# BP 34: Neuroscience

Time: Thursday 15:00–17:30 Location: H 1058

**Invited Talk** BP 34.1 Thu 15:00 H 1058

**How do we learn? Synaptic Plasticity across multiple time scales** — •Wulfram Gerstner — EPFL Lausanne

If we memorize a French word that is new to us, if we learn to play table tennis, if we meet our new boss, at all these occasions the connections between neurons in our brains change. These changes, called synaptic plasticity, happen on several different time scale: induction can be rapid (sometimes a single event is sufficient), but the stabilization of changes takes much longer. In this talk, I will overview mathematical models of synaptic plasticity that cover different temporal scales - and I will indicate how plasticity models can (or cannot) lead to functional memories.

BP 34.2 Thu 15:30 H 1058

**Spike rate models derived from recurrent networks of adaptive neurons** — •Moritz Augustin, Josef Ladenbauer, Fabian Baumann, and Klaus Obermayer — Technische Universität Berlin, Germany

The spiking activity of single neurons can be well described by a nonlinear integrate-and-fire model that includes somatic adaptation. When exposed to fluctuating inputs sparsely coupled populations of these model neurons exhibit stochastic collective dynamics that can be effectively characterized using the Fokker-Planck equation. Here we derive from that description four simple models for the spike rate dynamics in terms of low-dimensional ordinary differential equations using two different reduction techniques: one uses the spectral decomposition of the Fokker-Planck operator, the other is based on a cascade of two linear filters and a nonlinearity, which are determined from the Fokker-Planck equation and semi-analytically approximated. We evaluate the reduced models for a wide range of biologically plausible input statistics and find that both approximation approaches lead to spike rate models that accurately reproduce the spiking behavior of the underlying adaptive integrate-and-fire population. The low-dimensional models also well reproduce stable oscillatory spike rate dynamics that are generated either by recurrent synaptic excitation and neuronal adaptation or through delayed inhibitory synaptic feedback. The derived spike rate descriptions retain a direct link to the properties of single neurons, allow for convenient mathematical analyses of network states, and are well suited for application in large-scale brain network models.

BP 34.3 Thu 15:45 H 1058

**Modeling the electrical activity of pacemaker neurons: from milliseconds to days** — •Pablo Rojas and Martin Garcia — Theoretical Physics, Universität Kassel, 34132 Kassel, Germany

Molecular circadian oscillators in pacemaker neurons consist of interlocked feedback loops in gene transcription. Membrane electrical activity is regulated by genetic, and consequently exhibits a circadian pattern, but the mechanisms for this are object of current research [1]. Despite the usefulness of Hodgkin-Huxley model, few work has been done to account for a long-time behavior of membrane electrical activity[2]. Pacemaker neurons show autonomous circadian oscillations, but new properties emerge in the collective behavior [3]. Several properties found in electrophysiology recordings have been suggested to be linked to functional biological implications [4]. We propose an extension of the Hodgkin-Huxley scheme, that allows for computing the dynamics of electrical activity over long times, enabling inputs from molecular clock as well as coupling between neurons. Our results and predictions are discussed with the analysis of long-term in vivo electrophysiology recordings from Leucophaea maderae accessory medulla. Our model has been able to reproduce distinct patterns found in experimental data, and hint possible functional implications for the described behavior.

[1] CN Allen et al. Cold Spring Harb Perspect Biol 2017;9:a027714
[2] C Vasalou and MA Henson . PLoS Comput Biol 6(3) (2010)
[3] DK Welsh et al. Annu Rev Physiol. 2010 ; 72: 551-577.
[4] G Werner. Front Physiol. 2010; 1: 15.

BP 34.4 Thu 16:00 H 1058

**Optimal detection of a localized perturbation in random networks of integrate-and-fire neurons** — •Davide Bernardi[1,2] and Benjamin Lindner[1,2] — [1]Bernstein Center for Computational Neuroscience, Berlin, Germany — [2]Humboldt University, Berlin, Germany

Cortical networks operate in a chaotic regime, as both theoretical and experimental studies have shown. Therefore, neural coding is believed to rely on the mean activity of many cells. However, there is evidence that the brief stimulation of a single neuron can elicit a behavioral response, a theoretically unexplained result. We study how large recurrent networks of integrate-and-fire neurons react to the perturbation of one single cell and propose a simple readout mechanism to detect the perturbation. Biasing the readout towards specific neurons leads to detection rates similar to experimentally observed values, as our numerical simulations and analytical estimates show. We observe near-optimal detection for intermediate values of the mean coupling between neurons. Current research aims to capture how detection rates depend on the temporal structure of the stimulation.

Ref: Bernardi and Lindner, *Phys. Rev. Lett.* **118** (2017)

BP 34.5 Thu 16:15 H 1058

**Nonlinear response of noisy neurons** — •Benjamin Lindner and Sergej Voronenko — Humboldt Universität Berlin

We study the firing rate modulation of stochastic neurons in response to mixtures of periodic signals. For the leaky integrate-and-fire neuron with white Gaussian background noise, we calculate analytically the second order (weakly nonlinear) response of the instantaneous firing rate. We inspect several situations in which the nonlinear contributions shape the response significantly and a purely linear analysis would fail qualitatively. We demonstrate that similar effects are observed for a biophysically more realistic system, the NaK Izhikevich model endowed with channel noise.

Ref.: Voronenko & Lindner New J. Phys. 19, 033038 (2017)

BP 34.6 Thu 16:30 H 1058

**A memristive plasticity model of voltage-based STDP suitable for recurrent bidirectional neural networks in the hippocampus** — •Nick Diederich[1,2], Thorsten Bartsch[2], Hermann Kohlstedt[1], and Martin Ziegler[1] — [1]Technische Fakultät, Christian-Albrechts-Universität zu Kiel — [2]Neurologie, Universitätsklinikum Schleswig-Holstein

Memristive systems have gained considerable attention in the field of neuromorphic engineering, since they allow the emulation of synaptic functionality in solid state nano-physical systems. In this talk it will be shown that memristive behaviour provides a working framework for the phenomenological modelling of cellular synaptic mechanisms. For this purpose, the basic characteristics of memristive systems, i.e. the volatility and history-dependence of prior applied electrical signals, are used to derive a voltage-based plasticity rule. We show that this model is suitable to account for a variety of electrophysiology plasticity data. To show the network capabilities of the plasticity model, the plasticity model was incorporated into the circuitry of the hippocampal subfields. The obtained results are discussed in the framework of the processing of mnemonic information in the hippocampus.

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BP 34.7 Thu 16:45 H 1058

**Interkinetic nuclear migration as a stochastic process in the zebrafish retina** — •Anne Herrmann[1], Afnan Azizi[2], Salvador J. R. P. Buse[2], Yinan Wan[3], Philipp J. Keller[3], William A. Harris[2], and Raymond E. Goldstein[1] — [1]Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, United Kingdom — [2]Department of Physiology, Development and Neuroscience, University of Cambridge, Cambridge, United Kingdom — [3]Howard Hughes Medical Institute, Janelia Research Campus, Ashburn, VA, USA

In recent years evidence has been increasing that retina development is governed by stochastic processes rather than being tightly regulated. In this context, both the varying numbers of offspring from a single progenitor cell as well as the distributions of final cell fates have been explained using simple probabilistic models. We focus on interkinetic nuclear migration (IKNM), a movement of nuclei between the apical and basal surfaces of the cells in developing pseudostratified epithelia, that was first observed more than 80 years ago. Since, IKNM has been studied in multiple organisms but despite these efforts many questions about the role and precise mechanism of this process remain unsolved.

We combine *in vivo* light sheet microscopy and theoretical models and develop a quantitative description of IKNM in the zebrafish retina. Our findings support the hypothesis of IKNM as a stochastic process. Given that IKNM has been suggested to play a regulatory role in cell differentiation, these results have important implications for understanding the organisation of developing vertebrate tissues.

BP 34.8 Thu 17:00 H 1058

**Control of Wave Propagation in Neural Field Equations** — Alexander Ziepke, •Steffen Martens, and Harald Engel — Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Germany

The investigation of neural fields, describing dynamics of large networks of synaptically coupled neurons by means of continuous field equations, has gained interest over the last decades. In particular, neural field systems exhibit self-organized spatio-temporal structures, such as stationary and traveling fronts and pulses, spiral waves, and localized spot-like bump solutions. This makes them a convenient tool to describe various neural processes, such as working memory, motion perception and visual hallucinations, to name a few. Due to the important applications of neural field models, the question arises how to effectively control solutions in these systems.

In order to address this problem, we extend analytic control techniques, previously derived for reaction-diffusion systems [J. Löber, PRL **112**, 148305; arXiv:1703.04246], to neural field equations. The proposed open-loop control scheme enables shifting and rotating traveling bump and wave solutions according to a prescribed protocol of motion while simultaneously conserving their shape. Noteworthy, the control signal solely depends on the profile and velocity of the unperturbed solution, and thus, for applying the control scheme, a detailed knowledge of the internal dynamics is not required.

BP 34.9 Thu 17:15 H 1058

**Predicting animal behavior from neural dynamics** — •Monika Scholz, Ashley N. Linder, and Andrew M. Leifer — Department of Physics and Princeton Neuroscience Institute, Princeton, NJ, USA

How does a nervous system control animal behavior? While models of behavior and neural computation exist, investigating the connection experimentally is challenging in even the simplest organisms. It is only recently that tools have become available to image the behavior and neural dynamics simultaneously in the roundworm *C. elegans*. Its small nervous system with only 302 neurons and stereotyped behaviors allow us to probe how well simple models perform in predicting behavior from neural dynamics alone. We use a suite of microscopy tools and a calcium-sensitive fluorescent protein to image the activity of a large number of neurons in the animal's brain during locomotion. Using a linear model, we predict forward and backward velocity as well as turns and turn direction from neural activity. I will show our progress and discuss the implications for understanding neural computation in a model organism.