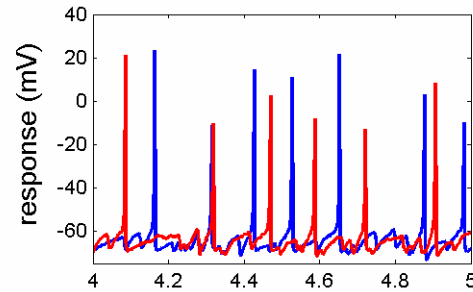
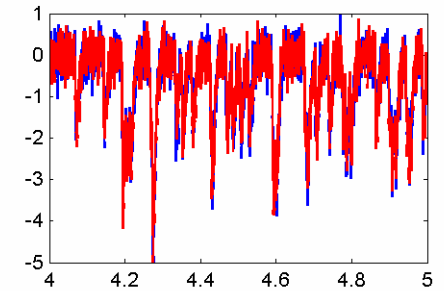
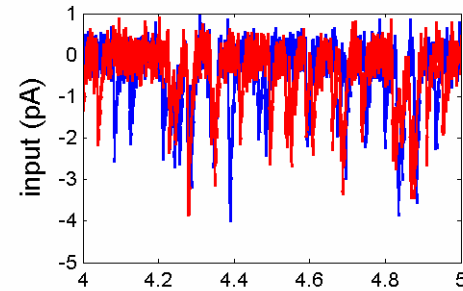
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Stochastic nature of synaptic interactions



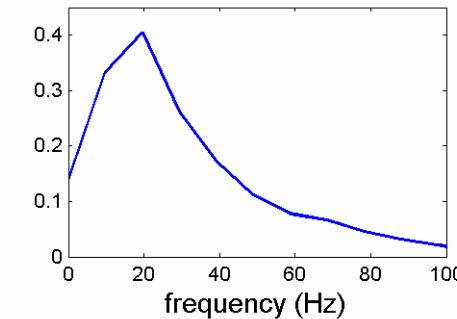
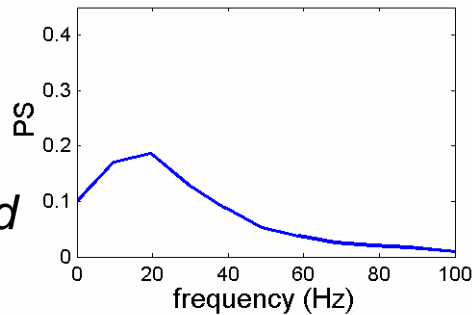
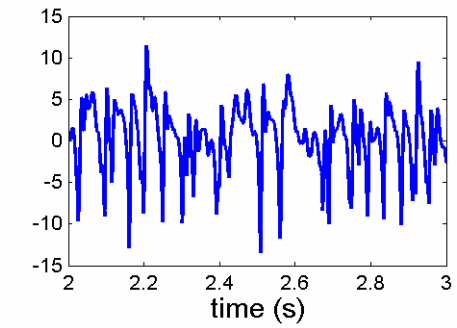
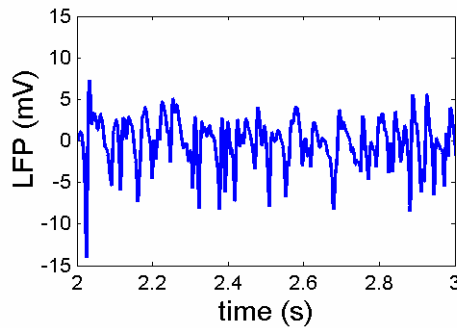
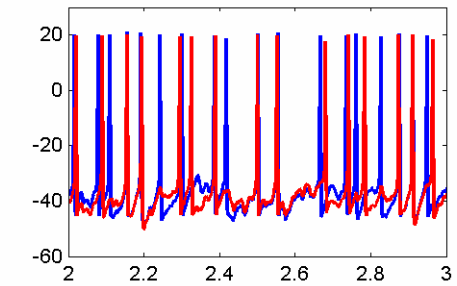
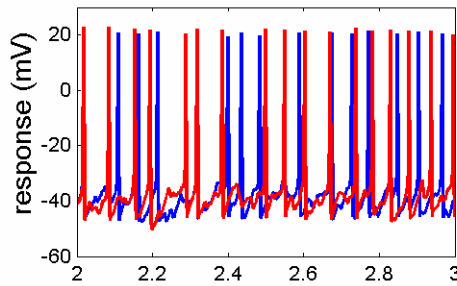
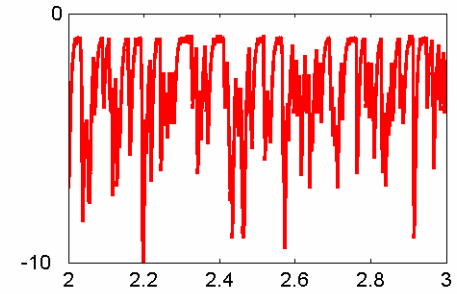
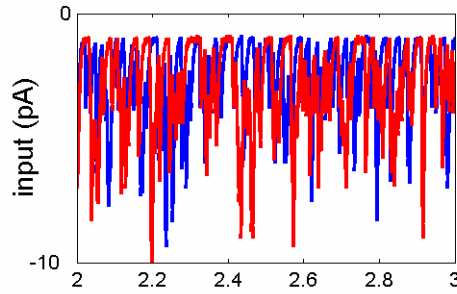
R.F.Galán et al. (2006) *J. Neurosci.*

Stochastic synchrony (simulations)



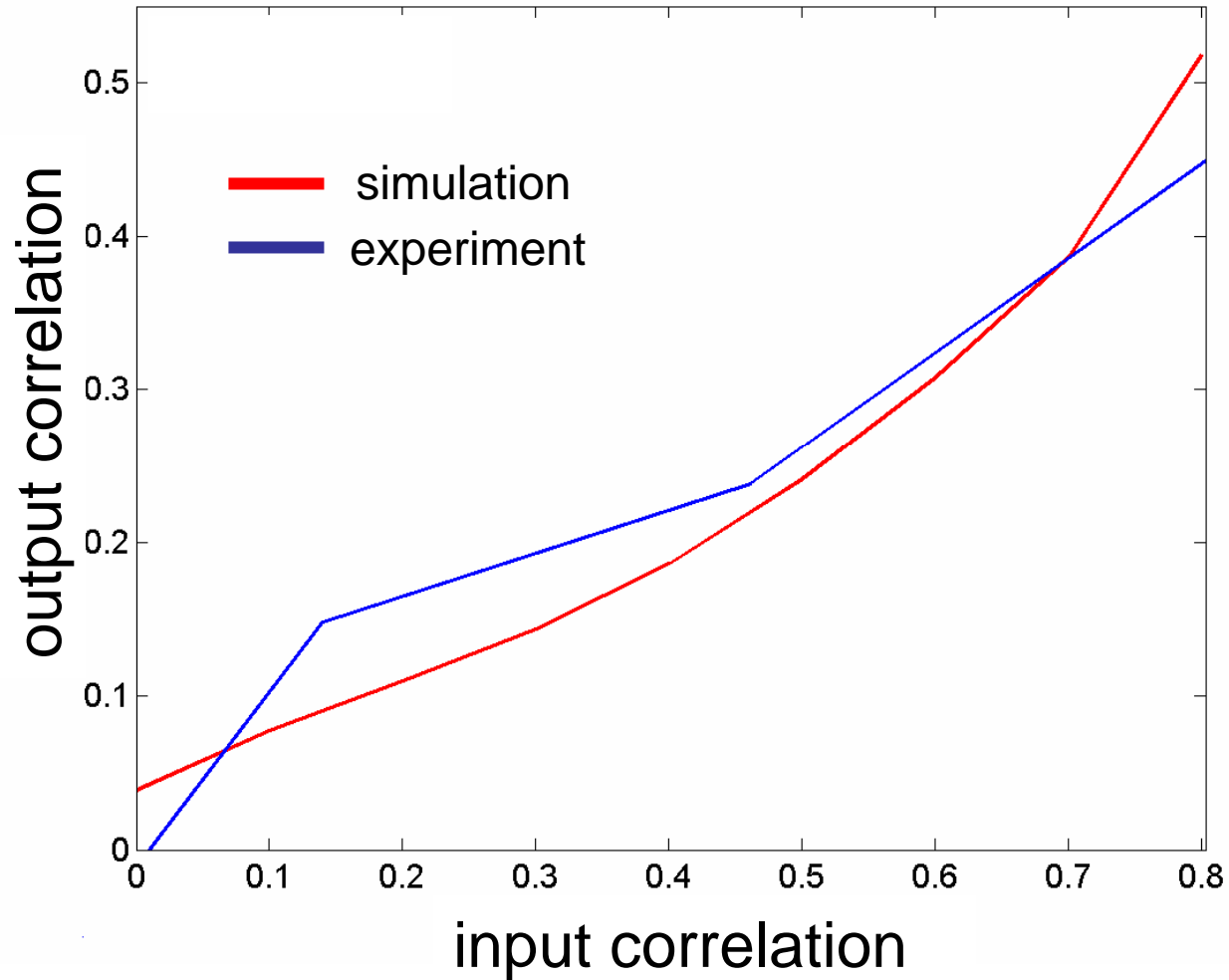
R.F.Galán et al. (2006) *Sensors and Actuators B*.

Stochastic synchrony (experiments)



R.F.Galán et al. (2006) *Sensors and Actuators B*.

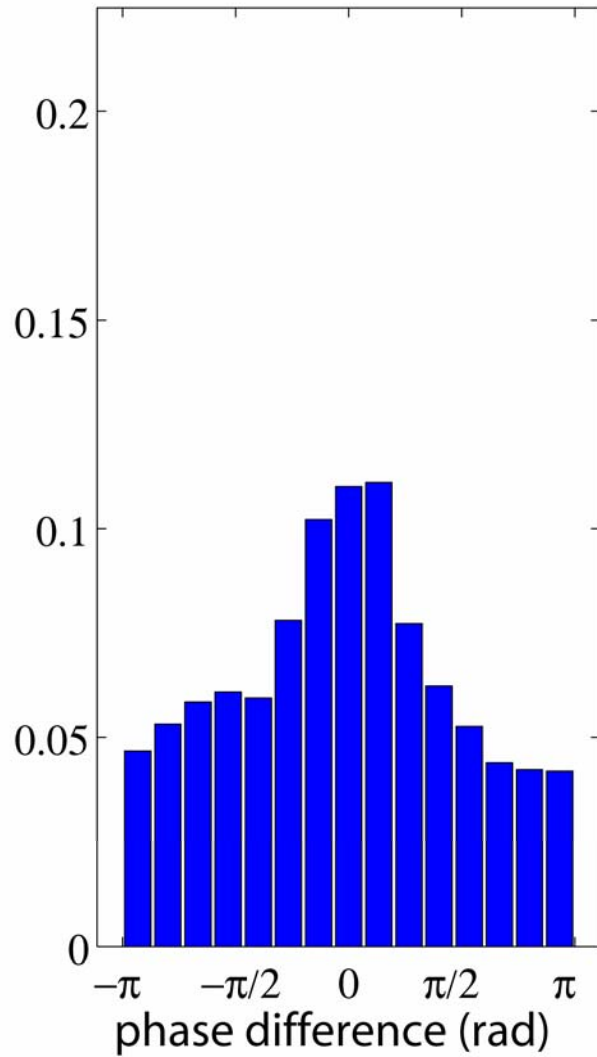
Input-Output response



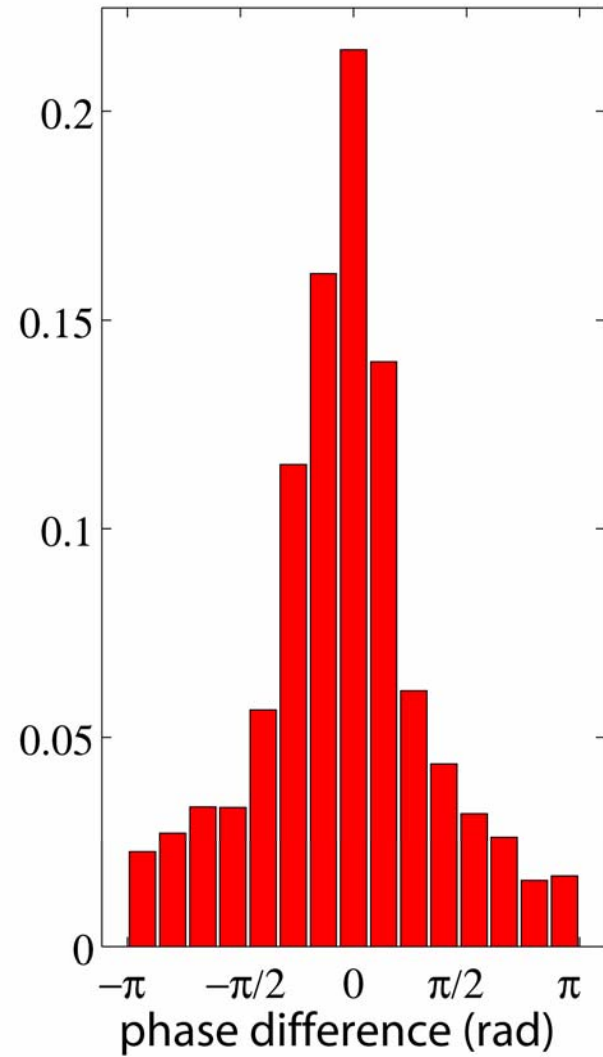
A deeper look into stochastic synchrony

- Single cell properties that facilitate stochastic synchronization: integrators vs. resonators
- Features of noisy currents that facilitate stochastic synchronization

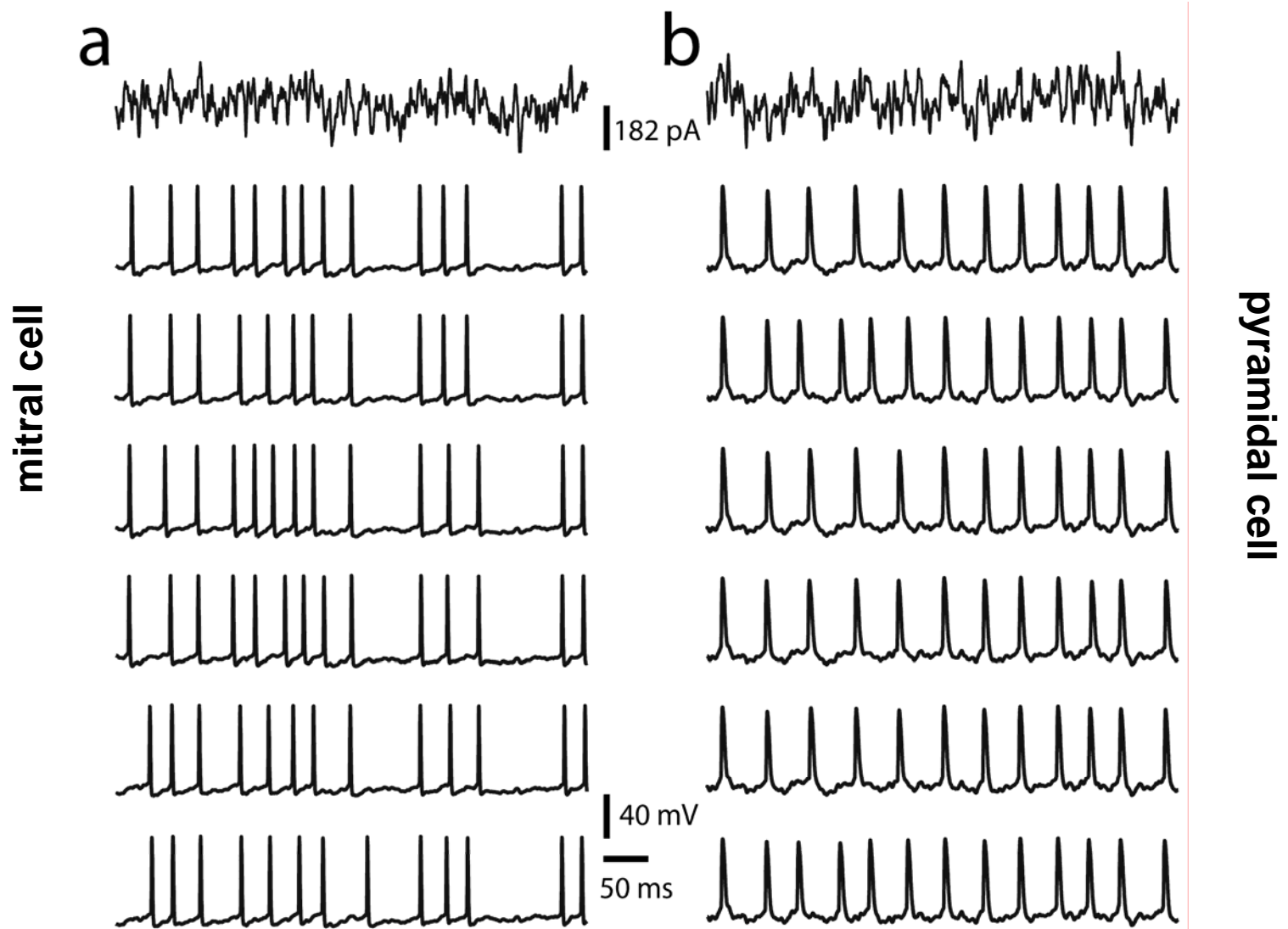
integrators



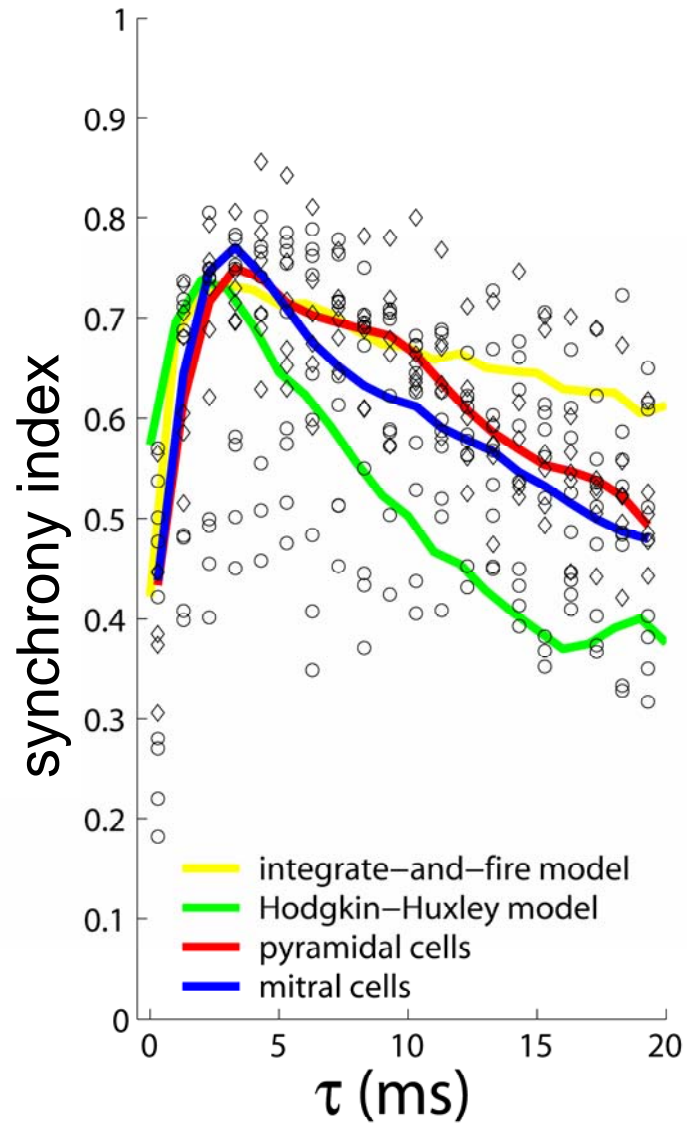
resonators



Optimal time scale for stochastic synchronization I



Optimal time scale for stochastic synchronization II



Brief appendix

Other examples of a constructive role of noise in biophysical systems...

I. Molecular motors: noise-induced transport

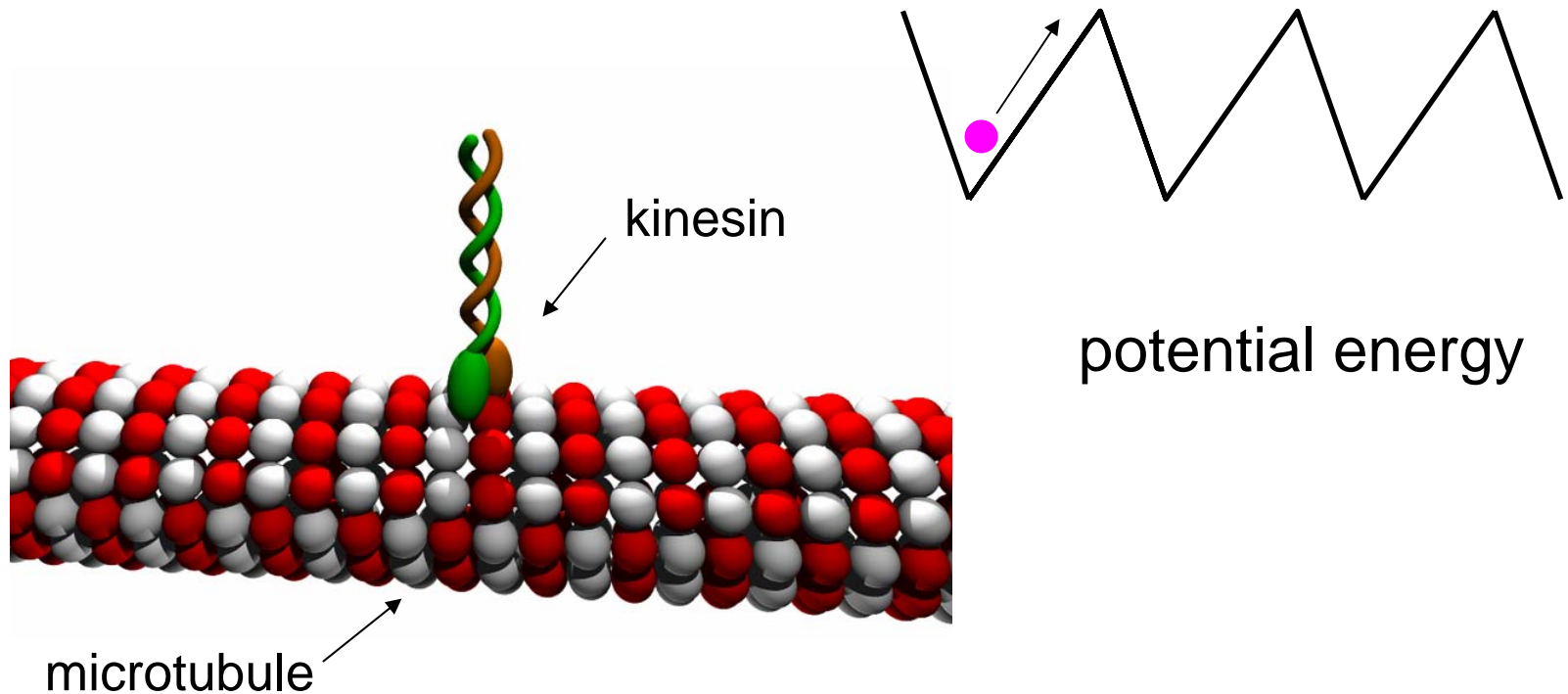


Image modified from Wikipedia

I. Molecular motors: noise-induced transport

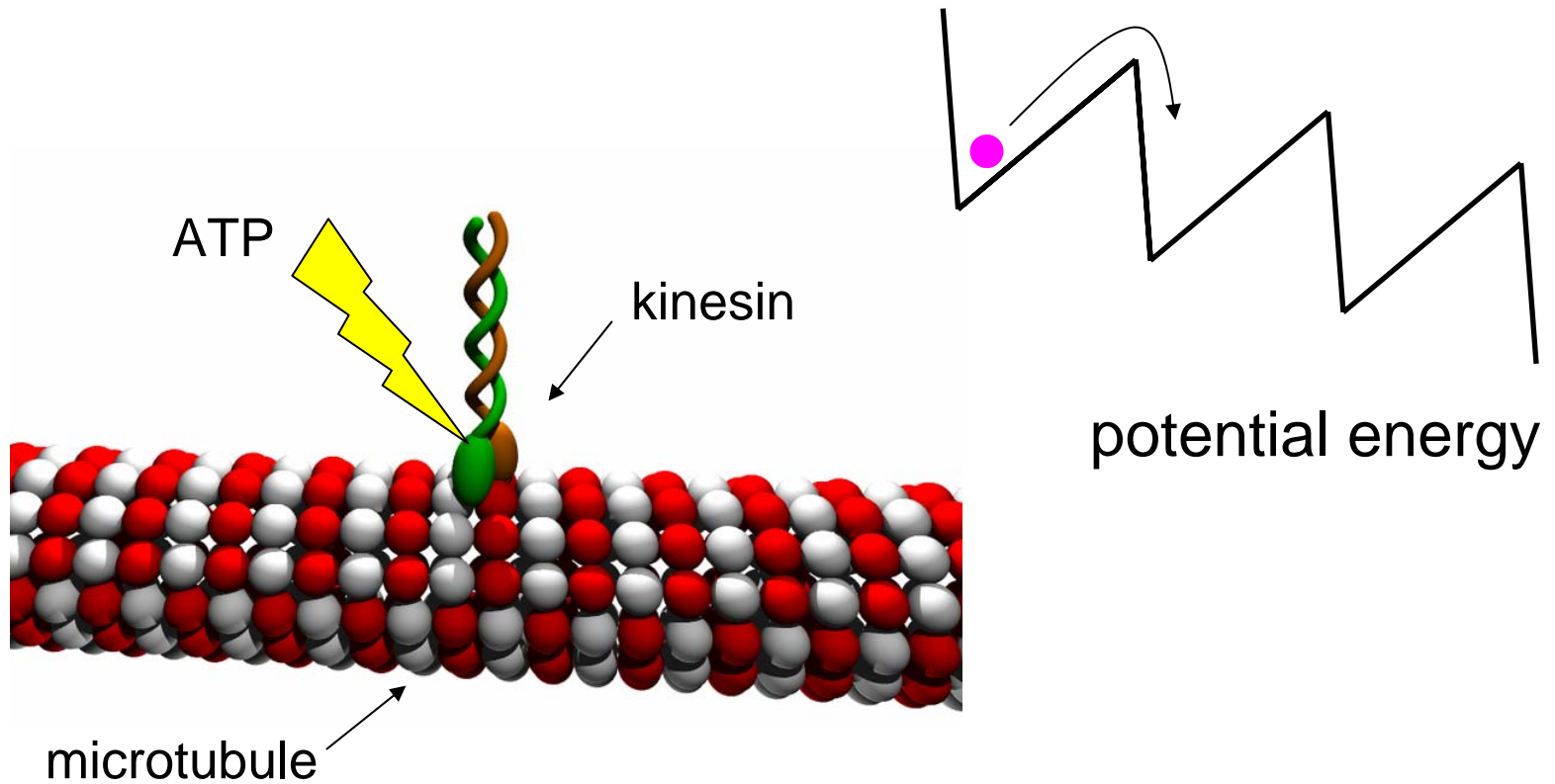
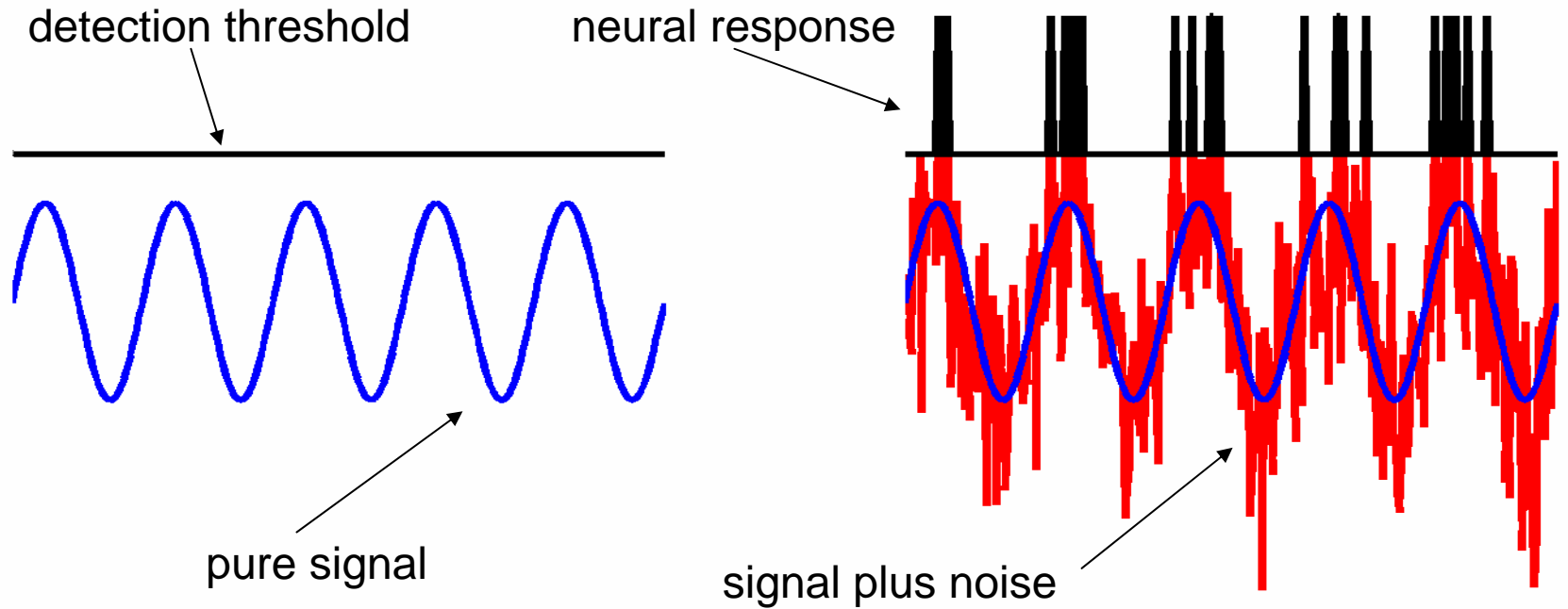


Image modified from Wikipedia

II. Stochastic resonance



K.Wiesenfeld and F.Moss (1995) *Nature*

Conclusions

- In biophysics and neuroscience, we need to reconsider the role of noise: random processes can be active, dynamic agents rather than destructive perturbations.
- In particular, here we have shown that random, but spatially correlated synaptic barrages create collective order in the form of neuronal synchronization.