Brainy Days in Jerusalem: an Interdisciplinary Celebration

June 22-25, 2015
Mishkenot Sha'ananim, Jerusalem

Organizing Committee: Yoram Burak, Yosi Yarom and Eilon Vaadia

Monday / June 22, 2015

9:00-9:50 Sagiv Shifman – *Department of Genetics, The Hebrew University*
Chromatin regulators in neurodevelopmental disorders

ABSTRACT:
Autism spectrum disorder (ASD) is mysterious because it involves deficits in social cognition and language, both of which are central to what makes us human. ASD is known to have a strong genetic basis, but little is known about the molecular and neuronal mechanisms. Recent studies identified mutations in hundreds of genes that may contribute to the risk of ASD. We have found that chromatin regulators, which are active during brain development, are central to ASD risk. However it still unclear how mutations in this type of genes lead to ASD? Remarkably, several studies identified overlapping set of genes in different neurodevelopmental disorders. This raises the question whether the molecular and neuronal mechanisms underlying ASD are shared with other disorders. To address these questions, we studied genes that harbor de novo mutations in different neurodevelopmental disorders. We found that across disorders, mutations tend to affect similar types of biological processes, and to be in genes expressed in cortical layers during development. The same genes and processes that are implicated in the disorders are negatively depleted from rare mutations in normally developing individuals, probably due to purifying selection. To study the specific mechanisms that are dysregulated we are investigating different cellular and mouse models. In one of our mouse models, we found changes in the level of neurogenesis, brain size and social and cognitive behavior. Still the factors that determine the specific human phenotypes and disorders remains poorly understood.

9:50-10:40 Leslie Vosshall - *The Rockefeller University, Howard Hughes Medical Institute, New York, USA*
The genetic basis of innate behaviors

ABSTRACT:
My group is interested in the molecular neurobiology of mosquito host-seeking behavior. Female mosquitoes require a blood meal to complete egg development. In carrying out this innate behavior, mosquitoes spread dangerous infectious diseases such as malaria, dengue

fever, and yellow fever. Humans attract mosquitoes via multiple sensory cues including emitted body odor, heat, and carbon dioxide in the breath. The mosquito perceives differences in these cues, both between and within species, to determine which animal or human to target for blood-feeding. We have developed CRISPR/Cas9 genome-editing in the yellow fever and dengue vector mosquito, Aedes aegypti, with the goal of understand how sensory cues are integrated by the female mosquito to lead to host-seeking behavior. Some of the questions we are currently addressing are: Why are some people more attractive to mosquitoes than others? How do insect repellents work? How are multiple sensory cues integrated in the mosquito brain to elicit innate behaviors? How do female mosquitoes select a suitable body of water to lay their eggs? Recent advances from my group in analyzing the molecular biology of host-seeking behavior will be discussed.

11:10-12:00 Omri Barak - *Faculty of Medicine, Technion – Israel Institute of Technology, Israel*
Neural dynamics of perceptual detection under temporal uncertainty

ABSTRACT:
Under uncertainty, the brain uses previous knowledge to transform sensory inputs into the percepts on which decisions are based. When the uncertainty lies in the timing of sensory evidence, however, the mechanism underlying the use of previously acquired temporal information remains unknown. We study this issue in monkeys performing a detection task with variable stimulation times. We use the neural correlates of false alarms to infer the subject's response criterion and find that it modulates over the course of a trial. Analysis of premotor cortex activity shows that this modulation is represented by the dynamics of population responses. A trained recurrent network model reproduces the experimental findings, and demonstrates a novel neural mechanism to benefit from temporal expectations in perceptual detection. Previous knowledge about the probability of stimulation over time can be intrinsically encoded in the neural population dynamics, allowing a flexible control of the response criterion over time.

12:00-12:50 Shaul Druckmann – *Janelia Farm Research Campus, Howard Hughes Medical Institute, Virginia, USA*
Dynamic attractors and non-coding spaces in a delayed working memory task

ABSTRACT:
Neural activity during delayed working memory tasks is highly dynamic with most neurons exhibiting complex temporal patterns (Brody et al., 2003). This is a far cry from the stable firing rate assumed in early models of maintaining memory during delay periods a discrepancy that has generated much discussion. In recent theoretical worked we show that there is no contradiction between highly varying network activity and perfectly stable network representation as long as the dynamics are confined to a representational null-

space (Druckmann et Chklovskii, 2010). Moreover, one can solve for the structure of networks that keep dynamics in the nullspace and they resemble cortical networks in their structural properties (Druckmann et Chklovskii, 2012). However, by its very definition the nature of dynamics in the nullspace is difficult to pinpoint theoretically and must be examined experimentally. Accordingly, here we consider recordings performed during a delayed motor task in mice by (Li et al., 2015). First, we find that recorded activity is highly consistent with nullspace activity predictions. Second, in a further set of experiments we perturb the network activity during the delay period while simultaneously recording neural activity. We find that the activity patterns were remarkably steady, largely recovering the correct temporal flow despite hundreds of milliseconds of strong perturbation. Crucially, these same trajectories can be used on a trial-by-trial basis to predict both perturbation-induced and natural mistakes. On the other hand, different dimensions of the activity did not recover from perturbation. These same dimensions did not contain reliable information on the animal's decisions, again consistent with the nullspace framework. In summary, we find strong experimental evidence for a model by which subspaces of the temporal activity are crucial for coding and are dynamically stable, whereas other subspaces, though containing substantial variability, are neither stable nor do they appear to contain significant information usable for decoding.

14:00-14:50 Inna Slutsky - *Dept. Physiology and Pharmacology and Sagol School of Neuroscience, Tel Aviv University, Israel*

Interplay between population firing stability and single neuron dynamics in hippocampal networks

ABSTRACT:
The ability of neuronal circuits to maintain the delicate balance between stability and flexibility in changing environments is critical for normal neuronal functioning. Despite a progress in understanding the homeostatic mechanisms that underlie stability of network firing properties, several key questions remain open. In my presentation I will address some of these questions: What are the basic properties of neural networks that are subjected to homeostatic control? Are homeostatic control systems equally precise at the level of individual neurons and neuronal populations? What is the trigger of synaptic homeostatic mechanisms? How do compensatory changes in synaptic strength affect network's functions? What are the molecular mechanisms enabling stability of population firing properties at extended timescales? I will describe the basic relationships between ongoing spiking properties of individual neurons, population dynamics and synaptic adaptive mechanisms.

14:50-15:40 Christian Lüscher – *Department of Basic Neurosciences, University of Geneva, Switzerland*

From synaptic causalities to blue prints for novel therapies in addiction

ABSTRACT:

Current models of addiction stem from the idea that aberrant function and remodeling of neural circuits cause the pathological behaviors. According to this hypothesis, drug exposure would trigger specific forms of synaptic and cellular plasticity, which in susceptible subjects would become persistent and lead to the disease. I will review the arguments in favor of abnormal neuronal plasticity underlying addiction and argue that future research must strive to obtain a comprehensive description of the relevant functional anatomy. To establish causality, I present experiments indicating that normalization of function can reverse pathological behavior. With these elements in hand, it will be possible to propose blueprints for manipulations to be tested in translational studies.

16:10-17:00 Matteo Carandini - *UCL Institute of Ophthalmology, University College London, UK*

Soloists and choristers in a cortical population

ABSTRACT:

In a seminal series of studies, Arieli, Grinvald, and Tsodyks outlined a key question in systems neuroscience: Are cortical neurons soloists or obedient members of a large orchestra? We find that the answer is “both”. In sensory cortex, the relationship of neurons to the overall population lies along a continuum, from cells whose firing is strongly correlated with it (“choristers”), to others that fire independently of it (“soloists”). This relationship is invariant to sensory stimuli, is causal, and is rooted in robust differences in synaptic connectivity. Moreover, this relationship is central to explaining seemingly complex population patterns. And what kind of signals do distant cortical neurons share? To answer this question we used optogenetics to cause activity in a local region of mouse primary visual cortex (V1), and measured its effects at distal V1 locations. These effects depended on visual contrast: activation at low contrast, and suppression at high contrast. The balance between the two is predicted by a simple equation: “divisive normalization”. Intracellular measurements reveal that it arises largely from increases and decreases in synaptic excitation. However, the strength of these interactions is controlled not only by visual context but also by behavior: it is much weaker during locomotion. These are tentative but promising steps towards understanding the relationship of neurons to populations, and the laws that govern the interactions among cortical neurons and their dependence on sensory and behavioral context.

17:00-17:50 Ranulfo Romo - *Instituto de Fisiología Celular-Neurociencias, Universidad Nacional Autónoma de México & El Colegio Nacional, Mexico City, Mexico*
Where and how in the cerebral cortex do single neurons process more than one sensory modality during perceptual judgments?

ABSTRACT:
Recent studies have reported that sensory cortices process more than one sensory modality, challenging the long-lasting concept that they process only one. However, both the identity of these multi-modal responses and whether they contribute to perceptual judgments are unclear. With my colleagues I recorded from single neurons in somatosensory cortices and primary auditory cortex while trained monkeys discriminated, on interleaved trials, either between two tactile flutter stimuli or between two acoustic flutter stimuli, and in cross modal trials. We found few neurons in these sensory cortices that responded to stimuli that are not of their principal modality during these tasks. The identity of the stimulus could only be decoded from responses of their principal sensory modality during the stimulation periods and not during the processing steps that link sensation to decision making. These results suggest that multimodal encoding and perceptual judgments in these tasks occur outside the sensory cortices. New experiments using the same discrimination sets described above showed that single neurons from the frontal lobe cortices have the capacity to encode the tactile and acoustic flutter stimuli during the stimulation periods, working memory and decision periods of these tasks. Furthermore, the single neurons from the frontal lobe encode in their activities the quantities of either tactile or acoustic stimuli and covary with the perceptual judgments in these two tasks.

Tuesday / June 23, 2015

9:30-10:20 Ehud Zohary - *Department of Neurobiology and the Edmond and Lily Safra Center, The Hebrew University of Jerusalem, Israel*
On the representation of viewed hand actions in the human cortex

ABSTRACT:
Parietal cortex is often implicated in visual processing of actions. Action *understanding* is essentially abstract, specific to the type or goal of action, but greatly independent of variations in the perceived position of the action. If certain parietal regions are involved in action understanding, we expect them to show these generalization and selectivity properties. However, additional functions of parietal cortex, such as self-action control, may impose other demands by requiring an accurate representation of the location of graspable objects. Thus, the dimensions along which responses are modulated may indicate the functional role of specific parietal regions. Here, we study the degree of position invariance

and hand/object specificity during viewing of tool-grasping action. To that end, we characterize the information available about location, hand- and tool-identity in the patterns of fMRI activation in various cortical areas: early visual cortex (EVC), posterior intraparietal sulcus (pIPS), anterior superior parietal lobule (aSPL), and the ventral object-specific lateral occipital complex (LOC). Our results suggest a gradient within the dorsal stream: along the posterior-anterior axis, position information is gradually lost, while hand- and tool-identity information is enhanced. This may reflect a gradual transformation of visual input from an initial retinotopic representation in early visual areas, to an abstract, position invariant representation of viewed action in anterior parietal cortex.

10:20-11:10 Galia Avidan - *Departmet of Psychology, Ben-Gurion University of the Negev, Israel*
Altered topology of neural circuits in congenital prosopagnosia

ABSTRACT:
Converging studies suggest that face processing is mediated not by a single, localized brain area, but rather by the contribution of multiple posterior 'core' and anterior 'extended' regions which constitute a coherent, distributed network. One approach to understanding the properties of this face network is to explore its dysfunction in individuals who have difficulties in face processing in the absence of any obvious brain abnormality and in the presence of intact sensory and intellectual functions (congenital prosopagnosia, CP). Intriguingly, individuals with CP exhibit a seemingly normal pattern of functional magnetic resonance imaging (fMRI) activation profile in the 'core' face system. However, both structural and functional MRI studies have documented impairments in the connectivity patterns between the 'core' and the 'extended' systems, and specifically, connectivity with the anterior temporal cortex. To evaluate the pattern of abnormal connectivity in CP, in the current study, using a novel, fMRI-based brain network procedure, we compared the cortical topology of neural circuits for face processing in participants with CP and matched controls. The anterior temporal cortex served as the major hub for the control participants but not for the CPs. In contrast, the CPs evinced hyper-connectivity in posterior visual regions. While consistent with our previous functional and structural results, these results offer new insights by providing a computational, quantitative framework for assessing network structure and topology in cases of impaired face processing and can be applied to other populations with neurodevelopmental perturbations.

11:40-12:30 Nikos Logothetis - *Max Planck Institute for Biological Cybernetics, University of Tubingen, Germany*
NET-fMRI of large-scale brain networks: Mapping dynamic connectivity in epochs of synaptic and system consolidation

ABSTRACT:
Neural-Event-Triggered fMRI (NET-fMRI) can potentially map whole-brain activity, associated with individual local events - or their interactions - in various brain structures. In my talk, I'll describe a number of characteristic states of widespread cortical and subcortical networks that are associated with the occurrence of thalamic, hippocampal and pontine events, which may be related to synaptic and systems consolidation of different memories.

13:30-14:20 Hermona Soreq - *The Edmond and Lily Safra Center and The Department of Biological Chemistry, The Hebrew University of Jerusalem, Israel*
Checks and balances of cholinergic signaling in brain and body functions

ABSTRACT:
A century after acetylcholine's (ACh) discovery, we recognize the ACh receptors, transporters and synthesizing and degrading enzymes as contributors to cognition, metabolism and immunity. However, recent discoveries highlight pre- and post-transcriptional ACh signaling controllers including SLEEPLESS, Lynx1 and Isl1 as governing the identity, functioning, dynamics and brain-to-body communication of cholinergic cells. Epigenetic mechanisms, alternative splicing and microRNAs coordinate an expanded yet well controlled diversity of these cholinergic components. Genome-related surveillance by transcriptional and post-transcriptional checks and balances enable regulated long-term maintenance of brain-to-body ACh signaling and reactions to nicotine, anti-cholinesterase therapeutics for Alzheimer's disease and agricultural pesticides. The functional implications of these controllers of cholinergic signaling are of utmost importance within and out of the brain, in health and disease.

14:20-15:10 Kobi Rosenblum - *Sagol Department of Neurobiology and Center for Gene Manipulation in the Brain, University of Haifa, Israel*
From Molecular and Cellular Mechanisms Underlying Cortica-Dependent Memories to Cognitive Enhancers

ABSTRACT:
In the past decade we have aimed at dissecting out cortical molecular and cellular processes underlying different phases of simple forms of incidental (positive) as well as associative (negative) taste learning paradigms. We have identified time-dependent transcriptional, translational, and post translational modifications that are correlated and/or necessary for different forms or phases of taste learning. Currently, we aim at better understanding the relationships between the different molecular processes and their localization within the relevant cortical circuit underlying taste behavior. In addition, following the identification of new pathways and molecular targets to enhance cognitive function, we are testing the possibility that pharmacological or genetic manipulation of the newly identified pathways

could ameliorate memory impairments in normal aging or rodent models of neurodegenerative diseases. One example for such pathway is the role of eIF2 and its kinases, GCN2, PKR, PERK in memory consolidation and sporadic Alzheimer disease.

15:40-16:30 Ami Citri - *The Alexander Silberman Institute of Life Sciences and Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Israel*
Behavioral Transcriptomics: A molecular perspective on experience-dependent plasticity

ABSTRACT:
In the Citri Lab for Experience-Dependent Plasticity we study how the nervous system encodes experience at the molecular, synaptic and neural circuit levels. A main focus in the lab is to understand how salient experiences, such as the experience of drugs of abuse, palatable foods and aversive experiences, are encoded in the reward circuitry to modify behavior. We utilize information obtained from studying dynamic gene regulation as an entry point to investigation of neural circuit plasticity .
Recently we have identified a nearly perfect correlation between robust and specific patterns of gene expression dynamics (induced in a number of different brain nuclei) and a variety of defined behavioral experiences. The expression dynamics differ between experiences to the extent that the recent behavioral experiences of individual mice can be inferred solely by examining transcriptional dynamics. We believe this approach, which we term “behavioral transcriptomics”, provides an exciting new platform for studying experience-dependent plasticity at the molecular level, and an entry point for identifying specific functions of gene products in encoding features of behavioral experiences.
Other projects in the lab are focused on studying the function of specific gene products in the development of the response to drugs of abuse, as well as in development of preference for palatable foods.
Additional projects are focused on identification of potential novel components of the reward circuitry, investigation of the input-output connectivity of these brain regions, and synaptic plasticity within these brain regions following the experience of drugs of abuse.

Wednesday / June 24, 2015

9:00-9:50 Israel Nelken - *Department of Neurobiology and the Edmond and Lily Safra Center, The Hebrew University of Jerusalem, Israel*
The transformation of surprise representations in the ascending auditory system

ABSTRACT:
Neurons in the auditory system, starting at least as early as the inferior colliculus (IC), show stimulus-specific adaptation (SSA) - the selective reduction in their responses to a repeated,

standard, stimulus that doesn't generalize to other, deviant stimuli. Subcortical SSA is strong in the so-called non-lemniscal pathway, but is weak in the core, lemniscal pathway from the brainstem to auditory cortex. We know that subcortical SSA does not depend on cortical feedback. On the other hand, primary auditory cortex (A1), which shows a substantial amount of SSA, is mostly driven by lemniscal inputs that do not show SSA. This picture suggests that SSA is computed at least twice in the auditory system: once in the IC, and a second time in A1. To test this hypothesis, we studied the responses of neurons in IC, the medial geniculate body (MGB, the auditory thalamus) and A1 in response to a large number of tone sequences and complex sounds. Here I will describe these results and interpret them in the context of adaptation in narrowly tuned modules (ANTM) models, arguably the simplest class of models that show SSA. Such models predict deviant responses that are the same or smaller than the responses to the same sounds in the deviant alone configuration or when presented as part of 'control' sequences. Furthermore, because of the tonotopic organization of the auditory system, such models predict no SSA to appropriately balanced broadband stimuli. I will show that these predictions hold in IC and in MGB, but fail in A1. In particular, the responses to deviants in A1 are larger than expected by the level of adaptation of the afferent inputs, and neurons in A1 show SSA to particularly well-balanced broadband stimuli that fail to evoke SSA in IC and MGB. I will discuss our approaches for unraveling the circuit mechanisms in A1 that may underlie these results. Together, these results suggest that cortical processing confers exquisite context sensitivity to the sensory responses over time scales of tens of seconds.

9:50-10:40 Anthony Zador - *Cold Spring Harbor Laboratory, New York, USA*
Corticostriatal circuits underlying auditory decisions

ABSTRACT:
To study how animals use sensory information to make decisions, we have developed a rodent model of auditory discrimination. We previously found that a subset of neurons in auditory cortex, those that project to the auditory striatum, play a central role in propagating information beyond the cortex. In my talk I will discuss recent experiments indicating that plasticity at corticostriatal synapses plays an essential role in the acquisition of the association between the sound and the action in this task. If time remains at the end, I may provide an update our on-going project to sequence the connectome.

11:10-12:00 Misha Ahrens - *Howard Hughes Medical Institute, Janelia Research Campus, Virginia, USA*
The neural substrate of a short-term motor memory

ABSTRACT:
Animals continually tune their behavior to feedback from the environment, leading to adapted behavioral states that can persist for prolonged periods of time. The persistence of this memory of adapted behavior, or "state memory", is presumably used to bridge periods during which the animal does not behave, or sensory feedback is unavailable or unreliable. Much is unknown about the neural origins of such persistent behavioral states. We used whole-brain imaging in fictively behaving larval zebrafish to find the locus of such a state memory in the context of motor adaptation. Analyzing neural activity in periods during which the state memory is maintained revealed localized populations of neurons that encoded the state memory and predicted future behavior. Ablation and optogenetic stimulation of these populations affected the state memory in opposite directions, and neural activity in these populations reflected both swimming activity and the slow buildup and maintenance of the memory. These results uncover a system for the maintenance of behavioral states arising from interactions with the environment, establishing robustness in flexible behavior.

12:00-12:50 Adam Cohen - *Departments of Chemistry and Chemical Biology and Physics, Harvard Stem Cell Institute, Harvard University, Massachusetts, USA*
Optical electrophysiology with microbial rhodopsins

ABSTRACT:
In the wild, microbial rhodopsin proteins convert sunlight into biochemical signals in their host organisms. Some microbial rhodopsins convert sunlight into changes in membrane voltage. We engineered a microbial rhodopsin to run in reverse: to convert changes in membrane voltage into fluorescence signals that are readily detected in a microscope. Archaerhodopsin-derived voltage-indicating proteins enable optical mapping of bioelectric phenomena with unprecedented speed and sensitivity. I will describe applications in primary and hiPSC-derived cultured neurons, and in transgenic zebrafish and mice.

14:00-14:50 Shimon Ullman – *Department of Computer Science and Applied Mathematics, Weizmann Institute of Science, Israel*
Atoms of Visual Recognition

ABSTRACT:
The human visual system makes highly effective use of limited information: it can recognize not only objects, but severely reduced sub-configurations in terms of size or resolution. Minimal images are useful for the interpretation of complex scenes but they are also challenging because by their nature they are non-redundant stimuli and depend on the effective use of all the available information. Human studies and computer simulations show that humans and existing models are very different in their ability to interpret minimal

images. I will discuss implications to the representations used for recognition, brain mechanisms involved, and algorithms for the interpretation of complex scenes.

14:50-15:40 Emo Todorov - *Department of Computer Science & Engineering, University of Washington, Washington, USA*
Synthesis of contact-rich behaviors with optimal control

ABSTRACT:
Animals and machines interact with their environment mainly through physical contact. Yet the discontinuous nature of contact dynamics complicates planning and control, especially when combined with uncertainty. We have recently made progress in terms of optimizing complex trajectories that involve many contact events. These events do not need to be specified in advance, but instead are discovered fully automatically. Key to our success is the development of new models of contact dynamics, which enable continuation methods that in turn help the optimizer avoid a combinatorial search over contact configurations. We can presently synthesize humanoid trajectories in tasks such as getting up from the floor, walking and running, turning, riding a unicycle, as well as a variety of dexterous hand manipulation tasks. When augmented with warm-starts in the context of model predictive control, our optimizers can run in real-time and be used as approximately-optimal feedback controllers. Some of these controllers have already been transferred to physical robots, via ensemble optimization methods that increase robustness to modeling errors. The resulting trajectory libraries are also used to train recurrent neural networks. After training the networks can control the body autonomously, without further help from the trajectory optimizer.

16:10-17:00 Haim Sompolinsky – *Racah Institute of Physics* and *the Edmond and Lily Safra Center, The Hebrew University of Jerusalem, Israel*
Computational perspectives on neuronal representations

ABSTRACT:
The multiplicity of neuronal representations of sensory signals has been a major topic in computational neuroscience; examples are Efficient Coding theory of early vision and David Marr's theory of the Cerebellum. I will discuss recent work aimed at assessing the computational benefits of transforming sensory signals across multiple feedforward stages, an architecture analogous to Deep Networks of machine learning .
In addition, the roles of recurrent connections as well as contextual top-down signals will be elucidated. Application to the olfactory system and to the hippocampus will be discussed.

17:00-17:50 Joshua Tenenbaum - *Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Massachusetts, USA*
Reverse-engineering common sense in the human mind and brain

ABSTRACT:
What is the essence of human intelligence — what makes any human child smarter than any machine learning or artificial intelligence system that has ever been built? Our work aims to answer this question in computational terms, with a precision sufficient to engineer this cognitive capacity in a machine and to generate testable predictions for both behavioral and neural experimentation. We start with foundational insights from recent developmental psychology, studying the basic commonsense knowledge of young infants and the basic learning mechanisms that let children grow this knowledge out over their first few years of life. What we call the ''common sense core'' is a set of integrated cognitive capacities for scene perception, physical and social reasoning, and rapid learning of rich abstract knowledge from sparse data. I will show how we are beginning to capture these abilities computationally using the techniques of *probabilistic programs* and *program induction*, embedded in a broadly Bayesian framework for inference under uncertainty. These methods also lay the foundations for more human-like approaches to artificial intelligence, and computational neuroscience approaches that connect more deeply with the core of human cognition.

Thursday / June 25, 2015

9:00-9:50 Yoram Burak - *Racah Institute of Physics* and *the Edmond and Lily Safra Center, The Hebrew University of Jerusalem, Israel*
Efficient coding of a dynamic trajectory in the entorhinal cortex

ABSTRACT:
Grid cells in rodents and bats provide a fascinating glimpse into the coding, deep within the brain, of an internally computed quantity - an animal's self estimate of its position in its environment. Recent experiments established that these cells are functionally organized in discrete modules, each containing neurons with uniform grid spacing, whereas the spacings seen in successive modules approximately follow a geometric progression. This result is in agreement with theories that postulate a role of grid cells in efficient coding of the animal's position. However, the experimental data suggests also that the number of cells decreases sharply with grid spacing, in marked disagreement with existing theories. In this talk I will introduce a hyposthesis that the entorhinal cortex is adapted to represent a dynamic quantity (the trajectory of the animal in space), while taking into account the temporal statistics of this variable. We recently developed a theory for efficient coding of such a variable. A central prediction of the theory is that neuron population sizes should sharply decrease with the increase of grid spacing, in agreement with the trends seen in the

experimental data. I will also discuss a simple, near optimal scheme for neural readout of the dynamic position from the grid cell code, in which model place cells linearly sum inputs from grid cells. Crucially, the summation involves a temporal kernel, whose characteristic decay time depends on the spacing of the presynaptic grid cell. The simple readout scheme requires mechanisms for persistence over time scales ranging from ~1 ms to ~1s, suggesting that diverse biophysical mechanisms for persistence may be involved in readout of the grid cell code.

9:50-10:40 Nachum Ulanovsky - *Department of Neurobiology, Weizmann Institute of Science, Israel*
Neural codes for 2-D and 3-D space in the hippocampal formation of bats

ABSTRACT:
The work in our lab focuses on understanding the neural basis of spatial memory and spatial cognition in freely-moving, freely behaving mammals – employing the echolocating bat as our animal model. I will describe our recent studies, including: (i) Recordings of 3-D place cells, 3-D grid cells, and 3-D head-direction cells in the hippocampal formation of freely-flying bats, using a custom neural telemetry system – which revealed an elaborate 3-D spatial representation system in the bat's brain; and (ii) Absence of theta oscillations in the bat's hippocampal formation – arguing against a central role of theta in spatial cognition. I will also describe our recent studies of spatial memory and navigation of bats in the wild, using micro-GPS devices, which revealed outstanding navigational abilities and provided the first evidence for a large-scale 'cognitive map' in a mammal. Overall, our general approach is to take advantage of the unique properties of bats – their temporally-discrete sensory system (sonar) and excellent vision, and their 3D flight abilities – in order to ask general questions in Systems Neuroscience; particularly questions that are difficult to address using rodents. Our long-term vision is to develop a "Natural Neuroscience" approach for studying the neural basis of behavior – tapping into the animal's natural behaviors in complex, large-scale, naturalistic settings – while not compromising on rigorous experimental control. We firmly believe that pursuing such an approach will lead to novel and surprising insights about the Brain.

11:10-12:00 Michael Häusser – *Wolfson Institute for Biomedical Research and the Department of Neuroscience, Physiology and Pharmacology, University College London, UK*
All-optical interrogation of neural circuits

ABSTRACT:
Neural circuits display complex spatiotemporal patterns of activity on the millisecond timescale during behavior. Understanding how these activity patterns drive behavior is a fundamental problem in neuroscience, and remains a major challenge due to the complexity of their spatiotemporal dynamics. The ability to simultaneously image and manipulate

patterns of activity in neural circuits at cellular resolution would open up new frontiers in neuroscience. I will describe a strategy for "all-optical" interrogation of neural circuits in vivo with single-spike and single-neuron precision. Two-photon calcium imaging is combined with two-photon optogenetic activation using coexpression of a red-shifted opsin and a genetically encoded calcium indicator. A spatial light modulator allows tens of user-selected neurons to be targeted for spatiotemporally precise optogenetic activation, while simultaneous fast calcium imaging provides high-resolution network-wide readout of the manipulation with negligible optical cross-talk. Proof-of-principle experiments in mouse barrel cortex demonstrate interrogation of the same neuronal population during different behavioral states and targeting of neuronal ensembles based on their functional signature. This approach extends the optogenetic toolkit beyond the specificity obtained with genetic or viral approaches, enabling high-throughput, flexible and long-term optical interrogation of functionally defined neural circuits in vivo.

12:00-12:50 Yang Dan - *Howard Hughes Medical Institute, Division of Neurobiology, Department of Molecular and Cell Biology, Helen Wills Neuroscience Institute, UC Berkeley, California, USA.*
Neural circuits controlling sleep

ABSTRACT:
I will discuss our recent efforts dissecting the hypothalamic and brainstem circuits for sleep control. We use a combination of optogenetic manipulation, recording, imaging, and virus-mediated circuit tracing techniques to identify the specific cell types important for REM and non-REM sleep and delineate their local and long-range connectivity.

14:00-14:50 Chris De Zeeuw – *Netherlands Institute for Neuroscience, Royal Academy for Arts and Science and the Department for Neuroscience, Erasmus Medical Center, The Netherlands*
Cerebellar conditioning and rebound: Two sides of the same coin

ABSTRACT:
Although our ability to store semantic declarative information can nowadays be readily surpassed by that of simple personal computers, our ability to learn and express procedural memories still outperforms that of supercomputers controlling the most advanced robots. To a large extent, our procedural memories are formed in the cerebellum, which embodies more than two-thirds of all neurons in our brain. In this lecture, I will focus on the emerging view that different modules of the cerebellum use different encoding schemes to form and express their respective memories. More specifically, zebrin-positive zones in the cerebellum, such as those controlling adaptation of the vestibulo-ocular reflex, appear to predominantly form their memories by potentiation mechanisms and express their

memories via rate coding ,whereas zebrin-negative zones, such as those controlling eyeblink conditioning, appear to predominantly form their memories by suppression mechanisms and express their memories in part by temporal coding using rebound bursting. Together, the different types of modules offer a rich repertoire to acquire and control sensorimotor processes with specific challenges in the spatiotemporal domain.

14:50-15:40 Andreas Lüthi - *Friedrich Miescher Institute for Biomedical Research, Switzerland*
Deconstructing fear

ABSTRACT:
Classical fear conditioning is one of the most powerful models for studying the neuronal substrates of associative learning and for investigating how plasticity in defined neuronal circuits causes behavioral changes. In animals and humans, the amygdala is a key brain structure within a larger neuronal network mediating the acquisition, expression and extinction of fear memories. My presentation will summarize recent progress in understanding how defined local and long-range circuits contribute to the acquisition and expression of fear and anxiety behavior by multiple mechanisms and at multiple levels. Moreover, I will describe how switches in the activity between distinct amygdala output pathways mediate rapid behavioral adaptations.

16:10-17:00 Adi Mizrahi - *Department of Neurobiology and the Edmond and Lily Safra Center, The Hebrew University of Jerusalem, Israel*
Coding new smells and new sounds in the transition to motherhood

ABSTRACT:
Motherhood is a dramatic event common across the animal kingdom. Motherhood is accompanied by new maternal behaviors that are most likely associated with how specific neuronal circuits process information, but these are not well characterized. I will discuss some of the functional changes and underlying mechanisms in the auditory and olfactory system in mother mice. We used electrophysiology imaging and behavior to study how specific sub-circuits in the auditory cortex and olfactory bulb change in new mothers and discuss how these may help to ensure the wellbeing of her offspring.