Plenary Lecture 1 by Martin Giurfa

PL-1

Rules and mechanisms of punishment learning in honey bees

Martin Giurfa[1]

CNRS - University Paul Sabatier Toulouse III[1]

Honeybees constitute established model organisms for the study of appetitive learning and memory. In the last years, the development of the olfactory conditioning of the sting extension response (SER) has yielded new insights into the rules and mechanisms of aversive learning in insects. In olfactory SER conditioning, a harnessed bee learns to associate an olfactory stimulus as conditioned stimulus with the noxious stimulation of an electric shock as unconditioned stimulus. We will review the multiple aspects of honey bee aversive responsiveness and learning that have been uncovered using Pavlovian conditioning of SER. From its behavioral principles and sensory variants to its cellular/molecular bases and implications for understanding the social organization of the hive, we will present the last advancements in the study of punishment learning in bees and discuss its perspectives in order to define future research avenues and necessary improvements. These studies underline the importance of studying honey bee learning not only from an appetitive, but also from an aversive perspective, in order to uncover behavioral and cellular mechanisms of individual and social plasticity.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Invited Symposium 1

IS1-1(10:00 - 10:30)

Neural codes for 2-D and 3-D space in bat hippocampus

Nachum Ulanovsky[1]

Department of Neurobiology, Weizmann Institute of Science[1]

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 head-direction cells in the presubiculum of crawling bats, as well as recordings from hippocampal 3-D place cells in freely-flying bats, using a custom neural telemetry system – which revealed an elaborate 3-D spatial representation in the mammalian brain; and (ii) recordings of 'grid cells' in the bat's medial entorhinal cortex, in the absence of theta oscillations – which strongly argues against the prevailing computational model of grid formation. I will also describe our recent studies of spatial memory and navigation of fruit 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.

[Topic1]Orientation and Navigation

[Topic2]Orientation and Navigation

Invited Symposium 1

IS1-2(10:30 - 11:00)

Timing matters: Representing space through sound

*Cynthia F. Moss[1], Melville Wohlgemuth[1], Ninad Kothari[1]

Department of Psychological and Brain Sciences, Johns Hopkins University, Baltimore, MD, USA[1]

Spatial navigation by echolocation depends on the dynamic interplay between auditory information processing and adaptive motor control. An important component of this adaptive system is the timing of sonar signals, which the bat adjusts, not only with respect to object distance, but also in the context of perceptual demands and planning. For example, the big brown bat, *Eptesicus fuscus*, produces stable groups of sonar signals, flanked by longer pulse intervals, when it is challenged by spatial tasks, such as figure-ground segregation and target trajectory uncertainty. This talk will summarize behavioral and neurophysiological findings, which indicate that the big brown bat's control over sonar call timing serves to sharpen its spatial representation of the environment. Behavioral studies were conducted in the laboratory and the field, as the bat tracked insect prey under a variety of conditions. Neural recordings from the midbrain superior colliculus of freely behaving bats show that auditory responses to echoes are modulated by the animal's production of sonar sound groups. Collectively, these data suggest that the bat temporally organizes its echolocation calls into groups as an active strategy to build a detailed representation of the sonar scene.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Audition

Invited Symposium 1

IS1-3(11:00 - 11:30)

How do echolocating bats listen to returning echoes: Recent findings

Hiroshi Riquimaroux[1]
Doshisha University[1]

Echolocating bats listen to their returning echoes for their navigation and capturing preys. It has been difficult for us to monitor what they listen to while they are flying. For us to monitor their emitting pulses and returning echoes we have developed a small and light, onboard wireless microphone system, Telemike. Both CF-FM and FM bats, *Hipposideros terasensis*, *Rhinolophus ferrumequinum, and Pipistrellus abramus*, were used for subjects. We let the bats with Telemike fly in a chamber to record their emitted pulses and returning echoes. Microphone arrays were also placed on walls of the chamber to examine direction of emitted pulses, when necessary. High-speed video images were simultaneously recorded, which allowed us to reconstruct 3D flight trajectories for analyzing relationships between their echolocation sounds and flight maneuvers. Data revealed Doppler-shift compensation, echo-amplitude compensation, and sequential time-sharing gazing for multiple targets. Microphone array data demonstrated horizontal scanning behavior during each pulse emission in *R. ferrumequinum*. Under acoustically jammed conditions produced by conspecifics, Doppler-shift compensations, paradoxical reference frequency shifts and enhancements in tFM1 were observed in *R. ferrumequinum*. Developmental changes in ultrasonic pulse emission will be also discussed. [Supported by ONR]

[Topic1]Sensory: Audition

[Topic2]Orientation and Navigation

Invited Symposium 1

IS1-4(11:30 - 12:00)

Different modes of auditory feedback in bats

Walter Metzner[1]

University of California, Los Angeles[1]

Auditory feedback from the animal ’ s own voice is essential during bat echolocation: to optimize signal detection, bats continuously adjust various call parameters in response to changing echo signals. Horseshoe bats exhibit a particularly well-developed form of audiovocal feedback. Their echolocation pulses are dominated by a constant frequency component that matches the frequency range they hear best. To maintain echoes within this “ auditory fovea ” , horseshoe bats constantly adjust their echolocation call frequency depending on the frequency of the returning echo signal (Doppler-shift compensation behavior). Echo frequencies also affect call durations, whereas echo delays determine call rates. When examining the Lombard effect in horseshoe bats we found that noise had different effects on call amplitude and frequency indicating different neural circuits and/or mechanisms underlying these changes. In contrast to Doppler-shift compensation, the Lombard effect did not require any auditory feedback from the animal ’ s own voice.
Bats also possess a large repertoire of communication calls, which differ greatly from those emitted during echolocation. We compared the variability of echolocation pulses and one common type of communication signal and found fundamentally different feedback mechanisms for echolocation and communication.
Therefore, in bats, auditory input affects vocal output in different, well-defined ways.

[Topic1]Sensory: Audition

[Topic2]Sensorimotor Integration

Plenary Lecture 2 by Sarah M. Woolley

PL-2

Neural mechanisms of auditory-vocal communication: mapping receiver tuning to sender behavior

Sarah M. Woolley[1]

Columbia University[1]

Communication is a strong selective pressure on brain evolution because the exchange of information between individuals is crucial for fitness-related behaviors, such as mating. Given the importance of communication, the brains of signal senders and receivers are likely to be functionally coordinated. We study vocal behavior and auditory processing in multiple species of estrildid finches whose species-specific songs differ dramatically in their spectral and temporal features. Our goal is to understand how species identity and early experience interact to shape the neural systems that subserve communication. Male finches learn to produce acoustically complex songs that are both species-specific and unique to each individual. Song learning occurs during a developmental critical period and depends on auditory processing. Both sexes rely on central auditory processing to learn to recognize individual songs. I will present our studies using manipulations in song learning, electrophysiology and the analysis of behavior to test: 1) relationships between the tuning properties of auditory cortex neurons and the acoustics of species-specific song; and 2) the role of vocal learning in the development of auditory cortical tuning.

[Topic1]Communication

[Topic2]Sensory: Audition

Heiligenberg Lecture

PL-9

Electric fish in the age of genomics

Harold H Zakon[1]

The University of Texas, Austin[1]

Electric organs (EOs) evolved independently at least six times in fishes. Darwin wondered "by what steps these wondrous organs have been produced?" Strong EOs are used for defense or predation, weak EOs, along with electroreceptors, are used for object detection and communication. In each of these separate evolutions EOs derive from muscle. First, I will show that in two lineages of weakly electric fishes (Gymnotiforms and Mormyriforms) the same muscle-expressing voltage-gated sodium channel gene lost its expression in muscle and became compartmentalized in the evolutionarily novel EO. This gene then evolved rapidly, presumably due to selection for its role in shaping species-specific EO discharges in both lineages. Then I will address the origin of EOs from muscle. A consortium of investigators is beginning to answer Darwin's question. Comparisons of transcriptomes of EO and muscle from three independently derived electrogenic lineages (Gymnotiforms, Mormyriforms, and an electric catfish) have revealed a group of genes including transcription factors and cellular growth pathways that have been repeatedly recruited in the evolution of EOs and, we suggest, are responsible for many of their key features.

[Topic1]Evolution

[Topic2]Sensory: Electrosensory

Invited Symposium 2

IS2-1(10:00 - 10:30)

Mind the gap: Gap junctions and neural circuit assembly in larval zebrafish

Vatsala Thirumalai[1]

National Centre for Biological Sciences[1]

Gap junctions are cytoplasmic continuities between cells, through which ions, second messengers and small molecules can be exchanged. They are formed by assemblies of connexin proteins in vertebrates. Of the several known isoforms of connexins, Connexin 36 (Cx36) in mammals and Cx35 in teleosts are predominantly expressed in the nervous system. Using immunohistochemical methods in zebrafish, we show that Cx35 is first seen in the commissures and the optic tectum at 2dpf. Other regions like the cerebellum acquire it later at 4-5dpf. Immunoreactivity was mostly punctate and localized in fiber tracts, neuropilar areas and on somata. In the cerebellum, we localized Cx35 puncta on Purkinje neurons using cell-specific markers. In the hindbrain, the Mauthner neuron was labeled at club endings and in the axonal cap region. To test the function of Cx35 during development, we designed and microinjected splice-blocking morpholino antisense oligonucleotides specific for Cx35 and validated that Cx35 mRNA was mis-spliced. I will discuss results of our recent experiments in the cerebellum and hindbrain, which implicate Cx35 in glutamatergic synaptogenesis and neuronal activity.

[Topic1]Motor Systems

[Topic2]Motor Systems

Invited Symposium 2

IS2-2(10:30 - 11:00)

Hindbrain Chx10 neurons in the excitation of spinal locomotor circuits during zebrafish swimming

*Shin-ichi Higashijima[1,2], Yukiko Kimura[1], Chie Satou[1]

Okazaki Institute for Integrative Bioscience[1] , National Institute for Physiological Sciences[2]

Neuronal circuits in the spinal cord and brainstem play an important role for producing locomotion in vertebrates. Investigation of locomotor circuits in amniotes, however, is not trivial due to enormous complexity of their neuronal circuits. Zebrafish locomotor circuits are much simpler, making it more feasible to address this issue. We have set to define the morphology and functional properties of neurons that express a particular transcription factor. In this symposium, we focus on our studies in chx10 positive neurons in the brainstem. We first analyzed the function of Chx10 neurons in locomotion by using of channelrhodopsin (ChR). Photo-stimulation of the hindbrain of Chx10:Gal4; UAS:ChR transgenic zebrafish reliably elicited swimming, indicating that activation of Chx10 neurons are sufficient to evoke swimming. Then, we performed electrophysiological recordings to ask whether hindbrain Chx10 neurons were active during fictive swimming. We found that some of the Chx10 neurons were active during fictive swimming. Finally, to confirm necessity of the activity of Chx10 neurons for swimming, we used halorhodopsin (Halo) for optogenetic inhibition. Halo-expressing fish in Chx10 neurons immediately stopped spontaneous swimming upon green light-application to the hindbrain. These results indicate Chx10 neurons in the hindbrain play indispensable roles to generate swimming.

[Topic1]Motor Systems

[Topic2]Motor Systems

Invited Symposium 2

IS2-3(11:00 - 11:30)

Both left-right swimming and synchrony are generated by the same circuit in *Xenopus Laevis* tadpoles

***Wen-Chang Li[1], Robert Merrison-Hort[2], Hong-yan Zhang[1], Roman Borisyuk[2]**

School of Psychology and Neuroscience, University of St Andrews.[1] , School of Computing and Mathematics, Plymouth University[2]

Many neural circuits are capable of generating multiple stereotyped outputs. We have previously identified the central pattern generator (CPG) for *Xenopus* tadpole swimming that involves anti-phase oscillations of activity between the left and right sides. Here we analyse the cellular basis for spontaneous left-right motor synchrony characterised by simultaneous bursting on both sides at twice swimming frequency. Spontaneous synchrony bouts are rare in most tadpoles and they instantly emerge from and switch back to swimming, most frequently within the first second following skin stimulation. Analyses show that only neurons that are active during swimming fire action potentials in synchrony, suggesting both output patterns derive from the same neural circuit. The firing of excitatory interneurons, dINs, leads that of other types of neuron in synchrony as it does in swimming. The occasional, extra mid-cycle firing of excitatory interneurons during swimming may initiate synchrony and mismatches of timing in the left and right activity can switch synchrony back to swimming. Computer modelling supports these findings by showing that the same neural network, in which reciprocal inhibition mediates rebound firing, can generate both swimming and synchrony without circuit reconfiguration. Modelling also predicts dIN synaptic/conduction delay determines the stability of synchrony.

[Topic1]Motor Systems

[Topic2]Computational Modeling

Invited Symposium 2

IS2-4(11:30 - 12:00)

Optical probing of sensory-motor loops in the spinal cord of zebrafish larva

*Urs Boehm[1], Kevin Fidelin[1], Jeff Hubbard[1], Lydia Djenoune[1], Andrew Prendergast[1], Claire Wyart[1]

Institut du Cerveau et de la Moelle epiniere (ICM)[1]

We are interested in closed-loop processes, during which mechanical sensory feedback modulates ongoing locomotor activity. Traditional fictive preparations, in which the spinal cord is isolated and/or the animal paralyzed provides an “ open-loop ” access to spinal circuitry. Here we will present on-going efforts to dynamically couple to electrophysiology innovative optical techniques for monitoring population activity of genetically identified cell types in the intact zebrafish larva, either paralyzed or freely moving.
Our results on paralyzed animals using the novel generation of genetically encoded calcium indicators reveal different spatiotemporal recruitment of neurons in the spinal cord during different types of fictive locomotion occurring at different swimming frequencies.
We develop an approach based on bioluminescence that we express Aequorin-GFP in genetically identified sensory and motor neurons compared during fictive and active locomotion in free tailed animals. Bioluminescence signals were synchronized with detection and categorization of locomotor maneuvres using a high speed camera. For motoneurons and sensory neurons, we observed that the kinetics and amplitude of the bioluminescence signals were correlated with the manoeuvre types and differ in close and open loops.
Measuring the recruitment of identified neurons when muscles are contracting and proprioceptive pathways operate may open new path of investigation of sensorimotor integration.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Invited Symposium 3

IS3-1(10:00 - 10:30)

New insights into the mechanisms of long-term memory maintenance in *Aplysia*

***David L. Glanzman[1,2,3,4], Diancai Cai[1], Shanping Chen[1], Kaycey Pearce[1]**

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Until recently, it was believed that memories undergo a single transition from a short-term, labile state to a long-term, consolidated state wherein they remain stable. But this view of memory has been challenged by studies suggesting that consolidated memories can be rendered labile and subject to elimination. We used a simple model system, long-term sensitization (LTS) in the marine snail *Aplysia*, to examine the permanence of long-term memory (LTM). We found, as reported in mammals, that LTM in *Aplysia* appears to be lost following blockade of reconsolidation; moreover, inhibition of PKM Apl III, a homolog of mammalian PKM ζ , apparently erases LTM. But do these disruptive manipulations permanently eliminate LTM, or do they merely suppress it? To answer this question, we examined whether the memory for LTS could be reinstated after it has been disrupted by reconsolidation blockade or inhibition of PKM. We found that truncated sensitization training, which was insufficient to induce LTS in naïve animals, could reinstate LTM following its apparent elimination when reconsolidation is blocked or PKM inhibited. Taken together with our previous work, our data indicate that LTM can be fully restored despite its apparent erasure, and argue against the idea that consolidated memories can be eliminated.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Learning, Memory, & Behavioral Plasticity

Invited Symposium 3

IS3-2(10:30 - 11:00)

Memory after training with inedible food in *Aplysia* is localized to multiple sites

*Abraham J. Susswein[1,2], Jeffry M. McManus[3], Shlomit Tam[1,2], Itay Hurwitz[1,2], Hillel J. Chiel[3]

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As learning tasks evolve to become more complex, progressively more aspects of behavior are altered by the learning. Changes in multiple aspects of behavior can be coded by changing one or a small number of neural sites that affect many behaviors, or by changing many sites, each of which controls a particular aspect of behavior. After *Aplysia* learn that a food is inedible, memory is expressed in at least three ways: 1) motor responses are changed; 2) animals stop responding to food earlier; 3) memory is specific to a particular food. Are all these manifestations of learning caused by a change at a particular neural site, or is memory localized to multiple sites? We have evidence for at least 2 sites at which memory is expressed: 1) motor changes are expressed in part by regulating the synaptic output of buccal ganglia mechanoafferent neurons to neuron B4, whose activity biases the choice of a consummatory behavior; 2) earlier cessation of responses, and specificity to a particular taste, are expressed in part by a decrease in response of cholinoceptive cerebral ganglion neurons to ACh released by cholinergic taste receptors. Thus, memory is expressed at multiple sites.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensorimotor Integration

Invited Symposium 3

IS3-3(11:00 - 11:30)

Evolutionary conserved mechanisms of associative learning in *Lymnaea*

Ildiko Kemenes[1]

Sussex Neuroscience, University of Sussex[1]

Lymnaea provides highly valuable experimental models for top-down analyses of associative learning and memory. Using classical and operant conditioning paradigms, molecular mechanisms of consolidation, maintenance, retrieval, reconsolidation and forgetting of associative memory have been investigated. Long-term memory (LTM) forms after multi-trial reward and aversive conditioning but unusually, also after single-trial reward conditioning (‘ flash-bulb memory ’). Molecular mechanisms of LTM involve highly conserved signaling pathways (NO/cGMP, cAMP/PKA, PKC, PKM, MAPK, CaMKII, NMDA and AMPA receptors), transcriptional regulation of gene expression by CREB and C/EBP and new protein synthesis. Cellular mechanisms of LTM involve synaptic or non-synaptic plasticity in key modulatory interneurons of the feeding network. Importantly, a number of conserved molecular processes involved in LTM have been traced from the behavioral level to single identified neurons.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Invited Symposium 3

IS3-4(11:30 - 12:00)

Conservation and convergence in the evolution of the cephalopod neural systems mediating learning and memory

*Tal Shomrat[1,3], Ana Turchetti-Maia[1,2], Binyamin Hochner[1]

Dept. Neurobiology, Silberman Institute of Life Sciences, The Hebrew University, Jerusalem, Israel[1] , The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University, Jerusalem, Israel[2] , The Ruppin Academic Center, School of Marine Sciences, Michmoret, Israel[3]

Octopuses achieve advanced, vertebrate-like behavior with a simpler invertebrate brain. Do they utilize conservative molluscan learning and memory (L&M) mechanisms or have they evolved novel mechanisms, possibly through convergent evolution with vertebrates? Answering this question may reveal evolutionary and biological principles of L&M systems. The octopus vertical lobe (VL), a brain region highly involved in L&M, functions in parallel to the circuitry controlling behavior. The VL has the typical connectivity of feed-forward ‘ fan-out fan-in ’ association networks, with non-NMDA activity-dependent LTP at the fan-out synapses. We recently discovered that this LTP is most likely mediated by NO. We have found that 5-HT has conserved its facilitative effect on molluscan synaptic transmission in the VL but has ‘ lost ’ its long-term modulatory effects. However, it indirectly enhances the activity-dependent LTP induction. Octopamine (OA) has a similar short-term facilitatory effect but, unlike 5-HT, it attenuates LTP induction and depotentiates consolidated LTP. Thus, 5HT and OA may convey opposing reinforcement signals. In summary, the octopus VL shares global properties with complex L&M systems of vertebrates and insects, yet its synaptic plasticity is based on extensive adaptations of conserved molluscan mechanisms. This suggests that convergence to complex L&M systems can be achieved in multiple independent ways.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Evolution

Poster Session 1

PO-1001(14:30 - 15:30)

Vision I: Landing determines pattern learning in bees

*Keri V. Langridge[1], Claudia Wilke[1,2], Olena Riabinina[3], Misha Vorobyev[4], Natalie Hempel de Ibarra[1]

University of Exeter, UK[1] , University of York, UK[2] , John Hopkins University, USA[3] , University of Auckland, New Zealand[4]

Unlike terrestrial vertebrates, most insects have fixed eyes and a relatively immobile head. Consequently, perception and action are coupled in a fundamental way, whereby the movement of the animal determines what visual information is extracted from the environment. While the effect is fundamental to the study of visually-guided navigation, its role in the perception of object features has not been considered. We show that convenient landing manoeuvres determine visual learning of flower-like patterns in bees. Bumblebees consistently approached vertical targets (single-colour and bicolour discs) from below centre, and subsequently developed a preference for the colour of the lower half. When the contrast line between two colours was off-centre, bees modified their approach trajectory in response to the distribution of salient edges within the pattern, and subsequent colour preferences reflected relative exposure to each colour during the approach. This simple but overlooked mechanism could underlie learning strategies in other visual discrimination experiments, e.g. the dorso-ventral asymmetries in pattern recognition widely observed in similar experiments with bees and attributed to central specialization and/or cognitive processes. Our study highlights that besides the widely discussed differences in senses and brain capacity, morphology and action patterns also influence how animals solve sensory and cognitive tasks.

[Topic1]Sensory: Vision

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1002(15:30 - 16:30)

Vision I: Effect of flower colour, size and scent on the search time of foraging bumblebees

*Miguel A. Rodriguez-Girones[1], Francismeire J. Telles[1]

Estacion Experimental de Zonas Aridas, Spanish National Research Council[1]

In laboratory environments with uniform green background, the foraging efficiency of bumblebees (*Bombus terrestris*) depends on the size and colour of the flowers they exploit. The aim of this study was to determine whether size and colour also affect foraging efficiency in more natural environments, and whether scent could counteract the effect of small size or inconspicuous coloration. To answer these questions, we trained bumblebees to search for nectar in blue or red flowers, scented or unscented, intermingled with foliage in large flight cages with heterogeneous backgrounds. Each bee was trained with three different sizes of a single flower type (blue or red, scented or unscented). With conspicuous blue flowers, the foraging efficiency of bumblebees was unaffected by the presence of scent. Foraging efficiency was lower with inconspicuous red flowers, and with these flowers scent increased detectability and enhanced foraging efficiency. Scent can therefore be used to direct bees to their targets even at close distance. Flower size had no effect on foraging efficiency, regardless of flower colour and scent presence. Our results confirm that although bees may exploit red flowers, they are at a disadvantage when competing against pollinators, such as birds, with higher sensitivity to long wavelengths.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 1

PO-1003(16:30 - 17:30)

Vision I: Three spectrally distinct photoreceptor types in a nocturnal bull ant, *Myrmecia vindex*

*Yuri Ogawa[1], Ajay Narendra[2], Jochen Zeil[2], Jan M. Hemmi[1]

School of Animal Biology & UWA Oceans Institute, The University of Western Australia[1] , Australian Research Council Centre of Excellence in Vision Science and Centre for Visual Sciences, Research School of Biological Sciences, The Australian National University[2]

The workers of the Australian bull ant *Myrmecia vindex* forage exclusively after sunset when light levels are very low. For navigation during foraging excursions they rely solely on visual cues. We investigated the spectral and temporal sensitivity of their apposition compound eyes in order to identify possible physiological adaptations for nocturnal vision. Electroretinography (ERG) using flicker stimuli and monochromatic adaptation lights revealed the existence of three spectrally distinct photoreceptors peaking at 360 nm, 450 nm and 550 nm (n=11, 12 and12 respectively). Intracellular electrophysiology confirmed the presence and peak sensitivity of these receptor classes (n=5, 7 and 24 respectively). Similar to other night-active insects with apposition compound eyes, these ants thus also retained the potential for trichromatic colour vision. ERG recordings were also used to estimate the temporal properties of vision as a function of light intensity. The critical flicker fusion frequency increases rapidly with light intensity, reaching 130 Hz at the highest tested intensity. While the temporal resolution is lower in *M. vindex than in Myrmecia croslandi* (200 Hz), a related diurnal species, it is higher than expected for a nocturnal animal.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Poster Session 1

PO-1004(17:30 - 18:30)

Vision I: Behavioral genetic investigation of columnar circuits for motion vision in *Drosophila*

*Shiuan-Tze Wu[1], Aljoscha Nern[1], Gerry M. Rubin[1], Michael B. Reiser[1]

Howard Hughes Medical Institute, Janelia Farm Research Campus[1]

Many animals rely upon vision to navigate through their environments. The genetic toolkit available in *Drosophila melanogaster* provides exquisite access to the neural circuits that support these visually guided behaviors. We have investigated the behavioral responses of tethered flies walking on an air-supported ball presented with diverse visual stimuli. We have organized these ~150 stimuli, which probe diverse aspects of motion and object vision, into a compact protocol for behavioral genetic silencing experiments. We used recently developed driver lines to silence distinct neuron types within the lamina and medulla (the first and second optic ganglia beneath the retina). We have confirmed previous results showing that silencing either the achromatic photoreceptors (R1-6) or the feedforward lamina neurons (L1, L2) resulted in losing most behavioral responses to motion-related visual stimuli. Intriguingly, silencing the feedback neurons C2 and C3 resulted in enhanced responses to slow motion stimuli and attenuated responses to fast motion stimuli. Moreover, our finding suggest that C2 and C3 inactivation affects the responses to both progressive (front to back) and regressive (back to front) object motion, implying that feedback neurons play an important role in the core circuitry of both the motion and object detection pathways.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Poster Session 1

PO-1005(14:30 - 15:30)

Vision I: Functional investigation of a visual projection neuron in *Drosophila*

*Mai Morimoto[1], Ming Wu[1], Aljoscha Nern[1], Gerald M. Rubin[1], Michael B. Reiser[1]

Janelia Farm Research Campus, Howard Hughes Medical Institute[1]

Fly visual systems have been used extensively for nearly a century to study diverse aspects of vision. While the investigation of local motion detection (mediated by columnar circuits of the medulla) has received much attention, the functions of other pathways within the optic lobes of flies have been much less explored. To functionally characterize prominent anatomically described pathways we are currently investigating the encoding properties of neurons that project from the lobula to the central brain (so-called visual projection neurons) in *Drosophila*. In recent work, thermogenetic activation of a one such cell-type induced flies to take off, implicating this cell-type as a likely conduit for visual features that elicit escape. Using split-GAL4 lines for *in vivo* two-photon GCaMP imaging, we are imaging from several cellular compartments of this cell-type, while presenting various visual stimuli. Preliminary data from axonal imaging reveal a receptive field size which is consistent with the small spatial extent of this cell type ’ s dendrites. Questions such as how retinotopic information is being conveyed, and whether a predator ’ s loom may be encoded by this cell-type, are currently under investigation.

[Topic1]Sensory: Vision

[Topic2]Cellular Properties

Poster Session 1

PO-1006(15:30 - 16:30)

Vision I: Multi-neuronal responses from locusts presented with complex object motion

*John R. Gray[1], Paul C. Dick[1]

University of Saskatchewan[1]

The migratory locust (*Locusta migratoria*) is an ideal model system for studying neural mechanisms of visually-guided behaviours. Two well-studied neurons, the Lobula Giant Movement Detector (LGMD) and its postsynaptic partner, the Descending Contralateral Movement Detector (DCMD) respond robustly to looming objects and have been implicated in producing visually-evoked collision avoidance behaviours during flight. Recent studies have shown that DCMD firing rate modulation also reflects trajectory changes of objects that deviate to or from looming. Another, recently identified, neuron, the Late DCMD (LDCMD) also responds to looming yet nothing is known of its responses to more complex object motion. We used multichannel electrodes to record neural activity from the prothoracic ventral nerve cord of locusts during presentation of objects traveling along simple or compound trajectories. Spike sorting revealed individual units that were then segregated into categories based on the response profiles. We found evidence of multiple neuronal units with responses to visual motion that are both novel and unique. In addition to DCMD responses, we observed additional units that responded to looming, translational or compound motion. These findings will allow us to explore putative population coding of complex visual scenes that relate to adaptive flight behaviours.

[Topic1]Sensory: Vision

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1007(16:30 - 17:30)

Vision I: Collision detecting neurons in the locust lobula and their input connectomes

*Frances Claire Rind[1], Stefan Wernitznig[1,2], Gerd Leitinger[2], Peter Pölt[3], Armin Zankel[3]

Centre for Behaviour and Evolution, Institute of Neuroscience, Newcastle University, Newcastle-upon-Tyne, NE1 7RU, UK[1] , Research Unit Electron Microscopic Techniques, Institute of Cell Biology, Histology and Embryology, Medical University of Graz, Austria, A-8010[2] , Institute for Electron Microscopy, Graz University of Technology, and Center for Electron Microscopy Graz, Austria[3]

Locusts are good at using vision to detect and avoid approaching objects. Selective responses to approaching objects are generated by two LGMD neurons in the lobula. One important step occurs when information is brought together from neighbouring regions of space onto the dendrites of each LGMD neuron. Using a combination of serial block-face scanning-electron-microscopy and transmission-electron-microscopy we map the paired synapses made by small-field afferent cells onto the main dendritic fan of each LGMD. A single afferent makes synapses over a 5µm radius. In the LGMD 1, each afferent makes 1-4 synapses and these are with up to 4 different afferent cells as the second member of the pair (N=44 afferents). In the LGMD2, each afferent cell makes 1-8 synapses and with up to 6 different afferents as the second member of the pairs (N=43 afferents). Synaptic density along a single LGMD 2 dendrite, 33.7 µm length, was 0.24/ μm^2 (116 synapses) over the thicker, proximal half and1.04/μm^2 (235 synapses) over the distal half. Local hotspots were also identified these had 2.16 synapses/μm^2 for the LGMD 2 and 3.12 synapses/μm^2 for the LGMD 1 when this was measured over a 2 µm length of dendrite.

[Topic1]Sensory: Vision

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1008(17:30 - 18:30)

Vision I: The effect of ocellar occlusion on the optomotor performance of the American cockroach

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The American cockroach, *Periplaneta americana* L., is a dark-active insect with a pair of apposition type compound eyes and two dorsal ocelli. It has an optomotor response down to light intensity of 0.005 lux. Here we compared the optomotor performance of untreated cockroaches with ones manipulated in two different ways: covering the ocelli or the compound eyes by opaque paint. For control, experiments were also done with both types of eyes occluded.

When the ocelli are occluded, the optomotor performance elicited by moving vertical black and white stripes at 5 lux is weaker than the response of the untreated animals at 0.05 lux. The lowest light intensity under which significant responses are found when ocelli are occluded is 0.05 lux. No significant responses are present when either the compound eyes or both types of eyes were occluded. The total turning distances covered and the maximum speeds achieved by the cockroach were both reduced by painting over one or both types of eyes.

These results support the idea that cockroach ocelli are detectors of average illumination. When the ocelli are occluded the cockroach behaves as if it were exposed to 10-100 times lower light intensity.

[Topic1]Sensory: Vision

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1009(14:30 - 15:30)

Vision I: Opposing effects of expansion and parallax cues in foraging butterflies

*Finlay J Stewart[1], Michiyo Kinoshita[1], Kentaro Arikawa[1]

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Flying insects presumably use motion cues to gauge the distance of nearby objects, but it is unclear which specific features of the visual scene form the basis for this process. We investigate this question by training swallowtail butterflies (*Papilio xuthus*) to feed from a coloured target presented on a monitor on the floor of a cage. The trained animals' flight is then tracked in 3D in real time, allowing the appearance of the target to be manipulated to create the illusion of depth from the butterfly's perspective. We quantify how smoothly the animals descend by measuring the altitude at which they achieve their maximal downward velocity. When only parallax cues are manipulated, illusory targets deeper “ below ” the monitor do indeed elicit more violent approaches. However, if only the rate of expansion is altered, the opposite effect is seen. More “ realistic ” stimuli with congruent parallax and expansion features elicit intermediate behaviour. We therefore conclude that retinal expansion (and/or angular size) has an attractive effect, which is moderated by repulsion based on retinal movement. Together these responses would allow the animal to fly towards food sources but land on them safely.

[Topic1]Sensory: Vision

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1010(15:30 - 16:30)

Vision I: A blue-absorbing pigment causing a dual-peaked blue receptor in the eye of the butterfly *Graphium sarpedon*

*Pei-Ju Chen[1,2], Hiroko Awata[1], Atsuko Matsushita[1], Kentaro Arikawa[1]

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The eye of the common bluebottle butterfly, *Graphium sarpedon,* is furnished with three types of ommatidia, which are distinguishable by strong, weak, and no fluorescence under UV epi-illumination. In the weakly fluorescing ommatidia, two of the nine photoreceptors (R1 and R2) express a blue-absorbing visual pigment. The spectral sensitivity of these cells however exhibits two distinct peaks at 400-420 nm and 500 nm, and thus we termed it a dual-peaked blue (dB) receptor. The spectral sensitivity of dB receptor does not match the predicted spectrum of any visual pigment, but the sensitivity can be reasonably explained assuming filtering by hypothetical photostable pigments. We found a yellowish perirhabdomal pigment located only at the distal tip of the photoreceptors of weakly fluorescing ommatidia. The yellowish pigment emits whitish fluorescence under blue-violet excitation, indicating that the pigment could act as a blue-absorbing spectral filter for the photoreceptors in the ommatidia. Modeling the effects of the yellowish pigment successfully reproduced a conspicuous dual-peaked profile similar to the recorded sensitivity of dB receptor. Complex interplay of visual pigments and spectral filter pigments makes the *Graphium* eye spectrally very rich, with 15 distinct spectral receptor types – the most among insects studied so far.

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Poster Session 1

PO-1011(16:30 - 17:30)

Vision I: How is wavelength information coded in photoreceptor axons and second order neurons in the lamina of the Japanese yellow swallowtail butterfly, *Papilio xuthus*?

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In animals with more than three spectral classes of photoreceptors the coding of wavelength information may be a problem. In such cases, the number of neurons needed in high order neuropils in a classical, pair-wise opponency system could be very large. *Papilio xuthus* has eight classes of photoreceptors and has been shown to be tetrachromatic when foraging. Detailed anatomy of the first optic ganglion, the lamina, suggests that the photoreceptor axons form synaptic connections with each other, in addition to their synapses with second order neurons, the LMCs. We performed intracellular recordings of >50 photoreceptor axons and >40 LMCs to find out if any colour processing takes place in the lamina. We found colour-opponency in a large proportion of the photoreceptors. All recorded LMC responses, however, were characterized by a similar, wide spectral sensitivity from UV to long wavelengths. Possibly these LMCs form an achromatic channel, like that formed by the R1-6 photoreceptors in flies, whereas the long visual fibres of R1 and R2 in *P. xuthus* would transmit colour information to the next neuropil, the medulla, already partly coded by the found opponency. This hypothesis and the previous findings of butterfly colour coding will be discussed.

[Topic1]Sensory: Vision

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1012(17:30 - 18:30)

Vision I: Visual acuity and contrast sensitivity for a large-field moving stimulus in budgerigars

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Coordinated visual motion in the large section of the visual field is caused by the self-motion. If motion of the visual scene is unidirectional for some time the gaze-holding behaviour occurs together with the gaze-changing behaviour in a nystagmic manner. The optomotor reflex moves the head and the optokinetic reflex moves the eyes in a pattern of interchanging slow pursuit and fast saccadic phases. We used the optomotor response to measure visual acuity and contrast sensitivity for a large-field moving stimulus in budgerigars. Achromatic sinusoidal gratings were presented on six computer monitors positioned in an arc. Using this method we found a cut-off visual acuity of 2 cycles/degree and a maximum contrast sensitivity of 29. Visual acuity measured this way is lower and contrast sensitivity is higher if compared to the thresholds for moving small-field gratings in the two-choice discrimination task. These behavioural results illustrate differential tuning for spatial information in the visual pathways, which are responsible for processing of large-field and small-field motion stimuli.

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Poster Session 1

PO-1013(14:30 - 15:30)

Vision I: Stimulus motion improves contrast sensitivity in budgerigars (*Melopsittacus undulatus*)

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Survival of small animals often depends on their ability to quickly notice environmental changes. Birds are thought to have excellent vision. However, earlier experiments showed that they have relatively low contrast sensitivity for stationary targets. We suggest that motion may be an important visual cue that could provide birds with higher contrast sensitivity. To test this hypothesis, we performed behavioural discrimination experiments with five budgerigars (*Melopsittacus undulatus*).
The birds were trained to distinguish between a homogenous grey stimulus and equally bright sine-wave gratings of spatial frequencies between 0.48 and 6.5 cycles/degree, and Michelson contrasts between 0.71% and 99.34%. The gratings were either stationary or drifting with velocities between 0 and 12.6 degree/second. Budgerigars were able to discriminate lower contrast when the gratings were drifting, which supports our hypothesis. The largest effects were seen with low spatial frequency, and contrast sensitivity increased with higher velocity of pattern movement. However, we did not see changes in spatial resolution.
Our findings indicate that motion cues can have strong positive effects on visual perception of birds. This is similar to earlier results on human vision. It appears that contrast sensitivity, tested solely with stationary stimuli, may underestimate the sensory capacity of the studied objects.

[Topic1]Sensory: Vision

[Topic2]Cognition

Poster Session 1

PO-1014(15:30 - 16:30)

Vision I: Optimising countershading for camouflage: matching the light environment increases survival

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Countershading, a gradation of colour whereby surfaces oriented towards the sun are generally darker is one of the most ubiquitous forms of animal colouration. A long accepted function of countershading is to counteract the gradient in reflected light caused by overhead illumination, and thus interfere with 3D object recognition via shape-from-shading. If true, the presence of countershading in prey would inform us about predator visual cognition. We have previously developed computational models to calculate what pattern of countershading would be optimally cryptic for location, weather and animal pose. We experimentally tested how carefully-tuned countershading needs to be to achieve crypsis. Avian baits were constructed from paper tubes, printed with the predicted optimal countershading for a specific location (Bristol, UK), date and different weather conditions (sunny or overcast). Predation rates were significantly higher for baits featuring the incorrect cryptic strategy – ‘ cloudy baits ’ were predated more often in sunny weather and ‘ sunny baits ’ were predated more often in cloudy conditions (GLMM; interaction delta deviance=28.08, df=6, $p < 0.0001$). Our results demonstrate that prey patterning must be optimised for illumination conditions, else crypsis is compromised. This work suggests that birds are likely to be relying upon shape-from-shading cues, and that counter-shading disrupt this.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 1

PO-1015(16:30 - 17:30)

Vision I: Colour and polarisation processing in Stomatopods

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The complexity of the stomatopod visual system, including its twelve colour channels, has long puzzled scientists. New results from behavioural experiments show that stomatopods have surprisingly poor colour discrimination, suggesting they process colour differently from other animals. Using an interval decoding strategy, combined with scanning eye movements, would allow them to perceive colour based on the peak sensitivity of the most responsive cell. This in turn would allow rapid and reliable colour recognition, but at the cost of fine discrimination. Interestingly, this ' winner-takes-all ' system shows computational parallels with the way the inferior temporal cortex (IT) of primates encodes colour and is not the first time such evolved convergence has been suggested between the visual systems of arthropods and mammals. We are now identifying neuronal pathways through the optic neuropils, confirming and describing the retinotopic connections of colour and polarisation information. Laterally extending collaterals of neurons representing the eye ' s equatorial chromatic channels, projecting to the lobula from the medulla, are now recognized as intersecting the lobula parallel relays from the achromatic upper and lower retina. This arrangement suggests information from the chromatic receptors is integrated with information from achromatic neurons in the lobula before projecting into optic glomeruli of the protocerebrum.

[Topic1]Sensory: Vision

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1016(17:30 - 18:30)

Vision I: Circular polarisation vision in the stomatopod *Gonodactylaceus falcatus*

*Rachel Templin[1], Martin How[2], Yakir Gagnon[1], Nicholas Roberts[2], Justin Marshall[1]

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Stomatopod crustaceans are best known for their destructive raptorial appendages, however, their visual system is an equally impressive and unique feature. Commonly known as mantis shrimps, stomatopods utilise multi-channel spectral information (including UV) but also both linear and circular polarisation, the latter being a unique ability in the animal kingdom. Circular polarisation vision may allow covert communication system as several but not all species also reflect circular polarised light from specific, often displayed body parts. *Gonodactylaceus falcatus*, a species of stomatopod commonly found in reef environments, provides strong support for this hypothesis as a large percentage of its body is covered in circularly polarised patterns. Transmission Electron Microscopy (TEM) of the circular polarisation vision photoreceptors and subsequent optical modelling suggest that this species has a near optimum system for detecting circularly polarised light. However, a two-way behavioural choice test has revealed that *G.falcatus* are unable to discriminate between left and right circularly polarised light (p=0.383). Our current hypothesis suggests that their evolved circularly polarised light sensitivity is for detection of mate-choice signals, for which, in this species, the handedness of the signal is unimportant.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 1

PO-1017(14:30 - 15:30)

Vision I: Electroretinogram of a stomatopod crustacean *Haptosquilla tuberosa*

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The eye of all Gonodactyloidea stomatopods is composed of three regions, a mid-band that is composed of 6 rows of ommatidia and two hemispheres separated by the midband. From molecular biology to behaviour studies, we know a great deal about the functional partition of the eyes of these stomatopods. However, information concerning the propagation of signal after retinular cells, except some morphological studies, are still lacking. In addition to redundancy, furthermore, some of the retinular cells show great difference in size for no obvious reasons. Here we use electroretinography (ERG) to analyse the light responses of *H. tuberosa*. The ERG of stomatopods shows a slow oscillation of potential after initial strong response similar to that of lobsters. However, the so called slow oscillation potential in stomatopod occurred at a relatively higher frequency than those observed in lobsters. By blocking hemisphere or midband with black paints, the bio-electric signal from various region of the eye were also analysed. We speculate that such slow oscillation potential in stomatopods may result from different response speed of retinular cells rather than the response of the neuronal responses of downstream neurons.

[Topic1]Sensory: Vision

[Topic2]Circadian Rhythms

Poster Session 1

PO-1018(15:30 - 16:30)

Vision I: Polarisation Vision: the new currency of communication

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Colour vision and use of colour for communication and camouflage is a rich sub-discipline in neuroethology. Polarisation vision for navigation and other ‘ matched filters ’ tasks, is equally well investigated. Here, we continue to reveal how, for some animals in some environments, polarisation signals and polarisation vision also provides the observer with information about object contrast. Both aquatic and terrestrial habitats are now revealing a rich language of polarisation signalling and communication but probably not camouflage. For many (but not all) cephalopods and crustaceans but probably not (most) fish, polarisation may be more useful than colour. This presentation attempts to summarise our current ideas (also included elsewhere at this conference), and shows results from a new generation of bio-inspired, nanofabricated, very cool polarisation video cameras, as well as anatomical, electrophysiological and behavioural explorations in this expanding area of visual neuroscience.

[Topic1]Sensory: Vision

[Topic2]Communication

Poster Session 1

PO-1019(16:30 - 17:30)

Vision I: Spectral sensitivity of two species of Southern Hemisphere Lamprey *Mordacia mordax* (Richardson) and *Mordacia praecox* (Potter)

*Rachael E Warrington[1,2], Nathan S Hart[1,2], Wayne IL Davies[1,2], Howard S Gill[3], Ian C Potter[3], David M Hunt[1,2,4], Shaun P Collin[1,2], Jan M Hemmi[1,2]

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Visual spectral sensitivity of downstream/adult stages of two closely related lampreys; short-headed lamprey, *Mordacia mordax* and precocious lamprey, *Mordacia praecox* were investigated using electroretinography. Responses to monochromatic lights (400 – 650 nm) were recorded from isolated eyecup preparations, revealing peak sensitivity at 517 nm for *M. mordax* and 559 nm for *M. praecox*. Monochromatic adaptation lights were applied to determine the number of spectrally distinct photoreceptor types. Clear shifts in spectral sensitivity could be achieved for *M. praecox* by short and long wavelength adaptation light, indicating a second photoreceptor type. No shift was found in *M. mordax*, suggesting one spectral photoreceptor type in the downstream migrant, supporting previous microspectrophotometry research. Both species possess a yellow/green eyeshine elicited from a retinal tapetum. This effects the spectral sensitivity, reducing reflectance of short wavelength light (approximately

Poster Session 1

PO-1020(17:30 - 18:30)

Vision I: Fiddling with eye design: the comparative architecture of polarization vision in the genus *Uca*

*Martin J. How[1,2], John Christy[3], Shelby E. Temple[1,2], Jochen Zeil[4], Justin Marshall[2], Nicholas W. Roberts[1]

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Polarized light in the natural environment is produced by the reflection, refraction, scattering and filtering of sunlight. Many animals are sensitive to polarized light, but most of our understanding of polarization vision comes from terrestrial insects, whose sensitivity is often restricted to the polarized sky field for use in navigation. Crustaceans differ in that their polarization sense can extend across the entire visual field and so is likely to play a role in a broad range of visual functions, including contrast enhancement and object detection. Fiddler crabs (genus *Uca*) show anatomical, electrophysiological and behavioural evidence for a highly sensitive, two-channel polarization vision system. Some *Uca* species show further anatomical adaptations specific to their polarization environment. Here we present comparative data gathered using transmission electron microscopy, which demonstrate variation in the architecture of polarization vision between species occupying different habitats. We correlate these findings with imaging polarimetry that describe the polarized light levels and distribution in intertidal habitats occupied by fiddler crabs.

[Topic1]Sensory: Vision

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1021(14:30 - 15:30)

Vision I: Recognition of depth-rotated human faces by fish

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Reliable vision-based recognition is of fundamental importance to many species. However, the task is far from trivial as an object ’ s appearance can vary greatly as a function of viewing direction. It has been hypothesized that animals with simpler brains, such as those lacking a cortex, tackle this problem in a fundamentally different manner to animals such as primates. However, the mechanisms underlying object recognition remain poorly understood. In this study we explored the extent to which fish, which lack a cortex, can recognize images of objects rotated in depth. Using operant conditioning, archerfish (*Toxotes chatareus*) were trained to discriminate between two frontal views of standardised human faces. We then tested whether they could continue to discriminate the stimuli when rotated in depth by 30 ° , 60 ° and 90 ° . All fish learned to discriminate the two frontal views and continued to discriminate images rotated by 30 ° and 60 ° but not 90 ° . These results demonstrate a considerable capacity for the fish to cope with changes in appearance, speaking against a strict template matching model. In fact, the results mimic those found in humans, suggesting that a common mechanism may be being utilised across these very diverse species.

[Topic1]Sensory: Vision

[Topic2]Cognition

Poster Session 1

PO-1022(15:30 - 16:30)

Vision I: Pop-out visual search of moving targets in the archer fish

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From detecting food to locating lurking predators, visual search -- the ability to find an object of interest against a background -- needs to be accurate and fast to ensure survival. In mammals, this led to the development of a parallel search mode, pop-out, which enables fast detection time that is not dependent on the number of distracting objects. Although it may be beneficial to most animals, pop-out behavior has been observed only in mammals, where its neural correlates are found as early as V1 in contextually modulated cells that encode aspects of saliency. This computation enables the target to pop-out due to its salient features. Here we show that archer fish can also utilize this important parallel search mode by exhibiting pop-out of moving targets. We then explore neural correlates of this behavior and report the presence of contextually modulated cells in the optic tectum. For additional support to link contextually modulated cells with saliency computation and pop-out behavior we found that both the behaving fish and cellular modulations exhibit additive response to multiple visual features. These findings indicate that similar neural computations may facilitate pop-out behavior in mammals and fish, suggesting a universality of pop-out mechanisms across vertebrates.

[Topic1]Sensory: Vision

[Topic2]Cognition

Poster Session 1

PO-1023(16:30 - 17:30)

Vision I: Stimulus specific adaptation of common visual features may contribute to "pop-out" perception: an electrophysiological study in the barn owl"

*Yoram Gutfreund[1], Arkadeb Dutta[1]

The Rappaport Research Center and Faculty of Medicine, The Technion[1]

In humans and primates, the so called "pop-out" effect governs saliency perception. It was recently shown that barn owls perceive targets that are differently oriented from background distracters as salient. The goal of this study was to search for neural correlates in the optic tectum (OT) of barn owls. Single and multi-unit responses to a bar placed inside the RF, were recorded, either alone (singleton condition), or embedded in an array of similar oriented distracters (uniform condition), or in an array of differently oriented distracters (pop-out condition). When the display was static on the screen, there was no difference between the responses in the pop-out condition versus the uniform condition. However, when the display was continuously moved on the screen, sensitivity to bars in the pop-out condition appeared. i.e., every time an odd target crossed the RF the neurons responded more compared to a distracter. In addition, we found that tectal neurons exhibit stimulus-specific adaptation to the orientation of a bar, a finding which may explain the "pop-out"-like sensitivity observed when the display was moving. These findings may explain the enhanced saliency of odd orientations in behaving owls that actively scan the visual display.

[Topic1]Sensory: Vision

[Topic2]Cognition

Poster Session 1

PO-1024(17:30 - 18:30)

Vision I: Visual search behavior in barn owls

*Julius Orlowski[1], Hermann Wagner[1]

RWTH Aachen University[1]

Despite many years of research it remains unclear whether primates and non-primates use similar mechanisms in visual search tasks. We study search strategies in barn owls. These animals have only small eye movements and use mainly head movements in visual search. This allows tracking gaze with a head mounted microcamera, the Owlcam.
Owls were confronted with full scene settings containing search arrays of varying difficulty. These search arrays contained a singular target and 15 – 63 distracters. We started with typical simple searches where the target differed in luminance (grey versus white discs) or orientation (differently oriented bars) from the uniform distracters, and trained our barn owls to detect these targets. Then, these features were merged to a conjunction task; here the odd target was a unique conjunction of orientation and intensity. We analyze their saccadic gaze paths, fixations, and search times in these settings to describe their search behavior. The independence of search time from the number of distracters in the simple search task shows that the owls employ similar mechanisms as humans do. The owls can also find the target in the conjunction-search task by using a serial search, again similar as in humans.

[Topic1]Sensory: Vision

[Topic2]Cognition

Poster Session 1

PO-1025(14:30 - 15:30)

Vision I: Seeing during the day and night - a novel application of a liquid crystal display for mapping the receptive fields of light and dark adapted photoreceptors in insects

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Advances in liquid crystal display (LCD) technology allow for high resolution, fast refresh rates (120 Hz) and relatively high luminance, approaching that of natural conditions. Using such a display we intracellularly recorded and mapped the spatial receptive fields of photoreceptors in the nocturnal sweat bee *Megalopta genalis.* For comparison we repeated this in two diurnal bees, the blue-banded bee *Amegilla cingulata* and the honeybee *Apis mellifera*. We used dark moving objects on a bright background and vice versa, allowing measurements in both in light- (LA) and dark-adapted (DA) states. Our preliminary data confirm the usefulness of LCD displays (in combination with models for optical blur) as a fast, reliable and accurate means to study spatial resolution in insects. Our honeybee data are in close agreement with physiological and behavioural results reported previously. LA photoreceptor acceptance angles in *Amegilla* are narrow, as expected for a fast-flying diurnal insect. Acceptance angles in *Megalopta* are considerably smaller in the LA day state than in the DA night state. Since these bees have very large rhabdoms (width 8 µm), these smaller LA day values imply the presence of iris pupillary pigments distal to the rhabdom that alter acceptance angle from day to night.

[Topic1]Sensory: Vision

[Topic2]Neuromodulation

Poster Session 1

PO-1026(15:30 - 16:30)

Audition I: A study for an application of bat sensing algorithm to radar systems

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Active sensing systems abound in nature. For example, echolocating bats emit ultrasonic signals and analyze returning echoes to measure their surroundings. Especially, bat echolocation enables an acoustic representation of the environment through precisely controlled outgoing sonar signals (frequency) to maintain an incoming signal (frequency) constant.

So, we aim an FMCW (Frequency-Modulated Continuous-Wave) radar system, which realizes high resolution at low cost, by mimicking the active sensing system of the bat. The basic principle of FMCW radar requires determining the frequency difference (beat frequency) between the outgoing and incoming signals. In this method, Fast Fourier Transformation (FFT) is used to determine the beat frequency. The problem of this method is that the frequency resolution of the FFT depends on the sampling rate and number of FFT points calculated. This means that in order to separate the two objects closely located, we need high sampling rate and a lot of FFT points. So, we propose to place LPF (Low-Pass Filter), in front of FFT, for removing one beat frequency for two objects closely located. Then, we also control of outgoing frequency to maintain an incoming frequency constant. By the proposed method, we have confirmed that resolution is improved to 0.5m from 1.2m.

[Topic1]Sensory: Audition

[Topic2]Sensory: Electrosensory

Poster Session 1

PO-1027(16:30 - 17:30)

Audition I: What ’ s the buzz? Sensory-motor coupling during high-speed echolocation in bats

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Bats can operate in darkness through echolocation. Immediately before prey capture bats increase call emission rates to a buzz with ³200 calls/s that seem too high for informed reactions, leaving the buzz ’ functional significance an enigma. To investigate sensory-motor control during the buzz of the insectivorous bat *Myotis daubentoni*, we removed prey, suspended either in air or on water, before expected capture. The bats adjusted their echolocation by shortening the buzz gradually the earlier the prey was removed. At removals later than ca. 100 ms (33 cm) before expected capture the full echolocation sequence was emitted. Bats trawling over water also performed the full sequence of capture movements, whereas in air bats aborted the capture sequence even when prey was removed very late. Thus buzz and capture movements are dynamically adapted based on sensory feedback. The results indicate that echolocation is controlled mainly by acoustic sensory feedback, whereas capture movements are adjusted according to both acoustic and somato-sensory feedback and points to separate (but coordinated) central motor control of the two behaviors emphasizing the importance of multimodal processing to control behavior. Bat echolocation provides a unique window to extremely fast decision processes in naturally behaving animals.

[Topic1]Sensory: Audition

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1028(17:30 - 18:30)

Audition I: Biosonar accommodation in phyllostomid bats

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Accommodation in vision is the process of lens shape adjustments to the object distance of interest. Studies in bat echolocation have demonstrated that vespertilionid bats are capable of dynamically adjusting their sonar beam shape in flight. If this is also the case for phyllostomid bats is unknown. Here we investigate whether phyllostomid bats (P. discolor) adapt their echolocation parameters such as sound pressure level (SPL), inter pulse interval (IPI) and sonar-beam footprint (SBF) when accommodating their sonar to objects at different distances. Four bats were trained to sit on a stationary platform while tracking an approaching object with echolocation. The object, a parabolic plastic strip (1.5 x 5 cm), was moved along a nylon string from >1.0 m distance towards the bat. Echolocation activity was recorded with a 45 channel parabolic microphone array at 1.9 m distance. All bats decreased not only the IPIs (as demonstrated for E. fuscus), but also SPLs with decreasing object distance. The -3dB SBF was measured in the horizontal and vertical distribution at a -3dB intensity relative the maximum recorded level applying a 3D Gaussian fit. Pilot data indicate a widening of the SBF for decreasing object distances below about 0.3 m.

[Topic1]Sensory: Audition

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1029(14:30 - 15:30)

Audition I: Direction and acoustic characteristics of pulses emitted by FM bats (*Pipistrellus abramus*) during group flight in the field

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In the field, echolocating bats are often observed to forage in a group. To investigate the jamming avoidance response of FM bats (*Pipistrellus abramus*), we measured the flight paths and sonar sounds emitted by wild bats during natural foraging with conspecifics using a 32-ch microphone-array, focusing on the terminal frequency (TF) of the bats ’ FM sounds. To remove the flight-induced Doppler error, we first confirmed the procedure for correcting the frequency of the Doppler-shifted sounds using a telemetry microphone and microphone array system in a laboratory flight chamber. The compensated TFs showed an error within ± 0.2 kHz, which is sufficiently small for investigating bats ’ TFs in the wild, which momentarily changes by a few kHz. When two bats were flying together, one bat often emitted pulses toward the other bat, suggesting that they detected the position of each other. Furthermore, the difference in the TFs between individuals was approximately 4 kHz whereas the TFs of the two bats were almost the same when one of the bats flew away from the foraging space. This suggests that the bats adjust their own TFs to avoid overlap of the TF frequency range with conspecifics while occupying the same space during foraging.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1030(15:30 - 16:30)

Audition I: An oddball task of sound sequence discrimination in songbird auditory forebrain

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Perception of spoken language requires discrimination and rule extraction of sound sequences. Songbirds like Bengalese finches are adequate species to explore the neural mechanisms of such abilities. Their songs are structurally and sequentially complex with branching transitions of sound elements or chunks, and birds may process these sound inputs with reference to complex sequential information. We examined the neural processing of sound sequences in an avian secondary auditory forebrain area NCM, which is hypothesized to store memory of conspecific vocalizations. Single-unit activities were recorded in anesthetized male Bengalese finches. We applied an oddball paradigm and compared the neural responses to frequently presented sound with infrequently presented sound. In a simple experiment, e.g. sound element A is presented at 10% probability as a target and B is 90% as a background in random order, around 40 % auditory neurons responded stronger to the target element. In an advanced experiment, e.g. sound sequence ABA is presented at 10% probability and sequence AAB is 90%, a few neurons strongly responded to the target sequence. Combination of these neurons may allow processing of higher-order sound sequences and rule abstraction. (Work supported by Grant in Aids from MEXT #2324033 and #25590202 to KO).

[Topic1]Sensory: Audition

[Topic2]Cognition

Poster Session 1

PO-1031(16:30 - 17:30)

Audition I: Functional changes between seasons in the songbird brain

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Songbirds are an excellent model for investigating seasonal plasticity in the perception of learned complex acoustic communication signals. European starlings (*Sturnus vulgaris*) sing throughout the year distinct types of song that bear either social or individual information. Although the relative importance of social and individual information changes seasonally, evidence of functional seasonal changes in neural response to these songs remains elusive. We thus decided to use in vivo functional magnetic resonance imaging (fMRI) and electrophysiological recordings to examine auditory responses of starlings that were exposed to songs that convey different levels of information (species-specific and group identity or individual identity), both during (when mate recognition is particularly important) and outside the breeding season (when group recognition is particularly important). Our results show an interaction between seasons and the level of information conveyed by starlings ’ songs. Starlings therefore appear to respond preferentially to different types of partners according to the time of the year and of the reproductive cycle. This study provides evidence that auditory processing of behaviourally-relevant (conspecific) communication signals changes seasonally, even when the spectro-temporal properties of these signals do not change.

[Topic1]Sensory: Audition

[Topic2]Cognition

Poster Session 1

PO-1032(17:30 - 18:30)

Audition I: Dopaminergic responses to song in the songbird auditory forebrain

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The auditory pathway of female songbirds responds selectively to male conspecific song. Studies in other vertebrates suggest that neural selectivity of responses to behaviorally relevant sounds is mediated at least partly by monoaminergic input. Male song induces monoaminergic activity in the auditory forebrain of female songbirds within minutes of its presentation, but whether this response occurs only for song, rather than for any sound, is not known. In this study, we exposed female white-throated sparrows to male song, behaviorally irrelevant tones, or silence and used high-performance liquid chromatography with electrochemical detection to measure the resulting monoamine release in microdissected brain areas of the auditory system. The dopaminergic response in the caudomedial nidopallium was higher in birds that heard song than in birds that heard tones, showing that the response may be selective for conspecific song. In this seasonally-breeding species, endocrine state is thought to change the behavioral relevance of song; however, in our study, selective responses for conspecific song were detected in both breeding and non-breeding endocrine states. Thus, although the behavioral relevance of song changes seasonally in this species, the dopaminergic response is unlikely to change accordingly.

[Topic1]Sensory: Audition

[Topic2]Neuromodulation

Poster Session 1

PO-1033(14:30 - 15:30)

Audition I: Anatomical and physiological characterization of the turtle sound localization circuit

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The turtle auditory system is interesting from both an evolutionary and a neural coding perspective. Focusing on the sound localization circuit, we characterized the anatomy and physiology of the turtle auditory system. Tract tracing techniques were used to describe the connections among the auditory nuclei. Turtles brain stem nuclei are connected in the same pattern as other reptiles, including birds. Distinct nuclei include nucleus angularis, nucleus magnocellularis, nucleus laminaris, the superior olive, and the torus semicircularis. Cell types in angularis, magnocellularis and laminaris were described and digitally reconstructed. An isolated head preparation was developed that enables in vivo-like, single unit physiological recording. Neurons were characterized by best frequency, threshold and phase locking. Additionally, binaurally responsive neurons were found in the region of nucleus laminaris, which exhibited a range of interaural time difference sensitive responses. Although the evolutionary position of testudines is not yet resolved, it is most likely that turtles share their most recent common ancestor with the archosaurs. We hypothesize that turtles likely reflect the ancestral condition of auditory processing for the archosaur clade.

[Topic1]Sensory: Audition

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1034(15:30 - 16:30)

Audition I: Encoding of temporal pitch revisited: Evaluation by cochlear microphonics

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Pitch is the perceptual correlate of periodicity of sound. Even if all the energy at the fundamental frequency (F0) is removed, a periodic complex tone retains the same pitch of missing fundamental frequency. The temporal pitch has been mostly discussed in the central auditory system while less reported in the peripheral system. The purposes of this study were to confirm that the F0 is created in the basilar membrane (BM) of the cochlea and to investigate how the temporal pitch is encoded in the cochlea. Cochlear microphonics (CM) were recorded from the round window for confirming frequency characteristics of vibration of the BM to periodic complex tones in order to generate F0. The experiments were carried out in the condition where a frequency component corresponding to F0 or frequency components of the sound stimuli were masked by low or high pass noises, respectively. The results showed that the fundamental frequency component existed in CM. The magnitude of F0 component decreased for high pass masking but little for low pass masking. The findings suggest that the temporal pitch is encoded by amplitude modulation rates of BM rather than the location on BM.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1035(16:30 - 17:30)

Audition I: Brain activity involved in semantic concepts from acoustic characteristics of phonemes

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This study investigated brain mechanisms for semantic processing of sounds of phonemes. It has been reported that not only words but also phonemes represent meanings. For example, front vowels (i and e) could associate with small and bright things, and back vowels (u and o) could associate with big and dark things. The link between phonemic features and their connotation is independent of language. It is reasonable to expect that there is a neural basis for the phoneme-meaning connection. Subjects attended to auditory primes, vowels or adjective words (control stimuli), and categorized brightness of visual targets as either bright or dark under functional magnetic resonance imaging. The acoustic primes had semantic relationship to brightness. It was hypothesized that incongruent prime-target combinations will interfere with the processes for visual recognition and elicit specific brain activation for each type of auditory prime. Therefore brain activity for the interference of semantic relationship could be identified. These result shed lights on the critical roles of the phonemic feature of speech sounds in semantic cognition.

[Topic1]Sensory: Audition

[Topic2]Cognition

Poster Session 1

PO-1036(17:30 - 18:30)

Audition I: Neural mechanisms for signal detection under noise in a katydid

*Konstantinos Kostarakos[1], Heiner Römer[1]

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Males of the katydid *Mecopoda elongata* produce calling songs (chirps) for female attraction. These species specific, broad-band calls are strongly masked by signals of a competing, sympatric living Mecopoda species, where males produce continuous trills of high amplitude. The males of chirpers, however, detect their signal reliably under these noisy conditions, even when the trill is much louder. The spectral properties of the two calling songs are rather similar, however, only the chirp includes a frequency band at 2 kHz.
By using intracellular recordings we identified auditory interneurons responding selectively to the chirp. Several types of interneurons revealed two major differences in response.
1. Neurons are initially strongly excited by the high frequency of the trill but the response is followed by strong adaptation. Due to the longer chirp period the neurons do not adapt to the chirp and respond to its low frequency components that differ from the trill. This mechanism is referred to as novelty detection.
2. Neurons respond only to the chirps, even at signal-to-noise ratios of -21 dB, as these neurons are sharply tuned to 2 kHz. Their dendritic arborisations overlap with the axonal terminations of low frequency receptors that reveal similar selective responses.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1037(14:30 - 15:30)

Audition I: A comparative approach to acoustic pattern recognition in crickets

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The songs of many crickets exhibit two time scales: a series of pulses with a given carrier frequency is broadcast at a particular pulse rate on the short time scale, while groups of pulses, also called chirps, provide information on the long time scale. Which spectral and temporal cues do female crickets evaluate for recognition of their conspecific song ?

For that goal we tested the phonotactic responses of female crickets of several species within the genus *Gryllus* (n=8) towards artificial song patterns. Preference functions for carrier frequency exhibited best responses at 4 – 6 kHz. The filter functions for pulse rate varied most between species, ranging from 30 pulses per second, pps, to 80 pps. Notably, species differed in the width of these filter functions and in the preference for pulse duty cycle. On the long time scale, two classes of preferences were observed. Females of some species preferred short chirps, equivalent to a low chirp duty cycle, for other species a preference for long chirps and thus high chirp duty cycles was observed.

Our comparative data on preference functions in crickets allows to trace the axes of evolutionary change for preference functions and song signals.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1038(15:30 - 16:30)

Audition I: Sensory adaptation affects sound localization cues in *Ormia ochracea*

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The parasitoid fly *Ormia ochracea,* a model organism for sound localization, finds its singing-cricket host using binaural differences in the latency and/or response strength of auditory receptor neurons as cues. Previous mechanical and physiological studies of localization cues have examined responses to single sound pulses, but the natural signal is a train of rapidly repeated pulses. Work on other systems shows that such signals induce adaptation of receptor-neuron responses that can affect binaural cues for sound location. We examined this issue in *Ormia* by recording compound action potentials from the auditory nerve and vibration of the tympanal membrane in response to cricket-like pulse trains.

Compound action potentials decrease in amplitude and increase in latency for successive sound pulses in a train in an intensity- and pulse-rate-dependent manner, resulting in a time-dependent decrease in binaural localization cues. Displacement of the tympanal membrane decreases slightly for successive pulses ipsilaterally but increases contralaterally, again decreasing binaural differences, although to a lesser extent than for receptors.

Our results suggest that sound-localization cues vary throughout the course of a stimulus depending on the intensity and temporal pattern of the stimulus, and provide predictions that can be tested in behavioral studies.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1039(16:30 - 17:30)

Audition I: Auditory perceptual binding in treefrogs

*Mark A. Bee[1], Katrina M. Schrode[1]

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Humans exploit environmental regularities in sounds to perceptually bind acoustic energy occurring simultaneously at different frequencies. Such abilities influence vowel perception in speech and timbre perception in music. Other animals solve similar binding problems in the recognition of species-specific acoustic signals. Moreover, they commonly do so using auditory systems that differ in notable ways from that of mammals. This study of two treefrog species investigated temporal and spatial coherence as cues that promote the perceptual binding of two spectral bands emphasized in their acoustic signals. In two-alternative choice tests, females preferred temporally and spatially coherent calls over alternatives in which the onsets/offsets of the two bands were time-shifted by more than 25 ms or in which the two bands were spatially separated by 7.5° or more. These results, which suggest temporal coherence and spatial coherence promote across-frequency auditory perceptual binding, are notable given differences in how the two spectral bands are processed by the anuran auditory system. Sound energy in the high-frequency and low-frequency bands primarily enters the auditory system via different pathways (tympanum and body wall, respectively) and is encoded primarily by different papillae in the inner ear (basilar papilla and amphibian papilla, respectively).

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1040(17:30 - 18:30)

Audition I: Optical stimulation to cochlear nerves evaluated by optical and acoustic interactions

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Infrared laser irradiation can be the substitute neural stimulation method of the electrical stimulation. Previous study showed that pulsed infrared laser irradiation to cochlear nerves in Mongolian Gerbil evoked the compound action potentials (CAP). Purpose of this study is to investigate differences between optically and acoustically induced CAP and whether auditory interaction occurs while optical and acoustic stimulation are simultaneously presented. Following laser parameters were used; wavelength (1.871 µm), pulse width (10-1000 µs), radiant exposure (0-2.06 mW) and repetition rate (100-10000 Hz). Click sounds were used as comparison stimuli. Click sounds had similar characteristics to the laser; click sound duration (10-1000 µs), sound pressure level (35-92 peak equivalent dB SPL) and repetition rate (100-10000 Hz). A recording electrode was set on the bony rim of the round window and the brainstem response was measured by algiloy electrode. Data showed that optical stimulation induced CAPs and the brainstem responses with similar characteristic of acoustically induced results. Optical stimulation with radiant exposure of 2.06 mw was masked by simultaneously presented white noise. Optically induced CAP decreased as the sound pressure level of white noise became higher. The present findings indicated the existence of interaction between optical and acoustical stimuli.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1041(14:30 - 15:30)

Audition I: Neural basis of vibratory signal processing of the honeybee *Ap is mellifera*

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In the waggle dance of the honeybee *Apis mellifera*, the dancer generates air-borne vibratory signals by wing-beats that consist of roughly 30 Hz pulses of 20 ms duration with carrier frequency of about 265 Hz. These vibratory signals are thought to transmit the distance information of food source to the dance followers. The followers can detect these air-borne vibratory signals with the Johnston ' s organ in the pedicel of the antenna and the vibratory signals are transferred to the dorsal lobe in the brain. To investigate the neural basis of vibratory signal processing of honeybee, we identified the vibration sensitive neurons in the dorsal lobe by intracellular recording and staining. Based on the frequency tuning, vibration sensitive interneurons were divided into three groups, which showed the highest response to 100Hz, 200-300Hz, and 400Hz stimulus respectively. Some of these neurons responded to a series of pulses depending on both duration and interval of each pulse. These results suggest that in the DL there are vibration processing mechanisms for detecting both frequency and temporal pattern of the vibratory signal. We will discuss how these identified interneurons contribute to the information coding and decoding in the waggle dance.

[Topic1]Sensory: Audition

[Topic2]Communication

Poster Session 1

PO-1042(15:30 - 16:30)

Audition I: Representation of auditory information and its integration with odor signals in the central nervous system of moths

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Whereas the projection pattern of the moth ’ s auditory sensory neurons has been well described, the second order pathway of the current system is relatively unexplored. By performing intracellular recordings combined with iontophoretic staining we found a particular brain region in the ventral protocerebrum being innervated by auditory neurons from the ventral cord. Also, we have used fluorescent labeling techniques combined with confocal microscopy for visualizing the projection pattern of the three sensory neurons originating from the tympanic ear. None of the auditory afferents targeted the moth brain, meaning that auditory signals are carried to the brain via central interneurons. Interestingly, we have identified a multisensory type of centrifugal neuron responding to ultrasound and odor, which projects into the primary olfactory center in the moth brain. The ipsilateral neuron, being found in two geographically isolated species of heliothine moths, responded to odor and ultrasound. Based on the numerous behavioural studies reporting about the moth ’ s ability to adapt its odor-guided behaviors according to the sound of an echo-locating bat, the current neuron type may be of significant importance for understanding how cross-modal information is integrated in the central nervous system.

[Topic1]Sensory: Audition

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1043(16:30 - 17:30)

Olfaction and Taste I: Odor-based mechanical transmission of bacteria by fly feces

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Flies are considered to be mechanical vectors of various pathogens, which simply convey them and are not essential for development and life cycle of these pathogens. We established a model system for mechanical transmission of bacteria using *Drosophila melanogaster*. GFP-labeled *Escherichia coli* was freely ingested by *Drosophila*. Substances excreted in the feces were easily observed as small spot with fluorescence, indicating that flies directly fed *E. coli* and disseminate them by excretion. Flies without antennae that contain a large set of olfactory receptors or deficient for *Or83b*, which encodes a broadly expressed odorant receptor, showed impaired dissemination of bacteria. The predominant compound produced by *E. coli* was indole along with lesser amounts of alcohols, which were identified by GC-MS. These data suggest that odorant-sensing system may promote feeding behavior in the presence of indole from pathogens, contributing to the transmission of infectious diseases such as food poisoning.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Genes and Behavior

Poster Session 1

PO-1044(17:30 - 18:30)

Olfaction and Taste I: Experience-dependent tuning of olfactory perception in honey bees

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Natural olfactory stimuli to which animals are exposed are normally complex and variable mixtures. The meaning and significance of the different components may change and the animals have to keep their olfactory sense adjusted to detect relevant odors. We asked if component detection is adjusted by experience–dependent plasticity in the olfactory processing in the antennal lobe. We performed calcium imaging in projections neurons of the honey bee antennal lobe and measured the neural representation of mixtures and pure components in naïve and in olfactory trained honey bees. Then we established algorithms that allow prediction of the pattern elicited by the mixture based on the patterns elicited by the pure components. We found that the way in which the pure components are combined to produce the representation of the mixture depends on the previous olfactory experience. The representation of the mixtures is biased toward the representation of the learned component and away from the background component. The effect is evidenced by a reduction in elements that encode the background odor, suggesting that the shift in the representation of the mixture is provided by strengthening of inhibitory interactions. The relevance of this mechanism is evaluated in behavioral experiments.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1045(14:30 - 15:30)

Olfaction and Taste I: Sensing the structural architecture of odor plumes with a single antenna

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In vertebrates and invertebrates, convergence of olfactory receptor axons of a given type in the same glomerulus is a unique adaptation for detecting and differentiating volatile chemicals. However, this convergence makes representation of stimulus topography challenging. We analyzed the structural and functional architecture of a sex-pheromone-specific macroglomerulus in male American cockroaches. Within the macroglomerulus, terminals of sensory receptor axons subdivide based on their point of origin on the antenna. This subdivision is reflected in the response properties of 11 pheromone-responsive interneurons in the macroglomerulus that exhibit small, medium or large receptive fields on the antenna. Beyond the boundaries of its own excitatory receptive field, each interneuron possesses an inhibitory receptive field that modulates the neuron ’ s responses depending on changes in the size, location or direction of the odor stimulus. Axon terminals of interneurons with different excitatory receptive fields converge in the lateral protocerebrum but occupy distinct domains within the mushroom bodies of the brain, suggesting a role for the mushroom bodies in discerning odor plume structure. The existence of interneurons that convey information about the architecture of odor plumes provides important new insight into odor processing and how insects navigate so effectively in olfactory space.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Orientation and Navigation

Poster Session 1

PO-1046(15:30 - 16:30)

Olfaction and Taste I: Sex pheromone source orientation by aim-then-shoot anemotaxis in moths

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When tracking an odour plume of sex attractant pheromone, flying moth males steer upwind by wind-induced visual drift, termed optomotor anemotaxis. However, males of potato moth, *Phthorimaea operculella,* locate conspecific females by a series of short and intermittent flights, or 'hops,' and seem to adjust their course upwind while they are on the ground. It is hardly conceivable that they navigate themselves upwind by vision-induced anemotactic mechanisms as in flying moths. To investigate pheromone-mediated anemotaxis in potato moths, we observed their behaviour in a wind tunnel. Moths whose wings or flagella of one antenna being amputated and intact moths in complete darkness successfully oriented upwind when encountered with pulses of pheromone-permeated air. However, when basal segments of antennae are immobilized with fixative, the direction of surge triggered by a pheromone pulse was influenced. We concluded that potato moth males orient upwind by mechanosensory cues obtained from mechanoreceptive organs on their antennae. Odour-source orientation by mechanosensory-mediated anemotaxis and straightforward flight is consistent with 'aim-then-shoot' mechanisms expected in some Diptera species. Our findings show that in Lepidoptera, two distinct anemotactic mechanisms based on different sensory modalities may coexist: the optomotor anemotaxis while in airborne and the mechanoreception-based aim-then-shoot while on the ground.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Orientation and Navigation

Poster Session 1

PO-1047(16:30 - 17:30)

Olfaction and Taste I: A novel class of visual motion detecting neurons in *Drosophila* integrates olfactory information

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Freely flying flies navigate odor plumes through noisy sensory environments in order to locate food sources, mates, and oviposition sites. This behavior is driven by multi-sensory integration. In the absence of strong visual cues, flies lose the ability to localize and stably track an odor plume in free flight and when tethered within an olfactory flight simulator. Experiments conducted within a visual flight simulator confirm that appetitive odor acts to enhance the gain of the optomotor response, thereby stabilizing flight heading within a plume. These results indicate bidirectional multi-sensory integration processes, but the mechanisms are unknown. We have characterized a novel directionally selective motion-detecting neuron that receives olfactory input. Using two-photon calcium imaging, we show that motion-response amplitude increases with paired odor stimulation, and remains heightened for approximately one minute, suggesting that odor increases the salience of visual stimuli even after it has dissipated. Other motion-detecting circuitry does not show odor enhanced responses with paired odor, which highlights specific cross-modal interactions rather than general arousal by odor. Finally, octopamine has been previously shown to participate in altering the gain of motion detecting neurons, and our results demonstrate that octopamine release is also required for stable plume tracking.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Sensory: Vision

Poster Session 1

PO-1048(17:30 - 18:30)

Olfaction and Taste I: Anatomical and physiological properties of antennal-lobe output neurons projecting in parallel tracts

*Elena Ian[1], Lillevoll Siri[1], Bente Berg[1]

Norwegian University of science and technology[1]

Previous studies of several moth species have shown that odor information is carried to higher brain centers via antennal-lobe output neurons projecting in three main tracts: the medial, the medio-lateral and the lateral tracts (mALT, mlALT, and lALT, respectively). Whereas a substantial amount of data including morphological and physiological characteristics of projection neurons passing in the mALT has been achieved, relatively little is known about neurons in the other tracts. Amon several unanswered questions of particular interest is whether the terminal projections of neurons within the various tracts target distinct or overlapping regions in the lateral horn and whether these neurons display particular response patterns.

We have identified antennal-lobe output neurons projecting in all three main ALTs. The methods used include intracellular recordings and stainings combined with confocal microscopy. Our results obtained so far include antennal lobe projection neurons passing in all three main tracts and their response patterns to antennal stimulation with female-produced pheromones and biologically relevant plant odorants. In addition to the three ALTs previously described, we have found a fourth tract splitting from the mALT dorsally of the mlALT. One of the antennal-lobe output neurons identified in the current study projects in this new tract.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1049(14:30 - 15:30)

Olfaction and Taste I: Insect gustation: neural responses, sensory projections, and behaviors in larvae of the cotton bollworm *Helicoverpa armigera*

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Food selection behavior of lepidopteran larvae is predominantly governed by the activation of taste neurons present in two sensilla located on the galea of the maxilla, termed *sensilla styloconica*. Here, we present ultrastructure and physiological properties of the current sensilla in larvae of the cotton bollworm, *Helicoverpa armigera*. Furthermore, we have mapped the central projections of sensory neurons encapsulated in the two sensilla. The axons from both sensilla projected via the ipsilateral maxillary nerve to the suboesophageal ganglion and further through the ipsilateral circumoesophageal connective to the dorso-anterior area of the tritocerebrum. As confirmed by the three-dimensional reconstructions, the target regions of the neural projections originating from each of the two sensilla styloconica were identical. The neural responses to the taste stimuli applied during the electrophysiological recordings differed in the two sensilla. Behavioral studies showed that the larvae prefer feeding on sugar-treated leafs. By combined molecular, electrophysiological, and behavioral studies, a putative taste receptor playing an important role for trehalose perception has been found in the larvae.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1050(15:30 - 16:30)

Olfaction and Taste I: The peripheral pheromone olfactory system in two moth species, *Helicoverpa armigera* and *Helicoverpa assulta*

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Sex pheromones released by female moths are detected by the olfactory sensilla with high specificity and sensitivity in antennae of conspecific males. The two closely related sympatric species, *Helicoverpa armigera* and *Helicoverpa assulta* share two major sex pheromone components, cis-11-Hexadecenal and cis-9-Hexadecenal, but in reversed relative concentrations, 97:3 and 7:93, respectively. We combined behavior, electrophysiology, molecular biology and optical imaging to investigate the peripheral coding mechanisms in males to their sex pheromone blends. Two groups of highly specific olfactory sensory neurons (OSNs) in two types of antennal sensilla are mainly involved in the pheromone coding. Three pheromone-binding proteins and one odorant-binding protein, five pheromone receptors from the two species were identified functionally. The projection of the axons of OSNs to the male specific macroglomerular complex in the antennal lobe was also compared between the two species. We conclude that evolution of the peripheral olfactory system in insects satisfies the need of specific-species pheromone detection.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Communication

Poster Session 1

PO-1051(16:30 - 17:30)

Olfaction and Taste I: Tarsal taste neuron activity and proboscis extension reflex in two moth species, *Helicoverpa armigera* and *Helicoverpa assulta*

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Phytophagous insects are exposed to a complicated environment filled with the chemosensory information of the plants. Gustatory chemoreception plays a crucial role in the process of host-plant selection by insects, especially after insects have landed on the plant surface. *Helicoverpa armigera* (Hübner) and *Helicoverpa assulta* (Guenée) are sibling species with different host-plant ranges. Both of them use their forelegs firstly contacting the plants when they land. Using the tip-recording technique, scanning and transmission electron microscopy, and behavioral bioassays, we characterized 14 gustatory trichoid chemosensilla on the fifth tarsomere of the prothoracic leg. Each sensillum contains 4 receptor neurons, but the dendrites of them have different diameters. The sensilla exhibited electrophysiological responses to plant metabolites including sugars, amino acids, and allelochemicals, but differed in their response spectra from broad to narrow. Sucrose had a strong stimulatory effect on proboscis extension reflexes, while sinigrin had a strong inhibitory effect on proboscis extension reflexes. We conclude that the tarsal gustatory sensilla play an essential role in perceiving sugars and allelochemicals and provide chemosensory information determining feeding behavior. Tarsal taste neuron responses to lysine are implicated in oviposition behavior.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Communication

Poster Session 1

PO-1052(17:30 - 18:30)

Olfaction and Taste I: Effect of a contextual odor on perception and response to sexual pheromone in the moth *Agrotis ipsilon*

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To find resources insects rely on odors. However, little is known about the way they integrate simultaneous odorant signals pertaining to different resources (e.g. food and mates). To clarify this point, we used male *Agrotis ipsilon* moths to study how mixtures of both odors are neurally coded and behaviorally integrated. These moths display a stereotyped orientation behaviors towards female-released sex pheromone (i.e. mate signal) and are attracted by heptanal, a volatile compound of the linden flowers *Tilia sp* they forage on (i.e. food signal). First, single-sensillum recording of antennal sensilla housing the pheromone receptor neurons showed that heptanal partly activated these receptors, acting as a partial agonist. Second, we used a wind tunnel to study the orientation towards a pheromone source in the presence of various heptanal backgrounds. Moths ’ orientation flight varied when heptanal was released with or next to the pheromone versus a large background plume around the pheromone source: their flight was less straight in the second case. Overall, these results show that the processing of pheromone and general odorant such as heptanal are not completely separated in the olfactory system; consistently, males integrate all the odors surrounding them (heptanal background and pheromone) to orient their flight.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Communication

Poster Session 1

PO-1053(14:30 - 15:30)

Olfaction and Taste I: Sensory system for nestmate-nonnestmate discrimination of ant, *Camponotus japonicus*: Receptor molecules and neurons

*Mamiko Ozaki[1], Yusuke Takeichi[1], Mosaru Hojo[1], Kenichi Ishii[2], Midori Sakura[1], Shuji Shigenobu[3,4], Koichi Ozaki[5], Koji Yasuyama[6], Nobuyuki Miyazaki[7], Kazuyoshi Murata[7]

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In the ant Camponotus japonicus, the discrimination of nestmate and non-nestmate hydrocarbon signals are archieved by female specific sensilla basiconica on the antennae, which houses ca 130 olfactory receptor neurons. Recent studies indicated that this sensilla basiconica are female specific, and we shows behaviorally that the male workers can not discriminate nestmate and non-nestmate hydrocarbons. Retrograde staining from this female-specific sensillum revealed that these olfactory receptor neurons project to the specific region of antennal lobe, the primary olfactory centor of insect brain. The region contains ca 130 glomeruli and absent in the male brains which suggest this female-specific neural systems are important to encode the hydrocarbons signature. To reveal the female specific sensory systems at gene levels, we conducted comparative RNA-seq analyses among the workers, alate queens and males. *Camponotus japonicus* has 342 olfactory receptors (ORs) and among then, 76 ORs shows female biased expression and phylogenetic analyses revealed that these female-biased genes shape the specific cluster in their phylogeny. These results suggesting that these OR gene cluster is candidate for hydrocarbon receptor. From these results we will discuss neural, and genetic bases of hydrocarbons discrimination in ants.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Communication

Poster Session 1

PO-1054(15:30 - 16:30)

Olfaction and Taste I: Sucrose influences fruit selection and consumption in wild spider monkeys (*Ateles geoffroyi*)

*Laura Hernández-Salazar[1], Miriam Pablo-Rodríguez[1], Filippo Aureli[1,2], Colleen Marie Shaffner[1]

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Spider monkeys (*Ateles geoffroyi*) depend mainly on ripe fruits as food. Experimental work in captivity showed that spider monkeys have a high sensitivity to sucrose, suggesting that the taste of such sugar has a direct influence on fruit consumption. We examined whether sucrose concentrations in fruits at different stages of maturity affect their selection and consumption by spider monkeys. The work was carried out in the protected reserve "Otoch Ma'ax Yetel Kooh “ , Punta Laguna, Yucatan, where we recorded the feeding behavior of 11 adult spider monkeys over a 9-month period. Using focal animal sampling, we recorded all feeding attempts and scored whether fruits were consumed or rejected. We collected 10 samples from the most consumed fruits by the monkeys, and we measure the sucrose concentration. We observed 2346 foraging attempts on fruit, of which 2036 fruits were consumed. In fruits that changed color during ripening we found differences in sucrose concentration between ripe and unripe fruits, and this was positively associated with the proportion of consumed fruits that were ripe. Our results suggest that relative sucrose concentrations play an important role in fruit selection and consumption in spider monkeys, which may be partially mediated by fruit color.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Ecology

Poster Session 1

PO-1055(16:30 - 17:30)

Mechanosensation: Responses of larval zebrafish to single neuromast deflections in the lateral line system

*James C. Liao[1], Otar Akanyeti[1], Aleksander Ballo[1], Melanie Haehnel-Taguchi[1], Rafi Levi[1]

The Whitney Laboratory for Marine Bioscience[1]

We performed recordings of posterior lateral line afferent neurons in larval zebrafish while deflecting individual neuromasts. We applied three stimuli: a single deflection to look at the response to variations in deflection velocity (0.01 – 30 µm ms^{-1}), pure sine waves to test for frequency tuning (1 - 90 Hz), and a broad frequency pulse stimulus to quantify the ability of cells to transmit information. For single deflections, we found that maximum spike rate increased with stimulation velocity, while the time delay between stimulus onset and maximum spike rate decayed exponentially as a function of velocity. For sine wave stimuli, we used firing rate and vector strength to characterize responses across frequency and found mainly one type of cell with band-pass qualities. For pulse stimuli, we found that spiking rate did not increase linearly with stimulation frequency. Rather, as stimulation frequency increased, cells transitioned from phase-locking with spontaneous activity to only phase locking, and finally to a decreased ability to phase lock. Cells with higher spontaneous firing rates showed a corresponding sensitivity to higher stimulus frequencies. Remarkably, we could elicit fictive swimming with 50 - 85% probability with a single deflection of an individual neuromast, revealing a surprising sensitivity.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1056(17:30 - 18:30)

Mechanosensation: Functional mapping of the somatosensory center of *Drosophila melanogaster*

*Tomoko Yano[1], Takeshi Yokoyama[1], Asako Tsubouchi[1], Kei Ito[1]

Institute of Molecular and Cellular Bioscience[1]

Insects and mammals share similar systems to detect diverse types of sensory signals. Somatosensation, such as detecting mechanical or heat stimuli, is one of them. Insect ' s visual, olfactory, gustatory, and auditory centers have been studied extensively to reveal similarities with mammalian counterparts. However, relatively little is known about the somatosensory center in their brains. In this study, we are performing calcium imaging for functional and morphological analysis of the *Drosophila* melanogaster brain by using GAL4-enhancer trap system to identify its first-order somatosensory center. We have established a new experiment system for analyzing somatic sensation in the fly nervous system. We use a two-photon microscope for calcium imaging, a piezo-electric device for mechanical stimulation, a gentle wind generator for wind stimulation, and infrared laser for heat stimulation. These devices are controlled by a pulse stimulator, enabling the application of stimuli in a reproducible manner for each experimental animal. We observed several neuronal activities that were induced by each type of stimuli, and determined the peripheral origins of the responded neurons. Our results show a glimpse of functional and spatial map in the putative somatosensory center of the fly brain.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1057(14:30 - 15:30)

Mechanosensation: The efficacy of vibration in behavioral selection

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Crickets usually probe forward when they walk or fight. However, antecedent to the initial stage of unexpected encounter, they probe the opponent standing in front of them with an antenna quickly and then unsheathe. What is the special cue to switch the antennal motor patterns in the part of their adaptive behavioral choice? Animals always walk in lying position. Sensory system on the ventral side include their legs always detect the vibration from the ground. This means some changes in surround could be transmitted by legs in the case of cricket. In this study, we focused on antennal moving and legs as the vibration detectors. Almost animals could not notice the opponent easily without ground vibration. Thus vibration must be the indispensable important cues to control their motor patterns choice between territorial behavior, courtship behavior and feeding behavior. In the expression of territorial claims action involving the struggle, especially, it was considered that the initial stage was quite important to decide following behavior.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1058(15:30 - 16:30)

Mechanosensation: Dynamics of mechanosensory and visual information integration in flies

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Multisensory integration is crucial for many animal behaviors. In flies, information from the mechanosensory halteres is combined with information from the visual system. Without this information, flies are unable to take off and fly. We ablated the halteres of fruit flies (*Drosophila melanogaster*) and found that they are indeed able to fly if glued to a rigid pin. This tethering prevents body rotations, but permits wing steering as in free flight. With this method, we were able to examine wing-steering responses to visual stimuli in the absence of halteres, which is not possible in free or rotating flight. In addition to reclaiming flight behavior, the artificial conditions of tethering permit a thorough analysis of sensory dynamics and the interactions between the visual and mechanosensory systems. We examined responses of haltereless flies to visual stimuli and found that they are effectively blind to open-loop visual stimuli presented to them during flight. Wing movements in haltereless flies are of similar amplitudes and frequencies as in intact flies, but we observe no correlation between steering effort and visual stimulus. Current research aims to understand how haltere removal affects the dynamics of wing-steering and head movement behavior in response to complex visual stimuli.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1059(16:30 - 17:30)

Mechanosensation: Substrate vibrations mediate startle behavior via femoral chordotonal organ in a cerambycid beetle

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Most insects can detect substrate vibrations in order to recognize predators and conspecifics. However, little is known about how coleopteran insects respond to vibrations. We investigated vibrational responses and associated sense organs in a cerambycid beetle, *Monochamus alternatus*. This beetle showed startle responses, such as freezing or fast movement against vibrations with low frequencies below 1 kHz, indicating that they detect low-frequency vibrations. We identified the sense organ responsible for this freezing behavior for the first time in a coleopteran species. The femoral chordotonal organ (FCO), located in the mid-femur, contained multiple sensory neurons and was distally connected to the proximal tibia via a cuticular apodeme. Beetles with all FCOs surgically ablated did not show freeze response to low-frequency vibrations during their walking whereas intact beetles did. These results suggest that the FCO is responsible for detecting low-frequency vibrations and mediating the startle behavior. We discuss the behavioral significances of vibrational responses in *M. alternatus* with respect to antipredator behavior and conspecific recognition.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensory: Audition

Poster Session 1

PO-1060(17:30 - 18:30)

Mechanosensation: Multisensory integration of auditory and cercal sensory inputs by ascending projection neurons in the cricket

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To detect and identify external events or objects of interest accurately, animals integrate multiple sensory inputs of different modalities. However, neural underpinning of the multisensory integration remains unclear. We focused on the cercal sensory and auditory system of the cricket to clarify the neural circuits integrating the directional information provided by different sensory organs. The cercal system monitors low-frequency airflow, and mediates oriented escape behavior. In contrast, auditory system detects high-frequency sound such as ‘ song ’ , and mediates positive phonotaxis of females to male ’ s song. In both sensory systems, directional information of the received stimuli is processed by distinct local circuits well-described at cellular level. In this study, we report the multisensory neurons which responded to airflow and sound stimuli. We extracellularly recorded ascending neural activities evoked by sound and airflow stimuli between the prothoracic and subesophageal ganglia, and sorted 50-60 units as a responding unit. We found that about 60 % of these units are multisensory types responding to both airflow and sound. These multisensory units exhibited larger increase in the firing response and blunter selectivity to the stimulus direction than uni-sensory units. Further, we tried optical imaging of prothoracic ganglion to illuminate neural circuitry involved in the multisensory integration.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensory: Audition

Poster Session 1

PO-1061(14:30 - 15:30)

Mechanosensation: Humidity sensation requires both mechanosensory and thermosensory pathways in *C. elegans*

*Josh Russell[1], Andres Vidal-Gadea[1], Alex Makay[1], Robin Laham[1], Jonathan Pierce-Shimomura[1]

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All terrestrial animals must find a proper level of moisture to ensure their health and survival. However, the cellular-molecular basis for sensing humidity is unknown in most animals. We found that the model nematode C. elegans orients to humidty gradients as shallow as 0.03% relative humidity per mm. Cell-specific ablation and rescue experiments demonstrate that orientation to humidity in C. elegans requires the obligatory combination of distinct mechanosensitive and thermosensitive pathways. The mechanosensitive pathway requires a conserved DEG/ENaC/ASIC mechanoreceptor complex in the FLP neuron pair. Because humidity levels influence the hydration of the worm's cuticle, our results suggest that FLP may convey humidity information by reporting the degree that subcuticular dendritic ensory branches of FLP neurons are stretched by hydration. The thermosensitive pathway requires cGMP-gated channels in the AFD neuron pair. Because humidity levels affect evaporative cooling, AFD may convey humidity information by reporting thermal flux. Thus, humidity sensation arises as a metamodality in C. elegans that requires the integration of parallel mechanosensory and thermosensory pathways. This hygrosensation strategy, first proposed by Thunberg over 100 years ago, may be conserved because the underlying pathways have cellular and molecular equivalents
across a wide range of species including insects and humans.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensory: Olfaction and Taste

Poster Session 1

PO-1062(15:30 - 16:30)

Mechanosensation: Responses of descending interneurons to mechanical & visual stimuli in Oleander hawk moths

*Umesh M.[1], Sunil P.[1], Sanjay P. Sane[1]

National Centre for Biological Sciences[1]

Flying insects use a variety of sensory cues to stabilize their flight. These sensory cues must be acquired, processed and must elicit responses within a few wing beats to ensure flight stability. In the hawk moth *Manduca sexta*, antennal mechanosensory input is crucial for normal flight. These nocturnal moths also use visual feedback during flight. Typically, visual stimuli are processed at slower rates than mechanosensory inputs especially under low light levels. How the central nervous system parses and handles the combined inputs from these two modalities is however not known. Because both visual and mechanosensory inputs are critical for flight stabilization, we hypothesized that the fast acquisition and processing of these inputs is carried out by few, sparsely connected neural circuits that integrate and transmit these inputs to flight control centers. To identify these, we recorded intracellularly from the axons of interneurons in the ventral nerve cord of the Oleander hawk moth *Daphnis nerii*. We were able to locate and record from the axons of descending neurons which respond to both visual and mechanosensory feedback. The properties of these neurons were then characterized to understand their filter properties and the nature of combinatorial responses.

[Topic1]Sensory: Mechanosensation

[Topic2]Sensory: Vision

Poster Session 1

PO-1063(16:30 - 17:30)

Mechanosensation: Anatomical and behavioral analysis of mechanosensory neurons in *Drosophila*

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Mechanical sensation is vital for the survival of animals. In *Drosophila* larvae, it is known that class IV multidendritic (md) neurons are nociception receptors whereas class II and III md neurons are required for behavioral responses to gentle touch. How these neurons play roles in natural larval behavior, however, remained unclear.

Parasitoid wasps are common predators that inject eggs with their sharp ovipositors into the body of *Drosophila* larvae. We first described behavioral responses of larvae to wasp attacks. Stimulation of larvae by the wasp ovipositor caused a variety of mechanosensory behaviors that include both gentle touch-like and nociceptive behaviors. We found that larval behavioral responses varied depending on the location of the wasp attack along the larval body. Such position-dependent responses imply the existence of somatotopic sensory arrangement in the locomotor control circuitry of the larval nervous system.

Adult flies also have several types of sensory neurons such as ciliated neurons, non-ciliated multidendritic neurons, and campaniform sensillia, all along their body surface to detect diverse mechanical stimuli. Detailed analysis of their projection patterns is currently under way in order to establish the topographic somatosensory projection map of the entire body in the adult central nervous system.

[Topic1]Sensory: Mechanosensation

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1064(17:30 - 18:30)

Mechanosensation: The transcriptome of the spider *Cupiennius salei* peripheral nervous system – identifying genes involved in mechanosensation

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Spider exoskeletons contain numerous mechanosensilla including slit-sense organs that detect strains in the cuticle. These are important for many behaviors, including locomotion, prey capture and courtship. VS-3 lyriform organs on the leg patella of the spider, *Cupiennius salei*, are compound slit-sense organs whose properties have been extensively investigated. However, the lack of genomic information has prevented experiments that require detailed knowledge of molecules involved in their functions. The VS-3 and numerous other sensory neurons are embedded in the hypodermis. We extracted RNA from *C. salei* leg hypodermis and used deep-sequencing to obtain fragmented cDNA (>400 million sequences of 100 nucleotides each). We then developed methods for discovery and complete assembly of genes potentially located in the mechanosensilla. Translated protein sequences were found for several groups of putative mechanotransduction ion channels, transmitter receptors, signaling molecules and molecules involved in glial cell function. Future work aims to use transcriptome information to pursue functional and morphological experiments using techniques such as RNA interference and antibody labeling and blocking. This transcriptome approach offers an effective way to discover and utilize protein sequences in preparations from many species that currently lack genomic data.

Supported by Canadian Institutes of Health Research

[Topic1]Sensory: Mechanosensation

[Topic2]Cellular Properties

PO-1065(14:30 - 15:30)
Mechanosensation: Perception of vibrations produced by potential prey in the Mexican horned pit viper *Ophryacus undulatus*

*Octavio Iván Martínez-Vaca León[1], Jorge E. Morales Mávil[2], Laura T. Hernández-Salazar[2], Ana Gloria Gutiérrez García[3,4], Blandina Bernal-Morales[3], Juan Francisco Rodríguez-Landa[3]

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Snakes respond to vibration stimuli in the air, in terrestrial substrates and in water, through a functioning cochlea and a somatic system. In reptiles, the use of vibrations has been associated mainly, with aspects of communication amongst individuals. However, it also can be a vehicle in the predator-prey interaction, favoring the efficiency and economization during the hunt. The aim of this study was to describe the ability of the snakes to detect and discriminate prey through their vibratory stimuli, which were obtained and reproduced with a vibrometer under a controlled, experimental condition. It was analyzed the capability of six Mexican horded pit vipers *Ophryacus undulatus* of detecting and discriminating potential prey (mouse and lizard) of different sizes, through the recording and reproducing of vibration that they emitted when moving. The results showed that this snake has the ability to detect vibrations ($p < 0.05$) but it doesn ’ t seem to differ prey or size. It is concluded that the auditory system of *Ophryacus undulatus* is important only as a first element to detect vibrations, and it is discussed that it requires the complementary use of other sensorial strategies as thermo perception or chemo perception, for recognizing its prey.

[Topic1]Sensory: Mechanosensation

[Topic2]Ecology

Poster Session 1

PO-1066(15:30 - 16:30)

Sensorimotor Integration I: Sensorimotor feedback maintains auditory objects formation

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In an international cocktail party, people are able to identify those who speak the same languages from background noise easier than those who speak other languages. It suggests that there must be neural mechanisms for listener to maintain the language sensitivity of his own languages. Reports in human studies that patients with damage to the Broca ’ s area suffered from aphasia, and also had difficulty in speech comprehension, imply that sensorimotor feedback may influence speech perception. In zebra finch, the sensorimotor nucleus HVC (higher vocal center) corresponds functionally to the Broca ’ s area. Both HVC and Broca ’ s area were mostly studied in motor domain, whereas feedback from motor domain to auditory domain in speech perception is less known. The aim of this study is to investigate the influence of HVC on auditory object formation with regard to the international cocktail party problem.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Audition

Poster Session 1

PO-1067(16:30 - 17:30)

Sensorimotor Integration I: Capability for rhythmic synchronization in two avian species

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Budgerigars and Bengalese finches were engaged for a key-pecking task to examine “ Vocal learning and rhythmic synchronization hypothesis ” . Birds were trained to peck a key during a transient period (300ms) indicated by a cue (light emission from the key and/or 3kHz pure tone). The cue was presented rhythmically and repeatedly as a metronome. The birds were required to follow the stimuli and peck the key without error until a food reward was provided. The number of required key-peck was gradually raised up to 5-6 times. The birds were tested with various tempi (600-1500ms).

Because a previous study reported Budgerigars could synchronize to an audio-visual metronome, this study focused to explore which sensory modality is more effective to the synchronization in Budgerigars. We found a trend that auditory cue was more effective than visual cue.

Bengalese finches were engaged just to see whether the species can synchronize to an audio-visual metronome as well as Budgerigars. We did not find evidence showing the key-peck timings were synchronized to the rhythm or the birds anticipated the stimulus timing. These findings may suggest that rhythmic synchronization requires some shared properties in both parrots and humans in addition to the ability of vocal learning.

[Topic1]Sensorimotor Integration

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1068(17:30 - 18:30)

Sensorimotor Integration I: Preciseness of tapping performance to auditory rhythm : Effects of attention on period and phase corrections

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Sensorimotor synchronization (SMS) is rhythmic entrainment of movement and perception. Empirically, SMS is commonly measured by synchronizing the finger tapping to isochronous sounds. Previous research has suggested that SMS is controlled jointly by phase correction and period correction, and these are conscious and unconscious process, respectively. The purpose of this study was to examine adaptation to tempo changes in order to confirm whether attention has an influence on two error corrections. Dual task method is applied to investigate the effects of attention. Subjects were asked to maintain synchrony with the sounds sequence and continue to tap even after the sound stopped. The tempo of last three sounds of the standard sequence was altered. Subjects answered whether they had perceived tempo change in each sequence. In dual task, subjects were also required to perform mental arithmetic with the tapping task. As results, phase correction was not related to both awareness of tempo changes and attentional resources. On the other hands, period correction was depended on both the awareness and the attention. This finding suggested that period correction and phase correction could represent processes of intentional cognitive control and automatic action control, respectively and be independent of each other.

[Topic1]Sensorimotor Integration

[Topic2]Motor Systems

Poster Session 1

PO-1069(14:30 - 15:30)

Sensorimotor Integration I: Cell types and coincident synapses in the ellipsoid body of *Drosophila*

*Alfonso Martin-Peña[1,3], Angel Acebes[1,5], Jose-Rodrigo Rodriguez[1], Valerie Chevalier[1], Sergio Casas-Tintó[1], Tillman Triphan[2,4], Roland Strauss[2,4], Alberto Ferrus[1]

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Cellular ultrastructures for signal integration are unknown in any nervous system. The ellipsoid body (EB) of *Drosophila* is thought to control locomotion upon integration of sensory signals with the animal internal status. However, the expected excitatory and inhibitory input convergence that virtually all brain centers exhibit is not yet described in the EB. Based on EB expression domains of constructs from the choline acetyl transferase (Cha), glutamic acid decarboxylase (GAD) and tyrosine hydroxylase (TH) genes, we identified a new set of neurons with the characteristic ring-shaped morphology (R neurons) which are presumably cholinergic, in addition to the existing GABA expressing neurons. The R1 subtype is represented in Cha and TH expressing classes. In addition, transmission electron microscopy identified a novel synapse type which exhibits the precise array of two independent active zones over the same postsynaptic dendritic domain that we named *agora*. This array is compatible with a coincidence detector role, and represents about 8% of all EB synapses. All R neurons contribute to coincident synapses. Silencing EB neuron subsets by driving tetanus toxin expression either reduces walking speed or alters movement orientation depending on the targeted R1 subset; thus, revealing functional specializations in the EB for locomotion control.

[Topic1]Sensorimotor Integration

[Topic2]Orientation and Navigation

Poster Session 1

PO-1070(15:30 - 16:30)

Sensorimotor Integration I: Interaction of odor environment, odor sensors and mode of locomotion determine plume tracking behavior

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Case Western Reserve University[1]

Animals tracking odor plumes while flying or swimming generate very different trajectories than those walking or crawling. These behaviors may arise from differences: (1) between the flow conditions in the boundary layer near the substrate and the free stream above it, (2) in the speed of movement generated by different types of locomotion (e.g., walking vs. flying), or (3) in the control rules the animals use to steer. Plume tracking animals might steer to maintain contact with the plume by simultaneously comparing the concentration of the odor between their two antennae (spatial sampling) or of successive sampling points along their track (temporal sampling). We tested this by comparing oriental fruit moths, *Grapholita molesta*, with one antenna removed to intact controls as they track an odor plume in flight and after their transition to walking. There were no differences in the plume tracking flight of intact controls moths and those with one antenna. However, after landing there were differences between the groups. Individuals with one antenna walked upwind along tracks and looped toward their intact antenna. This suggests that these moths change the way they use odor to track plumes from temporal sampling when flying to spatial sampling when walking.

[Topic1]Sensorimotor Integration

[Topic2]Orientation and Navigation

Poster Session 1

PO-1071(16:30 - 17:30)

Sensorimotor Integration I: Multilevel multimodal convergence starting at the earliest stages of sensory processing in a *Drosophila* larval escape circuit

*Tomoko Ohyama[1], Casey Schneider-Mizell[1], James W. Truman[1], Richard Fetter[1], Albert Cardona[1], Marta Zlatic[1]

Janelia Farm Research Campus, HHMI[1]

All nervous systems need to reliably transform multisensory information into appropriate motor outputs. Multisensory integration has been actively studied in the brain. Whether such integration occurs upstream of the brain, and how it is achieved at the level of cells and neural circuits, remain unknown. Here we demonstrate multisensory enhancement of rolling, an escape response naturally evoked by the sting of a parasitoid wasp in *Drosophila* larvae, and identify where this effect occurs within the circuitry that governs the behavior. Building on previous studies that identified larval nociceptive neurons as necessary and sufficient for rolling, we find that the frequency of rolling evoked by nociceptive neuron activation is greatly increased in the presence of vibration. We show that this integration of nociceptive and mechanosensory information occurs at a class of first-order projection interneurons (basin cells), which are necessary and sufficient for rolling. We also identify a pair of thoracic command (goro-goro, Japanese for “ rolling ”) neurons, which are functionally downstream of the basins and control rolling. EM reconstruction reveals that two distinct pathways downstream of the basins—one local and the other through the brain—converge onto goro-goro neurons. Collectively, our results demonstrate multisensory integration occurs at multiple layers.

[Topic1]Sensorimotor Integration

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1072(17:30 - 18:30)
Sensorimotor Integration I: Action selection during visually-evoked escape behavior

*Catherine R. von Reyn[1], Patrick Breads[2], Martin Y. Peek[3], W. Ryan Williamson[4], Gwyneth M. Card[5]

Janelia Farm Research Campus HHMI[1] , Janelia Farm Research Campus HHMI[2] , Janelia Farm Research Campus HHMI[3] , Janelia Farm Research Campus HHMI[4] , Janelia Farm Research Campus HHMI[5]

To navigate through dangerous, dynamic environments, an animal ’ s nervous system must be able to quickly recognize threats and select appropriate evasive maneuvers. How ecologically relevant behavioral selection occurs within the nervous system remains a key question in the field of neuroscience. We here have discovered a natural choice behavior in the genetically tractable organism *Drosophila melanogaster* that allows us to directly probe the neural mechanisms of an action selection process. In response to a predator-mimicking looming stimulus, a fly selects between a long-duration escape behavior sequence that initiates stable flight, and a distinct short-duration sequence that sacrifices flight stability for speed. Intracellular recording of the descending Giant Fiber (GF) interneuron during head-fixed escape reveals this choice is mediated by GF spike timing relative to parallel circuits for escape actions. The choice is well described by a simple model in which the GF circuit has a higher activation threshold than the parallel circuits but can override ongoing behavior to force a short takeoff. Therefore, we demonstrate that *Drosophila* must coordinate multiple neural elements in order to select an appropriate motor program for predator evasion.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Vision

Poster Session 1

PO-1073(14:30 - 15:30)

Sensorimotor Integration I: Neural recordings in the superior colliculus of freely flying bats

*Ninad B. Kothari[1], Melville J. Wohlgemuth[1], Cynthia F. Moss[1]

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Bats are champions at successfully navigating complex environments and capturing erratically moving prey using echolocation. Bats emit ultrasonic vocalizations and listen to echoes which give them glimpses into the environment. Bats actively adapt sonar vocal parameters to influence and maximize the echo information. In addition to changes in sonar vocal parameters, bats move their pinnae and head to maximize the incoming echo information. The midbrain superior colliculus (SC) is implicated in species-specific orienting behaviors, such as head and pinna movements, and in the bat, sonar call production. In echolocating bats, a large proportion of the SC is also involved in the representation of auditory space. We trained free-flying big brown bats to locate a platform and land on it. Single unit activity was recorded across the SC laminae, while high-speed audio and video recordings captured the bat ' s echolocation and flight behaviors. In order to reconstruct the timing of the echoes arriving at the bat ' s ears, we developed an echo model using the recorded sonar vocalizations, the bat ' s 3D head aim and position in space. Correlating the echo timing information with neural activity we can characterize neurons which respond to echo arrival times of different objects in the bats flight trajectory.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Audition

Poster Session 1

PO-1074(15:30 - 16:30)

Sensorimotor Integration I: LFP's in the superior colliculus of echolocating bats are tied to ongoing behaviors

*Melville Wohlgemuth[1], Cynthia Moss[1]

Johns Hopkins University[1]

Signal processing in the brain operates on multiple time-scales, from the high frequency spiking of individual neurons, to the longer-wave oscillations of local field potentials (LFP). Contemporary neuroscience research has focused on the action potential, but growing evidence suggests that LFP ’ s also convey important information about neural functions. Our research examines LFP ’ s in the superior colliculus (SC), a sensorimotor structure important for spatial orientation. We have chosen to study echolocating bats because the periodic nature by which they probe the environment with sonar vocalizations and echo returns allows for precise measurements of the temporal relationship between sensation, motor-coding, and phases of LFP frequency bands. We find a significant increase in the power of several LFP frequency bands when a bat is tracking an object by sonar. Furthermore, the timing of sonar call production is tied to particular phases of the LFP. Lastly, we find that the separate frequencies of the LFP become phase-locked at specific times with respect to the bat ’ s behavior. These results suggest that the LFP plays an important role in the active sensing system of the bat, and demonstrates the utility of the bat as model for research on the role of LFP ’ s in sensation and action.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Audition

Poster Session 1

PO-1075(16:30 - 17:30)

Sensorimotor Integration I: Identification of cerebellar neurons in Japanese catfish (*Silurus sp.*)

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Going toward to investigate the role of the cerebellum in sensorimotor integration in teleosts, we used electrophysiological methods to identify and characterize cellular types in the corpus cerebelli of Japanese catfishes. A good understanding of the cerebellar circuitry requires a study of the pattern activity of Purkinje cells as well as other cells. Despite of importance to have a comparative view about cerebellar physiology, few works have been done to characterize cellular activity in the cerebellum of Siluriforms and almost none in Japanese catfish (*Silurus sp*). The fish were anesthetized and a window was opened in the skull. They were immobilized by an injection of a neuromuscular blockade and the neuronal activities were recorded from exposed corpus cerebelli using a metal wire electrode. At least activity derived from Purkinje cells was identified and the firing pattern was similar to those reported for other teleost fishes. Cerebellar Purkinje cells showed spontaneous firing activities in the absence of external sensory stimulation. Some records showed an activity that includes tonic firing and bursting pattern. Simple spikes followed by characteristic complex spikes were found. To complement the above findings and to identify other neuronal classes, histological analysis is to be combined with electrophysiological method.

[Topic1]Sensorimotor Integration

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1076(17:30 - 18:30)

Motor Systems I: The sea urchin *Diadema setosum* uses only ca. 10 spines in fast walk

*Kazuya Yoshimura[1], Yosuke Sasaoka[2], Amy Johnson[3], Olaf Ellers[3], Tatsuo Motokawa[2]

Science & Education Center, Ochanomizu University[1] , Graduate School of Bioscience and Biotechnology, Tokyo Institute of Technology[2] , Biology Department, Bowdoin College[3]

We recorded the fast walk of the regular sea urchin *Diadema Setosum* in a glass tank with two cameras, one shooting the animal from below and the other from side. The video records were analyzed using the motion-tracking software. As we have reported, sea urchins walked forward with spines showing cyclic up-and-down motion whose fastest forward movement was found in the falling phase of the up-and-down. What we found was that the number of spines involved in one cyclic motion was very small, only about 10, among a few hundred spines carried on the test. The reasons we concluded that these 10 spines were the main players were: 1. The tips of these spines stayed the same place on the substrate for a few seconds, which suggested that these spines actively pushed the substrate during this period; 2. The averaged frequency of these spines coincided with that of the up-and-down movement of the animal; 3. The averaged frequency of the spines coincided with that of the largest peak in the spectrum of the Fourier-transformed velocity of the forward movement, which suggested that these spines contributed to the velocity.

[Topic1]Motor Systems

[Topic2]Genes and Behavior

Poster Session 1

PO-1077(14:30 - 15:30)

Motor Systems I: Activity and connectivity of *C. elegans* locomotion network

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Locomotion acts as the common output pathway for the majority of the behaviors studied in the nematode, *Ceanorhabditis elegans*, including foraging, escape, entry and emergence from quiescence, aspects of mating and thermo- chemo- and klinotaxis. The undulatory motor output is produced by a concise neuromuscular network consisted of 75 identifiable excitatory and inhibitory motoneurons and 75 muscle cells. However, the cellular and neuronal mechanisms that underlie the generation and propagation of undulations are still unclear. Furthermore, the synaptic connectivity data that exist for this network is partial. To overcome the gap in connectivity data, we constructed a connectivity model by extrapolating connectivity pattern in the existing data. Furthermore, we are currently using Serial Blockface Electron Microcopy to collect new connectivity data from multiple animals. Such data will allow not only to test the predictions made by our connectivity model and to fill in the data-gap, but also to provide new insight about variability of connectivity. To address the network activity, we use genetically encoded indicators in behaving animals; which we used to demonstrate that some classes of motoneurons are dedicated to forward locomotion while others are dedicated to backward locomotion or both.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 1

PO-1078(15:30 - 16:30)

Motor Systems I: Analysis of protocerebral neural activity relating to odor source searching locomotion of silkworm moth

*Ryo Minegishi[1], Daisuke Kurabayashi[1], Ryohei Kanzaki[2]

Tokyo Institute of Technology[1] , The University of Tokyo[2]

Odor source searching behavior of male silkworm moths is a good model to understand the relationships between sensory stimuli and behavioral responses, because their searching behavior is only triggered by their conspecific female sex pheromone. Furthermore, olfactory neural circuits in their brain underlying this searching behavior are well studied from sensory input region to premotor region. So far, phasic and long-lasting excitation patterns of single neurons in the lateral accessory lobe region were presumed to relate to locomotion command (surge and turn walking) in odor source searching behavior. However, direct observation of the neural activities during searching behavior has not yet been reported. In this study, we performed simultaneous measurement of neural activity and walking behavior by implanting wire electrodes into the brain of the tethered moth. Neural activities acquired by extracellular recording were sorted into unit activities. We classified the unit activities according to turn velocity and forward velocity during pheromone-triggered walking. We also analyzed the time delay between unit activities and walking velocities based on their correlation. From the analysis, we found that some units changing their firing rate preceded changes in turn walking.

[Topic1]Motor Systems

[Topic2]Sensory: Olfaction and Taste

Poster Session 1

PO-1079(16:30 - 17:30)

Motor Systems I: Parallel descending pathways for visually-evoked escape in *Drosophila*

*Martin Y. Peek[1], Shigehiro Namiki[1], Gwyneth M. Card[1]

Howard Hughes Medical Institute Janelia Farm Research Campus[1]

To understand how nervous systems accomplish fast visual-motor control, we investigated the neural basis of visually-evoked escape behavior in the fruit fly, *Drosophila melanogaster*. Previously we demonstrated that identical looming stimuli evoke two different modes of escape. The fast, unsteady mode requires a pair of descending interneurons, the giant fibers, whereas the neural substrates for the slower, steady mode remain unknown. To determine how slower escapes are controlled, we performed an anatomical search of the Janelia GAL4 expression pattern database for descending neurons that connect the same visual and motor centers linked by the giant fibers. These neurons could form information pathways parallel to the giant fibers to control slow escapes. We found six uniquely identifiable pairs of descending neurons that putatively receive the same visual input as the giant fibers. To assess their visual responses, we are performing somatic whole-cell patch clamp experiments while displaying sets of visual primitives. For one pair, loom-evoked excitatory responses largely overlap with the giant fibers. This pair could provide a parallel pathway for visual information to be conveyed to takeoff motor centers. In future work, we aim to study the behavioral consequences of the activity of these descending neurons.

[Topic1]Motor Systems

[Topic2]Sensory: Vision

Poster Session 1

PO-1080(17:30 - 18:30)

Motor Systems I: Speed of axial locomotion is regulated by local inhibitory interneurons in *Drosophila* larvae

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Axial locomotion is a major category of animal motions, including swimming, crawling and multi-leg walking. While some interneurons involved in axial locomotion have been identified, the neuronal mechanisms of speed control of axial motions in vivo remain unclear.
We use Drosophila larval crawling locomotion as a model system to dissect motor circuits. The crawling is generated by propagation of local muscle contraction from the posterior to anterior segments. We identified a class of interneurons, termed period-positive median segmental interneurons, or PMSIs, as inhibitory segmental pre-motor local interneurons. When the activity of PMSIs was silenced, the speed of locomotion was greatly reduced, indicating that these neurons play crucial roles in speed control of larval locomotion.
By dual-color Ca imaging, we found activation of PMSIs follows that of the postsynaptic motor neurons, suggesting that PMSIs limit the duration of motor bursting. To test this possibility, we acutely blocked the activity of PMSIs by optogenetics, while extracellularly recording motor nerve burst activity. We found that blocking PMSIs activity prolongs the duration of motor nerve activity. These results suggest that PMSIs control the speed of locomotion by limiting the duration of motor neuronal bursting in each segment.

[Topic1]Motor Systems

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1081(14:30 - 15:30)

Motor Systems I: Organization of descending interneurons in *Drosophila*

*Shigehiro Namiki[1], Michael Dickinson[2], Allan Wong[1], Gerry Rubin[1], Wyatt Korff[1], Gwyneth M. Card[1]

Howard Hughes Medical Institute, Janelia Farm Research Campus[1] , University of Washington, Department of Biology[2]

A population of descending interneurons (DNs) connect the brain and the thoracico-abdominal ganglion (TAG), and are thought to be a bottleneck of information flow in the nervous system. Using the Janelia and Vienna databases of GAL4-driven neural expression patterns in the fruit fly, Drosophila melanogaster, we conducted a systematic survey and analysis of DNs in this species. We identified 181 DNs (at least 90 different types) among a total number of about 350-400, as measured with photoactivatable GFP experiments. DNs send axonal projection within the TAG, including neck motor (44% of total), flight (43%), haltere (40%), and leg neuropils (23%). DNs often project to the same area in the TAG, suggesting the presence of functional map for motor command. We did not find any DNs that had innervation to the higher order centers such as the central complex and mushroom body. Our survey also indicates the conservation of basic anatomical features among insect species, suggesting the existence of ground pattern in the organization of descending motor pathway. We are currently working to identify the function of these DNs using genetic activation techniques with split-GAL4 lines, which label specific subpopulation of DNs.

[Topic1]Motor Systems

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1082(15:30 - 16:30)

Motor Systems I: Neural mechanisms controlling foreleg movements of the praying mantis: roles of coxal muslces in capturing behavior

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Graduate School of System Life Sciences, Kyushu University[1] , Department of Biology, Faculty of Sciences, Kyushu University[2]

Forelegs of the praying mantis play an important role in various behaviors such as prey capture, threatening and defense. In the present study, we attempted to unravel the neural mechanisms underlying controlling foreleg movements of the mantis *Tenodera aridifolia*. We first investigated roles of coxal muscles in controlling movements of coxo-trochantal (CT) joint of foreleg during capturing behavior. Capturing behavior consists of preparatory flexion, rapid extension and re-flexion of CT joint. The roles of coxal muscles were examined by observing the effects of cutting muscles on these movements. Main flexor muscle was required for maintaining preparatory flexion of CT joint until the start of extension. Bipennate muscle of main extensor was needed for generating rapid extension of CT joint, whereas fusiform muscle of main extensor was important for its large extension. Next, we attempted to identify all potential motor neurons controlling foreleg movements in the prothoracic ganglion. Motor neurons were identified by back-filling from each nerve branch of prothoracic ganglion. Sections of prothoracic ganglion were stained with hematoxylin and eosin to reveal its neuroanatomical organization. Motor neurons were classified according to the size and relative position of their somata to chief neuroanatomical features such as nerve fiber tracts and neuropiles.

[Topic1]Motor Systems

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1083(16:30 - 17:30)

Motor Systems I: Neural control of the rectum in the penaeid shrimp, *Mar supenaeus japonicus*

*Kosuke Tanaka[1], Shin Ito[1], Makoto Kurokawa[2]

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To elucidate the neural pathways of the rectum movement, we anatomically and electrophysiologically investigated neural control of the penaeid shrimp rectum. Musculature of the rectum was composed of inner longitudinal and outer circular muscle, in which striation was observed as other decapods. The dorsal root was originated from the 6th abdominal ganglion (AG6) towards the rectum. There was a branch of the dorsal root running to the rectum, the rectum nerve (RN). Repetitive stimuli applied to RN induced rhythmic contraction accompanying with increase of tonus in the rectum. The excitatory effects of the RN stimulation were blocked by perfusion of atropine containing saline. It is suggested that RN might include a cholinergic excitatory fiber on the rectum muscle. Repetitive stimuli to the connective between AG5 and AG6 evoked the excitatory effects on the rectum. A few kinds of efferent impulses were recorded spontaneously in RN. The stimuli to the connective increased the efferent impulses in frequency. These results suggested that some neural processes might be originated from AG6 to the rectum and be activated by neurons in other central ganglia.

[Topic1]Motor Systems

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1084(17:30 - 18:30)

Motor Systems I: Electromyographic analysis of goal-directed gripping action in American lobster

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Animals spontaneously initiate goal-directed action including foraging behavior based on their appetitive motivation. American lobster *Homarus americanus* shows gripping behavior with its crusher claw as foraging behavior which can be initiated in a memory-guided manner after operant conditioning. In order to quantitatively characterize the goal-directed gripping behavior with a time resolution fine enough for neurophysiological analysis of its initiation and control mechanisms, we made simultaneous electromyographic (EMG) recording from gripping related muscles of the crusher claw when animals initiated the behavior. We newly developed an *in vivo* extracellular recording chamber allowing the animal under a body-fixed condition to perform operant reward learning with claw gripping. Three muscles in the crusher claw (propodite-dactyl closer/ opener and coxal protractor) were found to be closely associated with spontaneous gripping behavior. Furthermore, we found that the timing of coxal protractor activation was closer to the grip onset and its activity lasted shorter for goal-directed gripping behavior in trained and hungry animals than for non goal-directed spontaneous gripping behavior in naive or satiated animals. These data suggest that the goal-directed gripping behavior of lobster could be characterized by efficient use of those muscles involved in the action.

[Topic1]Motor Systems

[Topic2]Cognition

Poster Session 1

PO-1085(14:30 - 15:30)

Motor Systems I: The role of the amygdala in the generation of different vocal patterns in *Xenopus*

*Ian C. Hall[1], Darcy B. Kelley[1]

Columbia University[1]

One function of the amygdala is to integrate sensory information for the purpose of action selection during social interaction. To communicate reproductive status and dominance, male and female South African clawed frogs (*Xenopus laevis*) produce vocalizations that are used in specific social contexts. Call patterns are produced by a hindbrain vocal pattern generator (VPG) that receives input from the central amygdala (CeA), a forebrain nucleus driven by auditory input, among other modalities. The isolated brain of male and female *X. laevis* can produce fictive vocalizations: activity recorded from the laryngeal motor nerve that closely matches male- and female-specific call patterns. Electrical stimulation of the CeA can initiate sex-specific fictive vocalizations. While bath application of serotonin also stimulates fictive calling, call types differ from those produced by CeA stimulation. These and other observations suggest that 1) serotonin is involved in vocal initiation and 2) that distinct neural pathways shape the output of the VPG. While the VPG receives a direct projection from the CeA, the CeA also projects to two populations of serotonergic cells in the pretectum and posterior tubercule. Using a combination of electrophysiological and pharmacological techniques, we examine the role of these nuclei in modulating vocal activity.

[Topic1]Motor Systems

[Topic2]Communication

Poster Session 1

PO-1086(15:30 - 16:30)

Motor Systems I: Neurocircuitry underlying vocal production of the African clawed frog, *Xenopus laevis*

*Joseph Perry[1], Kristy Lawton[1], Todd Appleby[2], Ayako Yamaguchi[2], Erik Zornik[1]

Reed College[1] , University of Utah[2]

Xenopus laevis vocalizations are powerful models for understanding the mechanisms underlying behavior because the central vocal networks in action can be studied *in vitro* using a “ singing brain in a dish ” preparation.

The vocal central pattern generator of *Xenopus* consists of two pairs of nuclei with extensive reciprocal connections; motor nuclei IX-X (n.IX-X) containing motor neurons and premotor nuclei, the dorsal tegmental area of the medulla (DTAM). Previously, we discovered a type of DTAM neuron, called fast trill neurons (FTNs) that dictate the rate and the duration of the fast trill, one phase of a male advertisement call. Here, we show that spike timing of FTNs relies, in part, on the ascending synaptic inputs from the motor nuclei.

Removal of an efferent motor copy to FTN results in deteriorated firing patterns, suggesting that inputs derived from the motoneurons shape the synchronous spike timing of FTNs.

Furthermore, electrical stimulation of the laryngeal motoneurons produced inhibition in the majority of the FTNs. This efferent motor copy appears to be mediated by cholinergic synapses. Application of the nAChR blocker tubocurarine blocked song, and induced fast bursting of FTNs, indicating that n.IX-X motor neurons provide inhibitory inputs to FTNs via nAChR-expressing interneurons.

[Topic1]Motor Systems

[Topic2]Communication

Poster Session 1

PO-1087(16:30 - 17:30)
Motor Systems I: Bilateral coordination of vocal pathways in African clawed frogs, *Xenopus laevis*

*Jessica Barnes[1], Todd Appleby[1], Ayako Yamaguchi[1]

University of Utah[1]

Vocalizations of *Xenopus* are well-suited model system to identify neural basis of behavior because fictive vocalizations can be studied *in vitro*. The central vocal pathways that consist of pairs of premotor (dorsal tegmental area of medulla, DTAM) and motor (n.IX-X) nuclei generate rhythmic motor outputs which in turn contract a pair of laryngeal muscles rhythmically to produce a series of click sounds. Because *Xenopus* sound production mechanisms require simultaneous contraction of the muscles, the motor outputs need to be bilaterally synchronous. Here, we explored how bilateral coordination is achieved by the central vocal pathways of *Xenopus*.

Transection experiments revealed that two distinct decussating fibers within the vocal pathways mediate bilateral synchronization depending on the vocal phase. Anterior fibers that connect the pair of DTAMs are responsible for bilateral motor synchrony during the fast trill phase of a male call. Posterior fibers connecting the pair of n.IX-X in turn synchronize the right and left motor output during the slow trill phase of a male call. An electrical stimulus delivered to the DTAM elicits an antidromic spike followed by EPSPs from a contralateral DTAM neuron, indicating that there are reciprocal excitatory connections between DTAMs that help coordinate the fast trill output.

[Topic1]Motor Systems

[Topic2]Communication

Poster Session 1

PO-1088(17:30 - 18:30)

Motor Systems I: Generating species-specific vocal patterns

*Charlotte, L Barkan[1], Darcy, B Kelley[1]

Columbia University[1]

Male *Xenopus frogs attract females with species-specific click patterns using* laryngeal muscle contractions driven by hindbrain motor neurons. For three species, we examined the contribution of the brain and larynx during vocal production. We recorded motor nerve compound action potentials (CAPs) from the isolated brain during fictive calling and sound and muscle activity (EMGs) from the isolated larynx in response to laryngeal nerve stimulation.

In *X. laevis* South Africa (SA), CAPs precisely match call patterns. In *X. laevis* Congo (Cg) and *X. victorianus*, fast CAPs do not match clicks 1:1. In X. *laevis* Cg, an EMG response and click follow the first stimulus pulse, while subsequent pulses lead to only an EMG response. In *X. victorianus,* a train of stimuli is required for a single click and results in potentiating EMG activity. In all species, premotor activity in a nucleus of the hindbrain vocal pattern generator, DTAM, sets the temporal structure of the call in an NMDA-dependent manner.

Thus, these closely related species use similar central mechanisms to pattern the temporal structure of their call, but use a variety of peripheral mechanisms to transform click rate and number.

[Topic1]Motor Systems

[Topic2]Communication

Poster Session 1

PO-1089(14:30 - 15:30)

Motor Systems I: Sound production and control of the songbird syrinx *ex vivo*

***Daniel M. Düring[1], Jeppe H. Rasmussen[1], Coen P.H. Elemans[1]**

Department of Biology, University of Southern Denmark, Odense M, Denmark[1]

Song behavior depends on integrated action of neural systems for auditory perception, song production, song learning and the processing of social information. Although many components of these neural circuits have been identified, mechanistic insights into their function remain incomplete. To understand the neural basis of birdsong we need a more detailed knowledge of how neural motor patterns are translated into sound in the vocal organ, the syrinx. However, the accessibility of the syrinx makes it difficult to visualize modulation of syringeal parameters in freely singing birds.
Here, we present an experimental setup that allows for studying the syrinx *ex vivo* under controlled conditions. The setup combines independent control of bronchial and air sac air pressure, with synchronized high-speed visualization of the vibratory tissues. These data allow for the quantification of syringeal dynamics and systematic exploration of the pressure control space in which vocalizations occur. Furthermore, the syrinx and its associated musculature can be kept alive for several hours using micro-perfusion techniques to study effects of muscle recruitment on 1) the biomechanical/kinematic effects of the modulation of structural elements and 2) acoustic modulations. This setup will allow comparative sound production studies in a variety of birds, mammals and amphibians.

[Topic1]Motor Systems

[Topic2]Communication

Poster Session 1

PO-1090(15:30 - 16:30)

Motor Systems I: Consequences of experimental dopamine depletion in the songbird basal ganglia

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Dopamine input from the midbrain modulates the activity of basal ganglia circuitry important for motor learning and control in a variety of species. In songbirds, dopamine is important for motivational behavior underlying reproductive drive. Within the zebra finch species, dopamine modulates social-context dependent behavior when the bird is vocally practicing alone versus performing to a potential female mate. During these singing behaviors, there are differences in dopamine levels within Area X, the specialized sub-region of the zebra finch basal ganglia dedicated to song learning and ongoing adult song maintenance. In the present study, we characterized natural changes in protein biomarkers of dopamine signal such as tyrosine hydroxylase across non-singing and singing behaviors via Western blotting. In a separate group of birds, we injected the neurotoxin 6-hydroxydopamine into Area X and assessed the effects of dopamine depletion on these biomarkers and on features of song in different behavioral contexts. With 6-hydroxydopamine depletion, measurable decreases in dopamine signal were detected, and select acoustic features of song became more stereotyped. On-going investigations will determine how this dopamine loss impacts receptor-mediated changes in the underlying neural circuitry.

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[Topic1]Motor Systems

[Topic2]Neuromodulation

Poster Session 1

PO-1091(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity I: Expression pattern of language-related genes in brain of Bengalese finch (*Lonchura striata var. domestica*) and white-rumped munia (*Lonchura striata*)

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Despite the evolutionary distance, songbirds are well established model for acquisition of human speech. They share not only learning tactics which refers to auditory feedback to modify vocal performance but also parallel neural basis. Moreover, *FOXP2*, a gene related to speech disorder, is shown to also express in songbird's brain and contribute to vocal learning. To investigate such "deep homology", we are performing *in situ* hybridization analysis as follows: (1) Comparison of *FoxP2* mRNA expression level between white-rumped munia (WBM) and its domesticated strain, Bengalese finch (BF), along development. During domestication, BF's song has become more plastic than its ancestor. Since FoxP2 is known to regulate song stereotypy, we anticipate there is some difference in its expression between them. (2) Testing whether other language-related genes e.g. genes responsible for dyslexia express in songbird's brain and concern vocal learning using BF. Here we present preliminary data. As for (1), *FoxP2* mRNA expression within striatum is stronger in adult BF than in adult WBM. Regarding (2), some genes are observed to change their expression pattern between juvenile and adult BF. We will advance the analysis and present detailed account. (Work supported by MEXT grant#26240019 to KO).

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Poster Session 1

PO-1092(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity I: Gating of the sensitive period for sexual imprinting in the zebra finch by GABAergic inhibition?

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Neuronal circuits of GABAergic, Parvalbumin immunoreactive neurons play a major role in the control of sensitive periods, as has been shown for the development of ocular dominance in the visual cortex of cats and mice (Hensch 2005). To test whether this may also apply for other early learning paradigms with sensitive periods like sexual imprinting, we examined in the zebra finch (Taeniopygia guttata) the density of inhibitory neurons within two imprinting relevant brain areas and several control areas. Measurements were performed in 107 day old birds, which were either isolated until day 100 and then exposed for 7 days to a female (imprinted birds) or isolated until day 107 (naive).
The density of GABAergic and Parvalbumin – immunoreactive neurons within imprinting relevant areas (Rollenhagen and Bischof 2000) increases significantly when, by a one week exposure, a male zebra finch is imprinted on a female. Other brain areas are unaffected, and no effect can be seen in nonimprinted controls. This result is a first hint for a participation of inhibitory control of sensitive periods in sexual imprinting, and it contributes to the view that such control mechanisms may also apply for early learning phenomena other than visual cortex plasticity.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1093(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity I: Sensory memory forms in the caudomedial nidopallium during song learning

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During the sensory period, juvenile male zebra finches memorize a tutor-song (TUT). Increasing evidence suggests that the neural substrate for TUT memory is located in the caudomedial nidopallium (NCM), an area homologous to the mammalian auditory-associated cortex. In this study we attempted to trace TUT memory in the NCM by performing multi-electrode recordings. Male juvenile zebra finches were isolated from their fathers before the sensory period (before 12 post-hatch days [PHD]). Starting at 55 PHD they were tutored by a male zebra finch for five days, before being subjected to electrophysiological recordings. Neuronal units throughout the NCM were probed with TUT and with familiar and unfamiliar zebra finch songs. In juveniles at 60 PHD, which did not have any auditory experience with adult song, only 2.3% of neuronal units (in 4/8 birds) showed biased responses to songs of their genetic fathers. However, in all the birds that had been tutored (9/9), a higher number of units (7.6%) showed TUT-biased responses. Neurons with TUT-biased responses were predominantly located in the medial and ventral part of the NCM. These results suggest that sensory memory for TUT forms in the auditory-associated cortical area within a few days of auditory experience.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Audition

Poster Session 1

PO-1094(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity I: Auditory imprinting in chickens: role of PKR and thyroid hormones

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Imprinting is a form of learning that allows newly hatched chickens to recognize a particular object. Visual and auditory cues associated with the object must be encoded and stored for long-term recall over a sensitive period. The mechanisms underlying these processes remain uncertain.
Thyroid hormones (THs) enhance visual imprinting and set the onset of its sensitive period. It is unknown whether THs can also affect auditory imprinting. To address this question we tested the effect of THs on the strength of visual and auditory imprinting separately. We found enhanced ratios of visual and auditory imprinting due to a decreased approach to novel stimuli. Furthermore, THs enhanced fear responses in a tonic immobility paradigm. Thus THs may be influencing imprinting by increasing fear responses to novelty.
In addition, we investigated the role of the double strained RNA-activated kinase (PKR) on the long-term memory underlying imprinting. It has been shown that PKR inhibition is crucial for memory consolidation in rodents. We tested the effects of PKR on imprinting. The PKR-inhibitor (PKRi) enhanced auditory imprinting the day after training. Notably, long-term visual imprinting was not affected by this manipulation, suggesting non-overlapping mechanisms for long-term visual and auditory imprinting.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Audition

Poster Session 1

PO-1095(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity I: Sleep and Fos-like immunoreactivity in a chick forebrain memory system after filial imprinting

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Sleep is important for memory consolidation, including that of imprinting in domestic chicks. Imprinting is a type of leaning whereby social preference becomes restricted to an object following exposure to that object. The intermediate and medical mesopallium (IMM) is a critical forebrain region for visual imprinting. Imprinting leads to an increase in the proportion of neurons in the IMM that are selectively responsive to a visual imprinting stimulus. This increase is dependent on undisturbed sleep 5-12h after exposure. We have enquired whether sleep during this period is associated with a change in neuronal activity in the IMM, using Fos immunoreactivity as a marker.

Dark-reared chicks (21-27h old) were imprinted by exposure to a red box for 2h. Chicks were assigned to a Rest group (immobilized wheel) or a Disturbed group (randomly rotated wheel to prevent continuous sleep) and killed 9 or 11h after onset of training. In the IMM, there were more Fos-positive cells in the Rest (ie strong consolidation) group than in the Disturbed (poor consolidation) group. In both groups, the left IMM contained more Fos-positive cells than the right IMM. These effects of sleep and hemisphere side were not found in the nidopallium.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1096(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity I: Convergence of putative multimodal sensory input to the protocerebral areas in *Drosophila*

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Integration of multimodal sensory information such as visual, gustatory, and olfactory information, is essential for animal life. However, its processing mechanism still remains unclear. *Drosophila melanogaster* is a suitable model to study this problem due to abundant genetic approaches combined with physiological methods. To first identify the brain regions which are connected with multiple primary sensory centers in *Drosophila*, we injected tracers into the primary sensory centers: visual optic lobe (OL), gustatory subesophageal ganglion (SEG), or olfactory antennal lobe (AL). We found that the fibers from these centers converged onto the same region within the mushroom body and posteriorlateral protocerebrum (PLP). In some insects, such as the honeybee, the mushroom body calyx (CA) received putative olfactory, visual, and inputs. Our results indicate the possibility that the mushroom body in *Drosophila* receives the multisensory inputs as well as the other insects.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1097(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity I: Critical evidence for the prediction error theory in associative learning

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In associative learning in mammals, it is widely accepted that the discrepancy, or error, between actual and predicted unconditioned stimulus (US) determines whether learning occurs when a stimulus is paired with a US. The theory stems from the finding of blocking by Kamin, who found that when a stimulus (X) is paired with a US in a compound with another stimulus (Y), learning of X is blocked if Y has been previously paired with the US. Kamin proposed that surprise is necessary for learning, and Rescorla and Wagner formulated it into the prediction error theory. Evidence for this theory, however, is still imperfect. Here we demonstrated blocking in classical conditioning in crickets, and investigated whether it is accounted for by the prediction error theory. Then we proposed a simple neural circuitry model, which predicts that pharmacological intervention of octopaminergic transmission during conditioning impairs learning but not formation of US prediction, thus it predicts no learning in subsequent training. We observed such an “ auto-blocking ” , which could be accounted for by the prediction error theory but not by other competitive theories. This study demonstrates validity of the prediction error theory and providing solid basis to elucidate computational mechanisms of the prediction error.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1098(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity I: Necessity knows no law - How hunger and context triumph over memory

*Etsuro Ito[1], Ken Lukowiak[2]

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The pond snail *Lymnaea stagnalis* can be classically conditioned to avoid food and to consolidate the learning into a long-term memory (LTM). This is referred to as conditioned taste aversion (CTA). Previous studies have shown that one-day food deprivation results in the best CTA-LTM; whereas five-days of food deprivation before training results in neither learning nor LTM. Here we asked if snails are food-deprived for 5 days and then subjected to taste-aversion training do in fact learn and form memory. If so, then the absence memory may be the result of the concept of ‘ necessity knows no law ’. In testing this idea that memory is being overwhelmed by snails being in a stressed-traumatic state due to severe food deprivation, we also found that CTA-LTM was also context dependent. That is, memory was only present if the snails were in the same context in which the taste-aversion training occurred. That context was a modest food-deprived state (one day of food deprivation). Thus, we see here that even in a relatively simple model system whose neural circuitry underlying feeding behaviors is well worked out, there is a complex interaction of hunger, context and memory formation in the establishment of a behavioral phenotype.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1099(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity I: Individual consistency in bumblebee speed-accuracy tradeoff decisions when foraging under predation threat

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Animal ‘ personality ’ has been described as the consistency of behaviour through time across contexts. Such constant individual differences have been investigated in many animals, but the formation and the ecological significance of the syndrome is still highly underestimated. We tested individual consistency in bumblebee speed-accuracy tradeoff faced with predation risks. Bumblebees showed individually repeatable strategies in foraging decisions when conspicuous predators were introduced in the meadow. Some bees made persistently careful choices, while others had shorter decision times and achieved less accurate choices. When we increased the task difficulty by adding conspicuous spiders, careful bees tended to become more careful and impulsive bees turned even more impulsive. We also calculated the foraging efficiency for each experiment and found that the optimal strategy changed with different experimental designs. The modelling showed that when flowers were rewarding at different levels, a slow-and-careful strategy was beneficial; however, when the penalty of making erroneous choices increased, an impulsive strategy led to higher energetic gains. Despite these predicted differences, bees maintained constant strategies instead of displaying behavioural plasticity depended on the environment.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1100(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity I: Classical heart rate conditioning and underlying cerebellar circuit in young zebrafish

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We developed classical heart rate conditioning procedures for larval and juvenile zebrafish. We adopted delay conditioning paradigm with a light-off as conditioned stimulus and an electric shock as unconditioned stimulus. The cardiac activity was monitored to examine the acquisition of autonomic conditioned responses. Zebrafish older than around 20 days post-fertilization were capable to acquire conditioned bradycardia, which was considered to be an conditioned fear response. This result, together with the previous reports, suggests that the ability to acquire fear-related cardiac responses develops as the heart-regulatory system matures in the early stages of zebrafish ’ s life. Cerebellar circuit is reported to be critically involved in this type of fear conditioning in other teleost fish. Recently, we succeeded in optically detecting cerebellar granule cell activities in transgenic zebrafish expressing calcium indicator protein in this class of neurons. We will report our attempts to reveal cerebellar circuitry involved in fear learning using this imaging technique in combination with the heart rate conditioning procedure.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1101(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity I: Combined extract of *Morus alba* and *Polygonum odoratum* improves memory impairment and osteoporosis in an ovariectomized rats model

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The novel intervention against menopause related symptoms such as memory impairment and osteoporosis is still required due to the increased breast cancer risk induced by hormone replacement therapy. Therefore, we investigated whether the combined extract of *Morus alba* and *Polygonum odoratum* improved memory impairment and osteoporosis in ovariectomized rats. Female Wistar rats were divided in to various groups; 1) control 2) sham 3) OVX 4) OVX plus genistein 5)-7) OVX plus combined extracts at doses of 5, 150 and 300 $mg.kg^{-1}$. All rats were subjected to the assigned interventions for 12 weeks. The memory assessment was using Morris Water Maze test. At the end of study, serum bone formation markers comprising of osteocalcin and calcium were analyzed. In addition, hippocampus and prefrontal cortex were determined malondialdehyde (MDA) level whereas tibia was determined thickness of cortical bone and density of osteocblast cells. The results showed that, all doses of combined extract improved both memory impairment and all bone formation markers together with enhanced bone cortical thickness and density of osteoblast including decreasing MDA levels. These data suggested that the combined extract improved memory impairment via the decreased oxidative stress while it improved osteoporosis by increasing bone formation and decreasing oxidative stress.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Poster Session 1

PO-1102(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity I: Conditioning parameters for long-term memory formation in the cockroach

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Animals can acquire memory through experiences and maintain it for a long time, which plays important roles in their survival. Cockroaches are one of the species in which brain mechanisms of behavior have been studied anatomically and electrophysiologically and they have also been used for study of learning. However, the stimulus parameters for induction of long-term memory (LTM) has not been studied in cockroaches. We studied stimulus parameters to induce LTM in cockroaches *Periplaneta americana* by using olfactory conditioning of maxillary palpi extension response (MER). We found that: 1) multiple-trial training with <30 sec of inter-trial interval (ITI) (massed-training) leads to LTM formation, although this training does not induce LTM in other insects, 2) four and five conditioning trials with 5 min ITI do not lead to LTM formation and 3) this inhibition of LTM is pairing-specific and also specific to the intervals from the preceding trials to the last trial, and not due to decreased motivation for learning (i.e., overtraining effect). This study is the first to report trial number-dependent and ITI-dependent inhibition of LTM formation, which may be because conditioning trials with specific ITI suppress foregoing biochemical processes for LTM formation.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1103(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity I: Reversal of phototaxis of the marbled crayfish

***Toshiki Nagayama[1], Nanoka Suzuki[1], Chihiro Shiratori[1]**

Yamagata University[1]

Many arthropods show positive or negative phototaxis in which sign is known to reverse depending on conditions such as the external environment and/or internal state. Marbled crayfish *Procambarus fallax* exhibit phototaxis, which reverses depending on environmental light condition. LD crayfish reared under a 12L/12D light period showed negative phototaxis during the daytime while positive phototaxis was exhibited at night-time. DD crayfish reared constant dark conditions showed positive phototaxis during the daytime. The injection of serotonin reversed phototaxis in LD crayfish from negative to positive, while dopamine reversed the negative phototaxis in DD crayfish. Although a reversal of phototaxis was also observed under light or dark adaptation (4 hrs) during the daytime, serotonin $5HT_1$ receptor antagonist blocked the reversal of phototaxis during dark adaptation, and dopamine D_1 receptor antagonist blocked the reversal of phototaxis during light adaptation. Furthermore, injection of a cAMP analogue during dark adaptation blocked the shift of phototaxis from negative to positive, and the injection of adenylate cyclase inhibitor during light adaptation blocked the shift of phototaxis to negative. These results suggested cAMP underlies the switch in phototactic behaviour of the marbled crayfish.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1104(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity I: Long-term memory of social dominant and subordinate statuses in the crayfish

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Yamagata University[1]

For territorial animals, dominance hierarchy formation is essential to maintain social stability. Larger animals usually win during agonistic bouts with smaller opponents, and the history of previous fights is also important to determine dominance hierarchy. In the crayfish *Procambarus clarkii*, a size difference of 3-7% is sufficient for larger animals to become winners. Smaller animals, however, frequently win with larger naive animals if they are winners in their previous fights. By contrast, large loser crayfish tend to lose in the next fight with smaller naive crayfish. It still remains unclear how long winner and loser effects are retained. Winner or loser crayfish were isolated immediately after the establishment of winner-loser relationship and paired with naive large/small crayfish 1,3,7,14, and 21 days after isolation. Small winners continued to beat large animals 14 days after previous fight, but winning probability declined 21 days after isolation. Large loser crayfish also tended to win against small crayfish from 21 days after isolation. Injection of a serotonin antagonist immediately after the establishment of dominance hierarchy blocked the formation of the winner effect, but injection 20min after had no effect. A possible second messenger signaling cascade responsible for the long-term winner and loser effect was analyzed.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1105(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity I: Serotonin and octopamine affect winner and loser effects during agonistic encounters of the crayfish

*Yuto Momohara[1], Toshiki Nagayama[1]

Yamagata University[1]

The establishment of dominant hierarchy is essential for territorial animal to maintain their social stability. Using pairings of crayfish, with a 3-7 % difference in body size, we analyzed the effect of previous social experience upon subsequent conflict and characterized the role of serotonin and octopamine quantitatively. We confirmed that physically larger crayfish were more likely to win encounters. Despite a physical disadvantage, small winners of the first pairings were more likely to win their subsequent conflicts with larger naive animals. By contrast, the losers of the first pairings rarely won their subsequent conflicts with smaller naive animals. These winner and loser effects were mimicked by the injection of serotonin and octopamine. Serotonin-injected small naive crayfish were more likely to win in pairings with larger naive crayfish, while octopamine-injected large naive animals were beaten by smaller naive animals. The winner effects of dominant crayfish were abolished by the injection of serotonin receptor antagonists, just after the establishment of social order of the first pairings. Injection of the octopamine channel blockers, by contrast, reduced the loser effects. From these results, serotonin and octopamine potentially play a crucial role in winner and loser effects, respectively.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1106(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity I: Allatostatins are inhibitory neuropeptides modulating appetitive learning in the honey bee

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Sequencing of the honeybee genome revealed many unknown neuropeptides and putative neuropeptide receptors. This is of interest because neuropeptides can modulate the release of classical neurotransmitters such as dopamine, serotonin and octopamine, which have key roles in the formation of memory.

We are focusing on allatostatins that were first identified as inhibitors of juvenile hormone synthesis, which occurs in the *corpora allata*. Two types of allatostatin peptides (ASTA and ASTC), and their respective receptors (ASTAR, ASTCR), have been identified in the honeybee. ASTAs have been localized in the brain, but not ASTCs, nor their receptors. We have shown that both allatostatins decrease appetitive learning (Urlacher et al., *in prep*). However, at present, the mechanisms at play remain unknown. Here we show with in situ hybridization that both receptor genes (astR-A and astR-C) are expressed in the brain, including in regions involved in memory formation. To examine their functional properties, we expressed each receptor in HEK293 cells. Activation of either ASTAR or ASTCR led to a decrease in intracellular levels of cAMP. Our results suggest that ASTA and ASTC both may act as inhibitory modulators of neural activity in circuits involved in olfactory learning in the brain of the bee.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1107(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity I: Aversive learning increases the expression of dopamine-receptor genes in specific cell populations of the honey bee brain

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Associative learning allows extracting predictive relationships in an environment, permitting us to use past events to predict the future and to adjust our behavior accordingly. Various mechanisms determine plastic changes in connectivities underlying learning and memory formation. We investigated the possibility that learning modulates expression of specific receptor genes, thereby changing the sensitivity to environmental signals. We quantified sting extension responses of honeybees to electric shocks and found that subsequent aversive olfactory learning induces a long-term decrease in shock responsiveness three days after conditioning. To uncover its mechanisms, we focused on Kenyon cells, which constitute the mushroom bodies, a structure in the insect brain that has been associated with learning and memory. We used laser-capture micro dissection followed by RT-qPCR to determine potential long-term changes induced by aversive learning in receptor-gene expression in subpopulations of Kenyon cells. We found that aversive learning promotes a long-term increase in the expression of the dopaminergic receptor genes *Amdop2* and partially of *Amdop1*. No changes were detected for *Amdop3*, the dopamine/ecdysteroid receptor gene *Amgpcr19* and the octopaminergic receptor gene *Amoa1*, which mediates appetitive-reinforcement. Thus, learning induces an increase of specific receptor genes, which may mediate a long-term decrease of responsiveness to the shock punishment.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1108(17:30 - 18:30)
Learning, Memory, & Behavioral Plasticity I: Facilitatory enhanced methods for taste avoidance conditioning in *Lymnaea stagnalis*

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Graduate School of Bioscience, Tokai University[1]

We succeeded in taste avoidance conditioning with sucrose as the conditional stimulus (CS) and an electrical stimulus (~1000V, 80 μA, 0.2 s) as the unconditional stimulus (US). Snails were evaluated with the number of mouth openings to a sucrose application following the conditioning paradigm at 10 min and/or 24 h as short-term memory (STM) and long-term memory (LTM), respectively. With 15 paired CS-US presentations on a single day, we were able to elicit both STM and LTM persisting for at least one week. However, while STM was elicited with 5, 8, 10, and 20 paired presentations of the CS-US on a single day, LTM was not. We found, however, that if we inserted a 3h interval between a first and a second set of CS-US pairings that both 8 and 20 paired CS-US presentations on a single day was now sufficient to cause LTM formation. Exposing snails to protein kinase C activator, bryostatin before or during training enhanced the snails ability to form LTM such that 8 paired presentations of the CS-US resulted in LTM. These findings suggested there is a critical period at around 3h following the last paired presentation of CS-US to enhance memory formation.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1109(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity I: Nitric oxide synthase (NOS) mediates activity-dependent plasticity in an area of the octopus brain involved in learning and memory

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Dept. Neurobiology, The Hebrew University, Jerusalem, Israel[1] , The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University, Jerusalem, Israel[2] , Interdisciplinary Center for Neural Computation, The Hebrew University, Jerusalem, Israel[3] , The Ruppin Academic Center, School of Marine Sciences, Michmoret, Israel[4]

The vertical lobe (VL) of *Octopus vulgaris* shows a robust activity dependent LTP related to learning. This LTP seems to be non-NMDA dependent and presynaptically expressed; therefore it seems that the associative mechanism that mediates the Hebbian property of octopus LTP has not converged to vertebrate like mechanisms. Here we examined the effect of NOS inhibitors on plasticity in slices of octopus VL. We observed that NOS inhibitors showed an inhibitory effect on LTP expression without affecting LTP induction by high frequency (50Hz) stimulation, as full LTP could be induced in the presence of NOS inhibitors (revealed after drugs washout). Once NOS inhibitors were applied to already induced LTP, they inhibited the synaptic field potential (fPSP), but did not depotentiate it. In contrast, slowly developed LTP (0.1Hz stimulation) was attenuated by NOS inhibitors possibly because of an indirect effect via blockage of nitric oxide (NO) induced synaptic facilitation. These results suggest that LTP expression occurs through synaptic facilitation induced by elevation of NO concentration, which is likely to be generated by activity dependent NOS long-term activation. We conclude that NO/NOS system is a conserved mediator of plasticity in networks involved in complex forms of learning in mollusks.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Neuromodulation

Poster Session 1

PO-1110(15:30 - 16:30)

Hormones and Sex Differences: A role for nonapeptides in zebra finch nesting behaviour

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During nest building in zebra finches (*Taeniopygia guttata*), several regions in the social behaviour network appear to be active. As the nonapeptides oxytocin and vasopressin play an important well-established role in mammalian social behaviour including bonding and parental behaviour, in this study, we tested the hypothesis that mesotocin-vasotocin neuronal populations in the social behaviour network are active during nesting. We labelled neural tissue from nesting and non-nesting male and female zebra finches for the production of Fos (an indirect protein marker of neuronal activity) and arginine vasotocin or mesotocin and quantified the number of double-labelled cells in vasotinergic and mesotinergic neuronal populations in the social behaviour network. In male finches, Fos activation in vasotocin neuronal populations in the bed nucleus of the stria terminalis (BST) was higher the more pieces of material picked up by nesting males and the longer a nesting finch pair were together in the nest. Fos activation in BST mesotocin neuronal populations was also higher in nesting male and female birds compared to controls. These findings suggest a role for the mesotocin-vasotocin system in nest building and a conserved function of mesotocin-vasotocin circuitry in the social behaviour network in mediating parental behaviour in birds and mammals.

[Topic1]Hormones and Sex Differences

[Topic2]Genes and Behavior

Poster Session 1

PO-1111(16:30 - 17:30)

Hormones and Sex Differences: Seasonal changes in testosterone levels, singing behavior and sensitivity to androgens in the HVC of an Amazon songbird, *Ramphocelus carbo* (Thraupinae), in a lowland equatorial population

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In songbirds, the development and production of songs are regulated by a network of brain nuclei, collectively named as song control system. One central nucleus of the song control system is the HVC, which functions as a sensorimotor integration area and expresses androgen and estrogen receptors. In several temperate zone species, transient changes in the structural and neurochemical characteristics of HVC parallel seasonal changes in song behavior and plasma levels of testosterone. Photoperiod is thought to be the primary environmental Zeitgeber for seasonal testosterone production. Here we assessed the seasonal androgen and estrogen receptor expression in the HVC of male Silver-beaked Tanagers (Ramphocelus carbo) in an equatorial population of the Brazilian Amazon. In addition we obtained testosterone plasma level and measured singing activity. Our results show seasonality in the expression of androgen receptor of the HVC. Besides, we found seasonal patterns in plasma levels of testosterone and in the morning singing of males. Thus, in this equatorial species some form of singing are as androgen sensitive as in temperate zone species although the environmental control mechanism seems to be different since there is little photoperiodicity.

[Topic1]Ecology

[Topic2]Hormones and Sex Differences

Poster Session 1

PO-1112(17:30 - 18:30)

Hormones and Sex Differences: Nutritional regulation of the brain levels of dopamine and tyramine to promote the transition from normal to reproductive workers in queenless colonies of honey bees

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Dopamine and tyramine have neurohormonal roles in the production of reproductive workers in queenless colonies of honey bees, but the regulation of these biogenic amines in the brain are still largely unclear. Nutrition is an important factor in promoting reproduction and might be involved in the regulation of these biogenic amines in the brain. To test this hypothesis, we examined the effect of oral treatments of tyrosine (a common precursor of dopamine and tyramine) in queenless workers and quantified the resulting production of biogenic amines. Tyrosine treatments enhanced the levels of dopamine, tyramine and their metabolites in the brain. Workers fed royal jelly had significantly larger brain levels of tyrosine, dopamine, tyramine and the metabolites in the brains compared with those bees fed honey or sucrose (control). Treatment with tyrosine also inhibited the behavior of workers outside of the hive and promoted ovarian development. These results suggest that there is a link between nutrition and the regulation of dopamine and tyramine in the brain to promote the production of reproductive workers in queenless honey bee colonies.

[Topic1]Hormones and Sex Differences

[Topic2]Social Behavior

Poster Session 1

PO-1113(14:30 - 15:30)

Hormones and Sex Differences: Behavioral characterization and hormonal basis of territory establishment in a year-round aggressive weakly electric fish

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The non-breeding territorial aggression of the weakly electric fish, *Gymnotus omarorum*, constitutes a remarkable example of non-sexually biased aggression, though its territory establishment remains unexplored. We used *G. omarorum* (adult females; n=20; 15-24cm; 20-50g) in semi-natural conditions (400L outdoor tanks) with 12 equally sized shelters symmetrically distributed. Two electrodes in each shelter allowed us to record the electric discharges of fish only if sheltered. Individuals of the nocturnal *G. omarorum* sheltered at daytime (85%) and remained restless at night (82%). However, we observed important heterogeneity in their sheltering habits: regular-habit fish, sheltering and leaving the shelter at dawn and dusk, respectively; and more active fish, sheltering less even during daytime. To study the settlement of individual territories under social interaction, we recorded sets of 5 females (1 large, 1 small and 3 medium) during 48 hours. We recognized 3 categories that we assumed to be hierarchical: 1) dominant fish (the largest), sheltered and defending the largest territory; 2) small-territory fish, sheltered and defending a smaller territory; 3) non-sheltered fish (without territory). Territories were acquired through aggressive encounters as injuries were negatively correlated with this hierarchy. Pharmacological steroid blockade will confirm if territory establishment in *G. omarorum* is under gonadal regulation.

[Topic1]Social Behavior

[Topic2]Hormones and Sex Differences

Poster Session 1

PO-1114(15:30 - 16:30)

Hormones and Sex Differences: Neuromodulatory effects of terminal nerve GnRH neurons in the fish visual system

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There have been some ethological analyses on seasonal changes in animal behaviors and sensory processing. For example, male goldfish during the breeding season are visually attracted by conspecific females. The central neural mechanisms that regulate such behaviors, however, are not well studied. The terminal nerve gonadotropin releasing hormone (TN-GnRH) neurons are suggested to modulate reproductive behaviors and are known to have massive projections to the optic tectum. Therefore, we hypothesized that TN-GnRH neurons play an important role in the modulation of the visual information processing according to the reproductive status. In order to verify this hypothesis, we analyzed the effects of GnRH peptide on synaptic transmission in the optic tectum by using the field potential and whole cell patch clamp recording. GnRH peptide modulated the evoked field potential responses that reflected the excitatory synaptic transmissions between the optic tract fiber and the target neurons in the optic tectum. Therefore, TN-GnRH neurons are suggested to modulate synaptic transmission from the optic tract fiber to the optic tectum.

[Topic1]Neuromodulation

[Topic2]Hormones and Sex Differences

Poster Session 1

PO-1115(16:30 - 17:30)

Hormones and Sex Differences: Modulation of anxiety-like behaviour by GABAergic compounds microinjected into the dorsal hippocampus in cycling female Wistar rats

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The hippocampus is a brain structure implicated in the control of anxiety-like behaviour in animal models, but it is unknown if participates in the anxiety-like effect of different GABAergic compound. Therefore, the effects of diazepam, allopregnanolone and flavonoid chrysin (0.5, 1 or 2 micrograms) microinjected into the dorsal hippocampus on anxiety-like behaviour were determined in cycling female Wistar rats. An increase in time spent on the open arms of the elevated plus-maze was found after intrahippocampal microinjection of 1 microgram of each GABAergic compound in metestrus-diestrus phase; however, 0.5 or 2 micrograms did not affect behaviour in plus-maze during this ovarian cycle phase. In proestrus-estrus phase 0.5 or 1 micrograms of GABAergic compounds did not affect behaviour in plus-maze, but 2 micrograms in this phase of the ovarian cycle produced anxiogenic-like effects. The anxiolytic-like effects of intrahippocampal microinjection of GABAergic compounds detected in metestrus-diestrus phase were blocked by intraperitoneal pre-treatment with 1 mg/kg of picrotoxin. Thus, inhibition of the hippocampus, mediated by these GABAergic compounds at the $GABA_A$ receptor, produces anxiolytic-like effects; which are dependent of the ovarian cycle phase in the Wistar rat.

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[Topic1]Neuromodulation

[Topic2]Hormones and Sex Differences

Poster Session 1

PO-1116(17:30 - 18:30)

Hormones and Sex Differences: Melatonin productivity influences male ultrasonic courtship vocalizations in laboratory mice

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Most of the inbred strains of laboratory mice are deficient in melatonin because they lack an enzyme necessity for the synthesis. Recently, it was reported that testis development was significantly promoted in melatonin-deficient mice, suggesting that melatonin promotes early sexual development. We therefore tested the hypothesis that Melatonin productivity affects courtship ultrasonic vocalizations (USVs) in adult male mice because of the effect of melatonin productivity on sexual development. We conducted recording with three mice groups; (1) a group capable of melatonin synthesis (Mel mice), (2) a group capable of synthesizing N-acetylserotonin, a precursor of melatonin (NAS mice), and (3) a group incapable of both Melatonin and NAS synthesis (none mice). We found that syllables of Mel mice are shorter than that of the others. In particular, the duration of “ complex ” syllable, which has three or more phases with frequency and no jump, in Mel mice is shorter than that in the others. However, there are no differences in the duration of other syllables, total duration of syllables and approach behavior to female among groups. These results indicated that melatonin productivity could make specific syllables simple and did not influence the physical function or courtship behavior.

[Topic1]Communication

[Topic2]Hormones and Sex Differences

Poster Session 1

PO-1117(14:30 - 15:30)

Hormones and Sex Differences: Estrogen receptor β interacting proteins in brain

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Estrogen mediates its multiple functions in the brain through the recruitment of a number of interacting proteins by ER (estrogen receptor) α and ERβ. Like other members of the nuclear receptor superfamily, both the receptors have three functional domains– *N terminal transactivation domain (TAD)* containing activation function (AF)-1, *DNA binding domain (DBD)* and *C terminal ligand binding domain (LBD)* containing AF-2. Further, estrogen responsive gene regulation is dependent not only on transcription factor activation but also on chromatin remodeling by a host of coregulators- *coactivators* and *corepressors* - which bind to TAD, LBD or both simultaneously. Although many proteins interacting with ERα have been reported, very little is known about the ERβ and its domain ' s interacting proteins in brain, particularly during aging, when the level of estrogen and its receptor declines. ERβ interacts with proteins the range of 30-203kD. Such studies and may be useful to understand the estrogen-mediated brain functions during neurodegenerative and age related disorders.

[Topic1]Hormones and Sex Differences

[Topic2]Cellular Properties

Poster Session 1

PO-1118(15:30 - 16:30)

Genes and Behavior I: Molecular characterization of long noncoding RNAs in *Drosophila*

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Long noncoding RNA(lncRNA) is the one particularly abundant but poorly understood class of ncRNAs. Although we presently know little about their function, lncRNAs ’ widely expressed in the nervous system suggested they ’ re likely to play potential critical roles in neural functions. Here, we described the molecular and original functional characterization of two *Drosophila* lncRNAs, including their exact expression and full length confirmation, coding potential evaluation, spatial-temporal neural expression pattern, conservation analysis and potential biological effects. We identified *lnc97* and *lnc10* as two neural long noncoding RNAs. In *Drosophila* genome, they partially overlaps with or locates within the 3 ’ UTR of the neighbour protein-coding genes respectively. *lnc97* is involved in the regulation on locomotion behavior. At the molecular level, they both have positive regulatory effects on the expression of their adjacent coding genes. The original results provided the molecular basis for the further investigation of their potential neural functions. Our study will enrich the present biological significance of lncRNAs and may provide potential insights into neural dysfunction.

[Topic1]Genes and Behavior

[Topic2]Genes and Behavior

Poster Session 1

PO-1119(16:30 - 17:30)

Genes and Behavior I: Mapping behavior to neural anatomy in *Drosophila melanogaster*

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To further the understanding of the structure-function relationship of the *Drosophila melanogaster* nervous system, we performed a thermogenetic activation screen using the GAL4-UAS system to target expression of the dTrpa1 channel to subsets of neurons. We screened 2215 of the sparsest lines from the Janelia GAL4 collection, video recording the flies ’ behavior in an open-field walking arena at the permissive temperature of the dTrpa1 cation channels. Our analysis pipeline tracked the body and wing pose of each fly in each of 19528 videos. From these trajectories, the pipeline computed metrics of flies ’ movements and social interactions. Using these metrics, we applied 14 automatic behavior classifiers created in JAABA (an interactive machine learning system) resulting in behavioral annotations of each fly in each frame of the videos. The behaviors detected by our automatic classifiers include locomotor and social behaviors such as walk and chase. We then identified groups of lines with similar behavior phenotypes and found the average image of the expression pattern of those GAL4 driver lines. The brain regions with significantly increased expression are likely to be involved in the production of the behavioral phenotype. This work results in putative brain-behavior maps.

[Topic1]Genes and Behavior

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1120(17:30 - 18:30)

Genes and Behavior I: γ-glutamyl transpeptidase specifically suppresses green-light avoidance via GABAA receptor in *Drosophila*

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Drosophila larvae innately show light-avoidance behavior. Compared with their robust blue-light avoidance, larvae exhibit relatively weaker responses to green light. We performed a screen for genes involved in *Drosophila* larval light-avoidance behavior. Compared with control, larvae with *γ-glutamyl transpeptidase 1* (*Ggt-1*) knockdown or *Ggt-1* mutation were found to exhibit higher percentage of green-light avoidance which is mediated by Rh6 photoreceptors in Bolwig Organs. In contrast, their responses to blue light did not change significantly. By adjusting the expression level of *Ggt-1* in different tissues, we found that functions of *Ggt-1* in malpighian tubules were both necessary and sufficient for green-light avoidance. Our results showed that the level of glutamate was lower in *Ggt-1* null mutants than in controls. Rather than directly functioning as a neurotransmitter, glutamate might affect green-light avoidance by acting indirectly through the inhibitory neurotransmitter GABA. The level of GABA was also lower in *Ggt-1* mutants than in controls. Mutants in *glutamate decarboxylase 1*, which encodes GABA synthase, and knockdown lines of $GABA_A$ receptor, both demonstrated elevated levels of green-light avoidance.

[Topic1]Genes and Behavior

[Topic2]Sensory: Vision

Poster Session 1

PO-1121(14:30 - 15:30)

Genes and Behavior I: Doublesex-expressing neurons controlling female reproductive behavior in *Drosophila*

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In *Drosophila*, a male and a female exhibit a typical repertoire of sex-specific behaviors for reproduction. When a male fly shows courtship behavior, a fully receptive female opens vaginal plates to facilitate copulation. An unreceptive female exhibits rejection behaviors such as kicking and ovipositor extrusion. After the copulation, the female searches appropriate site for egg deposition and inserts the ovipositor into the substrate and lays eggs. Sex-specific behavior should derive from sexually dimorphic neural circuitry in the CNS. Two sex determination factors, *doublesex* (*dsx*) and *fruitless* (*fru*), establish in most sexual dimorphism in the CNS. Although *dsx*-expressing neurons have been shown to be involved in female reproductive behavior, the neural circuitry underlying the female behavior is poorly defined.

To examine the roles of *dsx*-expressing neurons in female reproductive behaviors, we used the temperature-sensitive activator dTRPA1. Activation of all *dsx*-expressing neurons in females induced ovipositor extrusion response and egg-laying at very high levels. Applying the MARCM method to reduce the number of neurons expressing dTRPA1, we identified a cluster of *dsx*-expressing neurons that regulate the ovipositor extrusion and a female-specific neuron that would promote egg-laying. We will discuss the role of these identified neurons in female reproductive behavior.

[Topic1]Genes and Behavior

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1122(15:30 - 16:30)

Genes and Behavior I: Molecular modules of maternal care: Neural gene expression in the mouth-brooding cichlid *A. burtoni*

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Reed College[1]

Maternal care is an essential adaptive social behavior for many species, yet the underlying neural mechanisms have largely been addressed in mammalian systems. A new mother ’ s brain undergoes a fundamental transformation that shapes maternal behavior. We capitalize on the well-studied neural circuit plasticity for mammalian maternal behavior, “ the maternal brain ” , to study maternal mouth-brooding in the cichlid fish *Astatotilapia burtoni*. In this independently-evolved instance of robust care, the neural circuits regulating maternal behavior must interact intimately with the feeding circuits to allow voluntary starvation despite significant loss of body mass. Maternal mouth-brooding offers an extreme example of parent-offspring conflict in a tractable system for careful mechanistic studies. Using two different *A. burtoni* fish stocks, each showing a different level of maternal care, we have identified gene expression changes associated with the transition from mouth-brooding to overt maternal care. By aligning our gene regulation results with homologous anatomical networks we can determine the extent to which the cichlid maternal brain corresponds to that of mammals implying deep homology across vertebrates.

[Topic1]Genes and Behavior

[Topic2]Social Behavior

Poster Session 1

PO-1123(16:30 - 17:30)

Genes and Behavior I: Identification of genes involved in the pheromone signaling that regulates olfactory plasticity in *C. elegans*

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Pheromones of *C. elegans* were recently identified as mixtures of sugar derivatives called ascarosides. Ascaroside signaling regulates various behaviors, such as sex-specific attraction, repulsion, aggregation and dauer formation.
Olfactory plasticity is also regulated by the pheromones. *C. elegans* is attracted to a series of odorants; however, after prolonged exposure to the odor in the absence of food, worms stop approaching the odorant and disperse from it. We recently reported that abundant pheromone is required for olfactory plasticity. We further identified a key gene involved in this regulation, *snet-1*, which encodes a neuropeptide. Low concentration of pheromone results in an over-production of the SNET-1 neuropeptide, which in turn appears to inhibit the olfactory plasticity. *snet-1* is expressed in a subset of head neurons, including the pheromone-sensing neurons ASI, where expression of *snet-1* is observed only in the absence of the pheromone.
By observing the expression of *snet-1p::venus* in ASI neurons of mutant animals, we found that some of the known pheromone signaling molecules also regulate the *snet-1* expression: the *tax-4* cGMP pathway and the *daf-2* insulin pathway promote *snet-1* expression, while the *daf-7* TGF-β pathway represses the expression. In the regulation of *snet-1*, TGF-β pathway may require novel components.

[Topic1]Genes and Behavior

[Topic2]Cellular Properties

Poster Session 1

PO-1124(17:30 - 18:30)

Genes and Behavior I: High throughput phenotypic profiling leads to insights into mechanisms of habituation in *C. elegans*

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Using a novel high-throughput behavioral assay, we collected 13 distinct quantitative measures of movement, sensation and learning (habituation) from 508 known C. elegans mutants. From these data, we identified 6 independent phenotypic components for C. elegans tap habituation that are regulated by non-overlapping subsets of genes. We used two approaches to identify potential signaling pathways involved in regulating habituation: multivariate analysis to predict potentially undiscovered interactions and a candidate approach to characterize how known signaling pathways regulate habituation. The multivariate analysis predicted 1075 novel genetic interactions based on similarity in phenotypic profiles. Using the candidate approach, we characterized mutant strains that interacted genetically with one (or both) of the strongest habituation variants, goa-1 and eat-16. goa-1 and eat-16 are members of the heterotrimeric G-protein signaling pathway and have previously been shown to contribute to the regulation of synaptic release in nervous systems of C. elegans to mammals. Our analysis demonstrates that G α i and G α q signaling pathways share a broad role regulating habituation whereas the G α s pathway modulates the rate of habituation.

[Topic1]Genes and Behavior

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1125(14:30 - 15:30)

Genes and Behavior I: Searching for genes affecting visually-evoked startle response properties with inbred strains of Medaka (*Oryzias latipes*)

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In some social animals, individual behavioral differences (“ personalities ”) can influence social structure. For example, when a pair of sticklebacks (one is bold, and the other is timid), forage in an aquarium, the bold one tends to play a role as a leader, and the timid one behaves as a follower.
Behavioral characteristics are influenced not only by postnatal environments, but also by genetic factors. Thus it is possible to assume that genetic diversity can contribute to division of roles in groups. The possibility has not, however, been well examined.

To solve these problems, we have focused on Japanese small fish, medaka (*Oryzias latipes*), as a model organism. The medaka genome project, completed in 2006, revealed the highest intraspecific base substitution rate among known vertebrates. We analyzed behaviors of some inbred medaka strains and discovered remarkable differences in visually-evoked startle response properties. Quantitative trait loci (QTL) analysis with F2 progeny between HNI-II and HdrR-II strains highly suggested the presence of genomic loci related to reduction of response toward repeated light-to-dark stimuli.

Now we are generating congenic lines to narrow down the candidate region, and also investigating genetic effects on collective behaviors.

[Topic1]Genes and Behavior

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1126(15:30 - 16:30)

Genes and Behavior I: Robustness of developmental gene expression dynamics for vocal learning

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Birdsong, like human speech, is a complex vocal behavior acquired by sensorimotor learning on the basis of coordinated auditory input and vocal output to mimic tutor song. Song is primarily learned within a limited developmental stage, called the critical period. However, it is unknown how auditory input affects the critical period for vocal learning. Here, using deafened songbirds, we examined the contributions of auditory input to acquisition of complex vocal patterns and regulation of genetic programs in associated neural substrates. Compared with intact zebra finches, vocal development in early-deafened ones was delayed but song crystallization was eventually observed, characterized by individually distinct and structured vocal patterns. In contrast to the difference in vocal ontogeny between intact and early-deafened zebra finches, gene expression patterns and levels in the vocal motor circuit is conserved in an age-dependent manner even in deafened birds indicating audition-independent robustness of developmental gene expression dynamics for vocal learning. These results provide insight into generation of a stable complex vocal pattern at the end of the critical period by two different regulations, “ active ” crystallization mediated by the basal ganglia-forebrain circuit using auditory feedback and “ passive ” crystallization associated with intrinsic developmental gene expression dynamics.

[Topic1]Genes and Behavior

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1127(16:30 - 17:30)

Genes and Behavior I: A role of the gene fruitless in inheritance of the grasshopper song

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Previously, we studied a pattern of inheritance of the courtship song characters in sibling species of *Chorthippus albomarginatus* group. These species may be only reliably distinguished based on their courtship behaviour. Inheritance of the four song characters was shown to be consistent with a type-III genetic architecture, which involves complementary or duplicate pairs of loci. In three sibling grasshopper species of *Ch. biguttulus* group, which only differ in their calling songs, a coexistence of several copies of the gene *fruitless* (*fru*) was found (Ustinova, Mayer, 2006). Besides, *fru* was the first genetic marker, which supports differentiation of these three species at the molecular level. Currently, we compared *fru* among three species of *Ch. albomarginatus* group. As in species of *Ch. biguttulus* group, the coexistence of several closely related *fru* paralogues was found in species of *Ch. albomarginatus* group – a remarkable feature not known from *Drosophila* and other insects. If one of the functions of *fru* in grasshoppers is the song production, it is possible that duplication of *fru* could have participated in a rapid speciation based on divergence of acoustic signals. This work was funded by Russian Foundation for Basic Research (13-04-00376).

[Topic1]Genes and Behavior

[Topic2]Sensory: Audition

Poster Session 1

PO-1128(17:30 - 18:30)

Genes and Behavior I: Promoter analysis of the mushroom body-preferential genes of the honeybee

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The higher center of insect brains (the mushroom body, MB) is comprised of neurons called the Kenyon cells (KCs). The MBs of the honeybee have four types of the KCs (the large-, middle-, small-, and class-II KCs) with distinct gene expression profiles. However, how each KC subtypes are involved in the complex behavior of the honeybee is unknown. We expect that revealing function and regulatory mechanisms of genes expressed in a KCs-selective manner will help better understanding the social behavior of the honeybee.
We previously searched genes expressed selectively in the MBs. In this study, aiming at revealing the regulatory mechanisms in KC-subtype selective expression, we focused on *Phospholipase C epsilon* (PLCe), *Synaptotagmin 14* (Syt14), and *discs large homolog 5* (dlg5), whose expression in the MBs seemed to be more prominent than that of any other genes. Quantitative RT-PCR and *in situ* hybridization revealed that *PLCe* is expressed in whole MBs, while *Syt14* and *dlg5* are expressed in the lKC-selective manner, suggesting that they are appropriate for analyzing regulatory mechanism in the KCs. When we introduced reporter genes by electroporation, in which *gfp* is ligated downstream of genomic region of three genes, basic, not MB specific, promoter activity was detected.

[Topic1]Genes and Behavior

[Topic2]Social Behavior

Poster Session 1

PO-1129(14:30 - 15:30)

Genes and Behavior I: Analysis of high-temperature sensitive neural activity in the brains of honeybee workers using immediate early genes

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When a colony of Japanese honeybee (*Apis cerana japonica*) is attacked by giant hornet (*Vespa mandarinia japonica*), the honeybee workers form a ‘hot defensive bee ball’ by surrounding the hornet *en masse* and vibrating their flight muscles to produce heat. Our previous study using a neural immediate early gene (IEG) *kakusei* revealed that in the brains of worker honeybees some neurons in the mushroom bodies (MBs) were activated during hot defensive bee ball formation and that this neural activity was reproduced in 46 ° C (similar to the inner temperature of a bee ball)-exposed bees.
In the present study, to analyze and compare high-temperature responsiveness of the MBs, we exposed both Japanese and European (*A. mellifera* L.) honeybees to 40, 42, 44, 46, or 48 ° C for 30 min. Quantitative RT-PCR revealed that *kakusei* expression level was significantly increased at temperatures between 44 ° C and 46 ° C in both honeybee species. Another IEG, *Egr*, which was a conserved IEG between vertebrates and insects also upregulated over 44 ° C. These findings strongly suggested that the high-temperature responsive KCs which have an activation threshold between 44 ° C and 46 ° C were conserved even in European honeybee, which do not exhibit hot defensive bee ball formation.

[Topic1]Genes and Behavior

[Topic2]Social Behavior

Poster Session 1

PO-1130(15:30 - 16:30)

Development: Mum ’ s the word: trans-generational transmission of phenotypes programmed by early-life stress

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The traditional view of developmental stress is one of constraint. However, an alternative hypothesis recognises the potential for adaptive developmental programming of behaviour, which enhances fitness if developmental environments match those experienced later in life. One intriguing possibility is that these effects are transmitted to the next generation, increasing offspring fitness. We present experimental data on the neuroendocrine and behavioural effects of early-life stress within and across generations of Japanese quail. F1 birds that experienced pre-natal stress exhibited attenuated corticosterone responses to acute stress in adulthood, mediated by a higher intracellular glucocorticoid receptor expression in the hippocampus. These birds were also more willing to begin exploring a novel environment. F1 individuals that experienced both pre- and post-natal stress exhibited the highest levels of exploration. F2 quail from pre-natally stressed mothers showed the same heightened explorative behaviour and neuroendocrine changes as their mothers; the same was true for the offspring of mothers exposed to both stressors. Interestingly, the mother ’ s developmental experience seems to be the major factor affecting offspring behaviour, regardless of the environmental cues experienced during offspring development. This trans-generational transmission of a mother ’ s stress copying phenotype may serve to enhance their offspring ’ s ability to cope with stressful environments.

[Topic1]Development

[Topic2]Genes and Behavior

Poster Session 1

PO-1131(16:30 - 17:30)

Development: Function of object motion preference in newly hatched domestic chicks: facilitation of imprinting by point-light animation mimicking a walking hen

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An animation (motion picture) composed of a set of moving points of lights, if appropriately arranged, creates a vivid perception of living organism, a phenomenon known as Johansson's biological motion (BM). It has been reported that chicks have innate preference to BM, and that early visual experience induces the predisposed preference depending on sex. In this study, we tried to find out the fitness advantages of the BM perception, and investigated whether learned color preference by imprinting is facilitated by BM. Four groups of chicks were tested using binary choice (Red or Yellow) at 30 min (test1) and 24 hours (test2) after imprinting . Two groups were trained by color plate without motion (Red/plate and Yellow/plate), and the other two were trained by BM animation composed of colored point-lights mimicking a walking hen (Red/Wh and Yellow/Wh). Tests revealed that all 4 groups of chicks preferred the trained color. Particularly, the group Yellow/Wh showed a strong preference on test1. In both groups Yellow/Wh and Red/Wh showed stronger color preference than those trained by color plate in test2. Furthermore, when total run distance during was higher in Red/Wh than the others.

[Topic1]Development

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1132(17:30 - 18:30)

Development: A telemetry measurement for neural activities

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Echolocating bats measure their surroundings using a highly developed sensing system. Studying mechanisms of bat echolocation is very useful for us to develop our sensing system. We considered that a study to analyze bats neural activities for understanding ultrasonic-biosensing was important. Accordingly, we developed a telemetry system for measurement of neural activities from flying small bats (Pipistrellus abramus, Rhinolophus ferrumequinum, Hipposideros terasensis, etc.). A telemetry system comprises of a transmitter and a receiver. The transmitter is very small and weighs less than 1 g and has a 30 cm transmitting antenna. This transmitter is able to transmit radio wave for over an hour. The receiver has high sensitivity, that is, 2 - 3 m receiving area with 2 diversity receiving antennas. As the 1st step of this study, we placed the transmitter on the head of a Mogolian gerbil (Meriones unguiculatus), and recorded the cochlear microphonics from the round window of the cochlea. We report the telemetry system we developed, for monitoring the cochlear microphonics of ultra-sonic communication sounds emitted by free moving Mogolian gerbil.

[Topic1]Development

[Topic2]Sensory: Audition

Poster Session 1

PO-1133(14:30 - 15:30)

Development: Peripheral olfactory system in praying mantis (*Tenodera aridifolia*): its structures and development

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In insects, olfaction is mediated through antennae, which are divided into segments (flagellomeres) and where sensory receptive structures (sensilla) are located. The olfactory sensilla house neurons whose axons run along the antennae until antennal lobes where the terminations are organized into clusters (glomeruli). Hemimetabolous insects grow up by molting until reaching the adulthood. At each stage of development, the sensory structures develop and mature: new flagellomeres elongate the antennae, and new sensilla appear. In the present study, we investigated the peripheral olfactory system in mantis (Tenodera aridifolia) by measuring the features of flagellomeres and antennal lobes during the postembryonic development. For this study, we developed a new and innovative methodology to reconstruct the antennal development, and realized a complete database of each glomerulus. Even though the antennal sexual dimorphism completes at the adulthood (length of flagellomeres, sensillar distribution and antennal lobes) we found that it appears from the 6th instar with a larger number and wider flagellomeres in males. In addition, we measured an increase of the volume of a macroglomeruli during the 7th instar, before the appearance of “ sex-pheromone ” sensilla. These results pave the way to understand the development of olfactory receptor neurons in hemimetabolous insects.

[Topic1]Development

[Topic2]Sensory: Olfaction and Taste

Poster Session 1

PO-1134(15:30 - 16:30)

Development: Hippo signaling regulates a switch between retinal progenitor cell proliferation and photoreceptor cell differentiation in zebrafish

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The strict control of numbers and types of neurons through regulation of cell cycle progression and terminal differentiation is an essential aspect of neurogenesis. Hippo signaling plays a crucial role in promoting cell cycle exit and terminal differentiation in multiple stem cells, including retinal progenitor cells. When Hippo signaling is activated, the Mst1/2 kinases activate the Lats1/2 kinases, which in turn phosphorylate and inhibit the transcriptional cofactor Yap. At present, the precise mechanism by which the Hippo pathway regulates the differentiation of specific types of retinal neurons has remained obscure. In this study, we found that knockdown of zebrafish *mst2* induced early embryonic defects, including the retinal abnormalities. Similar abnormal retinal phenotypes were observed in zebrafish embryos injected with a constitutively active form of *yap* [*yap (5SA)*]. Microarray analysis revealed that *yap (5SA)*-expressing embryos exhibited decreased expression of transcription factors such as Otx5 and Crx, which orchestrate photoreceptor cell differentiation by activating the expression of *rhodopsin* and other photoreceptor cell genes. Co-immunoprecipitation experiments identified the photoreceptor cell differentiation factor Rx1 as a novel interacting partner of Yap. Our results suggest that Yap regulates the timing of photoreceptor cell differentiation by suppressing Rx1-mediated transactivation of the *otx, crx* and *rhodopsin* genes.

[Topic1]Development

[Topic2]Sensory: Vision

Poster Session 1

PO-1135(16:30 - 17:30)

Development: Analysis of mechanism underlying brain growth accompanied by neurogenesis using medaka fish (*Oryzias latipes*)

*Yasuko Isoe[1], Teruhiro Okuyama[1], Masato Hoki[1], Genki Yamagishi[1], Kiyoshi Naruse[2], Masato Kinoshita[3], Yasuhiro Kamei[2], Atsushi Shimizu[4], Takeo Kubo[1], Hideaki Takeuchi[1]

University of Tokyo[1] , National Institute of Basic Biology[2] , Kyoto Unievrsity[3] , Keio University[4]

In vertebrates, the basic brain neural networks are defined during embryonic development. The brain growth spurt occurs postnatally, accompanied by the rapid increases in cell number and brain volume. It remains unknown, however, how postnatal (post-hatch) neurogenesis contributes to the organization of neural network required for social behaviors. To address this subject, I focused on medaka fish (*Oryzias latipes*), which is a model animal for molecular genetics and show prominent post-hatch brain growth and social behavioral development. I generated transgenic medaka fish in which post-hatch neurogenesis can be genetically modified. In this line (*HuC*:loxP-*DsRed*-loxP-*GFP*), newly-born neurons in the adult brain were visualized. When stochastic recombination was induced by micro-injection of Cre mRNA into Tg embryos, it resulted visualization of clonally-related cells in compartmented regions in the telencephalon in the adult medaka brain. Nextly, heat induction of transgenic embryo (*HSP*:*Cre*) led to Cre-recombination in the nervous system. By using these both lines (*HSP*:*Cre* and *HuC*:loxP-*DsRed*-loxP-*GFP*), heat induction can induce different Cre-recombination pattern depending on individuals. Finally, by using infrared laser, induction of heat shock in a micro area in the developing brains led to visualization of clonally-related HuC-expressing cells in the adult medaka fish.

[Topic1]Development

[Topic2]Social Behavior

Poster Session 1

PO-1136(17:30 - 18:30)

Development: Characterization of molecules involved in neural development in the cricket, *Gryllus bimaculatus*

*Tamsin, E. M. Jones[1], Cassandra, G. Extavour[1]

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Germ cells are the cells that become sperm and eggs and thus are necessary for reproduction in animals. Oskar protein was first identified in the fruit fly *Drosophila melanogaster* as an essential component of the germ cell development pathway. *oskar* was previously thought to be a newly evolved gene, restricted to the holometabolous insects (insects that undergo complete metamorphosis). Previous research in the Extavour laboratory, however, identified *oskar* in the two spotted cricket, *Gryllus bimaculatus*. The presence of *oskar* in this basally branching insect suggests that *oskar* may have evolved at the base of the insect radiation, much earlier than previously thought. Further, Extavour lab studies on *oskar* in the cricket have shown that *oskar* ’ s function during development has changed during insect evolution. In contrast to *oskar* ’ s germ line role in *Drosophila*, *oskar* in the cricket functions in the development of the nervous system. To further understand *oskar* ’ s function in neural development, I have been characterizing the molecular control of early nervous system development in the cricket. Here I will present these results and compare them to what is known about the molecular mechanisms of neural development in *Drosophila*.

[Topic1]Development

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1137(14:30 - 15:30)

Development: The prenatal origins of “ innate ” vocalizations in marmoset monkeys

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In primates, a number of vocal behaviors are present at birth. These behaviors are often dubbed as “ innate ” but how they develop remains mysterious. As opposed to simply appearing *de novo* at birth, we hypothesize that vocalizations begin to self-organize prenatally through the interactions between spontaneous neural activity, fetal biomechanics and the physical constraints of the uterine environment. We investigated how fetal movements relate to the postnatal mouth movements required for vocal production by performing ultrasound imaging on awake, pregnant marmoset monkeys (*Callithrix jacchus*). Our expectations were two-fold (1) body parts linked to different behaviors become increasingly differentiated; and (2) body parts used for the same behavior become increasingly coordinated. We found that orofacial and head movements occur together early in gestation but gradually decouple and move independently by the end of gestation. Critically, we also observed that signature features of marmoset infant calls emerge prenatally as distinct patterns of orofacial movements: Late in gestation, the duration and syllable number of the phee call—a call produced by marmoset monkeys on the first postnatal day—are evident in the orofacial movements of fetal marmosets. Our study shows that aspects of vocal behaviors in marmosets have a period of prenatal development.

[Topic1]Development

[Topic2]Communication

Poster Session 1

PO-1138(15:30 - 16:30)

Development: Intestinal epithelial cells secrete acetylcholine as a non-neuronal autocrine or paracrine signal in mice

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Acetylcholine (ACh) has been considered a neurotransmitter residing in central, parasympathetic and neuromuscular synapses of mammals. Here, experiments using crypt-villus organoids that lack nerve and immune cells in culture led us to suggest that endogenous ACh is synthesized in the intestinal epithelium to evoke growth and differentiation of the organoids through activation of muscarinic ACh receptors (mAChRs). The extracts of the cultured organoids exhibit a noticeable capacity for ACh synthesis that is sensitive to a potent inhibitor of choline acetyltransferase (ChAT). Imaging mass spectrometry reveals distribution of endogenous ACh that is localized in the epithelial layer in mouse small intestinal epithelium in vivo, suggesting non-neural resources of ACh. Treatment of organoids with carbachol down-regulates growth of organoids and expression of marker gene for each epithelial cell. On the other hand, antagonists for mAChRs enhances growth and differentiation of organoids, indicating involvement of mAChRs in regulating proliferation and differentiation of Lgr5-positive stem cells. Collectively, our data provide evidence that endogenous ACh released from intestinal epithelium maintains homeostasis of intestinal epithelial cell growth and differentiation via mAChRs in mice.

[Topic1]Development

[Topic2]Cellular Properties

Poster Session 1

PO-1139(16:30 - 17:30)

Development: Behavioral and cerebral changes occur in cuttlefish with perinatal exposure to antidepressants

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The perinatal period is a critical window for development in the course of which environmental changes influence neural and behavioral maturation. Continuously released at low doses in marine environment, pharmaceuticals such as antidepressants can potentially have neural disrupting effects and impact on behavioral development of non-target organisms. Cephalopods are sophisticated marine invertebrates, their brain and their behavioral skills are of great interest in neuroethology. This project aims to assess the effects of subchronic exposure to waterborne antidepressant on brain and behavioral development in hatchling cuttlefish. The two antidepressants studied belong to the Serotonin (Fluoxetine) or Serotonin-Norepinephrine (Venlafaxine) Reuptake Inhibitors classes. Eggs or hatchlings were exposed (≤1 month) to several antidepressant concentrations (ng/L-μg/L). Results show that antidepressant exposure induces effects on the brain development from embryonic stages: changes in cell proliferation and in monoamine neurotransmission. Newly hatched cuttlefish cope autonomously with ecological demands such as finding food or avoiding predators. Results show some temporary and long lasting effects of antidepressants on camouflage and feeding behavior. All effects observed on juveniles depend on the respective pharmacological targets of the drugs and their concentrations. Perinatal exposure to environmental concentration of antidepressant may ultimately reduce the chance of survival for cuttlefish.

[Topic1]Development

[Topic2]Neuromodulation

Poster Session 1

PO-1140(17:30 - 18:30)

Evolution: The transcriptional basis of electric organ evolution

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Electric organs (EOs), developmentally derived from skeletal muscle (SM), have evolved convergently at least six times in fishes for the purposes of navigation, communication, and sometimes, defense. The Gallant laboratory, together with a consortium of investigators, hypothesized that a homologous " genetic toolbox " was repeatedly used in the convergent evolution of electric organs. We tested this hypothesis by comparing gene expression between EOs and SM in four lineages of electrogenic fishes (torpeniformes, gymnotiformes, mormyriformes, and siluriformes). Our analysis identifies a common set of transcription factors and cell signaling pathways likely to underlie many convergent aspects of electrocyte form and function.

One of these lineages, the mormyriformes, are among the most rapidly diversifying groups of ray-finned fishes, which is driven presumably by sexual selection on electric organ discharges (EODs) used in courtship. EODs differ in their duration, polarity, and complexity, and we hypothesize that differential expression of ion channel and cytoskeletal genes underlies these differences. We have begun to test this hypothesis by comparing patterns of gene expression among species of the mormyrid species flock *Paramormyrops*. Identification of genetic loci that contribute to species-specific differences in EODs will enable us to reconstruct the evolution of courtship signals.

[Topic1]Genes and Behavior

[Topic2]Evolution

Poster Session 1

PO-1141(14:30 - 15:30)

Evolution: Coadaptation between maternal and offspring genome mediated by X chromosomal loci

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Offspring development in mammals is crucially dependent on maternal provisioning. The close interaction between parents and offspring is predicted to result in coadaptation of parental and offspring traits such that specific combinations are favoured over others. Using a cross-fostering design between genetically variable BXD and genetically uniform B6 mice, we show that coadaptation between mother and offspring occurs and is conferred by closely linked loci on the X chromosome. We thus demonstrate that genetic variation in parent and in offspring indirectly influences key traits in the other, confirming formally the fundamental assumption of models of parent offspring interactions. We further identify an indirect genetic effect locus on chromosome 19 in offspring that influences the level of maternal provisioning, confirming that such traits can indeed evolve due their effect on offspring fitness via influencing the quality of maternal behavior.

[Topic1]Evolution

[Topic2]Genes and Behavior

Poster Session 1

PO-1142(15:30 - 16:30)

Evolution: Comparative studies and dynamic clamp analyses reveal diverse neural network mechanisms underlying analogous behaviors

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Computational simulations have suggested that similar patterns of rhythmic activity can be produced by neural circuits having diverse network architectures. To gain insight into general principles of central pattern generators (CPGs) and likely scenarios for their evolutionary paths, we compared the CPGs underlying similar swimming behaviors in three nudibranch species: *Dendronotus iris*, *Melibe leonina*, and *Flabellina iodinea*. We found that they contain homologous neurons which are organized differently to produce similar motor patterns. First, Swim Interneuron 1 is a key member of the CPG in *Melibe* and *Flabellina*, but not in *Dendronotus*. Second, the swim motor patterns of *Dendronotus* and *Flabellina* but not *Melibe* were blocked by d-tubocurarine (curare). Third, we identified curare-sensitive synapses within the CPGs of *Dendronotus* and *Melibe* that play distinct roles in rhythm generation. By artificially recreating the curare-blocked synapses in *Dendronotus* using the dynamic clamp technique, we could restore rhythmic bursting activity to the network. Furthermore, using dynamic clamp to rewire the *Dendronotus* CPG by giving it the synaptic configuration of *Melibe* also restored rhythmic activity in the presence of curare. The results demonstrate that these species use different circuit mechanisms to produce similar behaviors with the same sets of neurons. Supported by NSF-IOS-1120950.

[Topic1]Motor Systems

[Topic2]Evolution

Poster Session 1

PO-1143(16:30 - 17:30)

Evolution: Evolution of the tetrapod middle ear

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Recent research has shown that tympanic middle ears evolved independently in the major vertebrate groups and represent independent experiments in terrestrial hearing. Furthermore, the tympanic ear emerged quite late – approximately 120 mya after the origin of the tetrapods and approximately 70 my after the first truly terrestrial tetrapods emerged. One of the major challenges is to understand the transitional stages from tetrapod ancestors to the tympanic tetrapod ear, for example how a non-tympanic ear functions in terrestrial hearing.

Based on ABR and vibration measurements on recent lungfish, amphibians, lizards, snakes and alligators we can outline scenarios for the initial adaptations of the middle ear to non-tympanic hearing and assess the selection pressures later adapting the middle ear for tympanic hearingy. Hearing by bone conduction, sound induced vibrations of the skull, is found in snakes and some earless frogs, whereas urodeles and other earless frogs are more sensitive than predicted from sound-induced skull vibrations and may have specialized pathways to the inner ear. We propose four stages : 1) the unspecialized crossopterygian ear with immobile middle ear bone, 2) increased inner ear frequency ranges, 3) mobile middle ear structures and 4) the tympanic middle ear .

[Topic1]Sensory: Audition

[Topic2]Evolution

Poster Session 1

PO-1144(17:30 - 18:30)

Evolution: The energetic cost of vision in Mexican cavefish

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The Mexican cavefish *Astyanax mexicanus* has a range of evolved ecotypes, from eyed populations living in surface rivers, to eyeless individuals living in caves. One hypothesis for the loss of vision in cave phenotypes is the high energetic cost of neural tissue and low food availability. However, there is no data available on relative brain and eye mass, nor any measure of the cost of neural tissue, making it difficult to evaluate whether the ‘expensive tissue hypothesis’ is helpful in explaining the loss of vision during the evolution of the cave phenotype. We measured the mass and oxygen consumption of isolated eye and brain tissue in cave and surface dwelling Mexican cavefish. Here we show that the eyes and optic tectum represent significant metabolic costs in the eyed phenotype. The cost of vision was calculated to be 18% of resting metabolism for a 1 g fish, decreasing to 5% in an 8.5 g fish as relative eye and brain size declined during growth. Our results demonstrate that the loss of the visual system in the cave phenotype drastically lowered the amount of energy expended on expensive neural tissues during diversification into subterranean rivers, in particular for juvenile fish.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 1

PO-1145(14:30 - 15:30)

Evolution: Nerve ring of cnidarians: Origin and evolution of the central nervous system

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After I studied many aspects of hydra nervous system (structure, function, development) in many biological levels (from genes, molecules to an individual), I compared them to nervous systems of bilaterians. Then I am thinking the origin and evolution of the nervous system. My current hypothesis is The nervous system had all fundamental components when it appeared on the earth.
As to central nervous system, I think it is also a case. Some investigators have begun to propose that jellyfish has central nervous system. Rhopalia-nerve ring complex of cubomedusae, and two nerve rings in hydromedusae are really primitive central nervous systems.
As to the nerve ring of cnidarian polyps, little are known. Hydra polyp has the nerve ring in the head. After intensive examinations of the hydra nerve ring, I proposed the hypothesis, The nerve ring of hydra is a central nervous system- like neuronal structure.
Related to the hypothesis, I started to survey the nerve ring of the polyps and medusae throughout the whole phylum of the cnidarian. Results shows nerve ring is ubiquitous in cnidarians. Especially as anthozoans have the well-developed nerve ring, the nerve ring is the fundamental neural structure since the beginning of cnidarians.

[Topic1]Evolution

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1146(15:30 - 16:30)

Evolution: Phylogenetic comparative approach for detecting accelerated selective pressures in brood-parasitic cowbirds

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Inferring an evolutionary process of behavioral traits is challenging because those traits do not remain in fossils. Interspecies comparison is a powerful approach for this purpose, but researchers should consider a covariance structure (data non-independence) caused by phylogeny among species. By incorporating this covariance, phylogenetic comparative methods (PCMs) enable to estimate evolutionary parameters and test different evolutionary models. However, application of PCMs has not been common in neuroethology. In this study, we show a utility of PCMs by analyzing an evolutionary model in which a specialist species gradually speciated into generalist species. Five species of brood-parasitic cowbird constitute a monophyletic group, in which the number of host species notably varies among species (ranging from 1 to 216). Recently diverged species have a larger number of host species. We found that this unique dataset can be well explained by an accelerated directional selection model in which each branch is exposed to different selection pressures. In contrast, a commonly used model using Brownian motion was not supported. Although neural mechanisms behind such behavioral evolution remained unclear, this example suggests that PCMs can be applied to analyze various behavioural, and possibly neuroethological traits.

[Topic1]Evolution

[Topic2]Ecology

Poster Session 1

PO-1147(16:30 - 17:30)

Evolution: Microbial origins and physiological consequences of tetrodotoxin toxicity in the rough- skinned newt (*Taricha granulosa*)

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Tetrodotoxin (TTX) is a potent neurotoxin that inhibits electrical signaling in animal nervous systems through selective block of voltage-gated sodium channels (VGSCs). Many animals including pufferfishes and amphibians possess TTX as a defensive compound. Despite this, the source of TTX in amphibians and other terrestrial species is unknown. Marine animals accumulate TTX through symbiotic interactions with TTX- producing bacteria. To investigate the origin of TTX in amphibians, we are characterizing the epithelial microbiome of the rough-skinned newt (*Taricha granulosa*). We are employing 16S rRNA molecular surveys and ecologically-guided cultivation to investigate TTX production in newt symbionts. To date, we have cultured 24 distinct bacterial types, 6 of which are from genera with identified TTX-producing species. Furthermore, while many tetrodotoxic animals possess mutations in their VGSCs to reduce TTX binding affinity, the physiological consequences of these mutations are largely uninvestigated. We are sequencing and investigating the physiological effects of mutations in newt VGSCs. In one isoform (Nav1.6), we have identified a convergent replacement identical to a mutation found in the TTX-resistant retinal isoform (Nav1.3) in *Cynops pyrrogaster*. To our knowledge, this research constitutes the first in-depth investigation of the physiological trade-offs inherent in a relationship between host animals and symbiotic microorganisms.

[Topic1]Cellular Properties

[Topic2]Ecology

Poster Session 1

PO-1148(17:30 - 18:30)

Evolution: Stress-induced grooming in insect: similarity with rodent model

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Main features of grooming behavior are amazingly similar among arthropods and land vertebrates suggesting functional similarity. Grooming of various body parts in vertebrates is arranged as particular sequences of events with cephalo-caudal progression (Sachs 1988). Frustrated animals perform displacement activities identified as behaviors patterns of which are disturbed (Tinbergen 1951). Our data are argumentative for the existence of similar behavioral phenomena in the cockroach, *Periplaneta americana*. We found that the grooming sequences start mainly from antennae followed by forelegs and facultatively end with midlegs or/and hindlegs. 74.6±4.8 % of grooming events is arranged in sequences lasting 75.0±4.9% of total grooming time.
In rodents, exposure to novelty causes abnormal patterns and interrupted bouts (Smolinsky et al., 2009). Shorter grooming sequences displayed by cockroaches exposed to novel conditions appear to be a form of displacement behavior. Octopamine, the stress hormone and neuromodulator in insects, mimics some effects of novelty on grooming behavior.
Great similarity in grooming behavior and its stress-induced changes in vertebrates and insects is unlikely to be totally convergent but may reflect, at least partially, common origin of the nervous system.
The study was supported by Russian Foundation for Basic Research grant#1304-00610a

[Topic1]Evolution

[Topic2]Neuromodulation

Poster Session 1

PO-1149(14:30 - 15:30)

Orientation and Navigation I: Magnetosensitive neurons mediate magnetic orientation in *C. elegans*

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For thousands of years humans have used the magnetic field of the earth to help them navigate across vast distances. Only recently we have learned that other species also use the magnetic field to similar ends. Like us, many animals use the magnetic field to navigate horizontally in their environment. Still other organisms, like magnetotactic bacteria, use the magnetic field vector to migrate vertically in their environment. To date, no sensory neuron or transduction pathway has been described for magnetoreception in any animal. Understanding the neural and the genetic bases of magnetic detection remains a longstanding goal of sensory biology. We show that the nematode *Caenorhabditis elegans* detects and orients to earth-strength magnetic fields. Magnetoreception in worms requires a pair of identified ciliated sensory neurons. To our knowledge, these are the first magnetosensitive neurons described for any species. Magnetic transduction appears to involve a cyclic nucleotide-gated ion channel and the antenna-shaped villi at the end of these neurons. We propose a model where magnetosensory neurons integrate environmental information, including the magnetic field of the earth, to guide *C. elegans* in vertical soil migrations.

[Topic1]Orientation and Navigation

[Topic2]Genes and Behavior

Poster Session 1

PO-1150(15:30 - 16:30)
Orientation and Navigation I: Representation of goals in the bat hippocampus

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Navigation requires knowledge of one`s own location as well as the location of salient sites nested in the environment, such as rewards zones and other potential goals. To investigate how goal location is represented in the brain, we conducted wireless neural-telemetry recordings of single neurons from hippocampal area CA1 of Egyptian fruit bats that were trained to fly and occasionally land and crawl on elevated platforms (defined as "goals") in search for food reward. This allowed a comparison between hippocampal representations (1) during volumetric exploration of 3D space away from the goals, (2) during goal approaching, and (3) during locomotion on the goal itself - all within the same physical environment. Our preliminary results indicate that the same hippocampal neurons could have 3D place-fields in mid-air and 2D place-fields on platforms, with larger place-fields occurring in mid-air than on the platforms. Also, some neurons increased their firing when the bat was approaching the platform, reminiscent of the "goal-approach cells" reported in rodents. In addition, preliminary analyses indicate that more hippocampal place-cells had place-fields around the platforms than in mid-air, suggesting an over-representation of important goals in the environment.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1151(16:30 - 17:30)

Orientation and Navigation I: Developing methods for multi-channel neural recording and stimulation in freely flying bats

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A major goal of neuroethology and behavioral neuroscience is to elucidate the neural basis of behavior and cognition in naturally-behaving animals. This requires the development of methodologies that will allow conducting neural recordings from behaving animals in complex naturalistic laboratory settings, and ultimately also in the wild. We were recently able to use a wireless neural-telemetry system to record from three-dimensional place cells in the hippocampus of freely-flying bats. Here we report our progress in developing a new, highly miniaturized system, allowing: (i) High channel count (16 channels) recording of continuous high-bandwidth spikes and LFP, for 2 hours. (ii) Neural data stored on board (unlimited in range). (iii) On-line monitoring. (iv) 7 channels of wirelessly-controlled electrical microstimulation of up to 7 independent brain sites. (v) Synchronization to additional dataloggers, such as camera video-trackers, GPS, and 9-axis accelerometers – for measuring the animal's position, head-direction and other movement data.   Initial testing of the wireless microstimulation system was conducted by training bats on 3 different behavioral tasks, using microstimulation of the medial forebrain bundle as reward. The device was recently used to successfully record highly-stable single units from two brain areas of freely-flying bats.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1152(17:30 - 18:30)

Orientation and Navigation I: Echolocating bats suppress echolocation by bats flying around other bats

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Echolocating bats exploit a wide dynamic range of pulse emission patterns to finely tune their biosonar performance to different behavioral and environmental contexts. Bats in social groups mutually interfere with one another ’ s sonar, constraining useable dynamic range and forcing a shift in strategy. Precisely how bats optimize biosonar performance in social contexts is unknown. We first characterized the free-tailed bat ’ s pulse emissions across a range of navigational challenges and then reassessed their performance in both real and simulated social conditions. Here we describe experiments in which we used a tethered robotic bat flying with and without simulated biosonar pulse emissions to measure how acoustic interferences altered the bats biosonar strategies. The robotic bat ’ s flight movements triggered a dramatic increase in pulse emission rates in flying bats, indicating they viewed the robot as an obstacle. When artificial pulse emissions were added to the robotic bat ’ s flight, bats ’ lowered their emission rates and shifted temporal patterns. Similar results were derived from analyses of live pairs of bats. Thus, bats emit more pulses to accurately navigate around other bats, but hearing the pulse emissions of those same bats tempers this response.

[Topic1]Orientation and Navigation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1153(14:30 - 15:30)

Orientation and Navigation I: Influence of mouth opening and gape angle on the transmitted signals of big brown bats (*Eptesicus fuscus*)

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Bats dynamically adapt their transmitted echolocation signals for successful target representation and interception. In this study we further investigated the role of adaptive vocal-motor strategies for a stationary big brown bat (*Eptesicus fuscus*) performing a target detection task. We analyzed infrared video sampled at 240 fps synchronized to ultrasonic recordings from a Knowles Electret microphone sampled at 192 kHz. Mouth angles for each emitted echolocation pulse were calculated offline and compared to the pulse's time-frequency characteristics. Our results indicate that mouth opening does not have a large influence on transmitted signal characteristics. This suggests that the neural control of the larynx dominates broadcast sound characteristics, with the throat and open mouth largely acting passively as a radiating horn.

[Topic1]Orientation and Navigation

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1154(15:30 - 16:30)

Orientation and Navigation I: Modulating novelty in ant navigation

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Insect behaviour is frequently stereotyped. Many ants, for example, if trained to a reliable food site will learn a set of view-based heading directions that result in individually idiosyncratic routes that are highly consistent between trips. These route memories are supported by a framework of other cues – visual, olfactory and path integration – that guide an ants initial paths to the goal and that also persist and stabilise the routes. I show here that, despite these strong stabilising forces, the desert ant *Cataglpyhis fortis* is not constrained to follow a habitual route. In some circumstances they will abandon their habitual route memories and use the familiar visual cues to travel home in a new way. I examine the conditions that trigger the ants to follow those novel paths.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1155(16:30 - 17:30)

Orientation and Navigation I: Collision avoidance based on insect elementary movement detectors

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Avoiding collisions is one of the most basic needs for any mobile agent, both biological and technical ones. We propose a model of collision avoidance inspired by behavioral experiments in insects and properties of optic-flow. Some insects, such as flies and bees, separate the rotational and translational optic-flow components by employing an active saccadic strategy of flight and gaze control. The intersaccadic translational optic-flow contains information on the depth-structure of the environment, but to extract this information, self-motion parameters must be taken into account. We developed a simple model to extract the depth-structure from translational optic-flow by using local properties of a spherical eye. On this basis we computed a flight direction that ensures collision avoidance. Flying insects measure optic-flow by correlation-type elementary motion detectors (EMDs), which encode velocity non-linearly and ambiguously and mix in their responses velocity and texture information. Therefore, it is not trivial to extract the depth-structure from EMD responses. Nevertheless, our algorithm can successfully avoid collisions in several environments and replicates some characteristics of the collision avoidance behavior of insects. Finally, when the collision avoidance algorithm was coupled with a goal direction, the agent shows interesting behavior reminiscent of navigation behavior in insects in cluttered environments.

[Topic1]Orientation and Navigation

[Topic2]Computation

Poster Session 1

PO-1156(17:30 - 18:30)

Orientation and Navigation I: Integration of responses to antennal stimulation and phonotaxis in the walking cricket

*Hannah Haberkern[1], Berthold Hedwig[2]

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While navigating through a natural environment animals integrate stimuli of different modalities. This provides a precise representation of the environment and also is important for sensorimotor integration However, how are stimuli processed that initiate different responses but converge on the same motor structures? We investigated integration of acoustic and antennal stimulation in the context of course control in walking crickets.

Female crickets respond to playback of a conspecific male ’ s calling song by orienting towards and approaching the sound source, a behaviour known as phonotaxis. We simulated an obstacle in the cricket ’ s walking path by introducing a metal mesh into the reach of one antenna. In this paradigm the cricket itself generated the mechanosensory stimulus as it actively explored the presented object.

In response to antennal stimulation spontaneously walking crickets orient towards the object and reduce their forward speed. During phonotactic walking of the crickets we presented the antennal stimulus either from the same side or from the opposite side relative to the sound source. When the antennal stimulus is presented the auditory steering manoeuvres are heavily reduced for extended periods of time. However, the acoustic stimulation biases the antennal orientation response towards the direction of the sound source.

[Topic1]Orientation and Navigation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1157(14:30 - 15:30)

Orientation and Navigation I: How do walking silkmoths find the direction of an odor source?

*Noriyasu Ando[1], Ryohei Kanzaki[1]

The University of Tokyo[1]

Male silkmoths (*Bombyx mori*) perform the stereotypic zigzagged walking behavior to localize the conspecific female sex-pheromone source. The behavior begins with surge (straight-line walking) and the surge direction is determined by using bilateral olfactory inputs acquired by the right and left antennae (steering toward the highest odor concentration side), and is modulated by vision. However, whether the bilateral olfaction contributes to successful localization to the odor source is still unknown. In this study, we employed the mobile robot driven by an onboard silkmoth, and disturbed accurate olfactory inputs to the moth and motor output of the robot. The success rate of odor source localization was significantly reduced by crossing the right and left sides of olfactory inputs, and was fully recovered by crossing motor outputs with covering the visual field of the moth. Interestingly, the crossed olfactory inputs and crossed motor outputs did not affect equally under the visually occluded condition, but crossed motor outputs more impaired the capability to localize particularly when the bilateral olfactory inputs were less reliable. We speculated that other mechanisms such as a history of serial sampling of odor concentration might also contribute to the surge direction, as well as bilateral olfactory inputs.

[Topic1]Orientation and Navigation

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1158(15:30 - 16:30)

Orientation and Navigation I: Neural basis of robust behavioral control in insect

*Yoshinori Suzuki[1,2,3], Toru Aonishi[1], Yoichi Seki[3], Hiroyoshi Miyakawa[3], Takako Morimoto[3]

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Appropriate and robust behavioral control in accordance with a certain situation is important for the survival of most animals. Can the insect with a tiny brain also robustly recognize and respond to the meaningful information embedded in the noisy stimulus? In order to investigate how the insect brain processes such unapparent information and ensures appropriate behavioral reaction, the wide-field motion perception of noisy stimulus was examined at both behavioral and neural activity levels in *Drosophila melanogaster*. We measured the head yaw optomotor response and the activity of motion sensitive neuron with *in vivo* whole-cell patch clamp recordings. We found that flies have the robust motion discriminative capacity, witch is relatively unaffected by noise, while sensitivity to the stimulus is proportionally reduced with increase of noise. Furthermore, the activity of motion sensitive neuron is strongly correlated with the optomotor response and also showed the two distinct features. These results indicate that flies can robustly distinguish the moving direction of wide-field stimulus in terms of both behavior and neural activity even though the sensitivity of the response is attenuated by noise, and strongly suggest that the robust behavioral reaction originates from the specific neural activity.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 1

PO-1159(16:30 - 17:30)

Orientation and Navigation I: Fruit fly tracking responses and the visual horizon

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Flying insects navigate through cluttered spaces, and so have considerable need to gauge object distances. Humans use a variety of visual features to estimate distance, but small size and fixed eyes limit insects to a more limited range of possible depth cues. They use motion parallax, for example, but cannot use accommodation. The horizon is one of the most salient natural features, offering clues about orientation, altitude, and for humans, distance to objects. We set out to determine if flying fruit flies, like humans, perceive objects as farther off when they are near the horizon. Tethered flies respond strongly to moving objects they perceive as close, and we measured responses while independently varying the elevation of virtual objects and a virtual horizon. We found wide-field responses are unaffected by relative horizon elevation, but responses to vertical objects are strongly increased by negative elevations to the horizon. In other words, a bar that dips far below the horizon elicits a strong response, consistent with using the horizon as a depth cue. This could serve to judge distances of objects too far off for motion parallax.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 1

PO-1160(17:30 - 18:30)

Orientation and Navigation I: Orientation to the polarized light in flying honeybees

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Many insects use the polarization pattern of the sky to obtain compass information during orientation or navigation. In honeybees, it is well known that the waggle dance orientation is drastically affected by the e-vector orientation of the skylight. To investigate how they respond to the polarized light during flights, we constructed a flight simulator for a flying tethered bee. In this study, we analyzed flying behavior of the tethered bees while stimulating with zenithal polarized light using the flight simulator. To examine how the bee changes her flight direction under the zenithal polarized light stimulus, the horizontal movement of the abdomen was measured using a video camera. When the e-vector orientation of the polarized light was slowly rotated clockwise or anti-clockwise, the bee responded with periodic movement of her abdomen from side to side, whereas she did not show any clear periodic movement under the static e-vector orientation or the depolarized stimulus. The steering frequency of the bee was well coinciding with that of e-vector rotation of the stimulus, indicating that she showed clear polarotaxis during her flight. Our result suggests that the honeybees should utilize the e-vector information from the skylight to know their flight direction.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 1

PO-1161(14:30 - 15:30)

Orientation and Navigation I: An eye for every occasion: as light levels dwindle locusts switch from compound eyes to ocelli as their source of visual-feedback for roll

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In addition to a pair of compound eyes, almost all adult insects possess three simple

single-lens eyes, known as ocelli. The functional advantages of expressing two distinct eye types remain unclear. However, in flying insects it has been shown that ocellar and compound eye signals are combined before they are transmitted down the ventral nerve chord to flight motor ganglia, presumably to provide more robust sensory feedback. We present behavioural evidence that ocelli play a crucial role in flight stabilization after sunset when low light levels compromise the compound eyes. In response to dwindling light levels, locusts (Schistocerca Americana) alter the way they integrate ocellar and compound eye information. By filming head and steering responses to visual signals, we show that when compound eyes and ocelli receive conflicting roll signals during daylight they ignore those presented to the ocelli. However, as mean light levels decrease, the head response to light flashes delivered to the ocelli increases in amplitude, suggesting locusts no longer trust their compound eyes. Thus, we speculate that the superior light gathering ability of ocelli means they play an important role in enabling locusts to stabilize their gaze and flight in dim light environments.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 1

PO-1162(15:30 - 16:30)

Orientation and Navigation I: Modulation of height during the learning flights of the bumblebee, *Bombus terrestris*

*Sathish K. Raja[1], Théo Robert[1], Thomas Collett[2], Natalie Hempel de Ibarra[1]

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Bumblebees on first leaving their nest in the ground perform elaborate flights in which they learn the immediate visual surroundings of the nest-hole. The flights consist of a sequence of loops in which bees fly away from and then towards the nest. During the course of a flight speed of the bees increases and the loops become larger [1]. To study the way in which height changes during learning flights when bees are within 30cm of the nest, we employed two synchronized video-cameras (Panasonic HD camcorder) to obtain 3D trajectories and body orientations for bees flying in different configurations of landmarks placed around the nest-hole. Our preliminary data and analysis shows that height is low over the first half of each flight and then gradually increases to an average maximum of about 9cm. Height tends to be relatively high when bees are far from the nest-hole and to decrease as bees fly back to it. The height reached in the second half of each flight depends on the nature of the landmarks.

Reference:

Philippides, A., Hempel de Ibarra, N., Riabinina, O. and Collett, T. S. (2013). J. Exp. Biol. 216, 1093-1104.

[Topic1]Orientation and Navigation

[Topic2]Cognition

Poster Session 1

PO-1163(16:30 - 17:30)
Social Behavior I: Social equality and inequality affect stress-induced hyperthermia in mice

Shigeru Watanabe[1]

Keio University[1]

Stress-induced hyperthermia was examined in different social conditions in C57BL/6 mice. Placing animals in cylindrical holders induced restraint stress, and an infrared thermometer was used to measure body surface temperature. 1) Mice restrained in the holders alone showed stress-induced hyperthermia. 2) Mice restrained in holders at the same time as other cage mates (social equality condition) showed less hyperthermia. 3) This social equality effect was reduced when the subjects visually isolated each other by walls. 4) When the subjects were surrounded by mirrors, instead of cage mates, they did not show the social equality effect. Thus, the social equality reduced the stress but a mirror did not have such social effect. 5) Restrained mice with free-moving cage mates (social inequality condition) showed the highest hyperthermia. 6) On the other hand, free mice sounding by restrained cage mates did not show hyperthermia even though the situation was a kind of social inequality. The present results are consistent with a previous experiment using the memory-enhancing effects of stress and the stress-induced elevation of corticosterone, and suggest that social conditions affect the stress in mice.

[Topic1]Social Behavior

[Topic2]Cognition

Poster Session 1

PO-1164(17:30 - 18:30)

Social Behavior I: Social context modification of mouse song

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In 2005 Holy & Guo advanced the idea that male mice produced ultrasonic vocalizations (USV) like songs that are like courtship songs of songbirds. Since then, studies showed that mice are able to emit USV songs in different contexts, and possess a multisyllabic repertoire, but scientists still debate for and against plasticity in their vocalizations. In birds, modulating syntax has ethological relevance for mate preferences. Here we exposed adult male mice to different contexts and developed a new approach of analyzing USVs based on songbird syntax analysis. We found that male mice exposed to different stimuli modify their syntax, including sequences, length of sequence, repertoire composition, and spectral features, according to the social context. They emit longer and use simpler sequences of syllables when singing to a live or anesthetized female, but more complex sequences and syllables in response to fresh female urine. Playback experiments showed that the females prefer the complex over the simpler songs. To our knowledge, this is the first time that syntax modifications and their ethological relevance for potential mating are shown in adult mice. These results suggest that mice could be used as animal models for understanding some vocal communication features similarly as songbirds.

[Topic1]Social Behavior

[Topic2]Communication

Poster Session 1

PO-1165(14:30 - 15:30)

Social Behavior I: Distinct ultrasonic vocal repertoires are elicited by females and female chemosensory cues

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Howard Hughes Medical Institute[1] , Princeton University[2]

Mice produce ultrasonic vocalizations in a variety of social contexts. Many attempts have been made to quantify the mouse ultrasonic vocal repertoire. The most common method has been manual sorting of frequency contour shape, though clustering of extracted features has also been used. Previous studies have proposed two, four, nine or eleven syllable categories. We hypothesized that this variation in reported call types is due to variability in syllable spectrotemporal structure within and between individuals. We used t-distributed Stochastic Neighbor Embedding to compare the distances between 22,765 vocalizations from 19 adult male SWR/J mice. This allowed us to examine the full vocal repertoire, and revealed both distinct syllable types (vocalizations with abrupt frequency discontinuities) and a smooth gradation of sinusoidal vocalizations from simple FM upsweeps to M-shaped calls, recapitulating many of the syllable types observed manually. We then used this method to describe variation in vocal structure between two social contexts: exposure to a female, and exposure to female chemosensory cues. We show both quantitative changes across the repertoire (a global increase in duration) and that the two contexts elicit distinct, and mostly non-overlapping, syllable types.

[Topic1]Social Behavior

[Topic2]Communication

Poster Session 1

PO-1166(15:30 - 16:30)

Social Behavior I: Termination of positive emotion elicits negative vocalizations in rats

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JST ERATO Okanoya Emotional Information Project[1] , Department of Cognitive and Behavioral Sciences, The University of Tokyo[2]

Rats emit 22 kHz ultrasonic vocalizations (USVs) in association with negative emotional states. In this study, we examined the neutral state just after a strong pleasant stimulus was terminated using the 22 kHz USVs as an index of negative emotion. We hypothesized if rats felt unpleasant emotion after the termination of the pleasant stimulus, the number of 22 kHz USVs rats emit may increase. We gave electrical stimulus in the medial forebrain bundle (MFB), which is considered as a part of reward system and recorded rats ' USVs during stimulation and after stimulus termination. Rats emitted 22 kHz USVs just after the termination of electrical stimulus. Results can be explained using " the theory of adaptation level " . During the MFB stimulation, rats initially felt pleasure but as time passed their adaptation level shifted toward the pleasure state, and they felt the stimulated state as neutral. Thus, the non-stimulated neutral state, which is below the adaptation level in pleasure-affective axis, was perceived as unpleasant. This is the first demonstration of shift in adaptation level for emotion in rats. The experimental paradigm may help revealing the neural mechanism of adaptation level theory for emotion. (Work supported by JST ERATO).

[Topic1]Social Behavior

[Topic2]Cognition

Poster Session 1

PO-1167(16:30 - 17:30)
Social Behavior I: Preferences for hollow vs. filled social partners in young domestic chicks

*Elisabetta Versace[1], Giorgio Vallortigara[1]

Center for Mind-Brain Sciences[1]

Human infants as young as 8 month old expect animated objects to have insides and not to be hollow. This suggests that infants might attribute biological properties to animated objects (Setoh et al. 2013). Do chicks (*Gallus gallus*) exhibit similar biological expectations for social partners? We take advantage of social motivation of newly hatched chicks to investigate whether: (a) naïve chicks exhibit an unlearned preference for hollow *vs.* filled social objects; (b) imprinting is stronger for hollow *vs.* filled objects; (c) chicks imprinted on hollow, filled or occluded objects exhibit different filial responses. We show that naïve and imprinted chicks can prefer hollow to filled social partners. Our data show that " being filled " is not a requirement for social stimuli in these precocial birds.

[Topic1]Social Behavior

[Topic2]Cognition

Poster Session 1

PO-1168(17:30 - 18:30)

Social Behavior I: Competition meets risk to yield impulsiveness: suppressed representation of food reward in ventral striatum of domestic chicks

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Social factors involved in the behavioral control of choice impulsiveness were examined by using newly hatched domestic chicks as subjects. In binary choices between a large-reward / long-delay option (LL) and a small-reward / short-delay alternative (SS), those chicks trained in groups showed a more choice of SS than those trained in isolation. If, however, the risk (or consequent variance in food amount) was omitted in the competitive condition, those chicks trained in group failed to develop the impulsiveness. Competition is thus necessary but is not sufficient for the impulsiveness to develop. To further investigate the role of social contexts in the neuronal representation of food, we recorded single neuron activity in the medial striatum/nucleus accumbens of freely behaving chicks. Neurons showing distinct cue-period activity in rewarding trials were identified, and activity patterns were compared with those recorded during a subsequent pseudo-competition block. Comparison at neuronal population level revealed statistically significant suppression in the pseudo-competition block, suggesting that perceived competition generally suppressed the representation of cue-associated food reward. The delay- and reward-period activities, however, were not significantly different between blocks. Visual perception of a competitive forager per se weakens the neuronal representation of predicted food reward.

[Topic1]Social Behavior

[Topic2]Cognition

Poster Session 1

PO-1169(14:30 - 15:30)

Social Behavior I: Involvement of substantia nigra but not the dopaminergic neurons in social facilitation of foraging efforts in domestic chicks

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Social facilitation generally denotes increments in frequency and intensity of behaviors in the presence of one or more conspecifics (Crawford 1939). In domestic chicks, we have reported that foraging efforts are socially facilitated even without resource competition for food (Ogura & Matsushima 2011). We hypothesized that the neural substrate could overlap with the " reward system " that calculates food gain and the accompanying foraging effort. We focused on two major dopaminergic pathways, namely (1) ventral tegmental area (VTA) projecting to nucleus accumbens (NAc) and (2) substantia nigra (SN) projecting to medial and lateral striatum (MSt and LSt). We examined the effects of selective lesions of these two pathways on the foraging effort and its social facilitation. Electrolytic lesion to NAc/MSt (pathway (1)) suppressed the basal foraging effort, though the social facilitation remained intact. On the other hand, electrolytic lesion to SN (pathway (2)) suppressed the social facilitation while sparing the basal foraging effort unchanged. Furthermore, dopamine depletion by micro-infusion of 6-hydroxydopamine (in neither NAc/MSt nor SN) had no behavioral effects. These results suggest that neural substrate of the social facilitation is doubly dissociated from that of the reward-based foraging effort.

[Topic1]Social Behavior

[Topic2]Neuromodulation

Poster Session 1

PO-1170(15:30 - 16:30)

Social Behavior I: A mobile fish dummy for the investigation of electrocommunication patterns in weakly electric fish

*Martin Worm[1], Rowena Toma[1], Julia Prume[1], Gerhard von der Emde[1]

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Mormyrid weakly electric fish possess the ability to produce low voltage electric organ discharges (EODs) that are utilized both for active electrolocation and for electro-communication. While EOD-waveforms remain constant on a short time scale, inter-discharge intervals (IDI) are highly variable and strongly depend on the behavioral context.
In order to investigate the communicative content within a sequence of EODs in weakly electric fish of the genus *Mormyrus*, we used a mobile fish dummy equipped with active electrodes to produce playbacks of species specific EODs with both natural and artificial IDI-patterns. Natural IDI-patterns were adapted from real discharge patterns observed in different behavioral contexts and could be characterized by a certain average discharge frequency and/or by rather distinct discharge patterns. In order to discern the significance of pattern and frequency, artificial IDI-sequences with constant frequencies corresponding to the average frequencies observed in natural IDI-patterns were used.
Our results demonstrate that individual *Mormyrus rume* can be recruited from a sheltered area into an open arena by the moving dummy fish emitting species specific electric playback signals. While following the dummy fish, animals interact with it electrically and respond with electric signaling patterns that usually occur in social contexts.

[Topic1]Social Behavior

[Topic2]Communication

Poster Session 1

PO-1171(16:30 - 17:30)

Social Behavior I: Vasotocin and Isotocin neuronal activation in the courtship of a weakly pulse-type electric fish

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Social behavior exhibits a wide diversity among vertebrates though it is controlled by a conserved neural network, which is known to be modulated by hypothalamic neuropeptides. We have recently shown that in *Brachyhypopomus gauderio,* weakly electric fish that emit social electrical signals during courtship, the preoptic area (POA) is more active in social males than in isolated ones. We focused on the identification of vasotocin (AVT) and isotocin (IST) neurons in the POA of *B. gauderio* males. Two-days behavioral experiments were used. In the second night, the neuronal activation of AVT and IST neurons was immunoidentified in both isolated and social males that displayed electric courtship during the first night. For the first time in electric fish, we found double-labeled neurons (AVT/FOS and IST/FOS) and triple-labeled neurons (AVT/IST/FOS). We found no differences in the percentage of both total active AVT neurons and total active IST neurons between social males and isolated ones. There was no correlation between AVT/FOS or IST/FOS and locomotor activity of social and isolated males. Neuronal activation differences in the three populations of AVT cells (parvocells, magnocells and gigantocells) are currently being explored in both experimental groups.

[Topic1]Social Behavior

[Topic2]Neuromodulation

Poster Session 1

PO-1172(17:30 - 18:30)
Social Behavior I: Violence vs adaptive aggression in a non-traditional model system

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Violence is defined as an aberrant aggressive behavior, expressed out of context, without inhibitory control, lacking adaptive function. In humans, violence is a serious health and social problem. Understanding the distinctive neural bases of violence and normal adaptive aggression is a requirement for the search of applicable solutions. The neural bases of aggression depend on a neural network highly conserved among vertebrates. Ethical implications and methodological difficulties involved in the research of violence require the development of novel animal model systems. *Gymnotus omarorum*, a South American weakly electric fish, exhibits inter and intra-sexual non-reproductive territorial aggression. We tested the agonistic behavior of dyads of *G. omarorum* in small (n=6) and large (n=6) plain arenas. We observed violent-like behavior when dyads were tested in small tanks: short first attack latency, bites oriented to vulnerable parts, and the lack of dominants ’ response to subordinates ’ submissive signals. When tested in large tanks, the characteristics of violence dissaperared. First attack latency and contest duration increased, attack rate of dominants and electric submission significantly decreased, whereas the emission of submissive chirps and post resolution phase dominants ’ attacks disappeared. We further analyzed the behavioral effects of vasotocin (known neuromodulator of aggression) in both conditions.

[Topic1]Social Behavior

[Topic2]Neuromodulation

Poster Session 1

PO-1173(14:30 - 15:30)

Social Behavior I: Effects of concurrent activation of serotonergic and octopaminergic systems on posture and aggression of male crickets, *G. bimaculatus*

***Varvara Dyakonova[1], Alexey Krushinsky[2], Boris Boldyshev[2]**

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The roles of serotonin and octopamine in the mechanisms that control social status-dependent behavioral changes in crickets have been significantly clarified. The known effects of these monoamines appear opposite and complementary in the modulation of the behavioral state of a winner (Stevenson et al. 2005; Dyakonova, Krushinsky 2013). Here, we applied previously studied drugs, namely the precursor of serotonin 5-hydroxytryptophane (5-HTP) and the octopamine receptors agonist chlordimeform (CDM) to study the effect of concurrent activation of both monoaminergic systems. Crickets that had received both drugs had significantly higher (winner-like) posture and spent more time in higher posture than crickets injected with only one of the drugs or saline. 5-HTP alone also induced an elevated posture, while CDM tended to lower it, in comparison to the saline-injected control. 5-HTP+CDM treated males won significantly more fights against 5-HTP-treated (23 of 36, 68%, $p<0.01$) or against saline-treated males (29 of 48, 60.4%, $p< 0.05$). Our data indicate that, (1) CDM may have different effects at different level of serotonin synthesis; (2) the idea of concurrent activation of octopamine- and serotoninergic systems in the control of winner behavior in crickets should not be ruled out.

Supported by RFBR grant 14-04-00537.

[Topic1]Social Behavior

[Topic2]Neuromodulation

Poster Session 1

PO-1174(15:30 - 16:30)

Social Behavior I: How does the waggle dance communication mature after the adult emergence?

*Hiroyuki Ai[1], Noriko Kishi[1]

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Waggle dance is the most extensively studied behaviors in honeybees for recruiting the hivemate to the indicated flower. However it remains unknown how the waggle dance matures after the adult emergence. On this study we investigated the number of communication behaviors including waggle dance, dance following and these related behaviors depending on the age, by using observation hive. The rate of the dance following increases remarkably in the young and middle ages (less than 20 days old) and then that of waggle dance increases. The dance following often continue during the waggle dance at the middle and old ages, however a dance following to one waggle run was remarkably observed in the young age (less than about one week old). On the other hands the waggle dance consists of waggling and turns. On this study it was found that " incomplete waggle dances " which has only turn without waggling and only waggling without turns tend to grow up within 16 days after the adult emergence. Moreover the honeybees which emerge at more active period of the hive tend to be more precocious on the waggle dance and the dance following than those which emerge at the less active period.

[Topic1]Social Behavior

[Topic2]Communication

Poster Session 1

PO-1175(16:30 - 17:30)

Social Behavior I: Insights into the neural mechanisms of music from a cross-species perspective

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Two debates are whether music, language and the associated brain circuits are unique to humans and whether music shares features with language. To help resolve these debates, we break music and language into their individual features, separate perception and production, and take an evolutionary comparative approach across species. We hypothesize that universal features of music and language are song and speech, which exist along a continuum. Differences in song and speech are due to execution in brain circuitry, rather than control by different circuits. This song/speech circuit in humans is similar to forebrain vocal learning pathways in non-human vocal learning species, such as songbirds and parrots, whereas most vertebrate species have a rudimentary forebrain pathway for perception of song or speech and a brainstem pathway for production of innate vocalizations. The vocal learning pathways are embedded in a motor learning pathway for producing non-vocal music, dance and gesture, suggesting a deep homology in motor learning systems amongst advanced vocal learners. However, the song/speech production circuit has specialized differences in some neural connectivity genes relative to surrounding brain circuits. We propose testable experiments to falsify our hypothesis, and believe it can contribute to a more global definition and understanding of music.

[Topic1]Social Behavior

[Topic2]Communication

Poster Session 1

PO-1176(17:30 - 18:30)

Social Behavior I: Neurophysiological mechanisms underlying the defensive task allocation in termites

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Task allocation, i.e. division of labor, has independently been acquired in various social-insect lineages, such as bees, wasps, ants and termites, although neurophysiological mechanisms regulating task allocation have been studied only in a few lineages. The elaborate social systems seen in termites are thought to have evolved independently from social hymenopterans since the termite lineage has derived from a wood-feeding cockroach. Soldier caste in termites is a distinctive caste that is specialized in colony defense. Although soldiers share the same genomic background with other castes, they express extremely high aggression against predators. This behavioral differentiation is essential for the defensive task allocation, but the neurophysiological bases are completely unknown.
In this study, we focused on octopamine and tyramine as candidate neuromodulators responsible for the soldier high aggression in damp-wood termites *Hodotermopsis sjostedti*. Tyramine level in soldiers was significantly higher than in pseudergates (worker caste), while no difference between the two castes was detected in octopamine level. Furthermore, pharmacological application of tyramine clearly increased aggression of pseudergates. Because the particular somata of tyraminergic neurons were enlarged in a soldier-specific manner, projection area of these neurons may be responsible for the soldier high aggression, leading to the defensive task allocation in termites.

[Topic1]Social Behavior

[Topic2]Neuromodulation

Poster Session 1

PO-1177(14:30 - 15:30)

Computational Modeling: Modeling mantis prey tracking with head, prothoracic and thoracic movements

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We report on a neuromuscular model of the mantis *Tenodera sinensis*, created to investigate the role of sensory information in posture control during hunting. Mantises track moving prey with movements of the head and prothorax and rotations of the body by the middle and hind legs. Our model abstracts vision to the relative position of the “ prey ” . When a visual cue is simulated, the angle between the cue and the actual head orientation is encoded as a neural signal. This initiates a cascade of head, prothorax and body rotations to center the prey in the visual field.
Our model has 27 active degrees of freedom; six joints per leg for the middle and hind legs, two joints (pitch and yaw) at the prothorax, and one at the neck. Each joint is actuated by a pair of antagonistic muscles and controlled by conductance-based nonspiking neuron models. Desired body orientation is mapped to the joint controllers, allowing simple descending commands to drive more complicated lower-level adjustments. Our model uses its legs to adjust its thorax, which in turn adjusts the head while tracking prey. It provides a plausible prey tracking neural structure, and is a simple-to-manipulate platform to further investigate tracking behavior.

[Topic1]Computational Modeling

[Topic2]Motor Systems

Poster Session 1

PO-1178(15:30 - 16:30)

Computational Modeling: Delayed mutual information infers patterns of synaptic connectivity in a proprioceptive neural network

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University of Southampton, UK[1] , Federal University of Technology Parana, Brazil[2] , University of Sao Paulo, Brazil[3]

Understanding the patterns of interconnections between neurons in complex networks is an enormous challenge using traditional physiological approaches. Here we combine the use of an information theoretic approach to establish patterns of neural connections between layers of interneurons in a neural network responsible for mediating reflex movements of the hind limb of an insect. By analysing delayed mutual information of the synaptic and spiking responses of sensory neurons, spiking and nonspiking interneurons in response to movement of a joint receptor that monitors the position of the tibia relative to the femur, we are able to predict the patterns of interconnections between the layers of sensory neurons and interneurons in the network, with results strongly matching those known from the literature. In addition we used cross-correlation methods to establish the sign of those interconnections and show that they also show a high degree of similarity with those already known in these networks. The method proposed here has great potential to elucidate functional connectivity at the neuronal level in many different neuronal networks.

[Topic1]Computational Modeling

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1179(16:30 - 17:30)

Computational Modeling: Mathematical and experimental studies on prey pursuit by echolocating bats

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A mathematical model was proposed to describe nonlinear dynamics of echolocation by bats during pursuit flight for prey capture. In the model, it is assumed that an echolocating bat uses two direction parameters to determine its flight path; the direction from the bat to a prey position and also the flight direction of the prey. Numerical simulation of the model demonstrates that when the direction parameter from the bat to the prey position was more dominant than the parameter of the flight direction of the prey (the ratio of almost 10 to 3), the probability of successful prey capture becomes the highest. Then, the model parameters were estimated from the experimental results using Japanese horseshoe bats (*Rhinolophus ferrumequinum nippon*) while capturing moving moths (*Goniocraspidum pryeri*) in a flight chamber. The parameter estimation revealed that bat practical flight paths showed suitable parameters in the model, suggesting that the bats chose effective flight paths on the basis of the similar mechanism described by the model. Furthermore, the model was extended to the pursuit behavior of two preys. The parameter estimation from the behavioral results of bats during prey capture flights showed that bats shifted their flight attention between two preys before capturing.

[Topic1]Computational Modeling

[Topic2]Sensory: Audition

Poster Session 1

PO-1180(17:30 - 18:30)

Computational Modeling: Neural mechanism of phase-locked responses of inferior colliculus neurons to sinusoidally amplitude-modulated signals

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Most species of bats making echolocation use Doppler-shifted frequency of ultrasonic echo pulse to measure the velocity of target. The neural circuits involved in detecting the velocity feature have been well known. Neurons in the inferior colliculus (IC) of the mustached bat have been shown to respond with discharges that are tightly phase-locked to the waveform of sinusoidally amplitude-modulated (SAM) signals. However, it remains unclear how IC neurons emerge the tightly phase-locked responses. To address this issue, we developed a neural network model of bat ’ s auditory system for processing information of Doppler-shifted frequency. The model consists of the networks of dorsal nucleus of the lateral lemniscus (DNLL), medial superior olive (MSO), and IC. Each network has the tonotopical map in which frequency information of echo sound is represented by a linear array of neurons or columns. IC neuron was modeled with the Izhikevich neuron model. It receives an excitatory input from MSO neurons and an inhibitory input from DNLL neurons. We show here that the phase locking of IC neurons evoked by SAM signals is caused by an inherent property of IC neuron and a large noise involved in the input signal.

[Topic1]Computational Modeling

[Topic2]Sensory: Audition

Poster Session 1

PO-1181(14:30 - 15:30)

Computational Modeling: Analysis of binocular photosensory system of planarian, *Dugesia japonica*

*Yoshitaro Akiyama[1], Takeshi Inoue[1], Kiyokazu Agata[1]

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Overlapping visual field and semidecussation are believed to be the conserved structures evolved for binocular depth perception. Fresh water planarian, *Dugesia japonica*, has two eyes with a primitive structure with only two types of cells (pigment cells covering photosensory neurons for shutting out light from the covered side). Despite this simple eye structure, it has been reported that planarian photosensory neurons projecting their axons to both the right and left visual center (semidecussation) and GABAnergic neurons there involve the information processing. Therefore, this simple system should have an essential set of binocular photosensory system. In present study, we demonstrate the rough but whole mechanism of planarian photosensory system by formulating a mathematical model based on the data of behavioral analysis. We suggest that planarian makes asymmetry of input signal with the eye structure, roughly locates a light source by calculating the difference of input from the right eye and the left eye, and optimizes output by adding noise. If this model is completed and this study reaches the comprehensive understanding of planarian photosensory system, it might provide insights about more complex system in a big picture from the perspective of evolution.

[Topic1]Computational Modeling

[Topic2]Sensory: Vision

Poster Session 1

PO-1182(15:30 - 16:30)

Computational Modeling: Examination of stimulus pattern and neuronal morphology for efficient biophysical property estimation of neurons in the silkmoth antennal lobe

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For the precise computer simulation of neuron ' s electrical activities, we must use many model parameters of membrane properties, such as distributions of each ion channels on the cell membrane, kinetics of ion channels and morphological features of the cell. These parameters can be estimated by comparing physiological data and simulation, but in particular, ion channel distribution is difficult to obtain from voltage or current clamp experiment using simple constant or ramp stimuli. Our preliminary study showed that estimation of electrophysiological membrane parameters include channel distribution is improved by adding AC component to input ramp current. It is, however, unclear what input stimulus gives the best estimation of parameters to neurons of different morphology. In this research, we focus on neurons in the antennal lobe of the silkmoth, Bombyx mori, and examine suitable stimulus patterns for efficient parameter search of neuron models with different shapes. As a method of parameter search, we implemented massively parallelized covariance matrix adaptation evolution strategy (CMA-ES) on K computer. From the results of experiments, we discuss the relationship between morphology of neurons and membrane property parameters and input stimulus patterns. This research used computational resources of the K computer through the HPCI System Research project (ProjectID:hp140151).

[Topic1]Computational Modeling

[Topic2]Cellular Properties

Poster Session 1

PO-1183(16:30 - 17:30)

Novel Tools and Methods: The swimming test for neurotoxicological studies

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The swimming test is a tool usually employed for the screening of antidepressant drugs; however, the characteristics of the test allow evaluating the effects of drugs that alter the vestibular or motor systems in animals. Particularly, rats treated with substances that produce neurotoxic effects that are placed in a rectangular pool filled with water (5 min), display periods of rotatory or lateral swimming. Lateral swimming is characterized by a behaviour in which the rat swims slowly on its own side without maintaining horizontal balance, the hindlimbs remain extended and rigid, parallel to the water surface for short periods of time uncoordinatedly moving to achieve displacement, with one or both forelimbs retracted. Evaluating these behavioural variables has been possible to detect alterations in motor coordination associated with neuronal damage at brain level in rats. Thanks to this test a series of studies about food products derived from *Dioon spinulosum* (Cycad) or *Manihot esculenta* (cassava) have revealed the importance of neurotoxicological screening for food consumption in different processed products in rural areas.
Programa de Fortalecimiento Académico del Posgrado de Alta Calidad I010/458/2013, C-703/2013

[Topic1]Novel Tools and Methods

[Topic2]Motor Systems

Poster Session 1

PO-1184(17:30 - 18:30)

Novel Tools and Methods: A low cost Global Positioning System to study bird navigation

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Global positioning system (GPS) based bird tracking devices are now being widely used to study bird migration. A large number of systems are commercially available. An ideal Global positioning system receiver, for bird navigation experiments, should be lightweight, compact and can be used to study diverse species of birds. Here we propose a Do-it-yourself GPS system that can be built in a laboratory using off the shelf open source components, on a shoestring budget. The software used to analyse the GPS data is open source. Our system offers a high degree of temporal resolution as it acquires GPS position fixes at 5 Hz. It weights about 12 grams but it can vary based on battery capacity and sampling rate. The GPS receiver is enclosed in a plastic housing and is strapped to the birds back using elastic cord and cord locks. The only drawback of our GPS system is that we have to recover the bird in order to recover the micro SD card and Lithium battery for recharging. We used this system to study the homing behaviour of pigeons.

[Topic1]Novel Tools and Methods

[Topic2]Orientation and Navigation

Poster Session 1

PO-1185(14:30 - 15:30)

Novel Tools and Methods: Using FicTrac to accurately measure the motion of animals walking in virtual reality

*Gavin J. Taylor[1,2], Richard J. D. Moore[2,3], Angelique C. Paulk[2], Thomas W. Pearson[2], Bruno van Swinderen[2], Mandyam V. Srinivasan[2]

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Studying animals in a virtual reality can further our understanding of how sensory information guides behaviour. Measuring the physical responses of the animal accurately is important, particularly in closed-loop experiments, where the animal ' s actions control the stimulus. To this end, we have developed a novel computer vision-based tracking system, FicTrac (*Fic*tive path *Trac*king), which computes the fictive path taken by a tethered animal walking on an air-supported sphere. We have shown that FicTrac outperforms a low-cost implementation of the standard optical mouse-based tracking system, both in terms of accuracy and robustness to varying experimental conditions. Using FicTrac, we have demonstrated closed-loop visual fixation with tethered honeybees (*Apis mellifera*) and fruit flies (*Drosophila melanogaster*). Interestingly, the fixation behaviour of the honeybees varied depending on whether FicTrac or an optical mouse-based sensor was used to provide feedback. Specifically, honeybees were observed to increase their forward walking speed when the optical mouse-based sensor was used. We propose that this behaviour exploited a systematic tendency of the optical mouse-based system to underreport turning motions during simultaneous forward motion, thereby increasing the animals ' perceived control of the stimulus. This result demonstrates that insects may adapt to, and exploit, measurement errors in a closed-loop virtual reality.

[Topic1]Novel Tools and Methods

[Topic2]Sensorimotor Integration

Poster Session 1

PO-1186(15:30 - 16:30)

Novel Tools and Methods: Spiders in virtual space: A novel paradigm for studying cognition in jumping spiders

*Tina Peckmezian[1], Phillip W. Taylor[1], Greg J. Hunsburger[1], Rob N. Lee[1]

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Virtual reality (VR) environments are increasingly being used in the behavioural sciences to simulate the natural world while allowing precise control of experimental variables. Here, we outline a novel VR system for studying the perceptual and cognitive mechanisms of jumping spiders, which are well-known for their ability to solve complex computational tasks. We conduct two stages of experimentation with separate groups of spiders in order to (1) characterize behaviour within the virtual environment, and (2) determine its relationship to experiences and behaviour in the real world (RW). In stage 1, spider behaviour and activity patterns are characterized as spiders navigate a virtual world populated with objects of varying shapes and sizes, with both light and dark compartments. We find that spiders tend to treat virtual objects as real and spend more time in darker regions of virtual space. In stage 2, spiders build a nest paired (groupA) or unpaired (groupB) with a coloured beacon in the RW and are subsequently assessed for behaviour towards this beacon (nest site absent) in both RW and VR test trials. We find that spiders learn the beacon-nest site association in the RW, and that RW experience significantly influences behaviour in the VR.

[Topic1]Novel Tools and Methods

[Topic2]Cognition

Poster Session 1

PO-1187(16:30 - 17:30)

Novel Tools and Methods: Development of tools for behavioral neurogenetics in the field cricket *Gryllus bimaculatus*

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Crickets are model hemimetabolous insects in neuroethology and behavioral ecology. To investigate molecular and neural mechanisms of instinctive behaviors in the crickets, we have been developing reverse genetic approaches in the field cricket *Gryllus bimaculatus*. To conduct reverse genetics in *G. bimaculatus*, we need efficient method to generate transgenic cricket. We are establishing a novel transgenic system using a site-specific recombinase ΦC31 integrase. Integrase-mediated cassette exchange (IMCE) allows us to integrate transgene into predetermined chromosomal loci to overcome problems caused by copy number differences and genomic position effects in transgenic animals. In parallel with establishing the IMCE system, we isolated promoter regions for reverse genetic research in *G. bimaculatus*. To ubiquitously express transgenes in the cricket, we isolated the promoter region of the *Gryllus β-actin* gene, and examined its regulation mechanism. We isolated promoter region of the *Gryllus* Hu/ELAV homologue *found in neurons* gene as a potential neuron-specific promoter. To develop short hairpin RNA-mediated transgenic RNAi system, we isolated RNA polymerase III promoters of the *Gryllus U6* and *7SK* genes. In this conference, we present our recent advances in behavioral neurogenetics in *G. bimaculatus*.

[Topic1]Novel Tools and Methods

[Topic2]Genes and Behavior

Poster Session 1

PO-1188(17:30 - 18:30)

Novel Tools and Methods: Discovering neuropeptides in the ant *Cataglyphis fortis* - a novel approach on the investigation of neuropeptides

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The North African desert ant *Cataglyphis fortis* is known for sophisticated navigational skills. The ants undergo an age-related polyethism from indoor tasks to outdoor foraging. This transition is associated with remarkable synaptic remodeling in visual subregions of the mushroom bodies, brain centers associated with learning and memory (Stieb et al. 2012 *Dev Neurobiol*). Synaptic reorganization is triggered by first exposure to light, but causes for initiation of first orientation walks are largely unknown. We hypothesize that neuroactive peptides are involved in this transition and started to characterize bioactive peptides in a peptidomics approach. As genome or EST data were unavailable for *C.fortis*, neuropeptides were predicted using the *Camponotus floridanus* genome. Based on high neuropeptide conservation and alignment results in different Hymenoptera and *Drosophila*, we concluded that genome data is largely transferable between *C.floridanus* and *C.fortis*. We annotated 42 peptides in *C.floridanus* and mass spectrometrically characterized and confirmed the chemical identity of neuropeptides. Their presence and distribution was examined in both ant species using direct profiling and immunohistochemistry. Our results open up new avenues to study the role of neuropeptides in behavioral transitions and neuronal plasticity in *C. fortis.* Supported by DFG, SFB 1047 (B6 and B2) to WR, CW.

[Topic1]Novel Tools and Methods

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 1

PO-1189(14:30 - 15:30)

Novel Tools and Methods: Carbon fiber microelectrode arrays for chronic recording in insects

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It is becoming increasingly apparent that to understand the complex neural dynamics, we must simultaneously record from large numbers of neurons in a local population. While there has been significant progress in developing multielectrode arrays for mammals, insect electrophysiology is still typically limited to a handful of electrodes. This is partly because neural structures in insects are smaller and more densely populated, meaning large mammalian electrodes cause significant tissue damage to the structures they are recording. We propose a carbon fibre-based multielectrode array that will enable electrophysiological recordings from insect neural structures without significant damage. The array is small and light enough to be carried by a freely flying insect. The carbon fibres are sufficiently fine (~7 micrometers) to prevent glial scarring, thereby enabling chronic electrophysiological recording from the insect. Though carbon fibre polytrodes have recently been developed, the bundles are as thick as a traditional microwire and cause similar tissue damage. To the authors ’ knowledge, no true carbon fibre microelectrode arrays exist due to the inherent challenges in assembly. We suggest a scalable assembly technique that is accessible to replication by other researchers. We show preliminary recordings from the lobula plate of a blowfly with a carbon fibre microelectrode.

[Topic1]Novel Tools and Methods

[Topic2]Sensory: Vision

Poster Session 1

PO-1190(15:30 - 16:30)

Novel Tools and Methods: Development and performance evaluation of a novel cell-based odorant sensor element based on insect odorant receptors

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Research Center for Advanced Science and Technology, The University of Tokyo[1] , Janelia Farm Research Campus, Howard Hughes Medical Institute[2]

Odorant sensors based on metal-oxide semiconductor devices or quartz crystal microbalances have been used for practical odorant-detection applications. However, the performance of these sensors has been inferior to those based on living organisms in terms of selectivity, sensitivity, and response time. Therefore, we have developed a novel cell-based odorant sensor element based on insect odorant receptors. Here, we evaluated our proposed sensor elements in order to verify their abilities to meet the parameters necessary for practical cell-based odorant sensor. Our proposed odorant sensor elements based on Sf21 cell lines expressing insect odorant receptors possess the sensitivity at the scale of several tens of parts per billion in solution, the selectivity that can distinguish different types of odorants in accordance with the odorant selectivity of expressed receptors, and the response time of 10 and a few seconds. Specifically, we demonstrated that the established cell lines stably expressing insect odorant receptors were available for detecting odorants with invariable responsiveness over at least 2 months, thereby overcoming the short life span of biosensors for practical use. These results represent a first step towards practical cell-based odorant sensor that detect various kinds of odorants with high sensitivity and selectivity.

[Topic1]Novel Tools and Methods

[Topic2]Sensory: Olfaction and Taste

Poster Session 1

PO-1191(16:30 - 17:30)

Novel Tools and Methods: A high-throughput functional assay system of insect odorant receptors expressed in Sf21 cells

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Insects detect odorants with high sensitivity and selectivity by odorant receptors (ORs) expressed on olfactory receptor neurons. We showed that Sf21 cell lines stably expressing ORs and their co-receptor Orco along with Ca^{2+} sensitive fluorescent protein GCaMP3 can be used as highly sensitive odorant sensor elements for ligands of the expressed OR. For practical applications, it is important to select ORs with response spectra that are suitable for detection of target odorants. However, information of response spectra is limited to ORs from a few species. Here, we establish a method that enables high-throughput functional analysis of Sf21 cells expressing ORs using a fluorescent plate reader with high sensitivity comparable to conventional Ca^{2+}-imaging. We first determined optimal conditions for GCaMP3-based Ca^{2+}-measurement. Under the condition, responses of the Sf21 cells expressing a *Bombyx mori* sex pheromone receptor BmOR3 to its ligand bombykal and various odorants were measured simultaneously. The response sensitivity and selectivity of these cells were similar between the high-throughput and Ca^{2+}-imaging method, showing availability of the high-throughput method for rapid identification of response spectra of ORs. We are currently examining response spectra of ORs from various species using the method established in this study.

[Topic1]Novel Tools and Methods

[Topic2]Sensory: Olfaction and Taste

Poster Session 1

PO-1192(17:30 - 18:30)

Novel Tools and Methods: Constructing a massively parallelized morphological detailed neural circuit simulation of silkmoth brain with neuron database

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Japan and some countries plan to build Exa-FLOPS scale supercomputers as the next generation flagships. By our estimation, these supercomputers have comparable resource to simulate a whole insect brain (10^5-10^6 neurons) with morphological detailed multi-compartment Hodgkin-Huxley type neuron model in real-time speed. We have been challenging to construct these type of simulation from biological and computational aspect. We developed framework to make simulation models from morphological and physiological neuron data in database named BoND (*Bombyx* neuron database). These data in BoND have partially available to anyone in IVBPF (Invertebrate Brain Platform). This framework include many programs e.g. extracting morphology of neuron from 3D image stacks , mapping to standard brain and estimate method of membrane properties.
In computational aspect, we tuned neural circuit simulator NEURON to expand for massively parallelized computers and obtained 187 TFLOPS with K computer 196,608 cores.
These approaches would give us not only a new sight of silkmoth brain, but also a benchmark of mammal brain simulations.
We used computational resources of the K computer (RIKEN AICS) Oakleaf (Tokyo Univ.) and HAYAKA (Kyushu Univ.) (HPCI-Project hp140151). This work is partially supported by NIJC.

[Topic1]Computation

[Topic2]Novel Tools and Methods

Poster Session 1

PO-1193(14:30 - 15:30)

Novel Tools and Methods: 3-dimensional Image registration for the fluorescent confocal microscopy image stacks of the *Drosophilia melanogaster* brain

*Chloé I. Murtin[1], David Rousseau[2], Carole Frindel[2], Kei Ito[1]

The University of Tokyo[1] , Université Lyon 1[2]

The brain of an adult fruit fly *Drosophilia melanogaster* has a complex network of neuronal arborisations of about 100,000 neurons distributed within a 200 μm-thick volume. To study its properties, neurons are labelled by fluorescent proteins and illuminated by a laser to record the emitted fluorescence signal using a confocal microscope. However, the resolution of a 3D image stack acquired by such techniques decreases when the focal plane goes deeper. To overcome this problem, a sample can be imaged in two steps: two image stacks covering more than half of the sample are recorded from the front toward the centre and from the back toward the centre. High-resolution images of the entire fly brain should be obtained by the concatenation of such two images. However, small rotation and translation occur when the sample is flipped between the two acquisition sessions, leading to discontinuities in the final image stack. We propose an approach based on scale invariant feature transform (SIFT), a computer vision algorithm detecting local features in images known to be robust to scale modifications, translations and rotations. Common local features detected in the front and back image substacks are used as landmarks to perform the registration of the two stacks.

[Topic1]Novel Tools and Methods

[Topic2]Computation

Poster Session 1

PO-1194(15:30 - 16:30)

Novel Tools and Methods: Seeing a new silver lining: Imaging silver-impregnated histological preparations with confocal microscopy

*Cynthia M Harley[1], Mark A Sanders[1], Karen A Mesce[1], Karen J Thompson[2]

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For more than a century, the Golgi silver method has been used to stain neurons in the brain. More recently, Timm ’ s silver intensification method has enabled the visualization of fine neuronal arbors filled with cobalt. Such preparations are archivable and can be imaged repeatedly without photo-bleaching, a common problem with fluorophore labeling. Previously, metals have been imaged using reflectance confocal microscopy, but that does not offer the resolution or 3-D capabilities of traditional confocal microscopy. Recently, we discovered how to use spectral confocal imaging to image silver samples not based on reflectance. We believe the basis for this new image capture to be Localized Surface Plasmon Resonance (LSPR). When small spheres of metals are excited by a specific wavelength of light their outer-shell electrons begin to resonate, absorbing laser light and creating electron waves along the surface of the material labeled. The result is a higher energy (shorter wavelength) of light emitted than was used to excite the sample. Using this phenomenon, we can image preparations impregnated with silver by exciting them with a 561 or 640 nm laser, and collecting at lower wavelengths. This technique allows for the benefits of confocal imaging without the disadvantages of a traditional fluorophore.

[Topic1]Novel Tools and Methods

[Topic2]Anatomy & Neuroanatomy

Poster Session 1

PO-1195(16:30 - 17:30)

Novel Tools and Methods: Tetramethylpyrazine diminishes cerebral ischemic damage and improves survival time in experimental heat stroke

*Kuen-Bor Chen[1], Tsai-Hsiu Yang[2], Wu-Tien Huang[1], Hsin-Mao Tsai[1], Chia-Chyuan Liu[3]

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Tetramethylpyrazine ameliorates cerebral ischemic damage by decreasing the inflammation, oxidative stress, and excitotoxic monoamines releasing in many in vivo studies. In animals ’ heat stroke model, the rats display cerebral hypoxia, ischemia and neuronal injury in central, and reveal arterial hypotension, systemic inflammation response, and multiple organ dysfunctions in peripheral. We speculate that tetramethylpyrazine may have a great potential to improve the heatstroke-induced damage and achieve protective effectiveness. This study observed the effects of pretreatment with the vehicle and two doses of tetramethylpyrazine (50 and 80 mg/kg b. w., iv.) at 40th minute, 60th minute or 70th minute (the onset of heat stroke) after heat exposure start. The results showed that the mean arterial pressure, heart rate, colonic temperature were significantly increased with the time of heat exposure. Pretreatment with tetramethylpyrazine (80 mg/kg b. w., iv.) at 60th minute after heat exposure start was significantly increased the duration time and survival time. Additionally, it significantly decreased the inflammation, vital organ damage and neural injury during heat stroke by monitoring histological examination and analyzing glutamate oxaloacetate transaminase, creatine phosphokinase, lactate dehydrogenase. The findings indicate that tetramethylpyrazine may have important potential for development of new agents for effective treatment of heat stroke.

[Topic1]Novel Tools and Methods

[Topic2]Cellular Properties

Poster Session 1

PO-1196(17:30 - 18:30)

Novel Tools and Methods: Prevention of UVA irradiation-induced collagen decrement in human fibroblasts by lycogen

*Tsai-Hsiu Yang[1], Chia-Chyuan Liu[2], Tsuey-Pin Lin[1], Mei-Lin Tsai[2]

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UVA was known to contribute to the development of skin aging by inhibition of the synthesis of pro-collagen I and induction of several matrix metalloproteinase (MMP)-associated responses and signaling. Lycogen, the extracts of *Rhodobacter sphaeroides, may exert biological functions similar to that of lycopen. This bacteria-derived compound has been shown to possess biological effects including anti-inflammation and inhibiting melanogenesis. In this study, we attempted to examine whether* Lycogen^{TM} is able to suppress malondialdehyde (MDA) accumulation and to restore the downregulated procollagen I expression induced by UVA exposure. In human dermal fibroblasts Hs68 cells, UVA repressed cell viability and decreased procollagen I protein content accompanied with the induction of MMP-1 and MDA accumulation. Remarkably, incubation with 50mM Lycogen for 24 hours ameliorated the UVA-induced cell death and restored the UVA-induced downregulation of pro-collagen in a dose-related manner. This Lycogen treatment also prevented the UVA-induced MMP-1 upregulation and intracellular MDA generation in Hs68 cells. Activation of NFkB levels, one of downstream events induced by UVA irradiation and MMP-1 induction, were also prevented by Lycogen administration. Taken together, our findings demonstrated that Lycogen may be an alternative agent that prevents UVA-induced skin aging and could be used in cosmetic and pharmaceutical applications.

[Topic1]Cellular Properties

[Topic2]Novel Tools and Methods

Plenary Lecture 3 by Ryohei Kanzaki

PL-3
Analysis and synthesis of odor-source localization in insects: From genes, neural networks, and behavior to robot

Ryohei Kanzaki[1]

The University of Tokyo[1]

To elucidate the dynamic information processing in a brain underlying adaptive behavior, it is necessary to understand the behavior and corresponding neural activities. This requires animals which have clear relationships between behavior and corresponding neural activities. Insects are precisely such animals and one of the adaptive behaviors of insects is high-accuracy odor source orientation. In order to understand the neural basis of adaptive behavior, we employ a strategy that tackles the question at multiple levels, from genes, single cells of the neural system to the actual behavior. To examine the neural basis of the behavior, we implemented a model of the neural circuit, and integrated it with a mobile robot. Moreover, in order to understand the dynamics of the neural circuitry, we have developed an "insect-robot hybrid system" in which the insect or an insect brain controls a robot. At first in this lecture, odor-source orientation in the male silkmoth and its neural basis will be introduced. Second, the extent of adaptation in the behavioral strategy, as governed by the neural system and investigated via a robotic implementation, will be shown. Finally, I will demonstrate an insect-robot hybrid system and an example of genetic manipulation of insect behavior.

[Topic1]Sensorimotor Integration

[Topic2]Novel Tools and Methods

Invited Symposium 4

IS4-1(10:00 - 10:30)

A novel motor to auditory circuit is necessary for song learning

Todd F. Roberts[1]

University of Texas Southwestern Medical Center[1]

Songbirds, like humans, learn their vocalizations by imitating the vocal patterns of their parents or other adult vocal models using auditory feedback. This form of motor learning is thought to involve forward interactions between vocal motor and auditory circuits in the brain. Yet, we know little about the circuits connecting motor and auditory centers or their role in vocal imitation. We identified a class of neurons in HVC that project uniquely to a portion of the secondary auditory forebrain known as Avalanche (Av). Using an intersectional viral expression strategy to selectively ablate these neurons in HVC, we show that this pathway is necessary for accurate song imitation in juvenile birds, but has no effect on production of learned song in adult birds. Moreover, lesions to this pathway in adults preclude song degradation following deafening. Together, these findings define a novel motor to auditory brain circuit that plays a prominent role in experience dependent modification of motor performance and vocal plasticity. We conjecture that this circuit provides the auditory system with a motor estimate of auditory feedback important for evaluating song performance, and ultimately for vocal imitation.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Communication

Invited Symposium 4

IS4-2(10:30 - 11:00)

New approaches to vocal communication and template-based song learning

Richard Hahnloser[1]

Institute of Neuroinformatics[1]

The ways in which children learn to speak by listening to their parents are very similar to the ways in which young songbirds learn their songs by listening to an adult tutor. Recent behavioral data in zebra finches have strengthened this view, but many questions remain with regards to our understanding of behavioral song-learning strategies. In particular, it remains unclear how young birds change their songs as a function of both their momentary vocal ability and their memory of the tutor ’ s song. In my talk I will report about recent insights into learning strategies for song imitation. In addition, I will introduce computational advances for assessing similarity and variability of birdsongs, and for estimating dynamic latent variables from developmental and reinforced song trajectories. Finally, I will introduce a new non-invasive tool for dissecting vocal communication in songbirds.

[Topic1]Social Behavior

[Topic2]Computational Modeling

Invited Symposium 4

IS4-3(11:00 - 11:30)

Cycling in the brain: Molecular insights into procedural learning

Stephanie, A. White[1]

University of California Los Angeles[1]

The FOXP2 transcription factor has an unprecedented link to language: a single mutation in the DNA binding domain causes an inherited speech and language disorder with Mendelian inheritance. Yet, how FoxP2 contributes to learning of vocal communication signals remains unclear. FoxP2 is enriched in corticostriatal circuits of both human and songbird brains. Experimental knockdown of this enrichment in song control neurons of the zebra finch basal ganglia impairs tutor song imitation, indicating that adequate FoxP2 levels are necessary for normal vocal learning. In unmanipulated birds, vocal practice acutely downregulates FoxP2, leading to increased vocal variability and dynamic regulation of FoxP2 target genes. To determine whether this behavioral regulation is important for song learning, here, we used viral-driven overexpression of FoxP2 to counteract its downregulation. This reversed the effects of song practice on vocal variability and caused inaccurate imitation of tutor song. Taken together, these findings indicate that rather than absolute levels, dynamic behavior-driven regulation of FoxP2 in the basal ganglia is critical for vocal learning.

[Topic1]Genes and Behavior

[Topic2]Communication

Invited Symposium 4

IS4-4(11:30 - 12:00)

Neuronal representations of tutor song experience

Yoko Yazaki-Sugiyama[1]

Okinawa Institute of Science and Technology Graduate University[1]

Like humans learning to speak, song birds learn to sing from auditory experience during the juvenile period. Zebra finches first memorize tutor songs and then match their own vocalizations to the memorized tutor songs, using auditory feedback. Increasing evidence suggests that tutor song memory storage occurs in the auditory cortex. In this talk we will present our recent study about how tutor song memory is formed and represented as neuronal activity in the zebra finch caudomedial nidopallium (NCM, corresponding to the mammalian higher-level auditory cortex). Neurons in the NCM of juvenile finches showed no preference for any song stimulation prior to their having auditory experience with actual adult songs. However, after exposure to singing of a live tutor for several days, a group of NCM neurons began to show strong bias toward tutor songs over other zebra finch songs. Interestingly, strength of selectivity can be modified depending on whether the birds are awake, asleep or anesthetized, or by exposure to a live tutor singing. We will further discuss how auditory experiences during the juvenile period shape neuronal circuits in the juvenile zebra finch brain.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Communication

Plenary Lecture 4 by Barbara L. Finlay

PL-4
Integrating brain diversity with conserved developmental mechanisms: the case of the isocortex

Barbara L. Finlay[1]
Cornell University[1]

Neuroethologists studying the mammalian isocortex have focused on “ cortical areas ” as sites of special circuitry for species-specific adaptations, such as barrel fields in rodents, echo-delay maps in bats, and foveas in primates. Computational neuroscientists have emphasized uniform functions of the entire cortical sheet, such as association and prediction. An “ evo-devo ” approach connects the two, as several conserved developmental mechanisms scale and adapt the cortex over several orders of magnitude in volume, embedding species-specific specializations in a polarized, loosely hierarchical processing surface. A rostrocaudal gradient in duration of neurogenesis produces a corresponding gradient in neuron number per cortical column, highest in visual cortex. The inverse gradient develops in connection volume, resulting in greater intracortical connectivity frontally. Both are most pronounced in the largest brains. Along the same axis, “ feed-forward ” and “ feedback ” patterns polarize information flow. Early, topographically precise representations of the sensorimotor periphery seed the isocortex so as to generate a rough, multimodal, map of egocentric space dorsolaterally, while non-egocentric maps like chemosensation, tonotopic maps and object recognition group ventrally. Finally, species-specific alterations in attention and motivation, biasing the information reaching the cortex, deserve more consideration as an organizing force in cortex development and evolution.

[Topic1]Evolution

[Topic2]Development

Participant Symposium 1

PS1-1(15:00 - 15:20)

Sugar aversion: A newly-acquired adaptive change in gustatory receptor neurons in the German cockroach

*Ayako Wada-Katsumata[1], Jules Silverman[1], Coby Schal[1]

Department of Entomology and W.M. Keck Center for Behavioral Biology, North Carolina State University[1]

Glucose is a universal phagostimulant in many animal species. However, in response to the anthropogenic assault of toxic baits, populations of the German cockroach have rapidly evolved an adaptive behavioral aversion to glucose (a phagostimulant component of baits). Although the GA cockroaches incur significant fitness costs in normal foraging on insecticide-free foods, this trait confers greater survivorship under the strong selection pressure of glucose bait-based pest control. To understand the mechanisms that underlie glucose aversion, we characterized the electrophysiological responses of gustatory neurons involved in glucose reception. In both wild-type (WT) and glucose-averse (GA) cockroaches, D-fructose and D-glucose stimulated sugar-gustatory receptor neurons (GRNs), whereas the deterrent caffeine stimulated bitter-GRNs. In contrast, in GA cockroaches D-glucose also stimulated bitter-GRNs indicating that D-glucose is processed as both a phagostimulant and deterrent in GA cockroaches. However, stimulation of bitter-GRNs also suppressed the responses of sugar-GRNs. This newly acquired peripheral taste sensitivity underlies glucose aversion in multiple GA populations in the field.
Our results indicate that different sensory inputs in glucose reception result in opposite foraging behaviors in WT and GA cockroaches. The rapid emergence of this highly adaptive behavior underscores the plasticity of the sensory system to adapt to rapid environmental change.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Ecology

Participant Symposium 1

PS1-2(15:20 - 15:40)

Mechanosensory hairs on bumble bees (*Bombus terrestris*) detect electric fields

*Gregory P Sutton[1], Dominic J Clarke[1], Heather M Whitney[1], Daniel Robert[1]

University of Bristol[1]

It has been recently discovered that bees have the ability to perceive electric fields. This allows bees to differentiate between different flowers during pollination. The mechanism of detection is currently unclear. We show here that live bumble bees carry an intrinsic electric charge, a charge that may be critical to perceiving electric fields. This charge would cause the bee ' s body hairs to mechanically deflect in raction to electric fields. Laser vibrometry shows that this reaction is of a large magnitude. Complementary neurophysiological experiments show that these mechanical deflections are accompanied with neuron activity from the mechanoreceptors located at the base of the hair. Parallel studies of the antennae of bumble bees show an order of magnitude less motion in response to identical electric fields. This small antennal motion is not accompanied by neurophysiological activity. We thus conclude that bumble bees can detect electric fields by using mechanosensory hairs. The ability to detect electric fields with the hairs that surround the body may give the bee a full ' picture ' of the shape of an electric field, potentially providing the insect with a map of ambient charge, or information about the geometry of the electric field surrounding a flower.

[Topic1]Sensory: Electrosensory

[Topic2]Sensory: Mechanosensation

Participant Symposium 1

PS1-3(15:40 - 16:00)

Multimodal duetting in a paleotropical pseudophylline bushcricket

*Kaveri Rajaraman[1,2], Vamsy Godthi[3], Rohini Balakrishnan[1]

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Females of the pseudophylline bushcricket *Onomarchus uninotatus* do not show a typical phonotaxis response to the unusually low-pitched calling song of conspecific males. Females respond with tremulation bouts to individual chirps of the male call, sometimes followed after a minute by phonotaxis. We found that the female ’ s tremulation sent out a substrate-borne, time-bound vibratory signal, such that the male calling and female tremulation constituted an alternating acoustic-vibratory duet with a clear individual-specific relationship between chirp and tremulation timing. This is a novel example of a multimodal duet and of female tremulation in response to a male call among Ensifera. We found that males show a vibrotaxis response to the female tremulation signal but only if the signal is received in alternation with a played-back male call or in response to the male ’ s own calls. The male can localize the source of vibration, whether produced by a tremulating female or a vibrating speaker simulating her tremulation. This strategic shift from the behavioural paradigm of female phonotaxis towards an acoustic male call to male vibrotaxis to a tremulation response from a stationary female may be driven by the high predation pressure imposed by insectivorous bats on flying katydid females in this assemblage.

[Topic1]Sensory: Audition

[Topic2]Sensory: Mechanosensation

Participant Symposium 1

PS1-4(16:00 - 16:20)

Analysis of 3-D acoustic and flight attention of echolocating bats during attacking to multiple target preys in the field

*Miwa Sumiya[1], Emyo Fujioka[2,3], Ikkyu Aihara[4], Yoshiaki Watanabe[1,3,5], Hiroshi Riquimaroux[1,3,5], Tetsuo Ohta[1,3], Shizuko Hiryu[1,3,5]

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Three-dimensional direction and beam width of pulses that emitted by wild Japanese house bats (*Pipistrellus abramus*) during natural foraging were measured by using super microphone-array covering the area of 20 m × 20 m in the field. When the bats captured two successive target preys within one second (consecutive-capture), -6dB width of their sonar beam simultaneously covered the direction of these two target preys in the horizontal and vertical plane, suggesting that the bats ' *acoustic attention* precedes during flight for effective consecutive-capture. Furthermore, the bats tended to attack the first target prey flying in alignment with the next one, implying that the bats plan their flight paths with sonar beam control during flight. We then proposed a mathematical model for describing bats ' 3-D *flight attention* while approaching two successive targets based on the experimental results. The model parameter estimation of suggests that the bat alternately shifted the *flight attention* between two target preys before capturing the first one, and time course of *flight attention* showed different patterns in horizontal and vertical plane respectively. Combined with the acoustical analysis, mathematical modeling provides useful index to understand the relationships between echolocation and flight strategies of wild bats.

[Topic1]Sensory: Audition

[Topic2]Computational Modeling

Participant Symposium 1

PS1-5(16:20 - 16:40)

Adaptive changes in vibration attraction behavior and its sensory receptors promote eye degeneration in the cavefish, *Astyanax mexicanus*

*Masato Yoshizawa[1], Matthew J. McHenry[2], Kelly E. O'Quin[3], Alex C. Keene[1], William R. Jeffery[4]

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Astyanax mexicanus is a model cave-dwelling fish with sighted surface-dwelling and blind cave-dwelling forms. The surface ancestors of cavefish were separated in caves 1 - 5 million years ago and evolved multiple morphological and behavioral traits that appear to be adaptations to the dark cave environment. Cavefish, but not many surface fish, exhibit vibration attraction behavior (VAB), or the ability to swim toward the source of a water disturbance in darkness. We found that cavefish VAB is most effective at a frequency of 35 Hz, which corresponds to the stimulus generated by some prey. VAB is mediated by superficial neuromasts, which are relatively numerous and are most sensitive to water vibrations in cavefish. Ablation experiments further demonstrated a major role for superficial neuromasts restricted to the cavefish eye orbit in facilitating VAB. Finally, we used genotyping-by-sequencing technology to identify quantitative trait loci (QTL) for VAB, neuromasts at the eye orbit, and reduced eye size. We found that multiple QTL for these traits form two congruent clusters in the *Astyanax* genome. We thus conclude that natural selection for VAB and superficial neuromast enhancement may be an indirect cause of eye regression in cavefish through genetic linkage or antagonistic pleiotropy.

[Topic1]Evolution

[Topic2]Sensory: Mechanosensation

Participant Symposium 1

PS1-6(16:40 - 17:00)

The circatidal clock consists of the physiological bases different from the circadian clock in the mangrove cricket

*Hiroki Takekata[1], Aya Satoh[2], Hideharu Numata[3], Shin G Goto[1], Sakiko Shiga[1]

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It has long been controversial whether a circatidal rhythm is generated by a clock composed of the same physiological basis as the circadian clock. The mangrove cricket *Apteronemobius asahinai* shows simultaneously two endogenous rhythms in its locomotor activity; the circatidal rhythm generates active and inactive phases and the circadian rhythm modifies activity levels by suppressing activity levels during subjective day. From behavioral analyses, these rhythms are considered to be generated by the independent circatidal and circadian clocks. In this study, to compare the physiological bases of these clocks, we performed RNAi of the circadian clock genes, *period* and *Clock*, and surgical removal of the optic lobe, the locus of the circadian clock, and examined whether the circatidal and circadian clocks share the molecular and neuroanatomical components. The locomotor activity recording revealed that the circadian modification was disrupted after RNAi of either circadian clock gene and after removal of the optic lobes. However, the circatidal rhythm was maintained without remarkable changes in its free-running period in every experiment. Thus, the circatidal rhythm of *A. asahinai* would be driven by a circatidal clock physiologically distinct from the circadian clock.

[Topic1]Circadian Rhythms

[Topic2]Genes and Behavior

Young Investigator Award Symposium

YS-1(17:30 - 18:00)

FoxP2 overexpression in adult zebra finches impacts song

*Nancy F Day[1], Stephanie A White[1]

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Successful reproduction in zebra finches requires a complex, stereotyped courtship song, which is learned and perfected during a sensorimotor critical period. Auditory feedback is crucial for adult song maintenance; the song of deaf birds deteriorates. In adult males, the transcription factor FoxP2, a molecule known to influence human speech and language, is behaviorally regulated in the basal ganglia nucleus, Area X. Constitutive knockdown of FoxP2 abolishes social context dependent modifications to song, but the role of FoxP2 in song maintenance remains unknown. Interestingly, hearing and FoxP2 are linked: The more a bird hears himself practice, the lower his Area X FoxP2 levels; no correlation exists in deaf birds. Given that behavior-driven cycling of FoxP2 is critical for song learning, we predict that such cycles are also necessary for song maintenance. To test this hypothesis, we used an adeno-associated virus (AAV) to constitutively augment FoxP2 in Area X of adult zebra finches, and tracked song following deafening. Preliminary data suggest that overexpression of FoxP2 promotes song stereotypy and that songs of deafened AAV-FoxP2 birds deteriorate faster than those of deafened controls. These observations suggest that hearing and/or motor dependent modulation of FoxP2 impacts vocal precision throughout the lifetime of the animal.

[Topic1]Communication

[Topic2]Genes and Behavior

Young Investigator Award Symposium

YS-2(18:00 - 18:30)

Quantifying complex electrosocial interactions and movement in natural populations of *Eigenmannia*

*Sarah A. Stamper[1], Manu S. Madhav[1], Ravikrishnan P. Jayakumar[1], Eric S. Fortune[2], Noah J. Cowan[1]

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For decades, the analysis of social interactions of weakly electric fish has been restricted to a single behavior: the Jamming Avoidance Response (JAR). As such, it remains unclear how these animals interact—kinematically and electrically—in their natural habitat. Using a grid of submerged electrodes, we recorded signals from natural populations of *Eigenmannia* along the Napo River in 2011, 2012 and 2014. From our recordings, electrosensory data was automatically processed to estimate the state of each individual: its position, orientation, velocity, and electric signal parameters (frequency, amplitude, and phase). We found that although fish can avoid low frequency signals from conspecifics using the JAR and the SER (Social Envelope Response) they commonly do not and that behavior is far more complicated than previously realized. For example, we observed that *Eigenmannia* can actively ‘ jam ’ each other by changing their frequencies to approach rather than diverge, the opposite of what one would predict from the JAR. We observed hundreds of examples in which nearby fish had low-frequency-difference electrosensory signals due to three categories of behaviors: (1) sustained matching, (2) transient crossing, and (3) rapid jamming. This discovery challenges current understanding of the role of electrosensory interactions during natural behavior.

[Topic1]Sensory: Electrosensory

[Topic2]Social Behavior

Young Investigator Award Symposium

YS-3(18:30 - 19:00)

Motor consequences of visual adaptations for moths hovering in low-light environments

*Simon Sponberg[1,2], Jon P. Dyhr[1], Robert W. Hall[1], Tom L. Daniel[1]

University of Washington[1] , Georgia Institute of Technology[2]

How animals cope with challenging sensory environments requires understanding both neurobiological mechanisms and performance consequences. The hawkmoth, *Manduca sexta*, can hover and track moving flowers while feeding even in starlight. Their visual circuits are hypothesized to have a luminance-dependent delay, increasing sensitivity in low light but also increasing the lag in detecting motion. To test this hypothesis, we allowed moths to hover and feed from robotically actuated flowers at 300 and 0.3 lux. Using control theoretic tools we showed that their optomotor responses support the variable-delay hypothesis -- phase lag increases (~30%) as light levels drop. To explore possible trade-offs, we quantified overall tracking performance as a combination of gain and phase at each frequency. Performance did decrease under low light, but only in a frequency band between 2 and 6 Hz. We next took high-speed video of 5 species of hawkmoth-pollinated flowers blowing in a light breeze. Over 95% of the flowers ’ movements occurred below 2 Hz, where the moth ’ s performance does not suffer. Finally, used a modified flower to show that mechanoreception enhances motion tracking. Moths avert an apparent trade-off between increased sensitivity and reduced performance by tuning to the frequencies of natural flower movement.

[Topic1]Sensory: Vision

[Topic2]Motor Systems

Young Investigator Award Symposium

YS-4(19:00 - 19:30)

A functional role of the sky ’ s polarization pattern for orientation in the greater mouse-eared bat, *Myotis myotis*

*Stefan Greif[1], Ivailo Borissov[2], Yossi Yovel[2], Richard A. Holland[1]

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Animals can call on a multitude of sensory information to orient and navigate. In some cases they may calibrate these cues against each other to establish the most accurate information available. One such cue is the pattern of polarized light in the sky, which may be used as a geographical reference to calibrate other cues in the compass mechanism. Mammals, however, have not been shown to use this cue, even though they do calibrate a magnetic compass with cues at sunset. We demonstrate that the greater mouse-eared bat, *Myotis myotis*, uses polarization cues at sunset to calibrate a magnetic compass, subsequently used for orientation during a homing experiment. To our knowledge, it is thus the only mammal known so far to make use of the polarization pattern in the sky. This is an intriguing finding as currently there is no clear understanding of how this cue is perceived in this taxon.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Invited Symposium 5

IS5-1(10:00 - 10:30)

Leg coordination during cockroach locomotion: experiments and model-based analysis

*Einat Couzin[1,2], Philip Holmes[1,3,4], Tim Kiemel[5], Amir Ayali[2,6]

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Cockroaches are renowned for their ability to maintain dynamic stability when rapidly running over uneven terrain. Previous investigations suggested that this relies on passive properties of musculoskeletal structures, on interactions among central and local neural pattern-generators, and on proprioceptive feedback. To better understand how leg movements are coordinated and modulated, we study both reduced and intact preparations and compare data with simulations of coupled oscillator models of hexapedal locomotion. Specifically, we record motoneural activity in de-afferented preparations in which a single leg is manipulated; we also monitor leg kinematics in intact, freely walking preparations that are subject to magnetic perturbations applied to single legs. Records of de-afferented neural activity and leg kinematics are then compared with model-generated data, and maximum likelihood techniques are used to estimate coupling strengths among the six hemisegmental oscillators of the model. Our analyses provide insights on how sensory information from moving legs modulates centrally-generated patterns over a range of walking speeds. In particular, while coupling strengths vary among experimental preparations, we find that overall input levels to each oscillator are approximately balanced in a manner that allows fast and uniform recovery along the body when encountering perturbations.

[Topic1]Motor Systems

[Topic2]Computational Modeling

Invited Symposium 5

IS5-2(10:30 - 11:00)
Investigating weakly coupled oscillators in the stick insect locomotor system

Anke Borgmann[1]

University of Cologne[1]

Walking movements result from a complex interplay of central pattern generating networks (CPGs), local sensory feedback about movements and forces generated in the legs and coordinating signals from neighboring limbs. For the stick insect, the neural basis for inter-segmental coordination is still largely unresolved specifically with regards to the interaction of CPGs of the different segments. In general, sensory information plays a crucial role in inter-segmental coordination of the different legs (Ludwar et al. 2005, Borgmann et al. 2009). However, hardly anything is known about role and contribution of inter-segmental interactions between CPG networks. In stick insects, antagonistic muscles of each leg joint are driven by one CPG. Preliminary evidence suggested some inter-segmental influence between CPGs (Büschges et al. 1995). We therefore studied the coordination of segmental CPGs in and between thoracic ganglia in the completely deafferented nervous system of the stick insect in more detail. Our results clearly indicate for the first time that there exists weak intra- and inter-segmental neural coupling between the CPGs in the stick insect thoracic nerve cord. In my talk I will review the current state and our most recent advancements in unravelling the neural basis of inter-segmental coordination in insect walking pattern generation.

[Topic1]Motor Systems

[Topic2]Motor Systems

Invited Symposium 5

IS5-3(11:00 - 11:30)

Flexibility of the central pattern generator for locomotion in salamander

Jean-Marie Cabelguen[1]

Neurocentre Magendie, Institut National de la Recherche Médicale, U862 University of Bordeaux, France.[1]

In vertebrates, the axial musculoskeletal system plays a critical role in adapting locomotor movements to changes in external conditions and goals. However, we have only a rudimentary understanding of the neural processes involved in the flexible actuation of the body axis during adapted locomotion.

Among vertebrates, adult salamanders offer a remarkable opportunity to investigate the dynamics of the axial musculoskeletal system since these animals exhibit a rich locomotor repertoire, both on land and in water. Another advantage of salamanders is that *in vitro* isolated spinal cords, when chemically activated, produce fictive rhythmic motor patterns.

During the symposium, I will first present kinematic and EMG data showing that each rhythmic locomotor behavior exhibited by salamanders is associated with a distinctly different pattern of axial movements. Then, I will present *in vitro* data revealing a high degree of flexibility in the operating mode of the spinal networks producing the rhythmic activations of the axial musculature. Finally, I will discuss our current hypothesis of a functional modularity within the axial musculoskeletal system and how this modularity improves the dynamics of locomotion.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Invited Symposium 5

IS5-4(11:30 - 12:00)

The swimmeret system of crayfish: cellular mechanisms of coordination

Carmen, R. Smarandache-Wellmann[1]

Zoological Institute, Animal Physiology, Emmy Noether Group, University of Cologne, Germany[1]

The abdominal nerve cord of crayfish coordinates the movement of four swimmeret pairs. In this system a metachronal wave is observed *in vitro* and *in vivo*, such that the swimmeret movement starts in the last segment and the anterior swimmerets follow always with a latency of a quarter of a cycle. Each swimmeret movement is controlled by a neuronal microcircuit located in each hemisegment. The pattern generating microcircuit in each hemisegment consists of a set of two nonspiking interneurons which form a half center oscillator. The coordination between the microcircuits is ensured by a separate coordinating network, comprising exactly three neurons in each hemisegment: two spiking coordinating neurons, ASC_E and DSC, and one nonspiking interneuron, ComInt1. ASC_E and DSC encode information about the activity state of their microcircuit, enabled by direct input they receive from the CPG interneurons. Coordinating information is sent to all neighboring hemisegments arriving with a gradient of synaptic strength in ComInt1. The neighboring coordinating neurons always elicit bigger depolarizations in ComInt1 than those which are more remote. To close the loop ComInt1 decodes the coordinating information and synchronizes the activity of the microcircuits through its electric synapse to only one of the CPG interneurons.

[Topic1]Motor Systems

[Topic2]Motor Systems

Participant Symposium 2

PS2-1(15:00 - 15:20)

Neural organization of the optic lobe in controlling body patterns of cephalopods

*Tsung-Han Liu[1], Chuan-Chin Chiao[1,2,3]

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Cephalopods have the most sophisticated dynamic skin coloration for rapidly camouflage in nature. Previous studies have suggested that the pair of optic lobes located bilaterally in their brain plays a key role in controlling the expansion of chromatophores for generating diverse body patterns. However, the functional organization of the optic lobes and their neural control of various body patterns have not been examined systematically. In the present study, we applied electrical stimulation in the optic lobe to investigate the neural basis of body patterning in cuttlefish *Sepia pharaonis* and oval squids *Sepioteuthis lessoniana*. Animals were anesthetized by 3% magnesium chloride in sea water, and a tungsten electrode was inserted into their optic lobes with an aid of the stereotaxic instrument for electrical stimulation. The dynamic changes of body patterns were recorded by a video camera from above. We have observed that responsive areas of the skin upon electrical stimulation were positively correlated with increasing voltages and depths of the electrode in the medulla of the optic lobe. In addition, histological and brain imaging studies revealed that neurons aggregated as island-like clumps were varied systematically in the medulla, which suggests a hierarchical organization responsible for generating different body patterns.

[Topic1]Sensorimotor Integration

[Topic2]Motor Systems

Participant Symposium 2

PS2-2(15:20 - 15:40)

The role of the central body complex in the venom induced behavioral manipulation of cockroaches stung by the Jewel Wasp

*Maayan Kaiser[1], Frederic Libersat[1]

Department of Life Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel[1]

The Jewel Wasp stings cockroaches and injects venom into the cockroach cerebral ganglia, namely the SEG (Subesophageal ganglion) and the brain. The venom induces a long-term hypokinetic state in which the cockroaches show a dramatic decrease in spontaneous walking. Previous studies have shown that injection of venom or procaine (a voltage dependent Na channels blocker) to the SEG reduces neuronal activity and is sufficient to induce the decrease in spontaneous walking. Paradoxically, brain ablated cockroaches show increased spontaneous walking in comparison to control cockroaches. Yet, most of the venom injected by the wasp in the brain of cockroaches, thereby presumably decreasing neuronal activity, is primarily concentrated in and around the CBC (Central Body Complex). Thus, the venom could chiefly affect this brain region to contribute to the hypokinetic state. To resolve this discrepancy we used behavioral and neuro-pharmacological methods to first, demonstrate the role of the CBC in control of spontaneous walking and second, to show its possible contribution to the venom induced behavioral manipulation. Our results show that the CBC is necessary for the initiation of spontaneous walking and that focal injection of venom or procaine to the CBC is sufficient to induce the decrease in spontaneous walking.

[Topic1]Neuromodulation

[Topic2]Neuromodulation

Participant Symposium 2

PS2-3(15:40 - 16:00)

Central pattern generator neurons for species-specific singing in cricket species

*Pedro F. Jacob[1,2], Berthold Hedwig[1]

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Cricket acoustic signalling represents one of the most interesting invertebrate communication systems, with species-specific song patterns evolving from a common ancestor. As a consequence of sexual selection recent species may use very different sequences of chirping or trilling pulse patterns. My study aims to analyse the changes at the level of the singing Central Pattern Generator (CPG) that are instrumental for the generation of the species-specific patterns.
Males crickets sing by the rhythmic activity of the wing opener- and closer-muscles. Singing motor activity is driven by a CPG network, composed by opener- and closer-interneurons, localized in the abdominal ganglion (A3). Fictive singing was elicited by pharmacological brain stimulation and singing interneurons in A3 were recorded, labeled and manipulated in different species.
In *G. bimaculatus*, a single opener interneuron in A3 was shown to control singing. I identified in *G. assimilis* a corresponding opener-interneuron with a similar general arborization pattern. The neuron shows rhythmic activity in phase and spikes strictly before the opener motoneuron burst. Like in *G. bimaculatus* transient perturbations of the activity of the opener–interneuron reset and considerably alter the singing motor pattern. Besides these similarities both neurons reveal a different species-specific pattern of membrane potential changes.

[Topic1]Cellular Properties

[Topic2]Evolution

Participant Symposium 2

PS2-4(16:00 - 16:20)

Channels of escape: How the inward rectifying current Ih influences locusts’ predator detection

*Richard B. Dewell[1], Fabrizio Gabbiani[1,2]

Baylor College of Medicine[1] , Rice University[2]

Successfully escaping predation requires not just reliable detection of approaching predators, but successfully discriminating non-threatening stimuli as well. In locusts, visual detection of approaching predators can be accomplished by a single neuron within each optic lobe. This lobula giant movement detector neuron (LGMD) integrates inputs from every photoreceptor of the ipsilateral eye. The excitatory arbor of the LGMD is retinotopically organized, allowing the visual stimulation pattern to determine the spatial pattern of excitatory inputs. We investigated the role of the hyperpolarization-activated inward rectifying current (Ih) within the LGMD of *Schistocerca americana* to better understand the neural computations implemented within this looming sensitive neuron and their role in escape behavior. LGMD responses to looming objects decreased dramatically after Ih blockade; while visual stimuli with decreased spatial coherence elicited less frequent escape behavior and LGMD responses unaffected by Ih blockade. This suggests that not only does Ih play a key role in the processing of looming stimuli within the LGMD, but that its activity is also important to the animals' escape behavior. To further test this hypothesis, behavioral experiments were combined with electrophysiology and detailed neural modeling to confirm the role of the inward rectifying current in the production of escape jumps.

[Topic1]Sensorimotor Integration

[Topic2]Cellular Properties

Participant Symposium 2

PS2-5(16:20 - 16:40)

Kinematic analysis of neck-reaching action in Large-billed crows (*Corvus macrorhynchos*)

*Hiroshi Matsui[1], Ei-Ichi Izawa[1]

Department of Psychology, Keio University, Japan[1]

Reaching is one of the basic components of dexterous motor skills and is known, in primate, as a visual-guided behavior where arm movement is controlled with real-time monitoring in stable visual frame. This visual-guided arm-reaching is enabled by anatomical separation of head and arm in primate body-design. Contrastingly, avian neck-reaching accompanies head movement and thus produces unstable vision due to unseparation of eyes on the head. However, it remains unknown about sensory-motor mechanisms of avian neck-reaching. Crows are one of the ideal subjects to investigate sensory-motor mechanisms of neck-reaching because they show dexterous skills such as tool use. To verify visuo-motor mechanisms, kinematic analysis was performed on neck-reaching of large-billed crows (*Corvus macrorhynchos*) to a piece of cheese at various distances (7, 10, and 15cm). We found that the increase of movement time dependently on distance but the decrease of velocity as approaching to the target independently of distance. Moreover, convergent eye-movement during approaching was found. These suggest that vision could play a role to control velocity of approaching to the target irrespective of reaching distance.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Participant Symposium 2

PS2-6(16:40 - 17:00)

Ultrafast smashing in mantis shrimp: preparatory motor control through spring compression

*Katsushi Kagaya[1], Sheila, N Patek[1]

Duke University[1]

To circumvent the limits of muscle, ultrafast movements achieve high power through the use of springs and latches. The timescale of these movements is too short for control through typical neuromuscular mechanisms, thus kinematic control should happen prior to movement. We analyzed the ultrafast smashing behavior of mantis shrimp (Stomatopoda: *Neogonodactylus bredini*). Mantis shrimp use a lateral extensor muscle to compress a spring system and a lateral flexor muscle to control a latch. We tested the hypothesis that the flexor and extensor motor activity before a strike varies the kinematics of the raptorial strikes. We measured strikes using high speed imaging and electromyograms of the extensor and flexor muscles. During spring compression, both the lateral extensor and lateral flexor units were activated (co-contraction). Movement began a few milliseconds after the flexor units ceased activity. Thus, the flexor activity likely prevents spring release and determines the timing of strike initiation. Within individuals, the spike activity of the extensor muscle explains the variation of net spring compression as well as strike velocity. The results suggest that strike velocity can be varied by changing motor activity, thus supporting an upstream central nervous system-based control of ultrafast movement.

[Topic1]Motor Systems

[Topic2]Evolution

Invited Symposium 6

IS6-1(10:00 - 10:30)

In vivo monitoring of circadian clock ’ s tick by a bioluminescence reporter: environments to genes and genes to behaviors

*Sato Honma[1], Daisuke Ono[2], Ken-ichi Honma[1]

Department of Chronomedicine, Hokkaido University Graduate School of Medicine[1] , Photonic Bioimaging Section, Hokkaido University Graduate School of Medicine[2]

In mammals, the central circadian clock in the hypothalamic suprachiasmatic nucleus (SCN) entrains to environmental light-dark cycles and orchestrates peripheral clocks throughout the body to exhibit temporally coordinated circadian rhythms in physiology and behavior. The SCN is composed of cell-autonomous clock neurons which couple to each other to form regional pacemakers. Using transgenic mice carrying a luciferase reporter for clock gene *Per1* expression, we previously found that there are two separate oscillators in the SCN regulating photoperiodic changes in behavior rhythms. However, with *ex vivo* systems, we cannot directly assess the responses of the molecular circadian clock to environmental lights. We constructed an optical fiber system for real-time and continuous measurement of bioluminescence from the SCN of freely-moving conscious mice simultaneously with their spontaneous behavior. Using this system, we successfully monitored circadian rhythms in *Per1-luc,* PER2::LUC or *Bmal1-Eluc* expression for weeks with similar phase-relations to that in ex vivo recording. Interestingly, time course of phase shifts following the light exposure was different in different genes. Optical fiber system enabled us to analyze responses of the molecular circadian clock to environmental signals together with their behavioral outputs.

[Topic1]Circadian Rhythms

[Topic2]Genes and Behavior

Invited Symposium 6

IS6-2(10:30 - 11:00)

Depth perception from defocus of retinal images received by a three-dimensionally distributed visual pigment in a jumping spider eye

Takashi Nagata[1]

Department of Biology and Geosciences, Graduate School of Science, Osaka City University, Japan[1]

Animal eyes have evolved to achieve various visual functions. The principal eyes of jumping spiders, which play major roles in courtship and prey-catching behaviors by serving acute vision, depth perception and so on, have a unique retina with four-tiered photoreceptor layers. It has been known that light of different wavelengths is focused on each layer because of chromatic aberration of the lens. Our recent investigation of visual pigments and a related pigment in a jumping spider [1, 2] revealed that a relationship between an absorption characteristic and distribution of a visual pigment in the tiered retina causes defocusing of retinal images on one of the photoreceptor layers. The amount of defocus can theoretically provide a quantitative indication of the distances of visual objects, and our behavioral experiments strongly support our idea, a novel mechanism for depth perception based on image defocus. As a first step toward understanding the neural basis of the depth perception in jumping spiders, we recently investigated projection patterns of the photoreceptors. Based on these results, I will discuss the mechanism for depth perception from image defocus.
[1] Nagata et al., 2012 Science; [2] Nagata et al., 2010 J. Comp. Physiol. A

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Invited Symposium 6

IS6-3(11:00 - 11:30)

Photoreceptors regulating light-induced body color change in zebrafish

Daisuke Kojima[1]

Department of Biological Sciences, Graduate School of Science, The University of Tokyo, JAPAN[1]

In response to ambient light levels, many cold-blood vertebrates darken or lighten their body colours. The light-induced body colour change, also called background adaptation, is mediated by ocular photoreception in teleosts, as shown in the classical study by von Frisch (1911). This study aims to identify the photoreceptive molecule(s) responsible for the light-induced body colour change by using zebrafish as an animal model. To this end, we first generated a transgenic zebrafish line, in which rods and cones in the retina can be conditionally and selectively ablated. The rod-less, cone-less zebrafish larvae exhibited no significant difference from the intact animals in the body colour change under a saturated light condition. This light-induced behaviour is thus likely to be mediated by non-rod non-cone retinal photoreceptor neurons, possibly expressing non-visual opsins such as VAL-opsins and melanopsins. To infer the responsible photoreceptive molecules, we established a system to measure and quantify the body colour changes in zebrafish larvae in response to different wavelengths and intensities of light stimuli. Using this system, the spectral sensitivity for the light-induced body colour change was successfully determined in the wild-type zebrafish. The estimated action spectrum suggested involvement of multiple opsin-type molecules in this photic regulation.

[Topic1]Sensory: Vision

[Topic2]Genes and Behavior

Invited Symposium 6

IS6-4(11:30 - 12:00)

Melanopsin expressing retinal ganglion cells in health and disease

*Megumi Hatori[1,2], Ludovic Mure[1], Satchidananda Panda[1]
Salk Institute for Biological Studies[1] , Keio University Medican School[2]

In the mammalian retina, the photopigment melanopsin is fundamental for non-image forming vision including light sensitivity, pupil constriction, sleep and alertness. Melanopsin uses a transduction mechanism in intrinsically-photosensitive retinal ganglion cells (ipRGCs) distinct from the rod/cone opsin signaling pathway. However, pharmacological agents that specifically target melanopsin signaling are unknown. Here we describe the identification of melanopsin-specific “opsinamide” antagonists.
We used a high-throughput cell-based melanopsin photosensitivity assay to identify novel compounds from the sulfonamide family. *In vivo* administration of opsinamides to mice specifically and reversibly altered melanopsin-dependent light responses including photophobia and pupillary reflex to light (PLR) while leaving classical rod/cone photoreception largely unaffected (ERG).
These results demonstrate that opsinamides specifically inhibit melanopsin signaling and modulate ipRGCs-dependent behaviors. The discovery of opsinamides raises the prospect of therapeutic control of the melanopsin system to regulate light-dependent behavior and remediate pathological conditions.

[Topic1]Sensory: Vision

[Topic2]Circadian Rhythms

Participant Symposium 3

PS3-1(15:00 - 15:20)

The influence of sleep on song-related neuronal activity in RA – What role does Melatonin play?

*Susanne Seltmann[1], Lisa Trost[1], Andries Ter Maat[1], Manfred Gahr[1]

Max Planck Institute for Ornithology[1]

Sleep is essential for song learning and song production in birds. The song control nuclei HVC and RA, which both show changes in their neural activity patterns during sleep, play a crucial role in these processes. The presence of Mel-1B receptors in both nuclei suggests that melatonin may be directly involved. However, it is still largely unknown how melatonin affects song structure and its neuronal correlates. To address this question we used wireless transmitters to record the neuronal activity of individual premotor neurons in the RA of free ranging zebra finches while manipulating melatonin levels. Our results suggest a direct influence of melatonin on the activity pattern in RA. Melatonin was found to increase the interspike interval during the steady firing that RA projection neurons show during non-vocal periods, an effect normally observed in the transition to sleep. Furthermore, we found that melatonin is crucial for the occurrence of an auditory response in RA that occurs spontaneously, or can be triggered by playback of bird ’ s own song, during sleep. We therefore speculate that the effects of melatonin on RA firing properties are important for the sleep related maintenance of song structure and could also be involved in song learning.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Audition

Participant Symposium 3

PS3-2(15:20 - 15:40)

Sleep effects on visual selective attention in *Drosophila melanogaster*

*Leonie Kirszenblat[1], John John[1], Yanqiong Zhou[1], Bruno van Swinderen[1]

Queensland Brain Institute, The University of Queensland[1]

Sleep is common to most animal species, yet its functions remain debated. Sleep deprivation is known to impair cognitive processes in humans such as attention, although the underlying causes for this are unknown. Here, we have designed a novel paradigm to study the effects of sleep deprivation on selective attention in *Drosophila melanogaster*.
In our attention paradigm, freely walking flies responded to competing visual stimuli. Flies were able to fixate robustly on a target, by orienting themselves toward it, but could also be distracted away from the target by the addition of visual distractors. We found that sleep deprived flies were much more susceptible to visual distractors compared to non sleep-deprived controls. Importantly, sleep-deprived flies displayed normal responses to simple (non competing) visual stimuli, indicating that the sleep deprivation phenotype only arises with high visual processing load. Furthermore, visual selective attention in sleep-deprived flies was returned to normal after a night ’ s sleep, indicating that the phenotype is reversible. This suggests that one function of sleep is to optimize attention processes. We are currently investigating the neural substrates and molecular processes that are targeted by sleep in order to maintain normal visual attention.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Participant Symposium 3

PS3-3(15:40 - 16:00)

Learned toxin avoidance depends on satiety state in the honeybee

*Nicola, K. Simcock[1], Luisa, A. Wakeling[1], Geraldine, A Wright[1]
Newcastle University[1]

Toxins are common in plant defence; for this reason, most animals that eat plant material have physiological mechanisms for toxin detection. However, when food becomes scarce animals may make trade-offs in toxin digestion and obtaining nutrients by accepting food items they would otherwise reject. In this study we investigated how satiety state influenced learned toxin avoidance in the honeybee. We defined 4 hunger conditions based on volume and concentration of sucrose fed to bees 24 h prior to training. ’Starving’ bees had low levels of haemolymph sugars and elevated expression of two neuropeptide genes, neuropeptide F (NPF) and short-neuropeptide F (sNPF), associated with feeding regulation in other insects. Additionally, hungry animals also exhibited elevated expression of the putative fructose gustatory receptor, AmGr3, in brain tissue. Bees from each hunger condition were trained to associate an odour with sucrose containing the toxin, amygdalin. 'Starving' bees were less likely to express conditioned food aversions towards odours associated with the toxin. Unexpectedly, well-fed bees also failed to learn to avoid odours associated with amygdalin. We propose that there are multiple mechanisms for signalling satiety state in insects and that these mechanisms act in concert to regulate the intake of nutrients and toxins.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Participant Symposium 3

PS3-4(16:00 - 16:20)

Synaptic correlates of performance on an ecologically relevant visual discrimination task in the adult honey bee mushroom body

*Byron N. Van Nest[1,2,3], Glen S. Marrs[1,2,3], Susan E. Fahrbach[1,2,3]

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Mushroom bodies (MBs) are arthropod brain regions associated with memory formation. The dendrites of the intrinsic MB neurons (Kenyon cells) are in the calycal neuropil, where they receive input from primary sensory neuropils. The calycal neuropils are larger in honey bee foragers than in non-foragers, and generalist-foraging insect species tend to have larger MBs than specialist-foraging species, suggesting that larger neuropils promote learning of complicated foraging tasks. Prior studies focused on the experiences that promote MB growth and the cellular processes that cause this growth; however, the consequences of MB growth for an individual are unknown. Experience clearly fine-tunes brain structure in animals, but how does this feed forward onto behavior? We have developed a field-based visual discrimination task that mimics natural foraging. Foragers learn to associate the hue of an artificial flower with a sucrose reward. Each forager is monitored over 12 visits to the flower patch and scored on the rate at which the association is learned. This task revealed three behavioral cohorts: fast-learners (30%), slow-learners (30%), and non-learners (40%). Learning scores are then correlated to synaptic density in the MB calyces via whole-brain immunolabeling and confocal microscopy.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Participant Symposium 3

PS3-5(16:20 - 16:40)

Indications of visual lateralization in flight control

*Therese Reber[1], Marie Dacke[1], Emily Baird[1]

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To control flight, insects rely on the pattern of visual motion (optic flow) that is generated on the retina as they move through the environment. The diurnal meadow foraging bumblebee *Bombus terrestris* and the nocturnal rainforest bee *Megalopta genalis* navigate through very different visual environments. Previous work has suggested that these bees use visual information from different parts of the visual field for flight control. Here, we test this by presenting bees flying along a flight tunnel with strong optic flow cues in different parts of the visual field. We find no significant differences on flight speed and position control between the two species. Surprisingly, when optic flow cues were presented on only one wall, the strength of the response in both species depended on the side of the visual field in which these cues appeared. These results provide the first indication of visual lateralization in flight control. We further investigate the basis of this using anatomical studies.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Participant Symposium 3

PS3-6(16:40 - 17:00)

‘ Map-and-compass neurons ’ in the bat hippocampus

*Alon Rubin[1], Michael Yartsev[1], Nachum Ulanovsky[1]

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Most theories of navigation rely on the concept of a mental map-and-compass. Hippocampal place-cells are neurons thought to be important for representing the mental map; these neurons become active when the animal traverses a specific location in the environment (the ‘ place field ’). Head-direction cells are found outside the hippocampus, and encode the animal's head orientation, thus implementing a neural compass. The prevailing view is that activity of head-direction cells is not tuned to a single place, while place-cells do not encode head-direction. Here we recorded the activity of single neurons in the hippocampus of two evolutionarily distant bat species, Egyptian fruit bat and big brown bat, which crawled randomly in open-field arenas. We found that most hippocampal neurons, in both bat species, exhibited conjunctive sensitivity to the animal's spatial position (place field) and to its head-direction. Surprisingly, some hippocampal neurons preserved their head-direction tuning even outside the neuron's place field – suggesting that ‘ spontaneous ’ extra-field spikes are not noise, but in fact carry head-direction information. These findings suggest that hippocampal neurons provide the brain's navigation system with both map information and compass information, and are thus ideally suited to serve as the hub of spatial representation in the brain.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Plenary Lecture 5 by Motojiro Yoshihara

PL-5

The *Drosophila* feeding circuit to connect synaptic plasticity to memory

Motojiro Yoshihara[1]

National Institute of Information and Communications Technology, Kobe, JAPAN[1]

To investigate the mechanism of memory formation, my lab combines analyses on two models of synaptic plasticity: the *Drosophila* embryonic neuromuscular junction (NMJ) as a simple cellular model, and the *Drosophila* adult the feeding circuit for the correlation with learning behavior. We have recently identified a pair of neurons, "Feeding (Fdg) neuron" that commands the entire feeding behavior (Flood et al, 2013, *Nature*). The Fdg neuron has a large dendritic arborization, suggesting that it integrates information of various gustatory cues and metabolic cues, as well as signals of other modalities. This pivotal role of the Fdg neuron within the feeding neuronal circuit allows us to investigate synaptic plasticity during behavioral memory formation. Using a newly developed experimental system where neuronal activity and behavior can be observed simultaneously (Yoshihara 2012, *JoVE*), we can correlate plastic changes of synapses innervating a Fdg neuron to a behavioral change in Pavlovian conditioning. Our findings on the Fdg neuron combined with synaptic physiology at NMJ (Yoshihara et al., 2005, *Science* 310: 858-863) will likely allow us to understand the molecular and cellular mechanism of synaptic plasticity --- the basis of memory formation.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensorimotor Integration

Special symposium honoring Mark Konishi

SS-1(10:00 - 10:30)

Improvement of directionality and sound localization by internal ear coupling in barn owls

*Hermann Wagner[1], Jakob Christensen-Dalsgaard[2], Lutz Kettler[1], Ole N Larsen[2]

RWTH Aachen University, Germany[1] , University of Southern Denmark, Odense[2]

Mark Konishi was one of the first to quantify sound-localization capabilities in barn owls. He showed that frequencies between 3 and 10 kHz underlie precise sound localization in these birds, and that they derive spatial information from processing interaural time and interaural level differences. However, despite intensive research during the last 40 years it is still unclear whether and how internal ear coupling contributes to sound localization in the barn owl. Here we investigated ear directionality in anesthetized birds with the help of laser vibrometry. Care was taken that anesthesia and the stapedius reflex did not influence the results. When analyzed in narrow frequency bands, the data demonstrated a certain amount of internal ear coupling in the low-frequency range (<3 kHz), but not in the high frequency range (3-10 kHz). Although many cells in the auditory pathway are tuned to interaural time difference in the low-frequency range, barn owls hesitate to approach prey or turn their heads when only low-frequency auditory information is present in a stimulus they receive. Thus, the barn-owl ' s sound localization system seems to be adapted to work best in frequency ranges where interaural time and level differences may be simultaneously evaluated for localizing prey.

[Topic1]Sensory: Audition

[Topic2]Orientation and Navigation

Special symposium honoring Mark Konishi

SS-2(10:30 - 11:00)

From a non-uniform brain map to non-uniform behavior in the owl

*Jose L Pena[1], Fanny Cazettes[1], Brian J Fischer[2]

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A major challenge in Neuroethology is to understand how the activity of populations of neurons translates into behavioral responses. We have studied this question in the sound localization system of the barn owl. In the owl ’ s midbrain, auditory space is represented by a map. This map is, however, a distorted copy of space, where the front is overrepresented and the spatial tuning varies in width from front to periphery. We have investigated the non-uniform representation of space and how it translates into behavior. The interaural time difference (ITD) is a primary cue used to localize sound. Due to the filtering effect of the head, ITD varies depending on frequency and the presence of background noise. We found that at each direction there is a frequency range within which ITD is most invariant. We showed that neurons ’ preferred frequency matched this range. The frequency tuning could explain why spatial tuning width is non-uniform across the map. The relationship between frequency and ITD allowed us to manipulate the pattern of activity across the neural population and test the effect on behavior. We monitored head saccades in response to sound stimulation and assessed the consistency of the behavioral output with population decoding schemes.

[Topic1]Sensory: Audition

[Topic2]Computational Modeling

Special symposium honoring Mark Konishi

SS-3(11:00 - 11:30)

One 3D visual world constructed by two eyes and two cortical pathways

Ichiro Fujita[1,2]

Osaka University Graduate School of Frontier Biosciences[1] , Center for Information and Neural Networks[2]

The human brain can derive depth structure of objects and scenes from two flat images on the retinae, an ability called stereopsis. Because our two eyes view the world from slightly different vantage points, tiny positional differences exist in the visual features between the two eyes. The brain exploits these differences, or binocular disparities, to compute stereoscopic depth.
Processing for stereopsis starts in the primary visual cortex (V1). However, properties of V1 cells do not account for a number of perceptual aspects of stereopsis, suggesting that subsequent processing beyond V1 is responsible for conscious perception of depth. Disparity signals are indeed processed further along the visual pathway projecting to the parietal cortex (dorsal pathway) and along the pathway projecting to the temporal cortex (ventral pathway). The brain thus uses the two major cortical pathways for stereopsis. Why?
Recent studies are answering this question. Neurons in ventral pathway areas solve the binocular correspondence problem, compute relative disparity between adjacent visual features, and underlie fine disparity discrimination. Those in dorsal pathway areas encode binocular correlation, signal local absolute-disparity, and are involved in judgment of coarse disparity and in control of vergence angle. The two pathways contribute to stereopsis in a different manner.

[Topic1]Sensory: Vision

[Topic2]Computation

Special symposium honoring Mark Konishi

SS-4(11:30 - 12:00)

Connecting neurophysiology to movements in birdsong motor control: neuromechanics and neuroethology

Daniel Margoliash[1]

University of Chicago[1]

A seminal contribution of Mark Konishi was to identify the importance of auditory feedback for song learning, which brought mechanistic focus to the early behavioral studies. Students of Konishi learned first hand the lessons of the early ethologists, including the importance of detailed description of the actual movements an animal makes. Here we combine electrophysiological studies of the motor pathway for birdsong production with modeling of the syrinx and upper vocal tract to describe how a bird sings. Song is described as a sequence of subsyringeal pressure and syringeal tension movements, "gestures" that typically reside near bifurcations in the parameter space, following a nonlinear dynamical systems biophysical model from Gabriel Mindlin. Recordings of single neurons in the forebrain nucleus HVC, in singing birds or during fictive singing achieved by song playback during sleep, demonstrate that activity is related to the times of extrema in the gesture trajectories. Array recordings from populations of neurons extend these observations. Both HVC and syringeal muscle activity (collaboration with Franz Goller) occur with near-zero delay relative to singing or song playback. The data suggest independent forebrain and brainstem pattern generators, that are entrained during singing, promoting a new, neuroethological view of birdsong motor control.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Motor Systems

Plenary Lecture 6 by Jochen Zeil

PL-6
Visual homing in insects

Jochen Zeil[1]

Research School of Biology, The Australian National University[1]

Many insects, in particular ants, bees and wasps, are competent navigators and are known to rely heavily on vision to memorize places and routes. The landmark panorama, the sun, the pattern of polarized skylight and even the Milky Way provide them with an external compass reference. For visual homing, insects acquire scene memories at their nest or at newly discovered feeding sites during highly structured learning flights or learning walks.
Given the importance of navigational competence for all aspects of animal life, it is of great interest to understand the rules governing the active acquisition of visual representations and the algorithms insects employ during homing. Visual homing is a challenge for both biological and technical systems and insects are as good at it as any animal. They are quite unique, however, because they allow us to analyse in detail how visual place memories are actively acquired and subsequently used for homing.
It is an exciting time to study visual homing: Novel tracking and reconstruction techniques now allow us to quantify the navigational information content of different habitats, comparative analysis shows how the blend of navigational mechanisms depends on habitat structure and there are solid advances in theory and neuro-ethological simulation.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Huber Lecture

PL-10

The formation and function of the first networks controlling behaviour in a very small vertebrate

Alan Roberts[1]

University of Bristol, UK[1]

Understanding the function of neuronal networks in the brain requires the identification of neurons and knowledge of their properties and synaptic connections. During development, the core of all vertebrate nervous systems starts from a common plan with organized rows of neuronal precursor cells, which then grow axons to form the thousands of connections of the first neuronal networks. We use a vertebrate model, the hatchling *Xenopus* tadpole, to show that simple development processes can guide the assembly of a whole, functional, swimming network. By building models of axon growth and synapse formation, based on detailed measurements of the anatomy and physiology of each neuron type, we reconstruct full-scale network connectivity. When the resulting network is mapped onto a physiological model, it can ‘swim’ in response to sensory stimulation. This model represents the most complete description of a functioning network generating behaviour of a whole animal. The findings validate a developmental strategy for generating realistic networks. They also establish that basic functional neuronal connectivity and behaviour can result from simple rules which lay out the scaffold of the central nervous system without specific neuron to neuron recognition.

[Topic1]Sensorimotor Integration

[Topic2]Motor Systems

Poster Session 2

PO-2001(14:30 - 15:30)

Vision II: The effect of photon shot noise and phototransduction noise on information transfer in photoreceptors

*Iikka V Salmela[1], Jouni Takalo[2], Esa-Ville Immonen[2], Matti Weckström[2]

Dept. of Biology, Lund University and Dept. of Physics, University of Oulu[1] , Dept. of Physics, University of Oulu[2]

Night vision is hindered by noise introduced by the randomness of photons (shot noise) and stochastic biological processes within the visual system. Nevertheless, several nocturnal animals perform complex visually guided behaviour under very dim illumination, suggesting their visual systems efficiently extract and process information from a noisy light input.

We have studied the information processing in photoreceptors driven by low to high intensity dynamic contrast waveform stimuli. Using simulations based on experimentally characterized phototransduction noise, i.e. the variability of single photon responses (bumps), we have estimated the relative contributions of shot noise and phototransduction noise on information transfer.

Our simulations show that at very low intensities (<10 photons/s) phototransduction noise, i.e. the variation in shape and timing of bumps, is outweighed by the photon shot noise of the light input itself. At higher intensities variability in bump timing limits the information transfer, whereas bump amplitude variation remains insignificant. These results suggest the lack of evolutionary pressure to accurately control the parameters for bump production in darkness. In crepuscular or diurnal conditions, however, bump timing must be regulated to reach reasonable information transfer rates.

[Topic1]Sensory: Vision

[Topic2]Computational Modeling

Poster Session 2

PO-2002(15:30 - 16:30)

Vision II: Flight muscle coordination and body orientation during collision avoidance in flying locusts

*Cody W. Manchester[1], John R. Gray[1]
University of Saskatchewan[1]

Animals display a variety of adaptive behaviours responsible for collision avoidance with predators and conspecifics. Complex neural control mechanisms underly these behaviours, which are controlled by specialized neural circuits. *Locusta migratoria* is a model organism for examining flight muscle coordination of collision avoidance behaviour. Loose tether experiments have shown that locusts free to manoeuvre in 3-dimensional space will adjust wing beat frequency, coordinate timing of a single bilateral pair of flight muscles, and coordinate forewing asymmetry during the downstroke. Current experiments were designed to test two hypotheses: 1) Synchrony between 3 bilateral pairs of flight steering muscles increases prior to initiation of intentional flight steering behaviour. We analyzed EMG recordings from 3 bilaterally paired forewing (m97(1st basalar), m99(subalar), and hindwing (m127(1st basalar)) steering muscles. 2) Timing and synchrony of multiple flight muscle activity correlate with whole body motion within 6 degrees of freedom during intentional flight steering. Concurrent electromyographic (EMG) and high speed video allowed for measurements of muscle activity and body orientation. Preliminary analysis indicates increases in muscle synchrony and correlation with yaw, pitch, and role body orientation during a collision avoidance behaviour.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Poster Session 2

PO-2003(16:30 - 17:30)

Vision II: Navigation at night a balancing act: Head stabilisation in *Myrmecia* ants during twilight

*Chloe A. Raderschall[1], Ajay Narendra[1], Jochen Zeil[1]

Research School of Biology, The Australian National University[1]

As animals move, they generate image motion in their visual field. To reduce such unintended eye rotations, animals are known to perform compensatory head movements that help stabilise gaze.

Most studies investigating gaze stabilisation in insects have come from flying species. Yet, walking insects have a special problem because they are in direct contact with the substrate, which induces unpredictable body rotations as they walk.

Bull ants (*Myrmecia pyriformis*) are crepuscular animals that experience a wide range of light intensities during their foraging trips, yet they rely heavily on visual cues for navigation. To measure their ability to control head orientation in the presence of substrate-induced body roll, we induced ants to walk along a twisted band. We filmed ants from the front to quantify head and body roll in a range of light conditions in the ants ’ habitat, as well as in the laboratory.

We find that (1) ants are able to keep their head horizontally aligned against body roll of up to 60 degrees; (2) head stabilisation is partly visually controlled, because the response weakens as light levels drop; (3) the ants also achieve partial roll compensation in complete darkness, suggesting non-visual information contributing to head stabilisation.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Poster Session 2

PO-2004(17:30 - 18:30)

Vision II: Navigation and the visual world of the desert ant

*Paul B Ardin[1], Mike Mangan[1], Barbara Webb[1]
University of Edinburgh[1]

Desert ants are a model system of animal navigation. Initially path integration is important in finding the return route to the nest but after retracing the path the first time the ant can rely on vision alone to get home. To investigate possible mechanisms supporting this behaviour, the behaviour and the environment of the desert ant Cataglyphis velox has been captured in detail at our field site in Sevilla. Combining this information with anatomical data about the optical system from C. velox, and of the visual pathway of other hymenoptera, a sensory model is being developed which more accurately matches the animal than those which have been previously created. Of particular interest is how the optical sampling may combine with the motion and motion processing of the animal to create a unique visual input with which accurate route following can be achieved. We will evaluate this model of visual processing in the context of recent navigation algorithms.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Poster Session 2

PO-2005(14:30 - 15:30)

Vision II: Negative phototropotaxis using bilateral eyes in the terrestrial slug *Limax*

*Yuko Matsuo[1], Nana Uozumi[1], Ryota Matsuo[1]

Fukuoka Women's University[1]

The land slug *Limax* innately avoids a lighted place and prefers darkness. Such a mode of movement will be advantageous to avoid dryness in the animal ’ s terrestrial life. In the light-motivated movement, the slugs are believed to decide the direction of movement by comparing the light intensities from their bilateral eyes (phototropotaxis). As a supportive evidence for this notion, the unilateral eye removal causes the slugs to continuously rotate in the ipsilateral direction toward the removed eye, indicating that the slugs always move to subjectively darker side. However, there remains some gaps in the logic to connect the rotating behavior to phototropotaxis. Here in this study, we demonstrated that the rotating behavior was not observed in the absence of light, or when the cerebral commissure was surgically dissected. These results suggest that the information about light intensity is actually compared between the left and right eyes through the cerebral commissure. We also showed electrophysiologically that the optic nerves project directly or indirectly to the contralateral cerebral hemisphere through the cerebral commissure probably to exchange information about the light intensity.

[Topic1]Sensory: Vision

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2006(15:30 - 16:30)

Vision II: An insight into situational gaze movements of jumping spiders

*Cole Gilbert[1], Daniel B. Zurek[2]

Department of Entomology, Cornell University, Ithaca, NY, USA[1] , Department of Biological Sciences, University of Pittsburg, Pittsburg, PA, USA[2]

Visual properties of eyes are not uniformly distributed across the field of view, thus animals with moveable eyes change their direction of gaze to view objects of interest with the high acuity region of the retina. In jumping spiders, the principal eyes perform high acuity inspection and spectral analysis of objects. Their retinas can move to change the gaze direction through the lens, which is fixed in the exoskeleton. We have filmed these retinal movements in the horizontal plane as transparent spiders walked freely in a blank arena, tracked a horizontally moving target with retinal and body movements, and inspected a scaffolding to select an escape route. Retinal scanning movements occur independently or synchronously in the two eyes. Retinal movements may occur while the spider walks, but occur more frequently when stopped. The angular range of gaze movement is greater in the ipsilateral direction. Consequently, when a moving target approaches in the spider ' s peripheral visual field, the ipsilateral retina begins tracking the target first. As it passes into the contralateral field of view the other retina begins to follow the target more closely. When this retina reaches the end of its movement range, a body turn occurs.

[Topic1]Sensory: Vision

[Topic2]Sensorimotor Integration

PO-2007(16:30 - 17:30)
Vision II: Control of self-motion in water and air: fish do it differently from bees

*Christine Scholtyssek[1], Marie Dacke[1], Emily Baird[1]

Lund Vision Group, Functional Zoology, Department of Biology, Lund University, SE-22362, Lund, Sweden[1]

To move safely through their environment, animals must control their distance and speed relative to nearby obstacles. This is especially challenging for swimming and flying animals whose speed and direction of motion is influenced by the dynamic flow of water or air. Flying animals overcome this challenge by relying primarily on optic flow for self-motion control. *Drosophila*, bees and birds control their speed by keeping the rate of optic flow constant. In cluttered environments, bees and birds balance the rate of optic flow in both eyes to maximize the distance to surrounding obstacles. We investigated if swimming and flying animals use similar mechanisms for self-motion control by directly comparing the impact of optic flow on the velocity and the distance to obstacles. Zebrafish and bumblebees were trained to negotiate the same experimental tunnel whose walls displayed black-and-white patterns that produced either strong or weak horizontal optic flow cues on both walls, or strong optic flow cues on one wall and weak optic flow cues on the other wall. We show that zebrafish do react to manipulations of optic flow, but not in the same way as bumblebees, suggesting a special mechanism for self-motion control under water.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2008(17:30 - 18:30)

Vision II: The connection between single cells properties in the early visual system and natural scene statistics: a lesson from the archer fish

*Mor Ben-Tov[1], Ronen Segev[1]

Life Sciences Department, Ben Gurion University of the Negev, Israel[1]

Much effort was dedicated to understand the functional properties of receptive fields in the early visual system by assuming that the cells ’ output is tuned to represent the statistical structure of the natural visual scene in an efficient manner. According to this, theoretical analysis showed that it is possible to reproduce the receptive field properties of simple cells in V1. This influential theory however was not tested critically since generally it is impossible to change the visual environment statistics and observe changes in receptive fields. .The archer fish, which hunts both below and above water level, represents a unique opportunity to test this theory by examining the different parts of the visual system that are devoted to processing information in two different visual environments: aquatic and atmospheric. These two environments are known to have different statistical properties and therefore different receptive fields structure are predicted to be present in the regions which are devoted to the processing of the two environments. We measured single cells in the optic tectum, the main visual processing area in the archer fish brain, and discuss to what extent the structure of the receptive fields is determined by the statistical structure of the environment.

[Topic1]Sensory: Vision

[Topic2]Computation

Poster Session 2

PO-2009(14:30 - 15:30)

Vision II: Bird colour vision: Behavioural thresholds and receptor noise

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Birds have long been considered the masters of vision, and the retinal adaptations for colour vision among birds are impressive. Birds are tetrachromatic, meaning that four types of cone photoreceptors mediate their perception of colour. In addition, bird photoreceptors have coloured oil droplets that function as spectral filters. These filters are believed to enhance colour discrimination at the cost of absolute sensitivity.

However, it has never been tested whether birds can discriminate small colour differences better than humans. We tested this by training chicks to discriminate colour differences in bright and dim light, and by asking humans to discriminate the same colours. In bright light, the birds could indeed discriminate colours well, but not better than humans. Humans, however, could discriminate colours in dimmer light than the birds. Birds should still be able to see colours we cannot see, especially ultraviolet colours.

Within a visual system, photoreceptor noise sets the thresholds, and our results indicate that birds have relatively noisy photoreceptors. From our behavioural data we deduce that Weber ’ s law describes noise in bright light while in dimmer light, photon shot noise and dark noise must be assumed to explain the colour vision of birds.

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Poster Session 2

PO-2010(15:30 - 16:30)

Vision II: The avian photoreceptor as a composite optical device

***David Wilby[1,2,3], Matthew B. Toomey[4], Peter Olsson[5], Ruth Oulton[2], Almut Kelber[5], Joseph C. Corbo[4], Nicholas W. Roberts[1]**

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Birds possess some of the most acute spatial resolution and spectral discrimination of all animals, abilities afforded by the optics of the retinal photoreceptors. Cone photoreceptors of birds, using the domestic chicken as a model, have been investigated using advanced microscopy methods and electromagnetic simulations in order to determine the optical function of their component structures. Cones comprise elements acting as both spectral filters and fibre optics enhancing their performance as spectrally specific light detectors.

We have used digital holographic microscopy (DHM) and microspectrophotometry (MSP) to map refractive index in dissociated photoreceptors teamed with serial block face SEM to inform finite-difference time-domain optical simulations. We find that the dense mitochondrial ellipsoid of the cone acts to guide light along the photoreceptor and to alleviate reflection at the oil droplet interface, which itself acts as both an enhancing lens and spectral filter. These optical effects acting together enhance light capture in the cone by up to 400%, thereby improving signal-to-noise in the colour vision system.

[Topic1]Sensory: Vision

[Topic2]Computational Modeling

Poster Session 2

PO-2011(16:30 - 17:30)

Vision II: Vision in Australian crocodiles

*Nicolas Nagloo[1], Nathan S. Hart[1], Jan M. Hemmi[1], Shaun P. Collin[1]

School of Animal Biology and The Oceans Institute, The University of Western Australia, Crawley, WA, 6009, Australia[1]

The Saltwater crocodile *Crocodylus porosus* and the Freshwater crocodile *C.johnstoni* are two apex predators found in Australian waters. We investigated fundamental aspects of their visual system, such as spectral sensitivity, temporal resolution and spatial acuity. Considering how close both species are phylogenetically, differences in the visual system are likely to result from adaptations to environmental conditions. Microspectrophotometry showed that wavelengths of peak sensitivity of the rod pigment, the three cone pigments and the twin cone pigment in the freshwater crocodile (509,426,510,554 and 554nm respectively) were consistently long-wave shifted compared to those in the saltwater crocodile (502,424,502,546 and 546nm, respectively). Temporal resolution was measured using flicker electroretinography and in both species increase from 15 to 55Hz over the 4 log units of light intensities used. Ganglion cell distribution in retinal wholemounts revealed a region of elevated density in the dorsal retina that would facilitate acute vision in the ventral visual field. There were no differences in cell density but larger saltwater eyes resulted in 15% higher spatial acuity. While there are negligible differences in temporal resolution and spatial acuity, the interspecific differences in visual pigment spectral sensitivity likely reflect differences in the spectral composition of light in fresh and salt water.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2012(17:30 - 18:30)

Vision II: Evidence of short- and long-wavelength sensitive opsins in the retina and nerve cord of the crayfish, *Procambarus clarkii*

*Alexandra C. N. Kingston[1], Thomas W. Cronin[1]

University of Maryland Baltimore County[1]

The crayfish retina contains two photoreceptor classes: a long-wavelength sensitive (LWS) receptor in the main rhabdom and a short-wavelength sensitive (SWS) receptor in the R8 cell, distal to the main rhabdom. The main rhabdom is known to express a typical LWS opsin, but the opsin gene and protein expressed in the SWS receptor remain uncharacterized. Additionally, the caudal photoreceptor, a functional photoreceptor in the sixth abdominal ganglion of the crayfish ventral nerve cord, generates both electrical and behavioral responses to light. Here, we identify the SWS opsin gene using RT-PCR, and show retinal expression patterns of SWS and LWS opsins via immunohistochemical staining, in *Procambarus clarkii.* To explore the hypothesis that opsins are involved in light sensation in the caudal photoreceptor, we use RT-PCR to show that both the SWS and LWS opsin genes are expressed throughout the nerve cord and are not limited to the sixth abdominal ganglion. We hypothesize that both of these opsins are functional and responsible for light sensitivity in the caudal photoreceptor. Future work will explore where opsin proteins are expressed throughout the central nervous system.

[Topic1]Sensory: Vision

[Topic2]Cellular Properties

Poster Session 2

PO-2013(14:30 - 15:30)

Vision II: The humble humbug: a master of disguise

*Genevieve A. C. Phillips[1], Karen L. Cheney[2], Julia E. Lange[2], Martin J. How[1], Justin Marshall[1]

Queensland Brain Institute, The University of Queensland[1] , School of Biological Sciences, The University of Queensland[2]

Disruptive colouration using body patterns made up of contrasting elements can provide visual camouflage to animals, and is hypothesised to provide concealment to animals even when they do not match the background perfectly. Here we examined disruptive colouration in coral reef fish from the perspective of two ecologically distinct fish predators. Behavioural experiments were used to determine whether spatial frequency contrast between disruptively patterned prey fish and the background affected the likelihood of predation. We then modelled the experimental setup through a ‘ fish-eye-view ’ , using information on the predators ’ visual acuity. This allowed us to see the effectiveness of disruptive colouration on different experimental backgrounds. Finally, we modelled images of humbugs in their natural environment, to see if disruptive colouration provided them with an effective camouflage strategy against the variety of natural habitats they live in. Our results suggest that while prey fish were most camouflaged when viewed against backgrounds that were similar to their body pattern, backgrounds that were differed slightly (higher spatial frequency) provided a similar amount of protection from predation. Our results are the first to show behaviourally that disruptive colouration allows prey to move between different backgrounds whilst maintaining visual concealment from common reef fish predators.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2014(15:30 - 16:30)

Vision II: Complex visual adaptations in squid for different environments

*Wen-Sung Chung[1], Justin Marshall[1]

Queensland Brain Institute, The University of Queensland[1]

Many fish and most squid are successful visual predators. In contrast to well documented adaptive strategies among fish that encounter a large range of habitats and light conditions, our knowledge of visual adaptations in squid is poor. Here we use histology, MRI, and depth distributions to compare brains, eyes, and visual capabilities. A combination of MRI and histology has discovered several new adaptations of squid eyes, including deformation of eye shape, new photoreceptor arrangements, regionally differentiated retina, and a new form of complex retina including interneuronal layers previously unknown. These modifications of the ‘simple’ squid eye reflect habitat light level and some specific tasks.. As part of this work, a new generation of deep-sea video system, *Medusa*, has been used to film several squid species at depths between 500-800m. Both light-lure and food-bait triggered squid foraging and attacking behaviours, and provide unique glimpses of feeding behaviours in the giant squid *Architeuthis dux* and three other species. Bait-strike precision of the Humboldt squid was quantified over varying light levels and showed a clear threshold in deep-sea squid vision.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2015(16:30 - 17:30)

Vision II: The timing of escape responses under natural conditions in the crab *Neohelice granulata*

***Jan M. Hemmi[1,2], Daniel Tomsic[3]**

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Crabs have proven a valuable model system to study the neural control of escape, as it is possible to investigate their behaviour both under natural and laboratory conditions. The crabs ’ compound eyes provide only a limited amount of information about the level of threat posed by an approaching predator. Research in the fiddler crab *Uca vomeris* has suggested that this limitation requires the animals to use a sensitive but unspecific response criterion to make early escape decisions. In the laboratory fiddler crabs change their behaviour - they respond significantly later than in the field, use different response criteria and run directly away from the approaching object.

The crab *N.granulata* uses an angular size criterion to time its escape response in the laboratory. Never before tested under natural conditions, we present results from field experiments that show that in contrast to fiddler crabs, *N.granulata* still uses an angular size criterion in the field, even though they respond at much smaller angular sizes and run towards the burrow rather than away from the predator as in the laboratory. The similarity between their compound eyes suggests that behavioural context rather than the neural system is responsible for the observed differences between these species.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2016(17:30 - 18:30)

Vision II: Innate color preference is affected by plant odor in Japanese yellow swallowtail butterfly, *Papilio xuthus*

*Mina Yoshida[1], Yuki Ito[2], Hisashi Omura[2], Kentaro Arikawa[1], Michiyo Kinoshita[1]

The Graduate University for Advanced Studies[1] , Hiroshima University[2]

Innate color and/or odor preferences may play as important a role as feeding experience in shaping the foraging behavior of flower-visiting insects. To characterize color preferences in foraging, we presented blue, green, yellow and red disks to newly-emerged *Papilio xuthus* and recorded which one they visited first. Both sexes innately preferred blue in the absence of any specific odor.
To investigate the effect of odor, we next tested color preference with ambient odor from either flower essences (*Citrus* (Neroli), lily or lavender) or potted plants (flowering *Hibiscus* or *Citrus* trees). The preference of females shifted to red in tests with Neroli or lily, and to green with *Citrus* trees. This is probably because *Citrus* and lily are native to Japan, and *Papilio* oviposit on *Citrus* trees. However, males' preference to blue remained unchanged in all odor conditions. We further found that *Papilio* whose antennae were covered with mascara preferred blue even in the presence of *Citrus*. We argue that male odor sensitivity may be lower than that of females, and the identified sexual dimorphism must be related to either the olfactory system or the system integrating vision and olfaction, because no sexual dimorphism has been found in the visual system.

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Poster Session 2

PO-2017(14:30 - 15:30)

Vision II: Sexual dimorphism and its function in the " rough " eye of the Northeast Asian Wood White, *Leptidea amurensis*

*Hironobu Uchiyama[1,2], Michiyo Kinoshita[2], Kentaro Arikawa[2]

Genome Research Center, Tokyo University of Agriculture[1] , Department of Evolutionary studies of Biosystems, The Graduate University for Advanced Studies[2]

The eyes of the male Northeast Asian wood white, *Leptidea amurensis*, appear " rough " due to irregular arrangement of facets of different shapes and sizes, while the eyes of females are not. To clarify the functional significance of the sexual dimorphism and its function, we compared the structure, optical and physiological properties in their eyes. Here we found that their eyes consist of two sizes of ommatidia: one has large lens and rhabdom, and those in another are small. These differences are clear in males, but less prominent in females. Moreover, the facets are hexagonal in females as in most other insects, but they are irregular in shape in males. We recorded the light intensity-denpendency of electroretinogram to elucidate the overall sensitivity, and found that the dynamic range of the intensity-response function appears significantly wider in males than in females. Based on the anatomy of the ommatidia, we calculated the visual sensitivities of ommatidia:large ommatidia appear to be 1.4 times more sensitive than small ommatidia in males. The expanded dynamic range in males is probably attributed to the variability in sensitivity among ommatidia, and is probably beneficial for males to search for females in shaded patches in sunny grasslands.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 2

PO-2018(15:30 - 16:30)

Vision II: A twisted view of the world: why mantis shrimp rotate their eyes

*Ilse M. Daly[1], Martin J. How[1], Thomas W. Cronin[2], Justin Marshall[3], Julian C. Partridge[4], Nicholas W. Roberts[1]

University of Bristol[1] , University of Maryland Baltimore County[2] , University of Queensland[3] , University of Western Australia[4]

Stomatopod crustaceans possess one of the most complex animal eye designs known. Research has concentrated on the anatomical structure of the eye and the animal ’ s exceptional polarisation and colour visual systems, but relatively little is known about their unique eye movements, the eye rotations in particular.
Most animals use eye movements to re-orientate the eyes and to stabilize their gaze relative to the background. However, stomatopods appear to actively avoid gaze stabilisation by regularly performing rotational and scanning movements. During eye rotations, the centre of mass of the eye remains fixed, while the eye rotates through a range of approximately 90 ° about a central axis.
Using a stereo camera system to track markers on the eyes of stomatopods, we characterise, for the first time, their rotational eye movements in response to polarised visual targets. Results suggest that rotational movements in each eye can occur independently, or occasionally in synchrony. Some individual animals have a preference for maintaining one eye vertical while the other eye rotates.
Additionally, we describe a novel type of eye movement, the “ rotational scan ”, whereby both eyes rotate through 90 ° in synchrony, while maintaining an angular separation of 90 ° between the eyes.

[Topic1]Sensory: Vision

[Topic2]Ecology

Poster Session 2

PO-2019(16:30 - 17:30)

Vision II: Innate pattern recognition and categorization in a jumping spider

*Yinnon Dolev[1], Ximena J. Nelson[1]

University of Canterbury[1]

The jumping spider *Evarcha culicivora* preferentially preys upon blood-fed *Anopheles* mosquitoes, using their distinct resting posture and engorged abdomen as key elements for recognition. To understand *Evarcha* ' s perceptual categorization of objects, we investigated their predatory behaviour toward different digital stimuli - abstract ' stick figure ' representations of *Anopheles* constructed using known key identification elements, disarranged versions of these, non-prey items, and detailed images of alternative prey. We hypothesized that the *Anopheles* abstract images would be perceived as prey, and would be favoured over non-preferred prey. We found that *Evarcha* perceived *Anopheles* stick figures specifically as their preferred prey, attacking them significantly more often than non-preferred prey, even when the comprising elements were disarranged and disconnected from each other. However, if the relative angles between the elements of the disconnected stick figures were altered, the otherwise identical set of elements was no longer perceived as prey. We show that *Evarcha* is capable of making discriminations based on abstract concepts, such as the hypothetical angle formed by discontinuous elements. Our results suggest local processing rather than global processing or a holistic approach to object recognition by *Evarcha* and provide a glimpse of the underlying processes of object recognition in animals with minute brains.

[Topic1]Sensory: Vision

[Topic2]Computational Modeling

Poster Session 2

PO-2020(17:30 - 18:30)

Vision II: Photonic structures in the eyes of stomatopod larvae

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Light-reflecting structures in stomatopod larval eyes, produce bright, narrow band reflectance that camouflage the underlying dark retina in the pelagic light environment. Most reflective camouflage strategies in the pelagic environment are broad-spectrum, silvery reflectors, but larval eyeshine is the first reflective camouflage that is spectrally matched to this light environment. Based on previous descriptions of distal reflecting pigments in the eyes of adult stomatopods, we hypothesized that coherent scattering from a photonic structure was the mechanism responsible for producing larval eyeshine reflectance. Using transmission electron microscopy (TEM) we discovered a three dimensional lattice of vesicles at the junction of the retinular cells and the crystalline cones in six species of larvae (absent from the optical pathway of the rhabdom). The predicted reflectance spectrum of each species was calculated using a modified Bragg ' s theory model. We observed a novel photonic structure in both the early and late stage larval eyes of a seventh species: Pullosquilla thomassini. These larvae possess an intrarhabdomal structure consistent with a high-order photonic crystal. Investigations into the function of this intrarhabdomal structure and its potential role in producing eyeshine are in progress.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 2

PO-2021(14:30 - 15:30)

Vision II: Electrophysiological and behavioral approaches to understanding color vision in *Drosophila melanogaster*

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Many animals including insects can discriminate color based on the activities of several photoreceptor cells that have a distinct spectral sensitivity. However, neural mechanisms underlying color vision are not fully understood. *Drosophila melanogaster* offers a good model system for deciphering the neural basis of color vision due to progress in electrophysiological techniques combining genetic tools and behavioral assays. To examine spectral sensitivities from the neurons in the color processing pathway, we first set up the light stimulus system that can give monochromatic lights ranging from 300-700 nm wavelength. We evaluated the system by using electroretinograms and examined several basic conditions critical for recordings such as stimulus intensity and interval. We are currently working on establishing whole-cell patch-clamp recordings from second-order and third-order neurons in the color processing pathway. In addition to the electrophysiological approach, we aimed to evaluate the color discrimination ability of *Drosophila* using a behavioral experiment. We used an appetitive conditioning, where flies were given R/G/B light from the iPad LCD display as a conditioned stimulus (CS) and sucrose as a reward (unconditioned stimulus; US). We discuss how these approaches can be combined to understand the neural basis of color vision.

[Topic1]Sensory: Vision

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2022(15:30 - 16:30)

Vision II: Diversity and expression of opsin in mantis shrimp

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Visual pigments, often called " rhodopsins " , comprise an opsin protein surrounding a chromophore, retinal. The spectral absorbances of rhodopsin are mainly determined by amino acid residues of the opsin located near the chromophore in its binding pocket. Mantis shrimps have up to sixteen different photoreceptor classes, and at least 18 opsins in their retina have so far been identified. In order to comprehensively analyze the potential functions of mantis shrimp opsins, we isolated new opsins by transcriptome analysis followed by RT-PCR. Fifteen new opsins were found, for a total of 33. A phylogenetic analysis grouped these opsins into five MWS and five LWS sequence similarity groups. *In situ* hybridization in the retina showed that opsins belonging to the same group have identical or similar expression patterns and that the most dorsal photoreceptors express a unique set of opsins. Typical main photoreceptors in the peripheral regions coexpress multiple opsins, while photoreceptors in the midband generally coexpress only a few highly specific opsins. This result is consistent with the hypothesis that most of the photoreceptors in the midband function in color discrimination. We also discuss opsin diversity and functionalization in the retina by comparing the amino acid residues and the predicted maximum absorbances.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 2

PO-2023(16:30 - 17:30)

Vision II: Sexual dimorphism and species divergence following UV opsin duplication in *Heliconius* butterflies

*Kyle McCulloch[1], Adriana Briscoe[1]

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Butterflies are known to have some of the most spectrally diverse photoreceptor types in the animal kingdom. The genus *Heliconius* represents an adaptive radiation in which many species have formed Müllerian mimicry rings throughout Central and South America. Species of this genus have a duplication of a UV opsin gene typically expressed in short wavelength photoreceptor cells. Currently nothing is known about the spatial expression pattern of UV opsin proteins in the compound eyes of species with the duplicated gene. We fluorescently labeled cryosections of compound eyes with UV opsin-specific antibodies. The UV1 and UV2 opsins of 14 species in the genus *Heliconius* were labeled, representing all major clades in the phylogeny. We reveal strikingly different expression patterns among species in different branches of the *Heliconius* phylogenetic tree, including parallel gene and cell-type losses. We also note unexpected sexual dimorphism of opsin expression in several species, suggesting the strength of natural and sexual selection shaping the compound eye has varied considerably over the evolutionary history of the genus. Our findings show that a micro-evolutionary event (a sensory gene duplication) can lead to broader evolutionary changes in complex adaptive traits, and that these patterns are easily reversible.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 2

PO-2024(17:30 - 18:30)

Vision II: How do natural light environments maintain multiple-pigment visual systems? An answer from branchiopod crustacean vision and behavior in desert ephemeral pools

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All branchiopod crustaceans express four or more visual pigments, which brings up the question: what selective forces maintain these multiple-pigment visual systems, especially considering they have secondarily-reduced optic ganglia? We show that two coexisting species of branchiopod crustaceans found in ephemeral pools throughout Southwestern North America use light for vertical positioning in the water column. They use multiple visual pigments for phototactic behavior, matching the microenvironment of their observed depths in the field. *Triops longicaudatus* are benthic foragers, while *Streptocephalus mackini* are suspension feeders that swim higher in the water column. Due to a seasonal “ monsoonal ” wet period in Arizona, we have described light environments of ephemeral pools over the entire life cycle of these branchiopods in two regions. Light within these pools is wavelength-specific to soil region, and attenuates very quickly with depth. We find that regional light environments have shaped the spectral sensitivity of phototactic behavioral responses. We also find that *S. mackini* may use a single photoreceptor type for wavelength-specific positive phototaxis to maintain a specific depth in the water column. We compare phototactic behavior to extracellular ERG recordings. Future study aims to understand to what degree developmental plasticity versus selective history maintains these multiple-pigment visual systems.

[Topic1]Sensory: Vision

[Topic2]Evolution

Poster Session 2

PO-2025(14:30 - 15:30)

Vision II: Investigating binocular stereopsis in mantises using virtual 3D stimuli

*Vivek Nityananda[1], Judith Nicolas[1,2], Jenny Read[1]

Newcastle University[1] , University of Rennes[2]

Mantises are the only invertebrates known to possess 3D vision - the ability to combine images from the two eyes to compute depth. This ability enables them to accurately judge the range of a target and decide whether to strike or not. It thus serves an indispensable function for the insect. Yet since the initial pioneering experiments establishing binocular stereopsis in mantises, almost no research has further investigated the neural mechanisms of stereopis in mantises. We conducted preliminary investigations into these mechanisms using virtual stimuli in combination with polarizing filters similar to those used in 3D glasses. We affixed these filters to the mantises and presented them stimuli on 3D monitors. In separate experiments we presented mantises with different moving stimuli of differing disparities. We report our results across these stimuli and discuss the utility of using polarizing filters to investigate binocular stereopsis in the praying mantis.

[Topic1]Sensory: Vision

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2026(15:30 - 16:30)

Vision II: Role of a looming-sensitive neuron in decision making of whether to strike or to defend by the praying mantis

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In the mantis, a looming stimulus evokes the defense behaviors and occasionally evokes strike also. We have recently reported that precedently presenting a moving square (preceding stimulus) affected making decision in response to a looming stimulus: presenting 12 ° preceding stimuli increased strike rate to looming stimuli, while presenting 36 ° preceding stimuli decreased defense rate to looming stimuli. In the present study, role of a looming-sensitive neuron in this order effect on decision making was investigated. First, responses of the looming sensitive neuron were extracellularly recorded to investigate the effects of its firing pattern on decision making. Presenting 36 ° preceding stimuli appeared to decrease the neuron ’ s firing rate as well as defense rate, suggesting that low activity of the neuron might cause the low defense rate. Next, one of connectives between subesophageal and prothoracic ganglia was cut to obstruct the input from the looming-sensitive neuron. The lesion appeared to affect movements of the foreleg ipsilateral to the cut connective, rather than decision making.

[Topic1]Sensory: Vision

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2027(16:30 - 17:30)

Vision II: A comparison of human and praying mantis (*Sphodromantis lineola*) motion detection systems to moving complex scenes

*Lisa N. Jones[1], Ghaith Tarawneh[1], Claire Rind[1], Candy Rowe[1], Jenny Read[1]

Newcastle University Institute of Neuroscience[1]

The praying mantis primarily uses vision to hunt in cluttered visual environments. Here, we used the mantid ’ s optomotor response to measure the Mantis Dmax in pixels, the largest distance a pattern can be displaced before apparent motion breaks down. Using Dmax we can compare the response of the insect and human motion detection systems to a complex moving scene.

Mantids viewed a black-and-white random checkerboard stimulus moving either right or left in a succession of fixed-size jumps. We varied motion direction, size of jump step and size of the checkers. When the jump step was small, mantids leaned left or right in the same direction as the stimulus. When the jump step was too large, mantids ceased to track the stimulus motion, remaining stationary suggesting Dmax had been reached.

The human visual system is able to detect coherent motion of a complex scene between pattern jumps, where Dmax is dependent on the spatial frequency of the pattern. We have found just like humans, mantids have a “ Dmax ” ; their visual system is able to perceive coherent motion of a complex scene between pattern jumps, where Dmax is also dependent on the spatial frequency of the pattern.

[Topic1]Sensory: Vision

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2028(17:30 - 18:30)

Audition II: Auditory representations of vocal gestures in zebra finches

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Songbirds produce a large repertoire of communication sounds. These calls carry information about the behavioral context but also the sex, identity and emotional state of the emitter. Acoustical signature of these calls features and their auditory representations remain open. We investigate this using an ultra sparse representation provided by a simplified motor description to identify the information bearing features in calls and neural representation in the auditory system.
For this purpose we modeled the syrinx contractions and vocal tract filtering properties of Zebra Finches distance calls and were able to obtain very good synthetic models of all the vocalizations. We called this motor representation: the motogram. We show that motograms can be used for individual discrimination and that individual discrimination is more dependent on the syrinx dynamics than on filtering performed by the vocal tract.
By recording neural response in the auditory areas using motograms, we found neurons that were invariant to changes in vocal tract dynamics but sensitive syrinx contraction dynamics and vice versa. These neurons appear therefore to be tuned to acoustical features that are directly related to motor commands that could in turn explain how information about identity could be represented in the auditory system.

[Topic1]Sensory: Audition

[Topic2]Computational Modeling

Poster Session 2

PO-2029(14:30 - 15:30)

Audition II: Vocal behavior of paired big brown bats in cluttered environments

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Big brown bats are social animals that often forage in the presence of acoustic clutter. Previous work has shown that when two bats fly in a relatively open environment, one of them may go silent for periods up to several hundred milliseconds (Chiu *et al.* 2008), which may serve to minimize sonar interference between conspecifics and suggests “eavesdropping” behavior. Additionally, big brown bats adjust frequency characteristics of sonar vocalizations to avoid acoustic interference from nearby conspecifics (Chiu *et al.*, 2009). There is further evidence that individual bats adjust the frequencies of call pairs to disambiguate overlapping echo streams in a densely cluttered environment (Hiryu *et al.,* 2010). How though, does environmental clutter *and* the presence of conspecifics influence the bat’s call behavior? We investigated this question through multichannel audio and stereo video recording of bats engaged in insect capture under experimentally controlled conditions. We quantified the bats’ vocal behavior as they flew individually in an open and cluttered room, and while paired with conspecifics. Results of this study shed light on the strategies animals employ to negotiate a complex and dynamic environment.

[Topic1]Sensory: Audition

[Topic2]Orientation and Navigation

Poster Session 2

PO-2030(15:30 - 16:30)

Audition II: Causes of bandwidth-related decrease in echo delay acuity for echolocating big brown bats

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Echolocating big brown bats (Eptesicus fuscus) determine target range from echo delay. They can perceive changes in echo delay of fractions of a microsecond, approximately at the Cramer-Rao limit for echoes containing the full broadcast bandwidth at specified signal-to-noise ratios. However, reducing echo bandwidth causes disproportionately large decreases in echo-delay acuity in the same task. The origin of decreased delay acuity with echo bandwidth in delay-discrimination tests is associated with overloading of the perceptual process that underlies determination of object shape from spectral ripple, leading to prevention of clutter interference. How the blurring of delay/spectral images on time scales of tens to hundreds of microseconds is related to decreases in acuity on a time scale of fractions of a microsecond is an important question regarding the formation of perceptual objects on the delay axis.

[Topic1]Sensory: Audition

[Topic2]Computational Modeling

Poster Session 2

PO-2031(16:30 - 17:30)

Audition II: Integration of biosonar and visual information in the superior colliculus of bats

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Integration of sensory information from different modalities can improve the object-detection and -recognition abilities of an organism. The underlying neural basis has been studied intensively for the combination of passive hearing and vision in a variety of animals. The impact of biosonar information on the neural processing of visual cues in bats, however, has not been investigated so far.

Here we present completely novel neurophysiological data on biosonar-visual integration in the bat *Phyllostomus discolor*. We measured biosonar and visual spatial receptive fields of neurons in the superior colliculus (SC) of anaesthetized bats and investigated neural interactions of biosonar and visual stimuli presented within the particular receptive fields. As expected, neurons in the superficial layers of the SC were only responsive to visual stimulation and in the deeper layers only to biosonar stimulation. In a small transitional region between superficial and deeper layers, however, for the first time in bats we could discover bimodal neurons responsive to biosonar and visual stimuli. Even though in these neurons biosonar stimulation seems to have a mainly suppressive effect on the processing of visual information, our results indicate that echolocating bats may be able to integrate sensory information gained by their biosonar and visual system.

[Topic1]Sensory: Audition

[Topic2]Sensory: Vision

Poster Session 2

PO-2032(17:30 - 18:30)

Audition II: Strategies for CF-FM bats to conduct accurate echolocation under acoustically jammed condition created by multiple conspecifics

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Echolocating bats can fly freely by using echolocation even when their own echoes are masked by sounds created by conspecifics, indicating that they must have a way to extract their echolocation signals in such acoustically jammed conditions. In order to reveal this strategy, we flew multiple Japanese horseshoe bats (*Rhinolophus ferrumequinum nippon*) in a flight chamber and recorded individual bat's sounds through a wireless microphone (Telemike) mounted on the bat's head. When bats were flying together, particular changes in pulse characteristics were observed, i.e., emphasizing the fundamental component of terminal FM (tFM_1) and lengthening tFM duration, suggesting that bats emphasized tFM components for target range information under such conditions. Furthermore, the Telemike recordings demonstrated that the bats could perform Doppler-shift compensation (DSC) under conspecific jammed conditions. We also investigated echolocation behavior of bats during exposure to artificially synthesized jamming sounds mimicking CF-FM pulses consisted of the fundamental and the second harmonics from loudspeakers. In artificial jammed conditions, the bats also showed DSC behavior and similar changes in tFM components observed in the group flight condition. By manipulating the characteristics of artificial jamming sounds, we will quantitatively investigate their echolocation system in contexts of conspecific jammed condition.

[Topic1]Sensory: Audition

[Topic2]Orientation and Navigation

Poster Session 2

PO-2033(14:30 - 15:30)

Audition II: Dynamic frequency tuning in moth ear

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Moth ears have one of the simplest anatomical structures of any hearing organs. Each ear has a drum-like membrane with only one or two auditory receptor cells attached to the center of the membrane. The majority of data on the frequency tuning were, however, obtained in experiments on anaesthetized dissected animals through recordings from the tympanic nerve. The audiograms based on responses from these preparations demonstrate a prominent maximum of sensitivity at 15 – 25 kHz, which was thought to be determined mostly by the resonant properties of the tympanic membrane. It was generally accepted that moths are tone-deaf.
Here we present the most recent studies which were performed on flying moths and preparations without extensive dissection. Using newly developed electrophysiological and behavioral techniques, it was discovered that the true characteristics of hearing in noctuid moths are quite different from earlier observations in dissected preparation. Behavioral experiments showed that moths can dynamically adjust the maximum of sensitivity of the hearing organ. Our findings suggest that noctuid moths, in spite of the anatomical simplicity of their hearing organs, have ability to perform a frequency analysis of sound by scanning quickly, through wide range of frequencies.

[Topic1]Sensory: Audition

[Topic2]Orientation and Navigation

Poster Session 2

PO-2034(15:30 - 16:30)

Audition II: Auditory encoding of different duration bat calls by noctuid moths

*Shira D Gordon[1], Hannah ter Hofstede[1]

Dartmouth College[1]

Hearing evolved in moths multiple times in response to the ultrasonic echolocation calls of predatory bats. Noctuid moths exhibit two ultrasound-triggered evasive flight behaviors: negative phonotaxis, when the bat is far away, and last-ditch flight maneuvers, when the bat is nearby. Noctuid moths encode these calls with only two auditory receptors per ear. The onset of the less sensitive receptor (A2) is hypothesized to trigger last-ditch behaviors. However, if the more sensitive auditory cell (A1) saturates before the onset of A2, the moth will stop receiving directional information to steer away from the bat. We measured spike activity for the auditory neurons with different sound pulse durations corresponding to different bat species call durations. There was a significant difference in the number of spikes at saturation among durations for A1, with few spikes for short durations and many for long durations. This means that for bats with short duration calls moths gain no new information about the proximity of the bat over a large range of amplitudes as the bat approaches. Behavioral experiments are needed to determine if saturation at low spike levels reduces the effectiveness of moth behavioral responses to bats with short compared to long echolocation calls.

[Topic1]Sensory: Audition

[Topic2]Ecology

Poster Session 2

PO-2035(16:30 - 17:30)

Audition II: Is it beneficial, to record from axons instead of dendrites?

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Intracellular recordings may give valuable information about processing of a neuron and possibly its input from the network and allow morphological identification. Impalement with an electrode, however, causes cell injury and depolarization from intrusion of extracellular fluid. Thus, penetration artefacts may contaminate recordings and conceal or even alter relevant information processing. These artefacts are expected to have the strongest impact close to the spike generating zone near the dendrites. Recordings in axonal portions should therefore be less vulnerable with the drawback of providing less information about the synaptic input. For the bushcricket *Ancistrura nigrovittata* we present data of identified auditory neurons, which were recorded independently in their dendrites (prothorax) and axon (brain). The main difference encountered was significantly higher response variability and a tendency for higher spike activity in dendritic as compared to axonic recordings. Axonal recordings of a T-shaped neuron revealed graded potentials originating in the brain and modulating its spikes. Therefore, propagation must be passive in this portion, but some active channels appear to exist as well. Spike size is modulated in a potentially behaviourally relevant manner. Small physiological differences in two ascending neurons may nevertheless be important for understanding their contribution to song processing.

[Topic1]Sensory: Audition

[Topic2]Cellular Properties

Poster Session 2

PO-2036(17:30 - 18:30)

Audition II: Local neurons in the auditory system of the bush-cricket *Ancis trura nigrovittata*

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Auditory processing in insects was mostly dedicated to sensory cells, intersegmental neurons projecting into the brain and very few large local neurons. In the prothoracic ganglion, the first level of auditory processing, frequency dependent inhibition, directional and temporal inhibitions are found. The only well characterized local neuron, the Omega-neuron (homologous to crickets ‘ ON1), produces strong directional inhibition [1]. Previous data compiled on a bush-cricket demonstrate the likely importance of other local neurons for frequency and also temporal processing.

Additionally, frequency dependent inhibition in intersegmental neurons has been found, which may rely on groups of DUM-cells [2]. Several DUM-cells exist, directly responding to acoustic stimuli [3]. They exhibit a huge variety of frequency tuning: from cells responding only to vibratory stimuli to cells responding best in the audio or in the ultrasonic range and cells exhibiting clear IPSPs at certain frequencies. DUM-cells may also take part in temporal inhibition, since blocking Cl^--channels with picrotoxin changes the response of temporally selective neurons like AN2, and since first immunohistochemical data indicate that at least a part of the auditory DUM-cells contain GABA as transmitter.

[1]Molina and Stumpner, 2005. JEZ 303A:1085
[2]Stumpner, 1997. JEB 200:1089
[3]Stritih and Stumpner, 2009. Zool 112:48

[Topic1]Sensory: Audition

[Topic2]Cellular Properties

Poster Session 2

PO-2037(14:30 - 15:30)

Audition II: Broad selectivity to courtship song in the cricket *Gryllus bimaculatus*

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Courtship song in *Gryllus bimaculatus* is suggested to comprise two different elements: high-frequency ticks (12-16 kHz) and low-frequency pulses (4-5 kHz). However, we found that most of the courtship song elements in males from lab culture were quite variable (coefficient of variation in the range of 20-50%). In particular, ticks often contained substantial low-frequency power and one of the song elements, low-frequency pulses, may be completely absent. In experiments with playback of synthesized courtship songs to virgin females, we studied the importance of one stable and two variable song parameters for mating success. Alteration of one invariant trait, duration of ticks, had crucial effect on female response rate, decreasing female responsiveness to the level of that in negative control. The synthesized songs with different carrier frequency of ticks (5, 8, 11, 14, 17 kHz) were as attractive to females as the natural courtship. Effectiveness of stimuli without pulses was also comparable with that in positive control; moreover, mounting latencies were significantly lower for these stimuli than in positive control. Thus, changing of stable song parameter resulted in decrease of female responsiveness, whereas changing of variable parameters had no effect on female response rate and in some cases, increased song attractiveness.

[Topic1]Sensory: Audition

[Topic2]Evolution

Poster Session 2

PO-2038(15:30 - 16:30)

Audition II: Sound localization in *Ormia ochracea*: implications of distributed receptor-neuron thresholds

*Gerald S. Pollack[1,2], Andrew J. Masson[2], Andrew C. Mason[2]

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The parasitoid fly, *Ormia ochracea*, localizes sound with remarkable acuity based on interaural differences in tympanal-vibration amplitude as encoded by auditory receptor neurons. Most receptors respond with only one or a few spikes regardless of stimulus duration or intensity. Receptor thresholds span a range of >40 dB, so that interaural difference in number of receptors responding is a potential cue for sound location. Response latency varies with stimulus intensity, suggesting interaural latency difference as another potential cue. However, because receptor thresholds are distributed, latency for a given stimulus can be expected to vary across the population of responding receptors, despite their individually precise latencies.

We modeled a circuit in which receptor spikes converge on target intereurons, and analyzed the resulting compound EPSPs to explore how sound localization cues might vary with stimulus intensity. Parameters reflecting response magnitude (number of responding receptors; amplitude of modeled compound EPSP) were, in general, more reliable than those reflecting response timing (time to peak of compound EPSP; time to reach threshold in target neuron). Moreover, magnitude cues, but not timing cues, varied substantially and non-monotonically with stimulus intensity, providing predictions that are currently being tested in behavioral experiments.

[Topic1]Sensory: Audition

[Topic2]Computational Modeling

Poster Session 2

PO-2039(16:30 - 17:30)

Audition II: The immunohistochemical and ABR study on auditory system of two turtles

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During the long evolution process, the auditory nerve systems of animals have diversified into different structures according to natural selection. As the representative species of adlittoral and demersal turtles, red-eared slider and soft-shelled turtle were used as the subjects for this research.
Firstly, the immunohistochemistry is selected in observing the auditory nuclei between two turtles. The results show that, red-eared slider ’ s nucleus laminaris (NL) is composed of 1~2 layers of bipolar cells; but NL of soft-shelled turtle are unordered. And the structure difference of NL may be proved by different medium of sound.
Based on the difference of the NL of two species, the divergence of auditory function is speculated. The auditory brainstem response (ABR) recording is used for test the function of hearing. The range of frequency and trend of threshold are similar for both turtles. However, sensitivity, signal-noise ratio, and atypical ABR potentials of red-eared slider are superior to soft-shelled turtle.
In conclusion, hearing of red-eared slider is more complete and sensitive, and is suitable for signals from air and water; the auditory system of soft-shelled turtle has less sensitivity and signal-noise ratio, and is unstable in ABR latency. It may be specialized property for the demersal habitat.

[Topic1]Ecology

[Topic2]Sensory: Audition

Poster Session 2

PO-2040(17:30 - 18:30)

Audition II: Cave crawling in zebra finch skulls: which anatomical structures constitute the functional interaural canal?

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The middle ears of birds are acoustically coupled through an air-filled interaural canal, often illustrated and modelled as a simple tube. It allows sound to propagate through the skull from one ear to the other and considerably enhance the cues for directional hearing by interaction with the external sound field driving the eardrum vibrations. Theoretically, different combinations of frequency dependent gains and delays of sound in the interaural canal can produce very different directionalities of the ears but it still remains uncertain how interaural transmission gain and delay can be shaped by anatomical adaptations during evolution. A closer inspection of the zebra finch cranium using micro-CT scanning reveals that not only is IAC trabeculated and irregularly shaped but it also communicates with a set of highly complex, air-filled canals in the skull extending to the base of the beak. We tested the possible influence of these communicating cavities by measuring eardrum directionality and interaural transmission before and after filling the frontal cavities with dyed fat but found no dramatic effects. We will discuss what function the cavities serve and whether the ICA should be represented by a simple tube in future models.

[Topic1]Sensory: Audition

[Topic2]Evolution

Poster Session 2

PO-2041(14:30 - 15:30)

Audition II: Optical recordings of auditory responses in deeper areas of mouse ’ s inferior colliculus

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Optical recording is very important way to reveal neural networks. Many studies with confocal and fluorescence microscopes have been conducted. However, with those microscopes it has been difficult to record neural activities from deeper area than cortex (deeper than 800 µm) in *in vivo* study. Recently, to observe deep areas in the brain became feasible using optical fiber bundle as a penetrable endoscope. We developed a micro-endoscope system, which enables us to record fluorescence, local field potential (LFP), and multi-unit activities simultaneously. Using our micro-endoscope system, we succeeded recording the auditory responses as a change in fluorescence intensity of calcium ion indicator and electrical neural activities at the same time from an identical recording site in the mouse ’ s inferior colliculus (IC). The nucleus is large in dorsoventral direction which is beyond the observable range for the two-photon excitation microscope. We could measure frequency tunings of deep areas in IC (ex. 500µm from brain surface); and the best frequency shifted as recording sites deepened, demonstrating that our system is capable of measuring the dorsoventral organization of IC (i.e. tonotopicity) as an optical response. The present new micro-endoscope system will contribute to uncovering the neural network and the progress of neurosciences.

[Topic1]Sensory: Audition

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2042(15:30 - 16:30)

Audition II: Unsupervised clustering of rat ultrasonic vocalizations

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Ultrasonic vocalizations around 50 kHz (USVs) of rats are recently suggested to contain ecological signals reflecting their emotional states. It was however difficult to integrate previous findings since most of them were based on results from manual classification of USV types by visual inspection of spectrogram with different classification criterions. The present study proposed an automatic clustering procedure for the rat USVs using acoustic similarity indices to provide an objective, automated method for common usage. First, an unsupervised version of the random forest algorithm was applied on several acoustical features which represented amplitude and frequency modulations of recorded USVs, to obtain a similarity matrix among all USV samples. Then, the hierarchical clustering was performed on the similarity matrix using the Ward method. The number of cluster was determined as the most consistent value among three clustering indices that suggested the best cluster number and the classification result was validated by supervised decision tree. As a result, six clusters were successfully identified from the recorded USV dataset. The proposed method provides a robust index of rat USV and will contribute to classifications of various vocalizations of other animals.
(Supported by MEXT Grant #23118003 “ Adolescent Brain ”).

[Topic1]Sensory: Audition

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2043(16:30 - 17:30)

Audition II: The pattern of antennal movement is spatially represented in the brain of fruit flies

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Fruit flies respond behaviorally to sound, gravity, and wind. Johnston ’ s organ (JO), the antennal ear of the fly, serves as a sensory organ to detect these stimuli; sound, gravity, and wind vibrate or deflect antennae of flies, whereby are detected by specific subgroups of sensory neurons in JO. Five subgroups of JO neurons, subgroups A to E, reportedly have a specific brain target, the AMMC zones A to E, in the brain. Among them, the function of subgroup-D neurons is little understood. Here, we explored their physiologic properties by using GCaMP3-based calcium imaging. In contrast to other subgroups of JO neurons, all of which were reportedly activated either by vibrations or by static deflections of the antenna, subgroup-D neurons responded to both stimuli. This finding clearly revealed that subgroup-D neurons could encode the position and movement of antennae. The projection targets of JO neurons subgroups are now defined as three functionally distinct groups: (1) a primary vibration center, (2) a primary deflection center, and (3) a primary vibration and deflection center. A comparison of activity patterns between these groups could provide a basis for encoding information about complex movements of the antennal receiver in the fly brain.

[Topic1]Sensory: Audition

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2044(17:30 - 18:30)

Olfaction and Taste II: Amino-acid-feeding is dependent on the internal nutritional state in *Drosophila melanogaster*

*Naoko Toshima[1], Teiichi Tanimura[1]

Kyushu University[1]

Decision-making on food choice is important to maintain the internal nutritional state for organisms. *Drosophila melanogaster* needs to take essential amino acids especially for egg production in female. Previously we found that *Drosophila* have an ability to regulate the feeding behavior for amino acids depending on the internal nutritional state (Toshima and Tanimura, 2012). Flies that were reared on the amino-acid-deprived condition showed enhanced feeding preference for amino acids. Some of amino acids induced proboscis extension reflex only under amino-acid-deprived condition. We also found that *poxn* mutant flies, that have no external taste sensation, preferred amino acids over a low concentration of sugar, indicating that the external gustatory information are not always necessary to detect amino acids. These data suggest that *Drosophila* have amino acid receptors in several different taste organs and might have an internal amino acid sensor to regulate their feeding behavior depending on the internal amino acid level. To know which taste cells are sensing amino acids, we are utilizing Gal4-UAS system to silence a specific type of *Gr*-expressing neurons. We found that sugar-sensing neurons are not necessary to sense amino acids. We will present our ongoing project toward the identification of amino-acid-sensing gustatory neurons.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Genes and Behavior

Poster Session 2

PO-2045(14:30 - 15:30)

Olfaction and Taste II: Behavioral response thresholds modified by starvation in *Drosophila*

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Starvation can affect fly olfactory behaviors. It has been shown that hungry flies are more attracted to food smells in a fly trap assay and reach the odor source faster than fed flies. However, it has not been investigated if the behavioral response thresholds of smells can also be affected by starvation in flies. By using the T-maze choice paradigm, in which flies must choose between test smell and control in a shorter time than the usual fly trap assay, we analyzed the spectrum of odor concentrations which can attract flies. For this experiment, we first needed to screen for natural odors which can attract virgin male flies in our paradigm among female and food smells, and found that grape juice and sake lees attracted male flies. Then we tested various concentrations of these smells and found that 24 hr starved flies were attracted to a wider spectrum of odor concentrations than fed flies. Both low and high thresholds of odor concentrations could be modified by starvation. We are currently recording the responses to various concentrations of these smells from olfactory sensory neurons in both fed and starved animals and will discuss the neural responses correlated with these fly behaviors.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2046(15:30 - 16:30)

Olfaction and Taste II: Neural circuitry switching between courtship and aggression in *Drosophila*

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Sexually dimorphic behaviors such as courtship and aggression are performed without prior experience, thus the neural circuitries underlying these behaviors are considered to be genetically hard-wired. In *Drosophila*, sexual differentiation of the nervous system is controlled *via* sexually dimorphic expression of a putative transcription factor, Fruitless (Fru). The Fru-expressing neurons are thought to provide a fundamental neural substrate for controlling the sexually dimorphic behavior. A volatile pheromone, 11-*cis*-vaccenyl acetate (cVA), is synthesized in the male accessory gland and transferred to the female during copulation, resulting in attenuation of female sexual attractiveness, i.e., acting as an anti-aphrodisiac for males. Furthermore, cVA is known to increase intermale aggression and suppress intermale courtship. Recent studies revealed that the information of cVA is processed by Fru-expressing neurons from sensory input to descending output. However it remains to be demonstrated, whether these cVA-responding neurons, especially the brain interneurons, control sexually dimorphic behavior itself. By using newly developed thermogenetic technique, we found that the neural activity of one of the cVA-responding Fru-expressing interneurons, LC1, contribute to the switching between courtship and aggression.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Social Behavior

Poster Session 2

PO-2047(16:30 - 17:30)

Olfaction and Taste II: Selective expression of chemosensory protein genes in the female-specific chemosesillum of the ant *Camponotus japonicus*

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Chemical communication is essential for coordination of complex organization in ant societies. Recent comparative genomic approaches have revealed that chemosensory genes are diversified in ant lineages, and suggest that the diversification of chemosensory genes is crucial for social organization. However, how such diversified genes shape the peripheral chemosensory systems is largely unknown. To investigate this question, we annotated and analyzed the gene expression profiles of chemosensory proteins (CSPs), which transport lipophilic compounds toward chemosensory receptors. We identified 12 CSP genes from transcriptome analysis of the ant *Camponotus japonicus*, and phylogenetic analyses revealed that there are 4 CSP genes in the specifically expanded clade within the ant lineage. Among the ant specific CSP genes, 2 of them (*CjapCSP8* and *CjapCSP12*) were specifically expressed in chemosensory organs, and were differentially expressed among castes. Furthermore, these 2 CSP genes were co-expressed with *CjapCSP7*, which is known to bind cuticular hydrocarbons and is expressed in the female-specific sensilla basiconica. Because sensilla basiconica are involved in the discrimination of nestmate and non-nestmate hydrocarbon signals, our results suggest that *CjapCSP7*, *CjapCSP8*, and *CjapCSP12* work cooperatively in the sensilla basiconica, and this female-specific sensillum might be important to the coordination of social organization in ants.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Genes and Behavior

Poster Session 2

PO-2048(17:30 - 18:30)

Olfaction and Taste II: Sensory responses to the oriental orchid odors in the Japanese and European honeybees

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The Japanese honeybee (Apis cerana japonica) show many peculiar behaviors, which are not observed in European honeybee (Apis mellifera). It is well known that they are strongly attracted to the oriental orchid, Cymbidium floribundum. Many orchid species lure polinators olfactory and/or visually into the flower, but the C. floribundum attract not only workers but also drones and queens. Recently, Sugahara et al (2013) analyzed the chemical components of the C. floribundum flower and found that the mixture of 10-Hydroxy-2-Decenoic Acid (10-HDA) and 3-hydroxyanthranilic acid (3-HOAA) strongly attracts A. cerana japonica. Here, we examined the olfactory sensory properties of A. cerana japonica and A. mellifera to these two attractive components. First, we tested the neuronal responses of the antenna using the electroantennogram (EAG) technique. The antenna of A. cerana japonica clearly responded to both 10-HDA and 3-HOAA whereas that of A. mellifera showed no or very weak responses to these odors. In addition to the neuronal responses, olfactory learning performance for these components was compared with that for other general flower odors using the proboscis extension reflex (PER) assay. These results will be discussed with the EAG response of both species.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2049(14:30 - 15:30)

Olfaction and Taste II: Insights into honeybee aggression: role of the olfactory context

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The defensive behaviour of the honeybee *Apis mellifera* aims at the protection of its nest, which contains the food, brood and the only reproductive individual of the colony, the queen. Despite the common use of this insect as a model in neuroscience, few studies have investigated to date the neural and molecular bases of its aggressive behaviour. One possible reason for this was the lack of a reliable assay to assess the individual aggressiveness of bees under controlled laboratory conditions. Here we introduce a novel, arena-based assay that successfully induces bees to sting in a context different from that of the hive defence. We then used this assay to investigate whether plant odours or pheromonal compounds modulate aggression in the honeybee, when presented alone or along with the major alarm pheromone component isopentyl-acetate (IPA). We show that three plant odours (linalool, 2-phenylethanol and to a lesser extent lavender) significantly reduce the bees ’ responsiveness to IPA, even at very low concentrations (10% IPA vs 0.075% plant odours). Using an odour-conditioning assay, we further checked that plant odours do not simply 'mask' IPA when presented together. Our results highlight the crucial role olfaction plays in eliciting and controlling aggressive behaviour in bees.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Social Behavior

Poster Session 2

PO-2050(15:30 - 16:30)

Olfaction and Taste II: No sex without food atypical plant odour responses in the pheromonal processing system of a male moth

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Male noctuid moths rely on olfactory cues to find females for reproduction. They also use volatile plant compounds (VPCs) to find food sources and might use host odor cues to identify the habitat of calling females. Both the sex pheromone and VPCs trigger a well-described oriented flight behavior towards the odor source. Whereas detection and central processing of sex pheromones and VPCs were considered to be highly separated from each other, recent studies have shown interactions of both types of odors already early in the olfactory pathway. In addition to interactions, we show that even detection and early processing of pheromones and VPC can overlap. Using complementary methodological approaches, going from peripheral detection over central processing to behavior (single-sensillum recording of olfactory receptor neurons, intracellular recordings of macroglomerular complex neurons, *in vivo* calcium imaging in the antennal lobe, flight behavior in wind tunnel experiments), we show in the present study that a plant odorant alone, heptanal, activates the pheromone specific pathway in male *Agrotis ipsilon*. To our knowledge, this is the first report of a plant odorant with no chemical similarity with the molecular structure of the pheromone, acting as a partial agonist of a moth sex pheromone.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2051(16:30 - 17:30)

Olfaction and Taste II: Temporal activity patterns of two different types of projection neurons revealed by simultaneous intracellular recordings in the cockroach

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The cockroach, *Periplaneta americana,* has excellent capabilities of olfactory discrimination and learning. In this species, olfactory receptor neurons (ORNs) in antennal sensilla project to 205 glomeruli in the antennal lobe, and then synapse onto a moderate number of projection neurons (PNs) and local interneurons. Based on the projection patterns of ORNs in different sensillar types, ordinary glomeruli are morpho-functionally divided into two different groups; the antero-dorsal and the postero-ventral groups. Olfactory signals processed in the former and the latter groups are relayed by two morphological types of uniglomerular PNs, type 1 PNs (PN1s) and type 2 PNs (PN2s), respectively. The fact that PN1s and PN2s terminate in segregated areas in the mushroom body and the lateral horn indicates two parallel olfactory pathways from peripheral to higher brain centers. In this study, we intracellularly recorded olfactory responses from 124 PN1s and 63 PN2s, and identified olfactory properties of 109 glomeruli. In addition, simultaneous intracellular recordings from two different PNs exhibited that PN1s and PN2s have different latencies and spike activity patterns to a given odor, especially in early response phase. These results suggest that two parallel olfactory pathways in the cockroach brain have different neural algorithms to process olfactory stimulus.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2052(17:30 - 18:30)

Olfaction and Taste II: Dose-dependent aversion for acids in *Manduca sexta* (Sphingidae) and its ecological relevance

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Ionotropic receptors (IR) are a family of ancient and highly conserved olfactory receptor proteins expressed in cells known to be sensitive to chemicals largely distinct from those activating sensory neurons expressing canonical olfactory receptors. Single coeloconic sensillium recordings from *Manduca sexta* antennae revealed that cells expressing IRs respond primarily to acids and diamines. To study the biological relevance of IRs we evaluated how the presence of acids affects the response of gravid and starved females of *Manduca sexta* to plant odors. To this end, we devised a two choice wind tunnel assay where attractive host plant headspace was mixed with the air from a bottle containing dH_2O (solvent control) or either hexanoic acid or acetic acid in dH_2O and released simultaneously upwind. Our results revealed that both gravid and starved females avoided the odor sources containing acid in a dose dependent manner. We identified natural sources of hexanoic acid and acetic acid produced by organisms interacting with plant species on which *Manduca sexta* oviposit and feeds from. Altogether, our results suggest that IRs could mediate the interaction of *Manduca sexta* with plants based on the presence of other organisms.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Ecology

Poster Session 2

PO-2053(14:30 - 15:30)

Olfaction and Taste II: Inking defenses of molluscs: A comparison of mechanisms for different life-history strategies, Opisthobranch gastropods versus Cephalopods

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Ink defends two groups of molluscs, opisthobranch gastropods (sea hares) and cephalopods (squid, cuttlefish, octopus), from predators through several mechanisms and sensory channels. Ink operates through interspecific mechanisms (as predator deterrents) and intraspecific mechanisms (as alarm cues) and through a combination of chemical and visual properties. Mechanisms and sensory channels used depend on features of cues and life histories of the inking species. Slow-moving, benthic, and crawling species (sea hares) rely completely on chemical features of ink, as chemicals persist after contact with predator and allow sea hares to escape. A diversity of diet-dependent and diet-independent chemical defences of sea hares operate through several mechanisms, including aversion, phagomimicry, and sensory disruption. Fast-swimming pelagic species (squid, cuttlefish) rely predominantly on visual features of ink, as they act at a distance and delay attack long enough for the inker to escape. Chemical features can also function, especially if visual effects are insufficient to prevent the predator from contacting the inker, but these effects are weaker and more limited. The defensive molecules used by these molluscan groups differ, due to differences in their lifestyles: herbivorous sea hares derive defensive compounds from algae, unlike predatory cephalopods.
Supported by NSF IOS-1036742.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Ecology

Poster Session 2

PO-2054(15:30 - 16:30)

Olfaction and Taste II: The smell of molting: N-acetylglucosamino-1,5-lactone is a molting biomarker and candidate sex pheromone in the urine of two crabs, *Callinectes sapidus* and *Telmessus cheiragonus*

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Some brachyuran crabs mate immediately after females molt. In such species, premolt and postmolt females release molecules in their urine that are detected by males via their olfactory pathway and that trigger courtship and copulatory behaviors. Yet the molecular identities of these pheromones are unknown. Based on a model that this sex pheromone is a multicomponent mixture of molecules that in combination code the species, sex, molting, and reproductive status of females, we used biomarker targeting based on nuclear magnetic resonance spectroscopy to identify biomarkers of one of these conditions – molting. We identified *N*-acetylglucosamino-1,5-lactone (NAGL) as a biomarker for premolt animals of either sex in blue crabs *Callinectes sapidus*. We used calcium imaging to show that NAGL stimulates olfactory receptor neurons of male crabs, and behavioral experiments to show that males detect and respond to NAGL. Our results support the idea that NAGL is one component of a blend of molecules that constitutes the pheromone of females. Extending this work to another species, helmet crabs *Telmessus cheiragonus*, we showed that NAGL is also in the urine of premolt females. Thus, NAGL is a biomarker of molting and a candidate component of the sex pheromone of these two species.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2055(16:30 - 17:30)

Olfaction and Taste II: Infrared sensing in mammalian predators

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Warm-blooded bodies emanate heat as infrared radiation and a predator can take advantage of infrared sensing in finding prey. However, a detector of heat signals has to be colder than the radiation source. Our group has shown that the cold nose tips of dogs, called rhinaria, fulfill this criterion over a wide range of ambient temperatures. The cold rhinarium is suitably located at the front end of the body, pointing away from the dog ’ s own warm body. Now we have trained dogs to discriminate between warm and cold objects. Sensitivity of the dog rhinarium exceeds the sensitivity of human hands by far. Precise thresholds under varying ambient temperatures will be determined in the near future. We also measured rhinarium temperatures in more than 80 terrestrial mammalian species at various ambient temperatures. Carnivorans had cold rhinaria and herbivorous Artiodactyla and Perissodactyla had warm rhinaria. Infrared sensitivity seems to be widespread among mammalian predators, while herbivorous species appear to keep their rhinaria warm, up to 20 ° C above ambient temperature, for maximum tactile sensitivity. The findings of our group shed new light on the sensory worlds of mammals and on prey-predator relationships, and may improve the usefulness of dogs in human service.

[Topic1]Sensory: Olfaction and Taste

[Topic2]Ecology

Poster Session 2

PO-2056(17:30 - 18:30)

Electrosensation: Phase-locking behavior in a high-frequency gymnotiform fish, *Adontosternarchus*

Masashi Kawasaki[1]

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A gymnotiform weakly electric fish, *Adontosternarchus*, emits electric organ discharges at an individually fixed and stable frequency (900 to 1400 Hz). The otherwise stable frequency was found to shift in response to electrosensory stimuli that mimic electric organ discharges of other individuals in ways distinct from well-studied jamming avoidance responses of other gymnotiform fishes. Much like the jamming avoidance responses of other fishes, *Adontosternarchus* raised its discharge frequency in response to lower frequency electrosensory stimuli resulting in larger frequency separation. When encountering electrosensory stimuli with a frequency that is *higher* than its own, however, *Adontosternarchus* still *raised* the discharge frequency gradually leading to zero frequency separation. Immediately before the frequency separation asymptotes to zero, the phase of fish's discharges suddenly locked to that of the electrosensory stimulus. The phase-locked status could be maintained over several minutes with high accuracy (<~10 degrees, or <~20 microseconds). Fish's ability to advance or delay the phase of its discharge in relation to that of electrosensory stimuli was explored with a phase-locked loop device that generated electrosensory stimuli that were phase clamped to fish's discharges with variable phase differences. *Adontosternarchus* advanced or delayed its discharge phase depending on phase differences.

[Topic1]Sensory: Electrosensory

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2057(14:30 - 15:30)

Electrosensation: Multisensory object discrimination in the weakly electric fish *Gnathonemus petersii*

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Weakly electric fish *Gnathonemus petersii* can discriminate between objects through active electrolocation. In addition, *G. petersii* have a visual sense and a mechanosensitive lateral line system for hydrodynamic perception. We tested firstly, whether these fish can use vision or the lateral line for object discrimination, and secondly, whether cross-modal transfer is possible.

Individual fish were trained to discriminate between two differently-shaped objects of equal volume in a two-alternative forced-choice procedure in three conditions: (i) using all three senses, (ii) using only vision, (iii) using only active electrolocation. They were then tested for object discrimination under different sensory combinations.

Only one of five fish trained with all three senses available was subsequently able to discriminate between the objects without active electrolocation, suggesting that the electrosense overshadows the other senses during acquisition. All five fish trained with only vision were also able to discriminate when they were tested with only active electrolocation. Current tests will reveal whether cross-modal transfer also operates in the opposite direction.

Our results show active electrolocation may be *G. petersii ’ s* priority sensory modality. We propose that the representation of discriminanda is encoded as a higher order representation that can be subsequently accessed with other senses.

[Topic1]Sensory: Electrosensory

[Topic2]Cognition

Poster Session 2

PO-2058(15:30 - 16:30)

Electrosensation: Natural stimulus statistics of electric fish communication

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Sensory systems have evolved in an ecological context. In order to understand the neural functioning of these systems it is essential to learn about the sensory ecology of animals in their natural environments. We successfully developed a novel, multi-electrode-based method for large-scale monitoring of movements and communication behavior of populations of weakly electric fish. This method was applied in the fish ’ s natural habitat in the Panamanian rainforest before and during the fish ’ s reproductive season. Scenes of social interactions were identified and analyzed. Critical distances for the occurrence of distinct behaviors were derived and related to contrasts of the fish ’ s electric signals. We found highly stereotyped short-distance communication between individuals suggestive of reproductive behavior. The fastest responses to a communication partner ’ s electric signals occur within 40ms, providing constraints for the timescale of sensory-motor integration. Most of the observed communication occurs on short distances with high signal contrasts. However, resident-intruder interactions clearly show that detection of familiar conspecifics is possible over distances of up to 170cm. This demonstrates that the fish are able to successfully extract relevant social information at very low signal contrasts. Our results provide critical constraints for a detailed analysis of the function of neural circuits of electrosensory systems.

[Topic1]Sensory: Electrosensory

[Topic2]Communication

Poster Session 2

PO-2059(16:30 - 17:30)

Electrosensation: Phase and amplitude modulations of oscillatory sensory receptors mediate detection of high-frequency group communication signals in an electric fish

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The frequency tuning of peripheral sensory receptors is often well matched to the spectrum of species-specific communication signals. Here we describe a novel signal coding mechanism in the electroreceptors of a particular lineage of mormyrid fish. These receptors, which are clustered into three rosettes on either side of the head, have spontaneously oscillating (up to 2.2 kHz) potentials and do not generate spikes. Instead, they encode electric pulse stimuli using a novel phase reset mechanism. These receptors were most sensitive to stimulus frequencies more than an octave below the peak power frequency of conspecific EODs. Furthermore, the receptors responded with increases in oscillation amplitude for inter-EOD intervals corresponding to their intrinsic oscillation period (range = 0.5-1.0 ms), which was much shorter than the minimum intervals produced by individual signaling fish (~10 ms). Thus, these receptors do not appear to be tuned to any feature of individual conspecific electric signals. We found that inter-EOD intervals among a group of 38 interacting fish fell within the range of these receptors ’ maximum interval selectivity. We therefore conclude that the frequency tuning of these receptors is matched to the statistics of group signaling.

[Topic1]Sensory: Electrosensory

[Topic2]Communication

Poster Session 2

PO-2060(17:30 - 18:30)

Electrosensation: Cholinergic circuitry of the electrosensory system of gymnotiform weakly electric fish

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Acetylcholine (ACh) modulates many central nervous system processes, such as memory and sensory processing. As part of our investigation of cholinergic modulation of electrosensory processing in gymnotiform weakly electric fish, we studied the distribution of the different subtypes of muscarinic ACh receptors throughout the brain of *Apteronotus leptorhynchus* using mRNA *in situ* hybridization. The electrosensory lateral line lobe (ELL) showed expression of M3 receptor mRNA in the pyramidal cell layer of all the topographic maps of the body surface. Nucleus praeeminentialis (nP), a central component of the electrosensory feedback pathways, showed strong expression of M2 and M3 receptor mRNA. To determine the source of ACh released in these two nuclei, we first partially cloned the mRNA sequence for choline-acetyl transferase and performed *in situ* hybridization. This provided us with several candidate cholinergic nuclei. Using retrograde tracing of dextranamine coupled with a fluorescent dye, we identified the nucleus lateralis valvula as the source of ACh for nP, and the efferent octavolateral nucleus (EO) as the source of cholinergic fibers innervating the ELL. The latter finding is of particular interest, because EO is thought to be active only during locomotion, suggesting that it may play a corollary-discharge-like role in the electrosensory system.

[Topic1]Sensory: Electrosensory

[Topic2]Neuromodulation

Poster Session 2

PO-2061(14:30 - 15:30)

Electrosensation: Pauses during communication release behavioral habituation through recovery from synaptic depression

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People use pauses during speech to emphasize the words that follow. However, nothing is known about cellular processing of pauses during communication. Here, we studied pauses in electric communication of mormyrid fish (*Brienomyrus brachyistius*) and their effects on sensory processing in a pathway dedicated to electrocommunication. Mormyrids communicate with other fish by varying the intervals between electric organ discharges. The intervals are first decoded in the midbrain posterior exterolateral nucleus (ELp). We found that ELp is also the first place in the electrocommunication pathway that is sensitive to pauses: ELp field potentials diminished during repetitive electrosensory stimulation (at 33 Hz) *in vivo*; pausing stimulation led to recovery with a time constant of ~1 sec. *In vitro* intracellular recording revealed that this effect was due to synaptic depression and its recovery within local ELp circuitry. Fish ' s behavioral responses showed a similar pattern: habituation to repeated stimulation recovered in response to pauses with a similar time constant. Interestingly, fish housed with other fish generated more pauses than isolated fish. Thus, our results suggest that mormyrids actively use pauses during communication to release the ELp neurons of neighboring fish from synaptic depression, thereby maximizing the behavioral impact of the following signal.

[Topic1]Sensory: Electrosensory

[Topic2]Cellular Properties

Poster Session 2

PO-2062(15:30 - 16:30)

Sensorimotor Integration II: Visual control of movement changes with hunting strategy in the praying mantis (*Tenodera sinensis*)

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A predator tracking moving prey uses visual information to coordinate multiple independent joints. To maximize success, behavior must be sensitive both to external stimuli and internal states, e.g. proprioceptive information about the initial and ongoing positions of the joints, and physiological drives such as hunger. Here, we report that a praying mantis (*Tenodera sinensis*) tracks moving prey with movements of the head and prothorax, and rotations of the body using the mid and hind limbs. Each movement has a threshold, such that larger and faster deviations of a target from the center of the visual field successively recruit head, prothorax, and body movements to re-center the target. The threshold is decreased when the more distal joint is fully activated, showing a sensitivity to proprioceptive information between joints. Thresholds increase as a starved animal becomes sated, reducing the frequency of the larger (body and prothorax) movements. This effect can be partially reproduced with injection of insulin into the hemocoel. These results suggest that external and internal factors may modify semi-independent components of the behavior to produce strategies (active tracking versus ambush) suited to the current conditions. Finally, we report on targets of insulin signaling in the central complex of the mantis.

[Topic1]Sensorimotor Integration

[Topic2]Motor Systems

Poster Session 2

PO-2063(16:30 - 17:30)

Sensorimotor Integration II: Preceding auditory cue modulates walking direction in wind-elicited escape behavior in the cricket

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Escape behavior can be modulated by extraneous circumstance (Domenici et al. 2011). Recently, it has been reported that flash light preceding auditory stimulus increases response probability of startle reflex in zebrafish (Mu et al. 2012). This modulation will be due to cross-modal effect on escape behavior, but it is still unknown whether directional matching between two kinds of stimuli enhance the cross-modal effect. We test cross-modal effect on wind-elicited escape behavior in the cricket. Crickets exhibit oriented walking behavior in response to short air puff, which is considered as escape reflex from approaching predator. This wind-elicited behavior is mediated by cercal sensory system. Crickets also have auditory system that induces positive phonotaxis to approach a singing male. We examined whether preceding 10 kHz pure tone alters wind-elicited escape behavior or not. The tone sound preceding air-puff from lateral side alters walking direction of escape behavior backward, but does not modulate other locomotion parameter including turn angle, walking velocity, and reaction time. In addition, the auditory modulation of walking direction did not depend on the stimulus side of the preceding tone. These results demonstrated cross-modal effects between auditory and cercal sensory systems, but did not suggest multisensory integration of directional information.

[Topic1]Sensorimotor Integration

[Topic2]Orientation and Navigation

Poster Session 2

PO-2064(17:30 - 18:30)

Sensorimotor Integration II: Contributions of higher-order auditory cortical areas to adult song maintenance in the zebra finch, *Taeniopygia guttata*

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The brain must process raw sensory input to inform adaptive behavior. In the male zebra finch, *Taeniopygia guttata*, an auditory description of song the bird produces must inform song motor control areas in order for high-quality song production to be maintained. This sensorimotor integration seems to take place, at least in part, in HVC. Changes in auditory feedback lead to song perturbations and alterations in HVC activity. Higher auditory processing occurs in a network of areas, including nucleus interfacialis (NIf) and the caudomesopallium (CM), which both project directly to, and provide most of the auditory input to HVC. Additionally, CM contains a subregion, nucleus Avalanche (Av), which is reciprocally connected to HVC and NIf. To elucidate the nature of higher-order auditory processing in NIf, non-Av CM areas, and Av in relation to song production, we bilaterally lesioned one or both of CM and NIf and measured the effects upon long-term song output as compared with deafened and control birds. As previously shown, long-term loss of NIf had little effect upon song. Lesioning CM produced a variety of alterations in song, including merging and addition of syllables. Ultimately, we hope to discover how higher-order sensory processing informs adaptive motor output.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Audition

Poster Session 2

PO-2065(14:30 - 15:30)

Sensorimotor Integration II: Visual processing pathways and their roles in modulation of pheromone-triggered behavior in the male silkmoth, *Bombyx mori*

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In the fruit fly and flying moth, visual information plays a crucial role during odour-source localization. In the male silkmoth, our previous study suggests that the use of visual input is modulated by the sequential states of pheromone-triggered behaviour, which consists of surge and zigzagging. During surge, the moths perform optomotor response which is a reflexive behaviour by using visual-motion information from the surrounding (optic flow) for course compensation. On the other hand, the onset of optic flow stimuli modulates zigzagging behaviour in the opposite manner to that of optomotor response. However, the neural pathways underlying the interaction between visual and olfactory processing during pheromone-triggered behaviour is still unknown. In this study, we hypothesize that there are at least two pathways corresponding to visual modulation during the surge and zigzagging, and addressed this questions by conducting physiological studies. Firstly, we investigated the overall visual pathways by insertion of dye crystals into the optic lobe. The result showed neural connections to the lateral accessory lobe, anterior optic tubercle, contralateral optic lobe and suboesophageal ganglion. Currently, we are focusing on visual-motion related pathways by investigating the morphological and electrophysiological characteristics of motion-sensitive interneurons by intracellular recording.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Vision

Poster Session 2

PO-2066(15:30 - 16:30)
Sensorimotor Integration II: Biased visuomotor behavior suggests a simple computation underlying amphibian target tracking

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Visual object tracking is critical to many behaviors, yet how downstream brain areas use retinal output to accomplish this remains unclear. While many studies have explored the possibility of the brain optimally reconstructing a visual stimulus[1,2], recent work suggests a prominent role for sub-optimal computations that are simple but effective[3]. Here we further explore this in the context of shape discrimination. A linear model of post-retinal processing, based on a population vector average (PVA) of Off-center ganglion cells, predicts a shape-dependent bias in target tracking. This bias arises because Off-cells track the leading edge of a moving object, shifting the position estimate forward for targets with a body axis elongated in the direction of motion, but not for targets elongated in the orthogonal direction. In contrast, an optimal model could account for the retinal circuit dynamics underlying this asymmetry and achieve shape-invariant tracking. To test these ideas, we presented toads (*Anaxyrus terrestris*) with elongated artificial targets oriented parallel or perpendicular to the motion direction. In all cases tongue projections were consistent with the predictions of the PVA model. We suggest this circuit provides important context for understanding the classic worm/anti-worm observations of Ëwert *et al.*[4]

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[2]DOI:10.1523/JNEUROSCI.3305-05.2005
[3]DOI:10.1523/JNEUROSCI.2257-13.2013
[4]DOI:10.1016/j.bbr.2011.03.031.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Vision

Poster Session 2

PO-2067(16:30 - 17:30)

Sensorimotor Integration II: To pursue, or not to pursue, that is the question: A simple rule for dragonfly ’ s prey pursuit decision and its possible neural implementation

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Dragonflies are aerial predators that hunt small insects with impressive precision and speed. While flight performance is critical to success, dragonflies ’ strategic prey selection before takeoff also plays a significant role. However, the prey features that underlie the pursuit decision remain unknown. In this study, we quantified the takeoff statistics of the Common Whitetail dragonfly (*Libellula Lydia*) using a customized 3D tracking system. We systematically mapped the parameter space of target angular size and angular speed while varying the artificial prey size using a custom robotic system. In contrast to earlier hypotheses that dragonflies use motion parallax to compute the target distance, we found no evidence that dragonflies know the prey ’ s metric size, speed or distance. Instead, our results reveal that dragonflies use a constant acceptable angular size range and scale the maximum acceptable target angular speed according to the angular size. Using this simple rule, we could induce dragonflies to pursue fast targets they cannot catch or simply cannot exist in nature. The simplicity of the takeoff rule suggests it could be implemented with well-known feature detecting visual neurons. On-going work seeks the neural implementation of such rule with extracellular recordings of the target-selective descending neurons in behaving dragonflies.

[Topic1]Sensorimotor Integration

[Topic2]Sensory: Vision

Poster Session 2

PO-2068(17:30 - 18:30)

Sensorimotor Integration II: Proprioceptive descending interneurons in the stick insect antennal mechanosensory pathway – models and identified neurons

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Active tactile sensing is a widespread strategy for near-range orientation during adaptive locomotion. Stick insects constantly move their antennae to sample the space ahead for footholds, gaps, and obstacles while walking or climbing. Antennal contact can trigger rapid front leg movements aimed at the contact location. We recorded intracellularly from descending interneurons (DINs) that mediated information about antennal posture and movement to thoracic motor networks. DINs encoded much of the information needed to target a front leg towards an antennal contact location[1].
Here, we present a computational model which suggests that these DINs receive input from simple mechanoreceptors at the antennal joints – proprioceptive hairfields. The model uses linear filters and simple stochastic spike generators to first simulate the spike trains of the population of hairfield afferents, and to then integrate their activity to drive different DIN spike patterns. When receiving only hairfield input, modeled DINs had very similar properties as recorded DINs. Furthermore, we present the morphology of a sub-population of identified DINs that precisely, quickly, and synchronously mediate antennal movement velocity to thoracic motor networks.

1: Ache and Dürr, 2013: *Encoding of near-range spatial information by descending interneurons in the stick insect antennal mechanosensory pathway.* J.Neurophysiol. 110 (9)

[Topic1]Sensorimotor Integration

[Topic2]Computational Modeling

Poster Session 2

PO-2069(14:30 - 15:30)

Sensorimotor Integration II: Dual sensory network dynamics driving a context-dependent motor behavior

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To study the ability of sensory networks to organize two different context-dependent motor programs we used electrophysiological recordings and biophysical models of sensory, central and motor circuits. In the mollusk Clione limacina, the gravimeteric organs serve as sensory systems and also participate in the generation of motor programs. Our experimental and modeling results indicate that the sensory signals are modified according to the changing behavioral context, and they can be readily interpreted by the rest of the nervous system to produce the correct motor output. We show that a winner-take-all dynamics in the gravimetric sensory network drives the repetitive rhythm of Clione's wing CPG model during routine swimming. On the other hand, a winnerless-competition dynamics in the same sensory network organizes the irregular pattern observed in the wing CPG during hunting behavior. These two dynamics can be interpreted by the wing CPG to generate the characteristic rhythmic motion during routine swimming and the fast irregular motion that is observed during hunting behavior. Our modeling results also indicate that specific activation phase locks in the sensory network dynamics are transformed into specific motor events in the wing CPG. We propose that these activation phase locks are the basis for motor coordination.

[Topic1]Sensorimotor Integration

[Topic2]Computational Modeling

Poster Session 2

PO-2070(15:30 - 16:30)

Sensorimotor Integration II: Visual and wing mechanosensory control of *Manduca* flight posture

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The control of insect flight is mediated by the interaction of multiple sensory modalities including, but not limited to, visual and mechanosensory information. For instance, the halteres of flies are mechanosensory organs that encode inertial forces which, in concert with the visual system, aid rapid course correction during flight. Yet, it is unclear how the vast majority of all other flying insects use multimodal sensing to control body dynamics. As halteres are derived from wings, evolution suggests that wings may provide similar mechanosensory input. Indeed, both wings and halteres possess mechanosensory structures known as campaniform sensilla. We developed a method by which magnets and rotating Helmholtz coils provided a mechanical stimulus directly to the wings alone. That, coupled with a rotating visual drum, allowed us to explore responses to both visual and wing mechanosensory pitch stimuli. Moths subjected to the combination of visual and mechanical input exhibit an abdominal flexion response that is on average 36.2% greater than moths subject to visual input alone ($n = 11$; $P < 0.05$). These data suggest that wings can serve as inertial sensors in a manner similar to halteres.

[Topic1]Sensorimotor Integration

[Topic2]Evolution

Poster Session 2

PO-2071(16:30 - 17:30)

Motor Systems II: Neural basis of the fin movement in larval zebrafish

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Pectoral fins of fish are homologous to forelimbs of tetrapods. The structure of the pectoral fin in larval zebrafish is relatively simple, with one abductor and one adductor muscle receiving input from four pectoral fin nerves to power fin movement. During swimming, larval zebrafish show alternating pectoral fin movement. The neural circuits controlling this movement are expected to be a simple prototype of the neural circuits regulating rhythmic limb movement in tetrapods during locomotion. Here, we performed electrophysiological recordings from fin motor neurons by using of the transgenic zebrafish lines expressing GFP in abductor or adductor fin motor neurons. Both adductor and abductor fin motor neurons received rhythmic excitatory inputs during swimming. Toward the identification of spinal interneurons controlling rhythmic activity of fin motor neurons, we used calcium imaging during spontaneous beating of the pectoral fins without axial movement. We identified several types of spinal interneurons that were active during fin movement. The results are the first step toward understanding the neural circuits controlling fin movement.

[Topic1]Motor Systems

[Topic2]Genes and Behavior

Poster Session 2

PO-2072(17:30 - 18:30)

Motor Systems II: Splitting of a rhythmic neural sequence underlies the emergence of new syllables in juvenile birds

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Bird song is a complex behavior composed of multiple syllable types. In adult birds, each syllable is encoded by a distinct sparse sequence of bursts in the premotor cortical area HVC (used as a proper name), but how these sequences in HVC develop during song learning is unknown. Here, we recorded from population of HVC projection neurons in juvenile zebra finches throughout vocal development. We found that during subsong, HVC projection neurons exhibited brief bursts during singing and most of these bursts were not locked to the vocalization nor exhibited rhythmic patterns. As the bird entered the early plastic song stage, HVC projection neurons started generating rhythmic bursts (5-10 Hz) that were locked to the underlying vocalizations. Different neurons were active at different phases of this rhythm, thus forming a sequence. As new syllables emerged, some neurons were shared across emerging syllable types, while other neurons were specific for a particular syllable type. The fraction of these shared neurons decreased over development, and more neurons became specific for a particular syllable. These results support a model in which early vocalizations are generated by a rhythmic prototype motor program, and new syllables emerge through the splitting of this motor program.

[Topic1]Motor Systems

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2073(14:30 - 15:30)

Motor Systems II: Neural activity during goal-directed gripping behavior in operant-conditioned crayfish

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We studied gripping behavior of crayfish *Procambarus clarkii* as goal-directed action in order to study its central nervous mechanism. Applying operant learning procedures, we could successfully condition crayfish to grip a specific object for food reward. Tethered animals, kept in midair, were presented with a black acrylic bar (0.6 cm in diameter) as an object to grip that was lowered at velocity of 0.4 cm/sec. When the animal gripped the bar within ten seconds, we gave it food reward. When it did not grip the bar, we evoked the gripping reflex by touching its antennules or chelipeds with a stick manually. In this forced gripping the animal was provided with food reward. After the conditioning was completed, animals gripped the object more frequently within ten seconds. The neural activity was extracellularly recorded in conditioned animals from their circumesophageal commissure when they initiated gripping behavior. We found descending unit activities responding to the object presentation in the lateral half of the connective. These units showed spontaneous activities even when animals did not start gripping at the object presentation. We are now recording the neural activity of naïve animals to investigate whether these unit activities are specific to conditioned animals.

[Topic1]Motor Systems

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2074(15:30 - 16:30)

Motor Systems II: Network dependent activation of a hyperpolarizing conductance in motoneurons enhances neuronal synchrony

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Synchronous firing coordinates the activity of neurons within and across neuronal populations and is thus essential to brain function. *In vivo* intracellular recordings of vocal motoneurons in Gulf toadfish (*Opsanus beta*) revealed a set of intrinsic and network properties, leading to an astonishing level of synchrony. Motoneurons lacked spontaneous activity, only firing action potentials at frequencies matched to excitatory input from upstream vocal pacemaker neurons and concurrent with each distinct spike of a vocal nerve volley that directly determines natural call frequency and duration. Intracellular current injections revealed low membrane excitability with rapid accommodation of action potentials to current steps. Antidromic activation of motoneurons via the vocal nerve provided evidence for strong electrotonic coupling. Action potentials showed a prominent after-hyperpolarization during vocal activity, while intracellular chloride injections revealed a background membrane hyperpolarization blocked by application of bicuculline. A pharmacologically identified voltage dependent potassium conductance led to a gap of reduced probability of motoneuron activation during vocal activity and after antidromic vocal nerve stimulation. This conductance, together with motoneuronal intrinsic and network properties, namely a strong inexcitability upon intracellular current injection, gap junctional coupling, phasic excitatory and tonic inhibitory input, leads to an extreme level of neuronal synchrony.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 2

PO-2075(16:30 - 17:30)

Motor Systems II: Functional motifs composed of morphologically homologous neurons repeated in the teleost hindbrain segments

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Segmental organization along the neuraxis is a prominent feature of the CNS in vertebrates. Reticulospinal neurons (RSNs) are morphologically identified in goldfish and zebrafish, and those that share common morphology and the time of appearance are repeated in adjacent segments, and are called segmental homologs. The segmental homologs were hypothesized to be functionally related. To test this hypothesis, here we performed paired intracellular recordings of the goldfish Mauthner cells (M-cells), a pair of giant RSNs in segment 4 (r4) that are known to trigger fast escape behavior, and three (MiDcm, MiDi and MiV) series of homologous RSNs in r4 to r6 that are thought to be involved in control of escape. We found unidirectional connections from the M-cells to RSNs and the connectivities were closely correlated with morphological homologies of the target neurons and repeated in adjacent segments: inhibitory connections onto the dorsally located pairs of MiDcm and MiDi cells on the ipsilateral side and excitatory connections on the contralateral side (except MiD2cm), whereas bilateral excitation onto the ventrally located clusters of MiV cells. The intersegmental organization of RSNs suggests that each functional connection works as a functional motif during the M-cell initiated escape.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2076(17:30 - 18:30)

Motor Systems II: Structure and role of GABAergic nervous system in locomotion of sea urchin juvenile

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The present study was aimed to examine the regulatory mechanism of locomotion of sea urchin juvenile in which no neurotransmitters has been specified to date using whole-mount *in situ* hybridization and immunohistochemistry with the aide of 3D animation analysis and bioassay. The GABAergic nervous system appeared very early in development and retained in juvenile. The echinus rudiment develops five primary podia (PP) on the ventral side during the late pluteus stage. The muscle layer constituted major part of PP and its distal half was encapsulated in GABA-rich layer that extended numerous fibers at the distal tip at where they connected with the apical network of glutamate decarboxylase-expressing cells. The proximal region of PP lacked GABA-rich layer and its muscle layer was connected to dorsally localized circumgenital plate muscle ring that was associated with penta-radial GABAergic nerve ring (prGABA-NR) on the ventral side. The PP generate locomotion activity of juvenile. Inhibition of GABA synthesis with 3-mercaptopropyonic acid (3-MPA) severely inhibited locomotion of juveniles associated with considerable decreasing of GABA immunoreactivity at prGABA-ring but not at GABA-rich layer. Washing out 3-MPA from culture solution restored locomotion activity of juveniles and GABA immunoreactivity at prGABA-ring, suggesting prGABA-ring involvement in regulation of juvenile locomotion.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 2

PO-2077(14:30 - 15:30)

Motor Systems II: Comparative physiology of the autonomous movements of the gastrointestinal tract in mollusks

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In a wide variety of animals, the enteric nervous system (ENS), also called "the second brain", consists of a network of neurons intrinsic to the gastrointestinal (GI) tract. In this study, we compared the structure and function of the ENS between two molluscan species from Aplysiidae, *Aplysia* sp. and *Bursatella leachii*, which differ in feeding habit and gross anatomy of the GI tract. The former feeds on large seaweeds, and the latter on epilithic algae. In *Aplysia*, the crop was much larger than in *Bursatella*. In both species, ENS neurons exhibited autonomous periodic-burst activity. Dynamic image analysis of a GI tract preparation containing buccal, esophagus, crop, and gizzard revealed the correlation between burst activity and movement in each region of the GI tracts. The periodic bursts were followed one-for-one by autonomous contractions of the gizzard in *Aplysia* and the crop in *Bursatella*, as well as by peristaltic movements, which occured in the crop of *Aplysia* and the esophagus of *Bursatella.* The observations show that the ENS contains pacemaker neurons responsible for the neurogenic rhythmicity of these movements. The "pacemaker region" was localized on the posterior gizzard in *Aplysia* and on the crop in *Bursatella* in separation experiments.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 2

PO-2078(15:30 - 16:30)

Motor Systems II: Quadripedal walking in a cuttlefish

*Michael J Kuba[1], Andres Laan[1], Tamar Gutnick[1], Gilles Laurent[1]

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Among cephalopods, cuttlefish usually swim by jet propulsion (mantle and siphon) aided by lateral fins for stabilization, and controlled buoyancy. We observed that *Metasepia,* a small, cuttlefish, also evolved additional bipedal and quadripedal modes of locomotion. Like all cuttlefish, *Metasepia* can swim, using fins and siphon. Like some cuttlefish, *Metasepia* can run " on two legs " , using its two most lateral arms for traction on the sea floor. But unlike other cuttlefish, Metasepia can also walk on four apparent limbs that consist of the two arms and a pair of pseudo-feet in the back. These four " limbs " move in a diagonal gait similar to ones produced by many tetrapod vertebrates (e.g., trot or canter). This coordination holds for different walking speeds and backward walking. This observation is interesting from a neurobiological standpoint because: (i) it involves the coordination of true and pseudo- appendages that evolved separately and usually do not participate in a precisely, bilateral synchronized output; (ii) yet, this synchronization obeys the rules followed by quadripedal limbed locomotion, expressed by co-evolved central pattern generating circuits. This suggests the convergent evolution of central coordination mechanisms between neural circuits, towards the production of a common and stable mode of locomotion.

[Topic1]Motor Systems

[Topic2]Ecology

Poster Session 2

PO-2079(16:30 - 17:30)

Motor Systems II: Cuttlefish travelling waves: behavioral analysis and implications for neural control

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Travelling waves (from action potential propagation to swimming body motions or intestinal peristalsis) are ubiquitous phenomena in biological systems and yet diverse in form, function and mechanism. An interesting such phenomenon occurs in cephalopod skin, in the form of moving pigmentation patterns sometimes called “ passing clouds ” . These dynamic pigmentation patterns result from the coordinated activation of large chromatophore arrays by mechanisms that are as yet unknown. Here we introduce a new model system, *Metasepia tullbergi*, whose wave displays are very frequent and thus amenable to laboratory investigations. The *Metasepia* mantle contains four main regions of wave travel, each supporting a different propagation direction. The four regions are not necessarily all active simultaneously, but those that are always synchronize and maintain a constant wavelength and duty cycle despite a large range of possible periods (from 1.5 to 10 seconds). Wave patterns can superpose with other ongoing skin pigmentation patterns. Finally, a travelling wave can even disappear transiently and reappear at some other position, revealing ongoing but invisible propagation (a phenomenon that we call “ blink ”). These findings provide useful clues about classes of likely mechanisms for the generation and propagation of these travelling waves.

[Topic1]Motor Systems

[Topic2]Ecology

Poster Session 2

PO-2080(17:30 - 18:30)

Motor Systems II: Turtle swimming and scratching stimuli are integrated to generate one rhythm prior to motoneurons

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Does the spinal cord use a single network to generate locomotor and scratching rhythms or two separate networks? Simultaneous swim and scratch stimulation (“ dual stimulation ”) in immobilized, spinal turtles evokes a single rhythm in hindlimb motor nerves with a frequency greater than during swim stimulation alone or scratch stimulation alone (Hao et. al., 2011). This suggests that either a single network generates both rhythms or the two rhythms are integrated into one. If the latter, integration could occur in motoneurons themselves or earlier, in spinal interneurons. Here, we recorded intracellularly from hindlimb motoneurons during dual stimulation. Motoneuron membrane potentials displayed a regular oscillation at a higher frequency than during swim or scratch alone. In contrast, arithmetic addition of the oscillations during swimming alone and scratching alone with various delays always generated irregular oscillations. Also, the standard deviation of the dual-referent phase-normalized membrane potential was similar during dual stimulation and swimming or scratching alone. In contrast, the standard deviation was greater when pooling cycles of swimming alone and scratching alone. This shows that dual stimulation generates a single rhythm prior to motoneurons. Thus, either swimming and scratching share a rhythm generator or the two rhythms are integrated into one by interneurons.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2081(14:30 - 15:30)

Motor Systems II: Population gesture dynamics and coupled oscillators in the vocal motor system for zebra finch song

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Previously we have used a biophysical model of birdsong production coupled with forebrain single cell recordings to demonstrate coding of muscle trajectories in HVC, a sensorimotor area. Activity of HVC neurons is modulated at onsets, offsets, and certain maxima of the modeled muscle dynamics. The timing of HVC activity occurs with near zero delay relative to the vocal geesture muscle dynamics, too short a delay for those HVC spikes to modulate corresponding muscle movements. Here we use silicon probes to record simultaneously from numerous HVC neurons. Preliminary analysis of these larger data sets demonstrate a clear distributed code for gesture timing in HVC. Slow potentials (LFPs) apparently do not show the gesture timing, supporting the hypothesis that the precise gesture timing emerges at HVC.

We also recently reported syringeal muscle dynamics that represent a form of sleep replay, also with near zero delay when stimulated with song playback. We are currently making simultaneous recordings from the forebrain nuclei and syringeal muscles. The motor system for song may be organized as a series of pattern generators that can exhibit some independent activity from each other, but get coupled (entrained) at the onset of singing, or during sleep replay.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2082(15:30 - 16:30)

Motor Systems II: Detection and analysis of dynamics in the fly grooming behavioral sequence

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Grooming behavior in *Drosophila* is composed of stochastic sequences of cleaning subroutines performed on different body parts. When stimulated by dust, flies execute the subroutines in stochastic progression from high priority body parts (eyes, head) to lower priority ones (Seeds, et al). However, the precise dynamic structure of grooming sequence, namely, how flies decide, at any given time, whether to stay in a subroutine or switch to another, is poorly understood. Little is also known about neural circuits that affect the innate behavioral sequence generation.

Answering these questions has been difficult because grooming sequences are highly variable and therefore large amounts of annotated behavioral data are needed to gain sufficient statistical power. To this end we developed an automated method for detecting and annotating of grooming subroutines from video data.

Here we present the automated method, which is based on unsupervised learning and on spatiotemporal feature extraction. We show our pilot data on wild-type fly grooming, which led to a theoretical neural model that suggests how flies might make moment-to-moment decisions in order to optimize grooming sequence production. Finally, the preliminary findings from our screen for descending interneurons, connecting the brain and ventral nerve, are also shown.

[Topic1]Motor Systems

[Topic2]Computational Modeling

Poster Session 2

PO-2083(16:30 - 17:30)

Motor Systems II: Sequences decomposition of an odor-source searching behavior of a silkworm moth based on flight muscle electromyograms on 3 DOF servo-sphere

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In this study, we carried out experiments with silkworm moth, *Bombyx mori*, to investigate its odor source searching algorithm. A silkworm moth does not exhibit any voluntary movements except mating behavior driven by the sexual pheromone. In order to mate with a female moth, a male moth has to locate her according to the pheromone in the atmosphere. The searching behavior, called chemical plume tracing (CPT), is composed of two essential behaviors, surge and turning walking. To identify CPT behavior of a silkworm moth, we need to observe transitions between surge and turning. However, it is difficult to determine the transitions based on walking trajectories. Therefore, we focused on flight muscle electromyograms (EMGs), since it keeps flapping during searching behavior. We employed 3 degree-of-freedom servo-sphere to observe freely walking moth. According to the analysis of flight muscle EMGs, we decomposed behaviors of a silkworm moth into two types, surge and turning walking. We considered the phase gaps among the flight muscles EMGs could be the reference to know the transition from surge to turning.

[Topic1]Motor Systems

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2084(17:30 - 18:30)

Motor Systems II: The study for the locomotion of the polyclad flatworm: a robotic and mathematical approach

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Some species of polyclad flatworm show swimming behaviors; e.g., unidirectional swimming, hovering, and quick turns, with characteristic movements of its flat, soft body structure. However, the mechanism of locomotion, including the relationship between the large body deformation and the speed, direction of motion, attitude, and locomotion type is not fully understood. To address this issue, we constructed a robot and conducted experiments in the real world. In our robot, the oval, flat, soft body of the flatworm was represented by a rubber sheet. The sheet was controlled by controls with three degrees of freedom to allow flapping of both the lateral sides and the body axis. Swimming patterns, such as swimming forward, hovering, and swimming backwards, were achieved by coordinated movement of the lateral side flaps and the body axis of the soft robot. We also build a computer simulation model to investigate the interaction mechanism between the soft body and fluid dynamics in the effective swimming of the worm.

[Topic1]Motor Systems

[Topic2]Computational Modeling

Poster Session 2

PO-2085(14:30 - 15:30)

Motor Systems II: Compensatory plasticity directed by physical therapy facilitates locomotor recovery after removal of cephalic inputs

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Homeostatic plasticity is an important attribute of neurons and their networks, enabling them to recover functional activity after environmental or surgical perturbation. In this study, we determined whether the leech, *Hirudo verbana*, could recover its ability to crawl after its brain was separated from the crawl central pattern generators it regulates. We observed that coordinated crawl movements returned about 7-10 days after surgery, eventually becoming indistinguishable from motor patterns observed during normal crawling. This recovery was notable because the brain was shown previously to be both necessary and sufficient for leech crawling, especially for the intersegmental phase relationships needed for productive locomotion. Even following complete removal of the brain, we observed recovery of crawling behavior. Physical therapy involving proprioceptive stimulation decreased the amount of time needed to reach full recovery, but only if it occurred in an anterior to posterior direction. In addition, for an individual to benefit fully from physical therapy, multiple sessions were needed and had to occur soon after transection. Preliminary data indicate that the dopaminergic system, vital for crawling, may become reorganized to facilitate the posterior-directed wave of coordinated intersegmental activity needed for productive crawling.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2086(15:30 - 16:30)

Motor Systems II: Vibration diminishes the contractile performance of isolated mouse soleus and extensor digitorum longus muscles

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For many years vibration therapies have been employed within the sporting and medical communities following claims of improved muscle performance in both young athletes and the elderly, and in supplementing traditional rehabilitation methods. Exposure to vibration, however, is also a severe occupational hazard in many developed countries, triggering vascular, neurological and musculoskeletal symptoms, often resulting in Hand-Arm Vibration Syndrome. Few studies, however, have analysed quantitatively the physiological effects of vibration.

Here we applied single pulse stimuli directly to both soleus (slow-twitch) and the Extensor Digitorum Longus muscles (EDL; fast and slow-twitch) isolated from C57 mice, in the absence and presence of vibration at varying frequencies (20Hz – 200Hz). Both muscles showed diminished contractile performance when stimulated in the presence of vibration at all frequencies. The soleus and EDL, however exhibit different patterns of contractile force in response to the range of vibration frequencies applied. Distinctive patterns of potentiation during trains of stimuli at 0.1Hz were also observed during superimposition of 30Hz and 70Hz vibration.

These results largely contradict the claims of performance enhancement of vibration therapies and suggest a relationship between muscle fibre composition, function and dynamics in response to varying frequencies of vibration.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 2

PO-2087(16:30 - 17:30)

Motor Systems II: Regenerative therapy in experimental parkinsonism: Mixed population of differentiated mouse embryonic stem cells, rather than magnetically sorted and enriched dopaminergic cells provide neuroprotection

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By transplanting varied population of dopaminergic neurons, differentiated from mouse embryonic stem cells (mES) in the striatum, we aimed to correct experimental parkinsonism. mES differentiated by default in serum free media (7D), or by enhanced differentiation of 7D in retinoic acid (7R), or dopaminergic neurons enriched by manual magnetic sorting from 7D (SSEA-) were characterized and transplanted in the ipsilateral striatum of 6-hydroxydopamine-induced hemiparkinsonian rats. Neurochemical, neuronal, glial and neurobehavioural recovery were examined. 7R and SSEA- contained significantly reduced NANOG and high MAP2 mRNA levels, compared to 7D. Striatal engraftment of 7D resulted in a significantly better behavioural and neurochemical recovery, as compared to the animals that received either SSEA- or 7R. 7R transplanted animals neither showed improvement in behaviour nor in striatal dopamine level. The grafted striatum revealed increased GFAP staining intensity in 7D and SSEA-, but not in 7R cells transplanted group, suggesting a vital role played by glial cells in the recovery. Substantia nigra ipsilateral to the side of the striatum which received transplant showed more tyrosine hydroxylase immunostaining, as compared to sham control animals. We conclude that default-differentiated mixed population of cells are better than sorted, enriched dopaminergic cells or cells containing more mature neurons for transplantation recovery.

[Topic1]Motor Systems

[Topic2]Motor Systems

Poster Session 2

PO-2088(17:30 - 18:30)

Motor Systems II: Cardiovascular autonomic function in hypertensive subjects

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Objective: The aim of the study was to compare heart rate variability (HRV) and vibration perception threshold (VPT) of hypertensive subjects with control. Research design/ Methods: The study was conducted on 50 hypertensive subjects and 50 controls. The short term HRV and VPT were assessed in both the groups. Results: All the time domain measures, standard deviation of all RR intervals (SDNN) [26 (15.5-35) vs 36 (30-40.25) ms, P=0.002], the square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD) [25.9 (11.95-40.45) vs 36.65 (27.05-44.13) ms, P=0.002], and percentage of consecutive RR intervals that differ by more than 50 ms (pNN50) [3.5 (0.23-21.83) vs 16.4 (4.45-27.63) %, P=0.002] were significantly less in hypertensive subjects. In frequency domain measures, low frequency (LF) [115.5 (83.75-140.75) vs 141 (104.25-249.75) ms^2, P=0.021], high frequency (HF) [114.5 (74.5-179) vs 182.5 (104.25-247) ms^2, P=0.006], HF [33.3 (24.52-53.22) vs 56.8 (43.02-69.17) nu, P=0.002], LF [45.2 (35.4-57.02) vs 49.8 (36.97-69.55) nu] and LF/HF [0.85 (0.5-2.02) vs 0.98 (0.65-1.62) %] were significantly less in hypertensive subjects. However, VPT was comparable between the groups. Conclusion: The hypertensive subjects had reduced cardiovascular autonomic activity.

[Topic1]Motor Systems

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2089(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity II: Regulation of singing-driven gene expression in the song system during the critical period for vocal learning

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Vocal learning in human and other species requires coordination of sensory and motor experiences in order to mimic a set of previously perceived models. For vocal learning and production, songbirds possess specific neural circuits consisting of several brain nuclei, so called the song system, where many genes are regulated during singing. A male zebra finch develops its syllable acoustic features dramatically in the critical period; especially in morning time during juvenile stage. The singing-driven immediate early genes (IEGs) are strongly induced during juvenile stage, suggesting that the singing-driven IEGs may be regulated in a daily basis and contribute to modification of syllable acoustic features. Thus, we examined expression of the neuroplasticity-related IEGs in juvenile and adult birds, which sang at different time points during the day. We found that glutamatergic projection neurons in RA and NIf were selectively regulated with induction of IEGs matching syllable acoustic changes. In addition, the resulting IEG induction rates in the RA were dependent on singing experience in a day. These results indicate a singing amount-dependent mechanism for regulation of IEG induction in brain region- and critical period- specific manners.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Poster Session 2

PO-2090(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity II: Song-locked burst firing in the basal-thalamocortical circuit is critical for hearing-dependent plasticity in adult birdsong

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Oscine songbirds such as zebra finches learn to produce complex vocalizations, song, by imitating their tutor ' s song in early life, just as human infants learn to produce speech sounds from adults. Birds develop and maintain their song using a specialized basal ganglia-thalamocortical circuit, the anterior forebrain pathway. The cortical outflow nucleus of this circuit, LMAN, is required for song plasticity and normally exhibits increased firing during singing and song-locked burst firing. Here, we demonstrate that song-locked burst firing in LMAN is critical for song plasticity. Bilateral lesions of the basal ganglia nucleus Area X upstream of LMAN stripped the LMAN neurons of their burst firing during singing, without changing their spontaneous or singing-related firing rates. The same lesions also prevented song changes normally induced by deafening. These results suggest that Area X is essential not for normal firing rates in LMAN neurons but for driving their singing-related firing patterns, including bursts. Moreover, such patterned bursting appears critical for vocal plasticity. Given the high degree of homology between avian and mammalian basal ganglia-thalamocortical circuits, our findings imply that a key function of the intact basal ganglia is to modulate cortical activity to generate task-related firing patterns critical for motor plasticity.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2091(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity II: Auditory experience shapes neural selectivity to a tutor ’ s song in the songbird auditory cortex

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Juvenile songbirds memorize tutor songs during the sensory period, and then gradually match their immature songs to the memorized tutor songs using auditory feedback. A growing body of evidence suggests that tutor song memory is stored in the songbird ’ s auditory cortex. To date, however, it is unclear how auditory experience alters response properties of auditory neurons. Here, we examine how auditory experience during the sensory period changes the song selectivity of auditory neurons in the caudomedial nidopallium (NCM, corresponding to the mammalian higher-level auditory cortex). To this end, we recorded single-unit activity from the NCM through chronically implanted electrodes in freely moving juvenile zebra finches before and after tutor song exposure.
Without any song experience, NCM neurons showed non-biased auditory responses. However, we found a group of neurons that showed highly selective responses to tutor songs after more than 4 days of tutoring. These results suggest that auditory experience during the sensory period modulates auditory neuron circuitry in the higher-level auditory cortex of juvenile songbirds.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Audition

Poster Session 2

PO-2092(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity II: Maintenance of long-term potentiation at synapses in the accessory olfactory bulb requires both new protein synthesis and actin polymerization

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The pheromonal memory which sustains pregnancy in mice is based on the neural changes in the accessory olfactory bulb (AOB), the first relay in the vomeronasal system. Microcircuits in the AOB include the reciprocal dendrodendritic synapse between mitral cell projection neurons and granule cell interneurons. Long-term potentiation (LTP) at the mitral-to-granule cell synapse is expected to underlie the pheromonal memory. However, the mechanisms to maintain the LTP remain to be elucidated. We examined the effects of some reagents, which modify LTP maintenance in the hippocampus and the neocortex, on the late phase of LTP (L-LTP) at synapses in the mouse AOB. Using AOB slices, we measured field potentials (fEPSPs) derived from granule cells. Inhibition of new protein synthesis by anisomycin disrupted L-LTP, which was sensitive to zeta inhibitory peptide. Inhibition of actin polymerization by cytochalasin D also abolished L-LTP; the activation by jasplakinolide facilitated it. The results support the hypothesis that the maintenance of LTP at synapses in the AOB depends on both new protein synthesis and actin polymerization.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2093(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity II: Increased behavioral laterality and mouth morphology with development in Lake Tanganyika scale-eating cichlid fish

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The developmental of behavioral laterality which is ubiquitous in vertebrates, has been controversial. The scale-eating cichlid fish *Perissodus microlepis* in Lake Tanganyika is well known for exhibiting the laterally mouth morphology and lateralized behavior in robbing scales from prey fish. We investigated the intensity of behavioral laterality of predation and the mouth asymmetry from juvenile to adult fish. The distinct mouth asymmetry in lower jaw-bone in even juvenile, which had fed on plankton indicates the asymmetry appears at acquirement of lateralized behavior before. The bilateral differences of mouth was inclined to increase with body size up to approximately three times, suggesting a phenotypically plastic response to repeated attacks from one side. From the stomach content analysis, juvenile slightly foraged scales correspond to mouth morph, but adult fish exhibited an extremely foraging preference for a specific side of the flank. Because the predation success is higher in preferred side corresponding mouth morph than in non-preferred side, learning and experience of predation would lead to facilitate behavioral preference to attack a particular side. These findings indicate that genetics determine at least partly the dominant side of behavioral laterality and morphological asymmetry, but environmental input can alter the intensity of these traits.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Ecology

Poster Session 2

PO-2094(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity II: Tactile discrimination learning in intact *Octopus vulgaris* using a two choice maze

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Controlling eight flexible arms octopuses carry out many complex tasks, such as crawling, exploring, mating and swimming. With thousands of primary sense organs per arm the ability to receive coherent, specific information from single arms is a daunting task. Many studies have shown that octopuses could learn by reinforcement to accept or reject objects or different texture. However, to exclude other senses octopuses were blinded, often by invasive lesions to the optic nerves or tracts. Using a two choice, Y shaped, maze we presented tactile stimuli to single arms of intact octopuses. Octopuses were trained to insert a single arm into the maze and retrieve a food reward from the goal compartment of the side marked by a correct tactile cue. 6 of 7 animals learned to complete the task within 10-120 trials. Octopuses used one of the slower, yet most successful method of arm movement strategy, allowing for more time to explore the stimulus. Our results clearly show that octopuses learned to insert a single arm into the maze, enter one of the maze sides, investigate the presence of a tactile stimulus and then adjust the movement either by continuing or by attempting to switch side.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2095(16:30 - 17:30)
Learning, Memory, & Behavioral Plasticity II: Effect of acute nicotine exposure on NaCl chmeotaxis learning in the nematode *Caenorhabditis elegans*

*Tetsuya Matsuura[1], Hitoshi Miura[1], Asuka Nishino[1]

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Nicotine exposure is a major health concern for humans and exerts deleterious effects on motor activity and thus learning in many animals. In the present study, we investigated the effect of nicotine exposure on NaCl chemotaxis learning in the nematode *Caenorhabditis elegans*. The chemotactic response of wild-type N2 nematodes pre-exposed to 100 mM NaCl with 3.0 mM nicotine was almost the same as that of mock-conditioned nematodes unexposed to NaCl; however, the response of N2 nematodes pre-exposed to NaCl without nicotine was significantly lower than that of mock-conditioned nematodes. These results indicate that NaCl chemotaxis learning is inhibited by acute nicotine exposure. Inhibition of NaCl chemotaxis learning was observed when *cat-2* mutants with a defect in dopamine biosynthesis were pre-exposed to NaCl with 3.0 mM nicotine. Acute nicotine exposure did not cause inhibition of NaCl chemotaxis learning in *bas-1* mutants, which had defects in both serotonin and dopamine secretion, and *tph-1* mutants, which had a defect in serotonin secretion only. However, inhibition of NaCl chemotaxis learning was observed when *bas-1* and *tph-1* mutants were maintained on a growth plate that included serotonin. These results suggest that serotonin signaling plays an essential role in the modulation of the acute nicotine effects.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2096(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity II: Effect of activities of insulin signaling and oxygen intermediates on the establishment period of diacetyl adaptation in the nematode *Caenorhabditis elegans*

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The chemotactic response of *Caenorhabditis elegans* pre-exposed to odorant diacetyl was significantly smaller than that of non-exposed control nematodes, indicating diacetyl adaptation. Previously, we revealed that establishment period of diacetyl adaptation of pre-exposed nematodes correlated with the breeding maintenance temperature. When wild-type N2 nematodes were bred at 15 ° C, adaptation was observed between the young adult (YA) and 3-day-adult (A3) stages. When the nematodes were bred at 20 ° C and 25 ° C, adaptation was observed from the YA to A5 and A7 stages, respectively. The breeding temperature correlates with the aging speed. Here, we investigated the effect of aging speed, involving insulin signaling and oxygen intermediates, on the establishment period of diacetyl adaptation. The establishment period of adaptation in long-lived *isp-1* mutants, which reduced the rate of oxygen intermediates, and short-lived *gas-1* mutants, which had a hypersensitivity to oxidative stress, were shorter and longer than that of N2 nematodes, respectively. Life span is also related to insulin signaling. The establishment period of adaptation in long-lived *daf-2* and short-lived *daf-16* mutants were shorter and longer than that in N2 nematode, respectively. These results suggest that the establishment period of diacetyl adaptation relates with the interactions between activities of insulin signaling and oxygen intermediates.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2097(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity II: Involvement of dopamine in the enhancement of salt chemotaxis learning due to chronic nicotine exposure in the nematode *Caenorhabditis elegans*

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We previously showed that serotonin signaling plays an essential role in the inhibition of salt chemotaxis learning due to acute nicotine exposure. The present study investigated the effect of chronic nicotine exposure on salt chemotaxis learning in the nematode *Caenorhabditis elegans*. The chemotactic response of wild-type N2 nematodes exposed to 100 mM NaCl, which were pre-exposed to 0.3 mM nicotine during the larval stage, was significantly smaller than that of NaCl-conditioned nematodes, which were not pre-exposed to nicotine, suggesting that chronic nicotine exposure caused the enhancement of salt chemotaxis learning. Several mutants were analyzed to clarify the mechanism underlying the learning enhancement. Salt chemotaxis learning was enhanced when *tph-1* mutants with a defect in serotonin secretion were pre-exposed to nicotine during the larval stage. On the other hand, salt chemotaxis learning was not enhanced when *bas-1* and *cat-2* mutants with a defect in serotonin and dopamine secretion and dopamine secretion alone, respectively, were pre-exposed to nicotine. However, the enhancement of salt chemotaxis learning was observed when *bas-1* and *cat-2* mutants were maintained on a growth plate that included dopamine. These results indicate that dopamine is involved in the enhancement of salt chemotaxis learning due to chronic nicotine exposure.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2098(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity II: Effects of the artificial self-generated wind for the compensation of the escape direction in unilaterally cercus-ablated crickets, *Gryllus bimaculatus*

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The direction of the wind-evoked escape of the cricket, *Gryllus bimaculatus*, became incorrect after the ablation of one of a pair of cerci. Such a misoriented escape was corrected almost within 14 days after the ablation when crickets were permitted to walk freely (Kanou et al., 1999, 2002). The self-generated wind during walking is essential for the compensational recovery (Takuwa et al 2008, 2013). In the present study, effects of the delay, duration and velocity of artificial self-generated wind (self-stimulations; SSts) presented during stationary walking on the compensational recovery was investigated. Artificial SSts from a nozzle set in front of a cricket placed on a styrofoam ball for stationary walking were used for the training after unilateral cercus ablation. A particular duration SSt was given to a cricket synchronized or with some delay times from the start of walking. The velocities of the artificial SSts used in the present study were 60 mm/sec and 15 mm/sec. The effectiveness of the SSts on the compensation was investigated after 14 days training. Based on the results, the validity of our hypothesis for the mechanism of the compensation proposed in the previous paper (Takuwa et al 2013) is discussed.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2099(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity II: Observational learning in crickets

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In observational learning, animals learn by observation of other ’ s behavior, without own experience. In insects, observational learning is reported in a few species and is most extensively studied in foraging behavior of bumblebees. Bumblebees are social insects, living with many other conspecifics. We think if non-social insects like crickets can learn by observing conspecific ’ s foraging behavior, observational learning may be ubiquitous among insects. Thus, we studied whether crickets *Gryllus bimaculatus* exhibit observational learning.
At first, we investigated whether crickets have the ability of observation learning. A male crickets (observer) was allowed to observe visits of a live conspecific (demonstrator) to an odor source with water reward, and then odor preference of the observer was tested. Bumblebee prefers color of artificial flower, after observing the colored flower occupied by a dead conspecifics. Second, we thus studied whether crickets learn by observing a dead conspecific. In this experiment, observer was allowed to observe odor source with a dead demonstrator, and then its odor preference was tested.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Social Behavior

Poster Session 2

PO-2100(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity II: Oskar functions in adult neural stem cells to influence long-term memory formation in the cricket *Gryllus bimaculatus*

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Although *oskar* was first described for its role in the *Drosophila* germ line, recent studies have shown that this gene has additional functions in the nervous system of larval *Drosophila* and in the embryos of a basally-branching insect, the cricket *Gryllus bimaculatus*. The specific molecular functions of *oskar* in the nervous system of either species remain unclear. Here we show that RNAi *Gb-oskar* impairs long-term olfactory memory, but not short-term memory, in the cricket. Consistent with a role in memory formation, we show that *Gb-oskar* is expressed in the adult cricket brain in a cluster of neuroblasts that are responsible for adult neurogenesis in the mushroom body, the anatomical substrate of olfactory memory in insects. Previous studies have shown that killing these mushroom body neuroblasts specifically impairs olfactory learning in crickets. Thus, our results are consistent with the hypothesis that *Gb-oskar* is involved in adult neuroblast function (i.e. proliferation, maintenance, or survival), and that its role in long-term olfactory memory is mediated through these cells and/or their progeny. We discuss these results in both a functional and an evolutionary context, and propose necessary additional experiments to directly test the role of *Gb-oskar* in adult neuroblasts.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Development

Poster Session 2

PO-2101(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity II: Spiking activity of an identified mushroom body extrinsic neuron during olfactory memory acquisition in the honeybee

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The honeybee is a suitable model for studying neural mechanisms underlying learning and memory formation. The PE1 neuron, an identified neuron of the mushroom body (a crucial neuropil for olfactory learning), is known to show a learning-related plasticity. After the acquisition period consisting of 5 repeated trials of pairing an odor (unconditioned stimulus) and with sugar water (conditioned stimulus), the PE1 neuron reduced its responses to the paired odor (CS+) but not to the unpaired odor (CS-). However, it is still unknown whether and when the PE1 neuron changes its responses during the acquisition period. Using chronic recording from the PE1 neuron of a learning bee, we found that the response of the PE1 neuron to the CS+ was reduced in spike frequency after the establishment of learning. However, this reduction was not observed during the trial when the animal exhibited the first learning behavior but during one trial after that trial. Again the responses to CS- did not change. Next, we analyzed the spontaneous activity of the PE1 between acquisition trials. The spectrum analysis suggests that a low frequency component of the PE1 spiking activity is emphasized during the formation of memory.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2102(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity II: Reinstatement in honeybees is context-dependent

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During extinction animals experience that the previously learned association between a conditioned stimulus (CS) and an unconditioned stimulus (US) no longer holds true. Accordingly, the conditioned response (CR) to the CS decreases. This decrease of the CR can be reversed by presentation of the US alone following extinction, a phenomenon termed reinstatement. Reinstatement, spontaneous recovery and renewal indicate that the original CS–US association is not lost through extinction but can be reactivated through different processes. In honeybees (Apis mellifera), spontaneous recovery, i.e., the time-dependent return of the CR, has been demonstrated, suggesting that also in these insects the original CS–US association is not lost during extinction. We ask here whether honeybees show reinstatement after extinction. In vertebrates reinstatement is context-dependent. We demonstrate reinstatement in restrained honeybees and show that reinstatement is context-dependent. We show that an alteration of the wavelength of light illuminating the experimental setup suffices to indicate a contextual change. We conclude that in honeybees the initially formed CS–US memory is not lost after extinction. Rather, honeybees might learn about the context during extinction. This enables them to adequately retrieve one of the two opposing memories about the CS that have been formed after extinction.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2103(16:30 - 17:30)

Learning, Memory, & Behavioral Plasticity II: Memory updating in *Caenorhabditis elegans*

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How the nervous system encodes memory remains an enigma in neuroscience. *C. elegans* has a simple nervous system consisting of only 302 neurons and its connectome is revealed, thus making it an ideal system for analysis of the roles of neurons or neuronal circuits in the regulation of behaviors. Despite its simple nervous system, *C. elegans* has complex behaviors accompanied with associative learning. For instance, *C. elegans* can memorize ambient temperature in association with the presence of food and migrate toward that temperature on a temperature gradient. This behavior, called thermotaxis, is achieved with a simple neuronal circuit consisting of a small number of neurons. Interestingly, thermotaxis behavior itself is plastic; worms can learn the new temperature within a few hours after changing their cultivation temperature. We performed a forward genetic screen for genes responsible for this memory updating. One of the mutant alleles identified from the screen, *nj131*, showed a slow-learning phenotype during temperature up-shift, but not during temperature down-shift. Combining the SNP mapping and the whole-genome sequencing, *nj131* allele was then mapped to a gene locus encoding a potassium channel. Revealing the mechanisms of memory updating will pave the way for understanding the molecular identity of the memory.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Orientation and Navigation

Poster Session 2

PO-2104(17:30 - 18:30)

Learning, Memory, & Behavioral Plasticity II: Distinct dopamine subsets mediate reward signals for short- and long-term memories

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Memory of a momentous event persists for a long time. While some forms of long-term memory (LTM) require training repetition, biologically relevant potent stimuli such as food and poison are sufficient to induce LTM in a single training session. However, how a stable memory is acquired by a single training is poorly understood. In flies, a single presentation of a sugar reward paired with odour induces robust short- (STM) and LTM. The reward is represented by a cluster of dopamine neurons. Here we show that two distinct subsets of the dopamine neurons signal reward for STM and LTM, respectively. Appetitive memory of one subset decays within several hours, whereas the other subset induces memory that gradually develops after training. These dopamine neurons represent different reinforcing properties, sweet taste and nutritional value of sugar. They convey the reward signals to spatially segregated synaptic domains of the mushroom body (MB), where reinforcement signals converge with concomitant odour signals. Our results demonstrate that sugar ingestion drives STM and LTM traces in parallel. Temporally stable memory performance after a single training session thus comprises two memory components triggered by distinct reward signals of dopamine neurons.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Poster Session 2

PO-2105(14:30 - 15:30)

Learning, Memory, & Behavioral Plasticity II: Plasticity in the auditory behavior of the fruit flies

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Animals utilize acoustic signals to communicate with each other. During courtship male flies sing a courtship song by vibrating their wings to attract female flies. The artificial courtship songs also induced chain behaviors, a display of homosexual courtship behavior in male flies. This behavior has long been used as an excellent model for analyzing auditory behavior responses, outcomes of acoustic perception and higher-order brain functions. Recently we found that continuous exposure of the song decreased chain behavior and that a shift of the sound pattern immediately released this behavioral suppression. These results indicate that such continuous acoustic stimuli are temporally stored in the brain and affect its physiological condition (behavioral suppression and desuprresion). However it remains unclear how the fly brain stores (and processes) auditory information.

To explore the neural mechanism for this, we are now investigating 1) the neuronal substrates for a temporal storage of acoustic information that modify chain behavior and 2) molecular mechanisms that control suppression and desuppression of chain behaviors. We will discuss our recent progress in this meeting.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Audition

Poster Session 2

PO-2106(15:30 - 16:30)

Learning, Memory, & Behavioral Plasticity II: Towards a nociceptive aversive learning circuit in *Drosophila* larva form sensory inputs to motor outputs

*Claire Eschbach[1], Javier Valdes Aleman[1], Katharina Eichler[2], Marc Gershow[3], James W. Truman[1], Aravinthan D.T. Samuel[4], Andreas Thum[2], Bertram Gerber[5], Albert Cardona[1], Marta Zlatic[1]

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The larva of *Drosophila melanogaster* has become a powerful model organism to understand how neural circuits mediate behavior. Here we use a combined approach of behavior and electron microscopy reconstruction to identify the full circuit leading to learnt navigation away from an odor that has been repeatedly associated with a nociceptive stimulation.

We found that optogenetic activation of the elements of the newly identified nociceptive pathway, when coupled to an odor, is sufficient to evoke aversive memory. Via EM reconstruction we identified connections between the innate nociceptive sensory pathways and the dopaminergic reinforcing neurons that target the mushroom body Kenyon cells. These dopaminergic MB input neurons are also a sufficient reinforcing signal for aversive learning.

In addition, we discovered that after aversive learning the navigational decisions are modified: both the frequency of turn and the turn direction are affected, resulting in a decrease of attraction for the trained odor that is innately very attractive. To fully understand the role of the MB in modulating navigational strategies, it will be important to identify the connections between the MB neurons and the descending neuron pathways that drive these distinct navigational motor patterns.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2107(16:30 - 17:30)

Genes and Behavior II: Novel behavioral assay of noxious heat responses in *Drosophila* using decapitated flies

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Heat activates nociceptors and induces acute pain. The fruitfly, *Drosophila melanogaster*, as well as mammals, shows behavioral avoidance toward heat stimuli. When flies are placed on a hotplate (>45 °C), they show jump responses. In *Drosophila*, the Painless (Pain) Transient Receptor Potential (TRP) channel is thought to be a heat nociceptor because *pain* mutations inhibit the noxious heat responses. Pain is expressed in sensory neurons and the central nervous system including brain and ventral nerve cord (VNC). Thus, it remains unclear whether the defective noxious heat responses in *pain* mutant flies result from the dysfunction of sensory neurons or brain. Here, we established a behavioral assay toward noxious heat using decapitated flies. Decapitated wild-type flies showed tumbling, but not jumping, at 44 °C . Thus, the brain seems to be required for coordinating proper jumping. In contrast to the wild-type flies, frequency of tumbling was significantly reduced by *pain* mutations, indicating that tumbling behavior is a nociceptive phenotype in decapitated flies. In this current study, we established a novel behavioral assay of heat nociception using decapitated flies. This behavioral assay can be used to understand the molecular and neural basis of brain-independent noxious heat responses.

[Topic1]Genes and Behavior

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2108(17:30 - 18:30)

Genes and Behavior II: Neural correlates of male courtship following revealed by in vivo functional imaging in *Drosophila*

*Soh Kohatsu[1], Daisuke Yamamoto[1]

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In *Drosophila melanogaster*, cellular substrates of the male courtship behavior have been extensively studied, yet their physiological properties are largely unknown. To identify central neuron activities that are correlated with particular behavioral process of courtship, we optically measured calcium activities from interneurons expressing a sex determination gene *doublesex* in a male freely behaving on a treadmill. In the lateral protocerebrum, we detected multiple, transient calcium rises that coincided with behaviors including target following and wing extension/vibration, two of the hallmarks of normal male courtship, as induced by consecutive stimuli of female contact and horizontal visual motion stimulus. Mosaic analysis revealed that pC1 neurons, a subset of male-specific interneurons known to mediate courtship initiation, are responsible for the calcium activities observed during target following. The calcium rises that occur in the pC1 neurons were selectively associated with turns of the fly toward the side where their somata were located in the brain. It is suggested that pC1 neurons dynamically control the direction as well as activity level of courtship following relying on pheromonal and visual cues.

[Topic1]Genes and Behavior

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2109(14:30 - 15:30)

Genes and Behavior II: The painless gene is involved in female mate choice in *Drosophila*

*Kazuki Watanabe[1], Takaomi Sakai[1]

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In the fruit fly, *Drosophila melanogaster*, females evaluate potential mating partners and decide whether to mate or not. Female-specific sex pheromone triggers male courtship. Courting males frequently vibrate their one wing and produce courtship song. Female sexual receptivity is gradually enhanced by receiving courtship song, and then females accept male courtship. In contrast to normal winged males, wild-type (WT) females do not really mate with wingless males. We confirmed that WT females select winged males as a sexual partner when a winged WT male, a wingless WT male, and a WT female were introduced into an observation chamber. Both winged and wingless males vigorously and equally courted toward WT females. Thus, it is likely that females can decide which male to choose based on song detection. Interestingly, we found that females with a mutation of the *painless* (*pain*) gene, which encodes the transient receptor potential (TRP) channel, copulate with winged and wingless males equally. These results indicate that Pain TRP channels are involved in song-based female mate choice in *Drosophila*.

[Topic1]Genes and Behavior

[Topic2]Social Behavior

Poster Session 2

PO-2110(15:30 - 16:30)

Genes and Behavior II: Genes and cells that support mating barriers across closely related species

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The genetic and neuronal mechanisms that support behavioral barriers between closely related species are not well understood. During courtship, male *Drosophila melanogaster* rely heavily on input from multiple sensory modalities to detect these signals. Gustatory input is specifically important during sexual decision-making as it allows for tasting of the non-volatile cuticular pheromones of other individuals. Typically, gustatory receptors (*Gr* genes) are expressed in the proboscis, legs, wing margins, and female ovipositor. However, our data show additional atypical expression of some *Grs* in the fly abdomen. We hypothesize that *Grs* that are expressed in the abdominal oenocytes (cuticular pheromone producing cells) may be functioning pleiotropically in the perception and synthesis of pheromones. Thus, such genes may provide a simple evolutionary solution to the problem of maintaining species behavioral barriers during speciation events. We find that specific gustatory receptors function not only in the neuronal perception, but also in the synthesis of pheromones used for mating behaviors in the Drosophila lineage. We conclude that this dual role of gustatory receptors could have important implications for the process of speciation and the neuroethology of behavioral barriers between closely related species.

[Topic1]Genes and Behavior

[Topic2]Social Behavior

Poster Session 2

PO-2111(16:30 - 17:30)

Genes and Behavior II: *Drosophila* Dscam2 mutants have an inverted visual response

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The patterns of synaptic connections between neurons in the brain are key determinants of behaviour, but how specific neural circuits lead to distinct behaviours is largely unknown. Cell recognition molecules that mediate interactions between neurons play a crucial role in establishing synaptic connections. *Dscam2*, a repulsive cell recognition molecule, is required for photoreceptor synaptic specificity. In *Dscam2* mutant brains, these synapses still form, but the composition of the synapse changes. Here, we begin to dissect how these changes in neural circuitry affect visual system behaviours, such as the response to motion. Results show that compared to control flies, three different strains of *Dscam2* mutant flies have a decreased response to many different types of motion stimuli. In addition, the response to motion shows a strong trend towards an inverted response, suggesting that Dscam2 plays a role in the perception of motion cues. The removal of *Dscam2* from specific neurons in the motion circuit will allow us to correlate these behavioural abnormalities with specific neural circuits and with the previously described synaptic defects in the Dscam2 mutant.

[Topic1]Genes and Behavior

[Topic2]Sensory: Vision

Poster Session 2

PO-2112(17:30 - 18:30)

Genes and Behavior II: Identification of dopamine receptors in the mosquito *Aedes albopictus*

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Previously, we found that an elevation of the dopamine (DA) level decreases host-seeking behavior in adult female mosquitoes *Aedes albopictus* (*Ae. albopictus*). The effect of DA is presumed to be mediated by binding to specific DA receptors (DARs). However, *Ae. albopictus* DARs remain to be identified. To elucidate the existence of *Ae. albopictus* DARs, we identified sequences of DARs (Dop1, Dop2, Dop3 and DopEcR) in the mosquito *Ae. albopictus*. Total RNA was extracted from whole bodies of 30 newly-emerged adult mosquitoes *Ae. albopictus* and made into cDNA. Polymerase chain reaction was carried out with primers on the cDNA, which were designed according to the sequencing of *Aedes aegypti* (*Ae. aegypti*) DARs. The amplified fragments were used as templates for direct sequencing. DNA sequencing yielded a partial cDNA fragment of DARs as follows: Dop1, 967 bp; Dop2, 1240 bp; Dop3, 627 bp; DopEcR, 821 bp. The deduced protein sequences of DARs were compared with those of other insect G-protein-coupled receptors. As a result, the protein sequences of *Ae. albopictus* DARs have the highest level of similarity to those of *Ae. aegypti* DARs. This is the first report of identification of DARs in the mosquito *Ae. albopictus*.

[Topic1]Genes and Behavior

[Topic2]Ecology

Poster Session 2

PO-2113(14:30 - 15:30)

Genes and Behavior II: Flying behavior of tethered cyborg bees by stimulating their brain electrically

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Cyborg insects are becoming a promising rival for man-made micro air vehicles due to the unmatched flight performance of biological carrier insects. We tried to develop cyborg honeybees using electric stimulation on their brains. For tethered subjects, we firstly found that electric stimulation pulses (4 V_{PP}-40Hz-duty cycle 40%, pulse width 5ms, pulse number 30) on the bilateral optic lobes induced flight initiation reproducibly (success rate larger than 60% in average). Moreover, with voltage over 6 V, flight cessation was caused immediately in the success rate of 100%. Furthermore, we delivered electric stimulation on seven brain subregions with specifically designed brain locating instruments. It is shown that the success rate for inducing honeybee flight was decreased in the sequence of a-lobe, b-lobe, ellipsoid body, lobula, medulla and antennal lobe. These results provide the specific brain sites for inserting electrodes to induce the flight behaviour of cyborg honeybees.
During the research, we designed a fixation platform coupled with the standard stereotaxic apparatus to clamp the subjects stable, and insert electrodes accurately which was verified by checking the Prussian blue depositing points.

[Topic1]Genes and Behavior

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2114(15:30 - 16:30)

Genes and Behavior II: Dietary vitamin B12 restriction is associated with negligent maternal care behavior in C57BL/6 mouse

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Vitamin B12 deficiency is common in women especially during child-bearing age. Maternal vitamin B12 deficiency is known to have profound impact on the developing fetus and programs it to a number of complex adult-onset disorders like cardiovascular diseases, diabetes, neurological disturbances, etc. As little is known about the effects of vitamin B12 restriction on maternal care behavior, we have focused particularly on this in our study. Female, weaning C57BL/6 mice received *ad libitum* for 6 weeks a control diet (American Institute of Nutrition-76A) or the same with restriction of vitamin B12. After confirming the deficiency, the mice were allowed to breed with control males to obtain the F1 generation offspring. The different parameters related to maternal care were assessed (licking/ grooming behavior and pup retrieval test). Interestingly, mice fed on vitamin B12 restricted diet had significantly higher degree of negligent behavior in towards the pups. Also, the stress levels measured by plasma cortisol were quite high in mice fed on vitamin B12 restricted diet. To conclude, vitamin B12 deficiency is associated with increased stress in the mothers which may further lead to poor maternal care.

[Topic1]Genes and Behavior

[Topic2]Development

Poster Session 2

PO-2115(16:30 - 17:30)

Genes and Behavior II: Neural and genetic mechanisms underlying divergence in courtship behaviors between threespine stickleback species

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Divergence in courtship behavior can cause speciation between closely related species. Therefore, it is important to know the neural and genetic mechanisms underlying variation in courtship behaviors for a comprehensive understanding of speciation mechanisms. However, the mechanisms underlying courtship behaviors are poorly understood. The threespine stickleback exhibit great variations in courtship behaviors, and such variations may contribute to speciation. In the present study, we analyzed the brain regions and neural pathways involved in courtship behaviors in a Japanese Pacific Ocean population of threespine stickleback. To identify brain regions regulating a male courtship dance termed a zig-zag dance, we analyzed the expression of immediate early genes. We first exposed sticklebacks to a stimulant, pentylenetetrazole, and found that up-regulation of *c-fos* transcript occurred 30 min after exposure. Then we performed *c-fos in situ* hybridization and could identify brain regions activated during the zig-zag dance. Currently, we are performing RNA sequencing and retrograde neuronal labeling to elucidate the genes and neural pathways important for the expression of the courtship behaviors in this Pacific Ocean population. These results will provide us important information for further comparison with Japan Sea stickleback, which differ in several components of courtship behaviors from the Pacific Ocean stickleback.

[Topic1]Genes and Behavior

[Topic2]Evolution

Poster Session 2

PO-2116(17:30 - 18:30)

Genes and Behavior II: Distinct genetic architecture underlies the emergence of foraging-related behaviors in the Mexican cavefish

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Neural regulation of sleep, appetite and energy homeostasis is critical for an animal ' s survival and is under stringent evolutionary pressure. The Mexican cavefish, Astyanax mexicanus presents a powerful system for the analysis of adaptive behavioral traits including sleep and feeding. A. mexicanus consists of eyed ' surface ' populations that live in rivers and ponds throughout Mexico and 29 geographically isolated populations of cave-morphs have been identified in the Sierra Abra region of Northeast Mexico. Surface and cave forms are interfertile, representing a single species. Cave populations have adapted to survive in the dark, nutrient-poor cave environments and display a number of changes in foraging-related traits including sleep loss and vibration attraction behavior (VAB), which underlies predatory foraging. Our findings indicate that both sleep loss and VAB are present in independently derived populations of adult cavefish. Three of four independent cavefish populations showed reduced sleep suggesting the convergent evolution of this trait. Analysis of surface-cave hybrids reveals that independent genetic architectures underlie changes in sleep-wake regulation and VAB. Taken together, these findings demonstrate the independent convergent evolution of distinct foraging related traits and establish adult Mexican cavefish as a model for the study of evolutionarily derived sleep loss.

Poster Session 2

PO-2117(14:30 - 15:30)

Genes and Behavior II: Deeply conserved r-opsin phototransduction cascade genes may underlie a novel expansion response of chromatophores to light in isolated *Octopus bimaculoides* skin

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How do novel behaviors evolve? Do they use newly evolved underpinnings, or are pre-existing components repurposed for novel behavioral functions? Cephalopods like octopuses and squids dazzle prey, woo mates and seamlessly blend into the background by changing the pattern of their skin. Embedded in their skin are novel, colored organs called chromatophores that they use to perform these astounding color-changing feats. While changes in body patterning rely on eyesight, we have also found that bright white light causes the chromatophores in isolated *Octopus bimaculoides* skin to expand without eye or CNS input. We call this behavior Light-Activated Chromatophore Expansion or LACE. To identify potential molecular mechanisms that may underlie LACE, we found that r-opsin phototransduction genes are expressed in octopus skin, and identified peripheral sensory neurons in the skin that express r-opsin. LACE suggests that octopus skin is intrinsically sensitive to light, and that this dispersed light sense could contribute to their unique and novel camouflage abilities. Further, finding r-opsin phototransduction cascade genes expressed in octopus skin suggests that a common molecular mechanism for light detection in eyes may underlie LACE and may have thus been co-opted for light sensing in octopus skin.

[Topic1]Genes and Behavior

[Topic2]Evolution

Poster Session 2

PO-2118(15:30 - 16:30)

Circadian Rhythms: Neuronal population-specific circadian and photic regulation of val-opsinA and val-opsinB in the zebrafish

*Chong Yee Hang[1], Takashi Kitahashi[1], Ishwar S Parhar[1]

Monash University Malaysia[1]

Zebrafish possess two isoforms of vertebrate ancient *long* (VAL)-opsin, encoded by *val-opsinA* (*valopa*) and *val-opsinB* (*valopb*), which mediate non-visual photoreception of multiple *valop* cell populations in deep brain. However, gene regulation of the *valop* isoforms has yet to be explored, which would be important to understand physiological roles of VAL-opsin. This study used real-time PCR to quantify the mRNA levels of *valopa* and *b* in different *valop* cell populations in the brain at different time points of the normal light/dark cycles. Furthermore, effects of constant light/dark condition, luminous levels and melatonin receptor agonist/antagonist on the *valop* transcription were examined. Evening-peak *valopa* and morning-peak *valopb* transcriptions were seen exclusively in the thalamic *valop* population. The diurnal change in *valopa* transcription in the thalamic population was self-sustained, while *valopb* transcription during night phase was suppressed directly by light input. In contrast, the midbrain and hindbrain *valop* populations showed constant expression of *valopa* and *b* during the diurnal cycles. The differential regulation of *valopa* and *b* genes in the thalamic *valop* population and separate regulation in the midbrain and hindbrain *valop* populations implicate that the zebrafish VAL-opsin isoforms serve different functions important for evening-morning and constant light detection.

[Topic1]Circadian Rhythms

[Topic2]Cellular Properties

Poster Session 2

PO-2119(16:30 - 17:30)

Circadian Rhythms: The nuclear receptor genes HR3 and E75 play an important role in the circadian rhythm generation in the firebrat, *Thermo bia domestica*

*Yuichi Kamae[1], Outa Uryu[1], Taiki Miki[1], Kenji Tomioka[1]

Graduate School of Natural Science and Technology, Okayama University[1]

Insect circadian rhythms are generated by a circadian clock consisting of transcriptional/translational feedback loops, in which CYCLE and CLOCK play as key elements. They activate transcription of various clock genes such as *timeless* (*tim*) and *period*. In the firebrat *Thermobia domestica*, *cycle* (*cyc*) is rhythmically expressed. We identifed the orphan nuclear receptor genes *HR3* and *E75* as the major regulator of the rhythmic expression of *cyc* gene in *Themobia*. Our results show that *HR3* and *E75* are rhythmically expressed and their normal expression is required for persistence of locomotor rhythms. Their RNAi considerably altered the rhythmic transcription of not only *cyc* but also *tim*. The RNAi of *HR3* revealed rhythmic expression of *Clock* (*Clk*), suggesting that this ancestral insect species possesses mechanisms for rhythmic expression of both *cyc* and *Clk* genes. When either *HR3* or *E75* was knocked-down, *tim*, *cyc* and *Clk* oscillated in-phase, suggesting that the two genes play an important role in regulation of the phase relationship among clock genes. Interestingly, *HR3* and *E75* were also found to be involved in regulation of ecdysis, participating in the ecdysone signal pathway, suggesting that they interconnect the circadian clock and developmental processes.

[Topic1]Circadian Rhythms

[Topic2]Genes and Behavior

Poster Session 2

PO-2120(17:30 - 18:30)

Circadian Rhythms: Entrainment mechanisms for the eclosion rhythm in the fruit fly *Drosophila melanogaster*

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In the fruit fly, *Drosophila melanogaster*, adult emergence occurs within several hours around dawn. This eclosion time window rhythmically occurs, being determined by a circadian clock. In the present study, we examined light entrainment mechanisms for the eclosion rhythm using mutant lacking functional CRYPTOCHROME (cry^b) and those with visual system deficiency. Wild type and cry^b flies showed entrained eclosion rhythms under 12 h light-12 h dark (LD) cycles with an eclosion peak at light on. Eclosion rhythms of visual system mutants (e.g. so^1, $glass^{60j}$) were also entrained to LD cycles but the phase of eclosion was advanced towards the dark period. Double mutant of cry^b $glass^{60j}$ were not entrained but eclosed arrhythmically regardless of LD cycles. The results suggest that both visual system and cryptochrome were involved in the light entrainment mechanism but the light input via the visual system plays a prominent role for the entrainment of the eclosion rhythm.

[Topic1]Circadian Rhythms

[Topic2]Genes and Behavior

Poster Session 2

PO-2121(14:30 - 15:30)

Circadian Rhythms: Neural correlates of spontaneous and induced sleep in *Drosophila melanogaster*

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The fruit fly, *Drosophila melanogaster*, can be induced to sleep by activating sleep-promoting neurons in the brain, or by feeding the flies sleep-promoting GABA agonists. We compared brain activity in the sleeping fly brain for induced-sleep approaches, compared to spontaneous sleep. To record from the fly brain, we performed local field potential (LFP) and whole-cell patch-clamp recordings on tethered flies positioned on an air-supported ball. Overnight recordings revealed an overall decrease in LFP activity during spontaneous sleep, although the LFP appeared to change dynamically within a sleep bout. Feeding flies the insomnia drug Gaboxadol was sleep promoting, and associated with decreased LFP activity resembling spontaneous sleep. Interestingly, genetic activation of the dorsal fan-shaped body (dFB), which is a sleep-promoting structure in the fly brain, reliably produced an increase in LFP activity at lower frequencies. We are performing simultaneous LFP and whole-cell recordings to understand the interaction between intracellular activity in the dFB and extracellular activity across the brain during spontaneous and induced sleep in flies.

[Topic1]Cellular Properties

[Topic2]Circadian Rhythms

Poster Session 2

PO-2122(15:30 - 16:30)

Circadian Rhythms: Mode of inhibition of ovarian development by pars lateralis neurons responding to photoperiod in the blow fly *Protophormi a terraenovae*

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Many insects respond to photoperiod to control diapause for seasonal adaptations. *Protophormia terraenovae* suppress ovarian development under short days (SD). Previous studies have shown that the pars lateralis (PL) neurons are prerequisite for suppression of ovarian. The present study examined pathways in which inhibitory signals to ovaries are transmitted by severance of neural tracts and discussed mode of inhibition by PL neurons responding to photoperiod. The posterior lateral tract (PLT) of PL neurons was severed on various days after flies were transferred to SD on the day of adult emergence (day 0). Later was the day of the surgery, smaller was the proportions of ovarian development. Next, intact females were transferred to long days (LD) on various days after being transferred to SD on day 0, and examined ovaries on day 10 or 10 days after the transfer to LD. As the transfer to LD was made later, proportions of ovarian development decreased on day 10, but those were not different 10 days after the transfer. The results suggest that PL neurons send inhibitory signals through the PLT under SD and inhibitory signals by PL neurons can be canceled by LD received immediately after the photoperiodic transfer.

[Topic1]Circadian Rhythms

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2123(16:30 - 17:30)

Circadian Rhythms: Neuronal pathways for photoperiodism in the bean bug *Riptortus pedestris*

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The bean bug, *Riptortus pedestris* (Insecta, Heteroptera), enters reproductive diapause under short-day conditions. The previous study demonstrated that the central region of the compound eye (CE) plays a principal role in the photoreception for photoperiodism in *R. pedestris.* Two brain regions including somata of pigment-dispersing factor-immunoreactive (PDF-ir) neurons at the anterior base of the medulla (Me) and the pars lateralis (PL) are important for photoperiodic suppression of ovarian development. To find the neural mechanisms underlying photoperiodism, its plausible neural networks were morphologically examined. The retinal fibers from the central region of the CE terminated mainly in the central Lamina and some extended to the central Me. By introducing biotin-powders into the Me, fibers from the central part of the Me to the ipsilateral anterior-dorsal protocerebrum were revealed. Double staining with anti-corazonin antisera, which label two pairs of neurons with somata in the PL, and anti-PDF antisera showed their varicosities are closely connected in the dorso-lateral part of the protocerebrum, suggesting their potential neuronal interactions. These results suggest that photoperiodic information is transferred to an anterior-dorsal protocerebral region, and PDF-ir neurons directly send signals to PL neurons to suppress ovarian development under short-day conditions.

[Topic1]Circadian Rhythms

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2124(17:30 - 18:30)

Circadian Rhythms: Pigment-dispersing factor (PDF) signals not exclusively via adenylyl cyclase and inhibits inward and outward currents in circadian pacemaker neurons of the Madeira cockroach Rhyparobia maderae

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The insect neuropeptide pigment-dispersing factor (PDF) is a prominent circadian coupling factor important for synchronized circadian rhythms of clock genes and behavior. To study PDF signaling Ca^{2+} imaging and patch clamp experiments were performed on primary cell cultures of the accessory medulla (AMe), the circadian clock of the Madeira cockroach.
Amongst four different PDF-response types we concentrated on regular bursting type 1 cells which resembled differentially light-sensitive bright- and dark-rhythm neurons previously characterized in intracellular recordings of the AMe.
PDF-application dose-dependently and long-lastingly elevated Ca^{2+} baseline and frequency of oscillating Ca^{2+} transients via adenylyl cyclase activation. In hyperpolarized type 2 pacemakers PDF transiently raised intracellular Ca^{2+} baseline adenylyl cylcase-independently. Patch clamp experiments revealed that PDF inhibited outward potassium and inward sodium currents even in the same circadian pacemaker neuron. Thus, depending on the individual pacemaker neuron PDF can inhibit or activate action potential firing depending on the respective second messenger pathway employed and on the respective ion channels associated with the PDF receptors. [Supported by DFG grand STE531/18-1,2 and 21-1 to MS]

[Topic1]Circadian Rhythms

[Topic2]Neuromodulation

Poster Session 2

PO-2125(14:30 - 15:30)

Orientation and Navigation II: Large environments reveal the statistical structure governing hippocampal representations

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The environments rats navigate in the wild are much larger than those typically used in the laboratory to study the neural representations of space. In the hippocampus, place cells are spatially tuned, firing at specific locations in an environment. While much is known about place cells and spatial maps, far less is understood about their organizing principles. We recorded from rats exploring a novel 48-meter-long track, exposing a simple structure of place field activity across a population of dorsal hippocampal CA1 neurons. Individual neurons were well-described as having their own characteristic propensity for forming fields randomly along the track, with some cells expressing many fields and many exhibiting few or none. Due to the particular distribution of propensities across cells, the number of neurons with fields scaled logarithmically with track length over a wide, ethologically relevant range. These features constrain hippocampal memory mechanisms, may allow efficient encoding of environments and experiences of vastly different extents and durations, and could reflect general principles of population coding in the brain.

[Topic1]Orientation and Navigation

[Topic2]Computation

Poster Session 2

PO-2126(15:30 - 16:30)

Orientation and Navigation II: No movement-related oscillations in the entorhinal-hippocampal system of behaving bats despite low-frequency cellular resonance

***Tamir Eliav[1], Maya Geva-Sagiv[1,2], Michael Yartsev[1], Arseny Finkelstein[1], Alon Rubin[1], Liora Las[1], Nachum Ulanovsky[1]**

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The hippocampal formation of rodents and bats contains several types of spatial neurons – including place cells and grid cells – which share very similar functional properties between bats and rodents. However, while spatial neurons in rodents exhibit continuous theta-rhythmic firing, bat neurons were found to exhibit very little theta rhythmicity. This finding created a major controversy over the role of the mammalian theta-rhythm – for example, its proposed role in generating the grids, as posited by ‘ oscillatory interference models ’ . Recent *in-vitro* experiments reported possible intrinsic membrane resonance in bat entorhinal neurons at low frequencies, indicating the oscillatory interference model might perhaps work in bats – but at lower frequencies. To test this hypothesis, we recorded several new *in-vivo* datasets – including extensive new data from 3D place cells and hippocampal interneurons in flying bats. Analysis of these new and several existing datasets showed that grid cells, place cells and interneurons in bat entorhinal cortex and hippocampus do not exhibit *in-vivo* movement-related oscillations in their spike trains – neither at the theta-band nor at lower frequencies. These findings suggest that oscillation-based models cannot account for place-field and grid-field generation across mammals – neither at theta nor at lower frequencies.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2127(16:30 - 17:30)

Orientation and Navigation II: In search of 3D grid cells in flying bats

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Spatial orientation and navigation are crucial for all animals. ‘ Grid cells ’ are neurons in the mammalian hippocampal formation that discharge when the animal passes through the vertices of a two-dimensional (2D) hexagonal grid spanning the 2D movement surface. However, although many animals navigate daily through 3D space, no studies to date have attempted to characterize the 3D volumetric firing of grid cells, in any species. To address this, we used Egyptian fruit bats to investigate whether 3D grid cells exist, and to elucidate their 3D spatial code. We have previously found 2D grid cells in bats crawling on a 2D surface, as well as volumetric 3D place cells in freely-flying bats. Here, bats were trained to fly in a large flight room (~6 x 5 x 3 m) in search of randomly-positioned food, while we wirelessly recorded single-neuron activity in several brain regions where 2D grid cells are known to exist. Preliminary results indicate the existence of grid-like structures in recorded 3D firing-rate maps. We are now analyzing whether individual firing-fields are spherical, and if so – are such 3D spheres arranged in a mathematically-optimal packing arrangement, as predicted by computational models of 3D grid cells.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2128(17:30 - 18:30)

Orientation and Navigation II: Spectral and temporal jamming avoidance response in FM echolocating bat species, *Pipistrellus abramus* and *Miniopterus fuliginosus*

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Echolocating bats experience acoustical interference from sounds of other conspecifics bats flying together. To understand how bats change their echolocation signals to avoid acoustical jamming, we examined echolocation behavior of FM bats *Pipistrellus abramus* and *Miniopterus fuliginosus* by using artificial FM jamming sounds. Echolocation pulses were recorded using a telemetry microphone mounted on the bats ’ backs. We observed asymmetric frequency shifts in both two species: the bats significantly shifted their terminal frequencies (TFs) of FM pulse by 1—3 kHz when the TF of FM jamming sounds was lower than the bats' own pulses, meanwhile significant but slight TF shift (0.2—0.6 kHz) was observed in the case of TFs of FM jamming sounds higher than the bats' own pulses. These findings indicate that FM bats actively shift their pulse frequency to avoid overlap of their own TF frequency range with jamming sounds. Furthermore, both of FM bats show different behavioral responses in the context of temporal jamming, *P. abramus* lengthened their pulse duration while they were exposed to the jamming sounds however *M. fuliginosus* did not. This finding implies that bats have species-specific jamming avoidance response even though they emit similar time-frequency structure pulse.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Audition

Poster Session 2

PO-2129(14:30 - 15:30)

Orientation and Navigation II: The method for investigating insect spatial orientation with virtual reality

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Several insect species can use memory of visual landmarks for spatial orientation. To investigate how they extract the landmarks from complex real environment, we propose a method to conduct the insect navigational tasks in a computer-generated virtual reality.
We adopted the well-established paradigm for investigating insects place memory in an analogue of the Morris water maze with a safe cool spot in aversive hot area. To conduct this in the virtual reality, we developed a theater for walking crickets (Gryllus bimaculatus) and appropriate aversive stimuli.
A tethered cricket walked on a ball and two optical sensors measured the ball rotation. The position of the cricket in the virtual space was then calculated and corresponding visual circumstances were displayed on four LCD panels surrounding the cricket.
As to aversive stimuli, we adopted electrical stimulus and heat stimulus with an infrared laser diode. In the preliminary experiment, electrical stimuli were applied when the cricket was outside of a safe spot with visual cues where the stimuli were stopped. We observed that the time to reach the safe spot decreased in increasing number of trials. However we also observed decreasing locomotor activity after the repetitive stimuli. We further investigate appropriate stimulus conditions.

[Topic1]Orientation and Navigation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2130(15:30 - 16:30)

Orientation and Navigation II: Studying the fine details of simultaneous pheromone and visual cue use in navigating ants

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Navigating animals have to deal with multiple sources of information and studying how they manage cue integration can give an interesting insight into their style of information processing. The navigation of ants is an ideal model system for studies of cue integration. Foraging ants are easy to study and we can manage meaningful cue conflict in the lab between ants ’ learnt visual memories and olfactory trails. The integration of social (trail) and private (visual cues) has been well-studied from a behavioural ecology perspective. However we know little about the mechanistic details of this particular cue integration. Using automated tracking of navigating ants in an open arena, we have been able to record how ants respond to pheromone trails alone, and in combination with learnt visual cues. The simple fact that pheromone trail use is in an open arena, and recorded in fine details, rather than restricted to narrow mazes, allows novel descriptions of the sensori-motor behavior involved. Furthermore, we investigate whether detailed description of the sensori-motor motifs during single cue use can explain the apparent choice behavior when cues are in conflict.

[Topic1]Orientation and Navigation

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2131(16:30 - 17:30)

Orientation and Navigation II: Desert ants locate food by combining high sensitivity to food odours with extensive crosswind runs

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Desert ants feeding on dead arthropods have the challenge to forage for food that is distributed unpredictably in space and time in the Saharan salt pans. Scavengers of the genus *Cataglyphis* do not lay pheromone trails, but are rather equipped with a sophisticated personal navigational toolkit. They primarily rely on path integration when in unfamiliar terrain and as they become experienced they in addition rely on learnt information from visual and olfactory cues. While most studies focused on navigational mechanisms when targeting a familiar place, be it the nest or a learnt feeding site, less is known about the ants' strategies to efficiently localize sparse natural food sources. Here we show that *Cataglyphis fortis* is highly sensitive to and attracted by food odours, especially the necromone linoleic acid which enables them to locate tiny dead insects over several meters in distance. Furthermore on search for food the ants take far-reaching crosswind walks that increase the chances to localize food plumes. By combining high sensitivity toward food odours with extensive crosswind runs, the ants efficiently screen the desert for food and hence reduce the time spent foraging in their harsh desert environment.

Buehlmann et al, Current Biology (2014), http://dx.doi.org/10.1016/j.cub.2014.02.056

[Topic1]Orientation and Navigation

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2132(17:30 - 18:30)

Orientation and Navigation II: Loss of scent while following plume results in search-like behavior with little evidence of reliance on geomagnetic cues in the nudibranch *Tritonia tetraquetra*

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The nudibranch *Tritonia tetraquetra* (*T. diomedea*) is known to orient to the geomagnetic field, the purpose of this behavior and much of the underlying neurobiology is unknown. It has been hypothesized that their magnetic sense is used in response to situations when primary navigational cues (odor and flow) become undependable. We investigated the behavioral function by putting slugs in a flow-through arena with primary navigational cues and magnetic field distortion (with a permanent magnet). Before the slugs reached the magnetic distortion, primary navigational cues were turned off to test for the use of the magnetic sense. In these trials, the slugs changed directional heading repeatedly and significantly more (~3X more) after odor was turned off than before odor was turned off. The slugs turned 1.7X more in the distorted magnetic field compared to the normal field in the 40 s after the odor was removed, consistent with some magnetic influence on orientation. We performed sensory nerve CeN1 and single neuron (pedal neuron 5 and 6) recordings in semi-intact preparations with 60 ° CW and CCW magnetic field rotations. We observed some increases in the sensory nerve activity, but little change in the motor neuron activity in our limited number of trials.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2133(14:30 - 15:30)
Orientation and Navigation II: Unravelling the behavioural and physiological mechanisms of magnetic compass orientation and polarized light sensitivity in birds

Rachel Muheim[1]

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Birds are well known for their impressive migrations and the fascinating, and for their ability to sense the Earth ’ s magnetic field and see the polarization pattern of the sky, and use this information for orientation and navigation. However, despite of decades of intense research to unravel the behavioural and physiological mechanisms, the question of how birds can perceive geomagnetic field and polarized light information belongs to the big unsolved mysteries in sensory biology.

We have developed a behavioural assay, where zebra finches are trained to find a food reward in a trained magnetic direction and/or along a polarization axis, allowing us to test the behavioural and physiological properties of magnetic compass orientation and polarized light sensitivity in birds either separately or in combination with each other. Findings from this assay indicate a possible interaction between polarized light and magnetic compass cues, suggesting a closer relationship between the two senses than previously thought. They give support for intriguing parallels between the functional and physiological properties of polarized light reception and light-dependent magnetoreception which may point to a common receptor system.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 2

PO-2134(15:30 - 16:30)
Orientation and Navigation II: Context dependence of sensory signalling in locust central-complex neurons

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The central complex (CC) in the insect brain plays an important role in spatial orientation. Neurons of the locust CC are sensitive to the oscillation plane of polarized light, suggesting a role in sky compass orientation, respond to the simulation of approaching objects via looming stimuli, and change their activity during motor behavior (Pfeiffer and Homberg 2014, Annu Rev Entomol 59:165).
To better understand multisensory integration and the influence of motor activity on sensory processing, we tested the responses of CC neurons to combined looming and moving grating stimulation mimicking approaching objects during foraging behaviour. Additionally, we studied the effect of walking activity on neural responses to polarized light. Several CC neurons where sensitive to looming stimuli as well as to moving gratings. Combining both stimuli revealed the existence of neurons that are inhibited by moving gratings and excited by looming stimulation. This possibly improves the detection of approaching objects during foraging. Polarization-sensitive neurons showed changes in background activity during spontaneous leg movements. In a subset of neurons the responsiveness to rotation of the polarizer increased during leg movements or when animals were stimulated by touching their legs prior to polarized light stimulation.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 2

PO-2135(16:30 - 17:30)

Orientation and Navigation II: Finding the gap: A novel visual strategy for avoiding collisions in flight

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The tropical rainforest is arguably one of the most challenging natural environments in which to control flight and navigate due to its high spatial complexity, rapidly changing light intensities and thick canopy that obscures the sky. Despite these challenges – and the limitations imposed by their miniature brains and sensory systems – orchid bees (tribe: Euglossini) are capable of navigating over tens of kilometres through the rainforest in the search for food or perfume from spatially rare orchids. To achieve this remarkable feat, they must continuously negotiate the narrow gaps in the tangled undergrowth in a safe, reliable and efficient manner. How do they do this? Here, we investigate the collision avoidance strategy of orchid bees and find that, when flying through gaps of different shapes, they fly through the safest point – that is, the point that provides the greatest clearance from the edges. Moreover, instead of using a motion-based strategy to avoid the edges, as other insects do, orchid bees use contrast cues to find the gaps between them. This novel contrast-based gap identifying strategy presents a simple, instantaneous and computationally efficient method for locating the safest path through a cluttered environment.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 2

PO-2136(17:30 - 18:30)

Orientation and Navigation II: Comparison of the orientation flights of the bumblebee (*Bombus terrestris*) when learning about the location of its nest or feeder

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Wasps and bees learn the locations of their nest and a stable feeding site during specialised flights that the insects perform when they first leave these goals. Because *Bombus terrestris* nests in the ground and will collect nectar from low plants, it is possible to compare the learning flights of bumblebees acquiring information about the two goals in circumstances in which the visual surroundings of each goal are very similar. We have recorded the learning flights of individual bees as they learnt both goals set 3m apart. The locations of the inconspicuous nest-hole and feeder were each marked by three black cylinders. Flights were recorded with two video-cameras one above each goal. Preliminary analysis reveals some structural similarities between flight manoeuvres at the two goals, but flights at the feeder are conspicuously shorter than those at the nest. This difference may be related to the greater need of bees to remember the precise position of their nest-hole than the location of conspicuous flowers.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Poster Session 2

PO-2137(14:30 - 15:30)

Orientation and Navigation II: System identification and reconstruction of sensory neural activity during thermotaxis behavior of *C. elegans*

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Caenorhabditis elegans exploit environmental thermal gradients for searching behavior, which is called thermotaxis. Although the neural circuit governing thermotaxis of *C. elegans* has been almost completely identified, it remains to be understood how sensory signals are utilized for thermotaxis. Here, we identified the response property of the thermosensory neuron AFD during thermotaxis and reconstructed the output in response to given thermal input. Combination of our automated tracking system and a calcium imaging technique with Cameleon YC3.60 enabled us to monitor behavior and activity of AFD during thermotaxis simultaneously. Then we estimated how the AFD neuron responds to the temperature input while searching thermal gradient, as a response function. The estimated response function indicates a differential detection mechanism and its time window for temperature sensing. This characteristic of the response function was consistent between the animals cultivated in different temperatures, or on/off-food conditions. Then we reconstructed time courses of AFD responses for given temperature inputs based on the estimated response function, and compared with actual AFD responses. The reconstructed responses are highly correlated to the actual neural responses, so that our approach provides systematic understanding and modeling foundation of environmental recognition mechanisms in the sensory system working in naive conditions.

[Topic1]Orientation and Navigation

[Topic2]Computational Modeling

Poster Session 2

PO-2138(15:30 - 16:30)

Communication: Visual and auditory contributions in a highly synchronized duet song

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Plain-tailed wrens sing a duet song so precisely timed that it sounds like one bird is producing the song. The precise timing between individuals depends on sensory input from the sender that is matched with motor output from the receiver. We asked how visual and auditory timing cues influence duet production. Preliminary data suggest that blocking visual input does not change the patterns or timing of duet production, though it reduces the number of duets sung. Visual information, therefore, is not necessary to coordinate duet singing. To examine the influence of acoustic delays on duet timing, we varied the distance between pairs of duetting birds in cages. We found that pairs of wrens could produce coordinated duets up to 7 meters apart. This continued coordination with increasing acoustic delays could be due to global slowing of song production, a “ ping-pong ” strategy in which birds respond directly to acoustic cues, or other strategies. Preliminary evidence supports a ping-pong model in which delay lengths are limited by the underlying motor program.

[Topic1]Communication

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2139(16:30 - 17:30)

Communication: Duet matching in plain-tailed wrens

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Male and female plain-tailed wrens sing duet songs in which participants rapidly alternate syllable production. This behavior requires that birds learn their own unique song syllables. Previous work suggests that pairs of birds may sing up to 10 duet variants. In an effort to understand the structure and organization of these song variants, we conducted playback experiments using local dialect variants, and dialects from distant populations. Pairs of birds matched their duet singing to the playback songs. This matching included temporal matching of both male and female syllables, and matching of the time-varying spectral content of syllables. After playbacks, birds quickly reverted back to their own dialect. This matching behavior suggests a far greater degree of flexibility in song production in this species.

[Topic1]Communication

[Topic2]Social Behavior

Poster Session 2

PO-2140(17:30 - 18:30)

Communication: Syrinx morphomes: Interactive 3D models for understanding the fundamentals of avian sound production

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The songbird system is a widely used experimental animal model for understanding the underlying neural mechanisms responsible for vocal production learning. The translation of neural impulses into precise motor behavior of the complex vocal organ (syrinx) to create song remains poorly understood. To allow for precise mapping of the song system onto the periphery, we first need to establish a detailed understanding of the structure and function of the syrinx. We combined non-invasive (high-field magnetic resonance imaging, micro-computed tomography) and invasive techniques (histology, micro-dissection) to quantify syrinx geometry. We identified and annotated syringeal cartilage, bone, musculature and oscillatory membranes in 3D datasets, termed morphomes. In zebra finches, the syringeal skeleton is optimized for low weight driven by physiological constraints on song production. The refinement of muscle organization and identity elucidates how apposed muscles actuate different syringeal elements and affect orientation of the sound producing labia. Our approach allows for precise predictions about muscle co-activation and has important implications for muscle activity and stimulation experiments. We extended this approach to several bird species and construct interactive three-dimensional models that greatly improve the communication of complex morphological data.

[Topic1]Communication

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2141(14:30 - 15:30)
Communication: Neuronal correlates of unlearned calls in male and female zebra finches

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In songbirds, the emergence of the ability to produce learned vocalizations coincides with the evolution of the forebrain vocal control system, an interconnected network of brain nuclei that shapes the song during learning and organizes the motor output when singing. These structures are missing or have only rudimentary neural homologs in non-learning relatives.
We present evidence that, in addition to learned song production, social calling patterns also involve the song control system. We first describe patterns of calling between individual zebra finches living in dense groups using wireless backpack microphones and show that one type of unlearned soft calls, the stack call, is exchanged almost exclusively between bonded partners. To study the neural activity underlying this communication pattern we performed neuronal recording from free ranging males and females, interacting with their partners.
Local field potentials and multiunit activity recorded from males and females show a strong association with the production of stack calls.
Thus, the song control circuit in males could have evolved from a more basic system necessary to differentiate between the partners call and that of other group members and develop a pattern of precisely timed close range vocal exchange.

[Topic1]Communication

[Topic2]Social Behavior

Poster Session 2

PO-2142(15:30 - 16:30)

Communication: Reproductive advertisement: chemical signals in relation to estrus status in the urine of female giant pandas (*Ailuropoda melanoleuca*)

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Urine plays a crucial role in chemical communication in giant pandas. Swaisgood et al. (2002) found that the urine of female pandas contains chemical cues by which males discriminate females based on their estrous status. To reveal the functional roles, we collected urine samples from pandas of Chengdu Research Base of Giant Panda Breeding and examined the chemical components by using gas chromatography-mass spectrometry (450-GC/320-MS; Bruker Inc.). The content of estradiol (pg) / creatinine(mg) in the urine was also measured by enzyme immunoassay(EIA) to determine the reproductive stages of females. We found that the female panda urine contained more components than male ' s. We also compared components of female panda urine in different estrous status (pro-estrus, estrus, post-estrus and non-estrus), and found that they changed in a complex manner. The relative intensity of a component [6-(3, 3-Dimethyl-oxiran-2-ylidene)-5, 5-dimethyl -hex-3-en-2-one] reached its peak before estrus in 6 out of the 7 females examined. The remaining one individual failed in reproduction in that year. Therefore, we suggest that the relative intensity of this component is related to the estrus status and serve as a reproductive advertisement.

[Topic1]Communication

[Topic2]Sensory: Olfaction and Taste

Poster Session 2

PO-2143(16:30 - 17:30)

Communication: Resonance properties created by vocal-tract characteristics for discriminating individuals in Japanese macaques

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Japanese macaques utter the species-specific communication sound called “ coo call ” for their communication within groups. Monkeys could discriminate individuals only by listening to the vocalizations, but it has been still discussed how the fundamental frequencies (F0) and vocal-tract characteristics (VT) can contribute to the individual identification. The purpose of this study was to determine the acoustical properties to discriminate individuals in Japanese macaques. We trained two animals with standard Go/NoGo operant conditionings to discriminate coo calls of Monkey A (cooA) and Monkey B (cooB). Both cooA and cooB were recorded from unfamiliar monkeys. The F0s of cooA and cooB were about 300 Hz but different. Test stimuli were series of morphed coo calls (from cooA to cooB) along with one acoustic parameter (F0 or VT), while other parameter stayed constant as that of cooB. Monkeys responded to the morphed stimuli as cooB. Data suggested that both F0 and VT contributed to individual identification in monkeys. We are going to re-train and test using novel stimuli (F0 of all calls were modified to be normalized into the average between cooA and cooB). These results will be discussed.

[Topic1]Communication

[Topic2]Cognition

Poster Session 2

PO-2144(17:30 - 18:30)

Communication: Cope ’ s gray treefrogs exploit regularities in natural scene statistics for improved call recognition and discrimination

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Male Cope ’ s gray treefrogs (*Hyla chrysoscelis*) produce advertisement calls within large, noisy, breeding aggregations. High levels of chorus noise can impair females ’ abilities to detect, recognize, and discriminate among calls. Such natural soundscapes may exhibit amplitude fluctuations that are correlated (comodulated) across the frequency spectrum. We measured the statistics of chorus noise using a frog-inspired auditory filterbank. A cross-covariance analysis of envelopes extracted from the output revealed significant comodulations corresponding to the spectral peaks (1.3 and 2.6 kHz) of *H. chrysoscelis* calls. In behavioral experiments, signal recognition and discrimination were tested in quiet, or in “ chorus-shaped noise ” comprised of two narrowband noises centered on the spectral peaks of the call. The narrowband noises were either unmodulated (flat), independently modulated (deviant), or comodulated with identical modulators. At a masker level of 73 dB SPL, females experienced a 2.6 dB and 6.9 dB release from masking in comodulated noise compared to deviant or flat noise, respectively. Compared to flat noise, females were more likely to discriminate in favor of an attractive call in comodulated noise, and less likely to do so in deviant noise. *H. chrysoscelis* may encounter and can rely on comodulations in chorus noise for improved call recognition and discrimination.

[Topic1]Communication

[Topic2]Sensory: Audition

Poster Session 2

PO-2145(14:30 - 15:30)

Communication: Neural correlates of signal detection in modulated noise

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Many animals communicate acoustically in large groups, where intense background noise levels can mask signals of interest. Detection is often improved when the background noise fluctuates in amplitude over time. A prominent explanation is that when the amplitude fluctuates, receivers are able to catch “ acoustic glimpses ” during dips in the amplitude, a phenomenon known as dip listening. Recent behavioral work found that females of Cope ’ s gray treefrog (*Hyla chrysoscelis*), but not the green treefrog (*H. cinerea*), were able to exploit temporal fluctuations to improve detectability of a conspecific communication signal (call) in sinusoidally amplitude-modulated (SAM) noise. However, it is unknown to what extent the underlying mechanism derived from dip listening. An alternative possibility is that stochastic resonance, resulting from the temporal fluctuations in the noise, improved the detectability of the calls. In neural recordings from the auditory midbrain, we evaluated these two hypothesized mechanisms by manipulating the timing of calls such that they were either centered in a dip or at a peak of the background noise. We compare detection thresholds under these manipulations and between species to identify potential species-differences in the mechanisms underlying exploitation of temporal fluctuations in noise.

Funding was provided by NSF DDIG 1311194

[Topic1]Communication

[Topic2]Sensory: Audition

Poster Session 2

PO-2146(15:30 - 16:30)

Communication: Song pattern recognition by an auditory feature detection circuit in the cricket brain

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Phonotactic behavior of female field crickets is sharply tuned to the temporal pattern of the male calling song. Auditory responses to the calling song are forwarded towards the brain via a single ascending interneuron. A small circuit of identified local brain neurons recognizes the species-specific sound pulse pattern and exhibits properties fundamental to a feature detection circuit based on delay-line and coincidence-detection mechanism. A constant internal delay that matches the pulse period of the calling song is provided by a non-spiking brain neuron. Upon acoustic stimulation it receives a transient inhibition that triggers postinhibitory rebound depolarization. Direct (ascending neuron) and delayed (non-spiking neuron) excitatory responses converge in a coincidence detector neuron. The coincidence detector neuron responds best to the pulse pattern of the species-specific calling song when the rebound activation of the non-spiking neuron temporally coincides with the response of the ascending interneuron to the subsequent sound pulse. The output of the coincidence detector neuron is further processed by a feature detector neuron that receives an additional inhibitory input to suppress unselective responses and background activity. The sparse but highly pattern selective spike response of the feature detector neuron closely matches the pulse period tuning of the phonotactic behavior.

[Topic1]Communication

[Topic2]Sensory: Audition

Poster Session 2

PO-2147(16:30 - 17:30)

Communication: Sensory exploitation of startle behaviour leads to a new communication system in crickets

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Female field crickets phonotactically approach singing males guided by the low-frequency calling song, whereas they avoid high-frequency sounds like bat echolocation calls. These two antagonistic behaviours are controlled by the brain, which receives auditory information from two identified interneurons: AN1 tuned to low frequencies and AN2 tuned to high frequencies. In one group of crickets (Eneopterinae, Lebinthini), however, males produce exceptionally high-frequency calling songs that females of other species would avoid. We found that females of these species do not show phonotaxis but produce a vibrational signal in response to each male call advertising their location. The tuning curves for the vibrational responses closely match tuning curves recorded for the AN2 interneuron in other cricket species. Intracellular recording and staining in the brains of the eneopterine crickets revealed AN and brain neurons with high frequency tuning typical of AN2. The most likely origin of the vibratory response is an acoustic startle response (ASR), which is specific to high-frequency sounds in field crickets. Our data suggest that the high-frequency harmonics in the calling songs of the ancestral eneopterines increased in amplitude until they induced an ASR in females, and males exploited the resulting vibrations in the plant substrate to locate females.

[Topic1]Communication

[Topic2]Sensory: Audition

Poster Session 2

PO-2148(17:30 - 18:30)

Communication: The possible usage of circular polarization vision for covert signals in stomatopods

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Stomatopod crustaceans are amongst the few animals that reflect circular polarized (CPol) light and the only ones that can see it. While a few functions for their CPol vision have been proposed (i.e. sexual signaling and an improved contrast in turbid environments), evidence of one has yet to be shown. Aggressive by nature, stomatopods avoid potentially deadly confrontations when inspecting new burrows using olfactory cues. It is likely that they would harness other sensual modalities for this task. We therefore tested whether CPol light affected burrow choice in *Gonodactylaceus falcatus*. To test our hypothesis, specimens were placed in an arena and presented with a choice of two burrows. One burrow entrance was partly blocked by an unpolarized filter while the other was blocked by a spectrally similar CPol filter. Both filters resembled a stomatopod telson. In a second test, the burrows were dimly backlit with unpolarized light or spectrally identical CPol light. In both experiments *G. falcatus* significantly preferred the unpolarized borrow over the CPol one. We postulate, therefore, that *G. falcatus* are using CPol light as a secret communication channel to warn other stomatopods of their presence while hiding from prey and predators at the same time.

[Topic1]Sensory: Vision

[Topic2]Communication

Poster Session 2

PO-2149(14:30 - 15:30)
Communication: Signal recognition in the auditory system of grasshoppers: new solutions for an old problem

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Grasshoppers use acoustic signals to identify and attract mates. Behavioural experiments revealed that the temporal patterns of amplitude modulations provide the decisive cues for signal recognition. We developed a feature detector model that uses a combination of linear filters and nonlinearearities to predict the behavioral responses. The output of the feature detectors is then integrated over time – i.e. the exact temporal position of a feature is discarded – and combined to yield a prediction of the stimulus attractiveness measured in behavioural tests. The specific shapes of the filters and nonlinearities were found via a genetic learning algorithm that started from various random solutions and was trained on a subset of behavioural data obtained with a large sample of different stimulus patterns. Using only two feature detectors, this LN-model yielded a high predictive power, explaining ~90% of the variance in behavioral data of the investigated species. This model further shed light to several so far enigmatic observations of behavioral tests as well as of neurophysiological experiments, and it raises a caveat for the interpretation of single cell recordings. By extending this approach to other species such models may yield insights into evolutionary constraints of song evolution and speciation events.

[Topic1]Communication

[Topic2]Computational Modeling

Poster Session 2

PO-2150(15:30 - 16:30)

Communication: The importance of different courtship stimuli in mate choice in sibling species of *Drosophila virilis* group

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The courtship rituals of *Drosophila* include an exchange of several signals with different modalities, chemical, visual, acoustical and tactile stimuli, between sexes. We studied the role of signals of different modality in mate recognition in three sibling species of *Drosophila* (*D. virilis, D. lummei, D. littoralis*) after a selective blocking of signals and receptors using a video-computing approach. Removing the aristae of the females or the wings of the males resulted to blocking of the auditory signals. Removing the tarsal sense organs of the males resulted to partial blocking of the chemical cues. To suppress contact chemoreceptors of the foreleg tarsi and antenna, we treated them with zinc sulphate. The selective blocking of auditory and chemical cues reduces the mating success of both sexes in different degree in various species. The lack of chemical cues has been found to be critical in all species studied.

[Topic1]Communication

[Topic2]Evolution

Poster Session 2

PO-2151(16:30 - 17:30)

Cognition: Neurons in medial striatum of domestic chicks may code actual reward and reward prediction to compute prediction error signal

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It is important for survival that animals are capable to reliably predict future outcomes by using relevant environmental cues. To make and update such predictions, animals need teaching signals that indicate discrepancy between actual outcome and the current prediction. This “ prediction error signal ” has been assumed in the midbrain dopaminergic neurons. However, it is not fully understood how brain computes the error. Using freely behaving domestic chicks as subjects, we recorded single neuron activities from medial striatum that projects to midbrain regions rich in dopaminergic neurons. Subjects were trained to associate color cues with different food amount. While recording neuronal activities, the food associated with one color cue was experimentally omitted. Before the omission, 24 out of 49 recorded neurons showed significant excitatory (19) or inhibitory (5) responses during the reward period. After the omission, responses immediately vanished in most of the excitation-type neurons (9 out of 11 units with sufficient omission trials). In the inhibition-type neurons, on the other hand, immediate vanishing occurred only in 1 out of 4 neurons. The present result implies that medial striatum contains two groups of neurons, one coding actual reward and another coding reward prediction, thus serving to compute the error signal.

[Topic1]Cognition

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2152(17:30 - 18:30)

Cognition: Do cuttlefish know the concept of sameness?

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Although abstract thinking has long been considered only existed in vertebrates, a previous study has shown that honeybees, an invertebrate with a smaller brain, also possess the ability of knowing the concept of sameness and difference. To examine if cuttlefish (*Sepia pharaonis*) know the concept of sameness, a 3-D maze was developed to apply the delayed matching-to-sample (DMTS) paradigm. Cuttlefish were trained to choose from two background patterns on the bottom tier (the secondary pattern) that was identical to the background of the upper tier (the primary pattern). Once cuttlefish reached the learning criterion, animals proceeded to a transfer test to exam if cuttlefish could apply the concept of sameness when they encountered a different pair of background patterns. Surprisingly, none of cuttlefish was able to reach the criterion in 96 trials. Based on these preliminary results, we concluded that cuttlefish are unable to extract the concept of sameness, at least in our training paradigm, but one cuttlefish is able to perform the DMTS task well. This suggests that cuttlefish may be able to associate the background pattern with what they have seen a short while ago, an indication of possessing the visual working memory.

[Topic1]Cognition

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2153(14:30 - 15:30)

Cognition: Do monkeys have a sense of agency?

*Koji Toda[1], Geoffrey K. Adams[1], Jean-Francois Gariepy[1], Michael L. Platt[1,2,3]

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We asked whether rhesus monkeys show evidence of self-agency in a two-stage joystick-movement task. Each trial consisted of a manipulation stage and a subsequent decision stage. In the manipulation stage, two dots and a target were presented on the display. Movement of one dot was correlated with the monkey ' s manipulation of a joystick (avatar), while the movement of the other dot replayed the manipulation from the previous trial. Monkeys were required to move the avatar to the target. In the subsequent decision stage, monkeys were required to choose the avatar they operated in the manipulation stage by moving a dot to one of two targets. We compared internal and external cue conditions. In the internal cue condition, monkeys were required to detect the avatar by comparing proprioceptive information with visual feedback. In the external cue condition, dot color indicated the appropriate avatar for the monkey to select. Two monkeys learned to detect and report the avatar in both conditions. There were significant differences in performance between the internal and external cue conditions, suggesting that monkeys used internal information as a cue. The results suggest monkeys have a sense of agency, thus permitting direct investigation of the neural basis of self-agency.

[Topic1]Cognition

[Topic2]Social Behavior

Poster Session 2

PO-2154(15:30 - 16:30)

Cognition: The different representation in human brain electrical activity while performing simple mental arithmetic

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Speed and high accuracy of mental arithmetic are important in the learning process. Previous studies showed multiple areas of brain activation during performance task, but the condition of calculation were sparsely investigated. The objective of this study is to compare the neural representation between addition and subtraction during mental arithmetic. Nine healthy university students aged between 20.75-32.25 years old participated in this study. Electroencephalography was recorded when subjects were requested to add or subtract a single digit and then select the correct answer. The questions were classified into four groups including small-size addition (result < 10), large-size addition (result ≥ 10), small-size subtraction (result > 0), and large-size subtraction (result < 0). The behavioural analysis showed that subjects performed better at addition than subtraction (accuracy rate = 90.00% vs 86.89% and reaction time = 360.72 ms. vs 372.97 ms. in addition and subtraction respectively). The P300 wave elicited during addition had a shorter latency than subtraction. The large-size subtraction condition produced larger P300 than small-size subtraction. In conclusion, mental arithmetic produces cognitive waveform (P300) that differs in condition and difficulty level. Thus, the difficulty level is the primary determinant of the neural processing of mental arithmetic.

[Topic1]Cognition

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2155(16:30 - 17:30)
Cognition: Effect of GABAB receptor antagonist CGP 55845 on learning and memory formation of albino mouse following hypoxia ischemia insult

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GABAB receptor plays an important role in learning and memory.GABAB receptor antagonist are experimentally proved to act as spatial memory enhancers in mouse models but has not been studied under Hypoxic Ischemic insult.To study the effect of GABAB receptor antagonist CGP 55845 on learning and memory in albino mice following hypoxia ischemia insult, 10 days old albino mice were subjected to Murine model of hypoxia and ischemia. Following brain damage, mice were fed on normal rodent diet till they were 13 week old. At this time point, mice were divided into two groups. Group 1 received saline and group 2 intrapertoneally CGP 55845 1mg/ml solvent/Kg body weight for 12 days. A battery of tests used to assess long term neurofunction along with brain infarct measurement. It was observed that, overall CGP 55845 improved the motor function in male and female albino mice but effects were more pronounced in male albino mice. In OF, CGP 55845 did not affect exploratory and locomotory behavior of male albino mice but female albino mice had poor results for this test. During MWM test, CGP 55845 had no significant effect on learning and memory formation in both genders following hypoxia ischemia encephalopathy.

[Topic1]Cognition

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2156(17:30 - 18:30)

Cognition: Lateralized behavior in the attacks of largemouth bass on freshwater gobies corresponding to their morphological antisymmetry

*Masaki Yasugi[1], Michio Hori[1]

Kyoto University[1]

Vertebrates show left–right biases in turning direction, limb usage, predator-escape response and use of sensory organs. In particular, some fishes are known to have such lateral biases corresponding to their morphological antisymmetry. To reveal the effects of these laterally biased behaviors on predator–prey interaction, we conducted behavioral tests of predatory events between largemouth bass and freshwater gobies, both of which have individuals with a well-developed left side and individuals with a well-developed right side. The left (right)-developed bass tended to approach the goby clockwise (counterclockwise) from behind. Congruently, left-developed gobies began their escape maneuvers at a longer distance from bass when they were approached clockwise than counterclockwise, whereas right-developed gobies showed the reverse tendency. The longer distance from bass at the start of goby escape delayed the subsequent bass strike. Therefore, predation should be more successful when a left (right)-developed bass meets a right (left)-developed goby. This prediction was consistent with the difference in predation success in our test and in field data. We conclude that lateral biases in the behavioral direction of each morphological type will generate bias in predation success between different combinations of predator and prey types.

[Topic1]Cognition

[Topic2]Ecology

Poster Session 2

PO-2157(14:30 - 15:30)

Cognition: Acquisition of a visual discrimination paradigm by use of secondary reinforcement in the zebra shark (*Stegostoma fasciatum*)

*Martin Lührmann[1,2], Guido Westhoff[3], Jenny A. Byl[2], Lars Miersch[2], Guido Dehnhardt[2]

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Based on behavioural evidence, some sensory but particularly cognitive abilities of large elasmobranchs are poorly understood and rarely investigated. Most studies utilize small specimen or small species, mainly due to space constraints in research facilities. In those studies, mazes are commonly used instead of complex behavioural training. Here, we demonstrate how an adult zebra shark (*Stegostoma fasciatum*) can be conditioned to perform a behavioural chain and learn a simple visual discrimination, while operating in an experimental parcours under open field conditions. This was achieved by applying secondary reinforcement in form of an acoustic stimulus. Secondary reinforcement has never before been reported to be successfully implemented into behavioural experiments with elasmobranchs. In contrast to previous studies, this method offers a useful means to investigate sensory and cognitive capabilities of large elasmobranchs on a behavioural basis, i.e. in public aquaria, without the need for structural measures. The observed learning durations exceeded those observed in previous studies focusing on comparable discrimination tasks. We propose that this discrepancy is caused by more extensive perceptual filtering processes due to a more complex experimental environment correlated with an increased number of distracting stimuli rather than substantial interspecific differences in learning capacity or learning speed.

[Topic1]Cognition

[Topic2]Novel Tools and Methods

Poster Session 2

PO-2158(15:30 - 16:30)

Social Behavior II: Light exposure affects reorganization of microglomeruli in the mushroom bodies and hormonal titers in the honeybee

*Christina Scholl[1], Ying Wang[2], Markus Krischke[1], Martin J. Mueller[1], Gro Amdam[2,3], Wolfgan g Roessler[1]

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Light represents an important sensory stimulus for animals and may affect circadian rhythms, orientation and navigational skills. Honeybee colonies depend on age-related division of labor, and first exposure to light is an important sensory stimulus at the transition from indoor duties (nurse bees) to outdoor duties (foragers). In this study we precociously exposed young bees to light. Subsequently, we quantified synaptic complexes (microglomeruli, MG) in the mushroom bodies (MB) and hemolypmph levels of juvenile hormone (JH). MBs are important centers for sensory integration, learning, and memory. The natural nurse-forager transition goes along with a JH increase and an associated decrease in vitellogenin (Vg). Precocious exposure to light triggered a significant decrease in MG numbers indicating synaptic pruning. Using gene knockdown to disturb both Vg and JH pathways, we tested whether these hormones are involved in MB synaptic remodeling. The results show that MG numbers remained unchanged. However, mass spectrometry JH detection revealed that precocious light exposure triggered a significant increase in JH hemolymph levels of young bees. This suggests a dual effect of light exposure via activity driven effects on MB synaptic plasticity and a potential positive feedback on JH hemolymph levels. Supported by GSLS, University of Wuerzburg.

[Topic1]Social Behavior

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2159(16:30 - 17:30)

Social Behavior II: Improving tracking accuracy of the software to track multiple honey bees, K-Track

*Toshifumi Kimura[1], Mizue Ohashi[1], Karl Crailsheim[2], Thomas Schmickl[2], Ryuichi Okada[1], Gerald Radspieler[2], Hidetoshi Ikeno[1]

University of Hyogo, Japan[1] , Karl-Franzens-University Graz, Austria[2]

To reveal the behavior of social animals, it is important to identify exact location of each individual. The honeybee is the one of social insects, and many researchers are researching it as a model animal. They can record the long-time behavior of bees using a digital video camera, easily, to analyze their movements. By contrast, it is difficult for them to obtain behavioral parameters from the recording movies. Even now, this work continues to require manual work of many researchers. In the past, we developed the software, K-Track, to track multiple bees, simultaneously (Kimura et al., 2014). However, the software cannot identify a bee near the wall, infrequently. In this presentation, to improve this problem, we are developing modified software using moving prediction based on moving history of each bee. We used four states, were classified by the Artificial Life Laboratory, Karl-Franzens-University Graz, as one-bee moving state and analyzed eight movies with 30-minute length. As the results, we made state transition diagram from the "current ” and “ former ” states of a bee. We also got the principle components of behavioral variation from five parameters using the Principle Component Analysis. We improve our software using both the diagram and principle components.

[Topic1]Social Behavior

[Topic2]Computation

Poster Session 2

PO-2160(17:30 - 18:30)

Social Behavior II: Queen controls dopamine levels of workers in an ant

*Hiroyuki Shimoji[1,2], Hitoshi Aonuma[2], Masato S. Abe[3], Kazuki Tsuji[4], Toru Miura[1], Yasukazu Okada[3]

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In eusocial insects, it has been believed that queen signal is the principle cue that regulates fertility of workers, which leads reproductive division of labor. Recently, some studies are focusing on dynamics of brain biogenic amines to reveal how queen signal regulates worker ’ s behaviors. In some species, dominance hierarchy is a key mechanism to regulate stability of the colony. Although previous studies indicated correlation between rank and amine level, little is known how such heterogeneity among individuals are caused. In *Diacamma* sp., the queen signal transfers to workers by direct contact with the queen, and dominance interaction among workers frequently occurs in colonies without queens or in large colonies. We firstly investigated correlation between worker rank and amine levels of worker ’ s brains (dopamine, serotonin, octopamine and tyramine) using colonies with the queen. The results indicate that octopamine level shows opposite pattern to the dopamine although dopamine level is higher in dominants than in subordinates. Secondly, we examined how amine levels change through isolation with the queen. We reveal that only dopamine level and the variance increase after 3 hours into isolation from the queen. Finally, we discuss the role of dopamine as a key factor constructing the hierarchy.

[Topic1]Social Behavior

[Topic2]Ecology

Poster Session 2

PO-2161(14:30 - 15:30)

Social Behavior II: The use of a controllable fly dummy to explore object recognition and visual tracking during courtship in *Drosophila*

*Sweta Agrawal[1], Steve Safarik[1], Michael H. Dickinson[1]

University of Washington, Dept of Biology[1]

Animals rely on sensory cues to classify objects in their environment and respond appropriately. However, the spatial structure of those sensory cues can greatly impact when, where, and how they are perceived. In this study, we examined the relative roles of vision and chemosensation during *Drosophila melanogaster* mate recognition using a robotic fly dummy that can be programmed to interact with individual or groups of flies via a sophisticated machine-vision system. By pairing male flies with dummies of various shapes, sizes, and speeds, or coated with different pheromones, we determined that visual and chemical cues play specific roles at different points in the courtship sequence. Vision is essential for determining whether to approach a moving object and initiate courtship: males were more likely to chase objects with the same approximate dimensions as another fly. However, once started, males continued chasing for a similar length of time regardless of the dummy ’ s shape. Female pheromones did not affect the probability of chase initiation, but did influence chase duration. Male pheromone both inhibits chase initiation and shortens chase duration. Thus, visual cues are dominant when males decide whether to approach an object whereas chemosensory cues determine how long the male continues pursuit.

[Topic1]Social Behavior

[Topic2]Sensory: Vision

Poster Session 2

PO-2162(15:30 - 16:30)

Social Behavior II: Characterization of synchronous waving display in the ocypodid crab *Ilyoplax pusilla*

*Akira Hirose[1], Jiro Okada[1], Kensho Fujisaki[2], Seiichi Uchida[2]

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The males of many ocypodid crab species exhibit a characteristic mating behavior on the surface of mudflats—repeated up-and-down movements of the claws—which is used to attract mates during the breeding season. It is known that this behavior, termed waving, is often synchronized with the movements of neighboring crabs. In this study, we investigated waving in *Ilyoplax pusilla* using specially developed motion analysis software. Adult male crabs collected from a mudflat in Nagasaki Prefecture, Japan, were transferred to an artificial mudflat system in the laboratory and maintained for 1 to 2 weeks under routinely controlled light/dark (LD) and tidal conditions. In each container of the artificial mudflat were placed 15 male crabs, and their waving behavior during the light and low-tide period was video-recorded daily for approximately 1 hour. Both group and individual waving activities were registered frame-by-frame at 30 Hz. The group waving activity tended to change according to the natural tidal rhythm, even under the daily fixed LD and tidal conditions. Spectral analyses of the group waving activities showed that the peak frequencies appeared at around 1.2 Hz. The variation in the extent of waving synchronization is discussed with respect to possible environmental factors.

[Topic1]Social Behavior

[Topic2]Ecology

Poster Session 2

PO-2163(16:30 - 17:30)

Social Behavior II: Male skill and female discrimination: Female bark beetles prefer male calling performances that include chirps containing complex motor patterns

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Carleton University[1]

Bark beetles (Scolytinae), a group of ecologically and economically important insects, produce complex acoustic signals during interactions with conspecifics. Yet, there is limited understanding of the functional significance of these signals. Using the red turpentine beetle (*Dendroctonus valens*), we tested the hypothesis that females choose males based on pre-mating signal characteristics. It was found that larger males produce more chirps at a faster rate. Moreover, males produce two distinct types of chirps - simple and interrupted - and larger males will produce more interrupted chirps. Females assessed a male based on whether he included interrupted chirps in his performance. Males that included any interrupted chirps were successful at gaining entry 100% of the time, while males that produced exclusively simple chirps were rejected as often as males that were silenced. The motor skill and vigor required to produce interrupted chirps may make them a more energetically costly display: using high speed video analysis, we found that complex movements of the abdomen are required to generate interrupted chirps, and they are longer and often produced at a faster rate than simple chirps. We suggest that interrupted chirps serve as a proverbial ‘ password ’ for male entrance to a female's gallery.

[Topic1]Social Behavior

[Topic2]Ecology

Poster Session 2

PO-2164(17:30 - 18:30)

Social Behavior II: The presence of an audience affects male mouse ultrasonic vocalization behavior

*Kelly M. Seagraves[1,2], Ben J. Arthur[2], S.E. Roian Egnor[2]

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Adult mouse ultrasonic vocalizations are a behavioral display elicited by the presence of conspecifics and can therefore be used as a tool for investigating the neural circuits underlying social behavior. However, the function of these vocalizations is widely unknown, and our understanding may be limited by the common practice of studying vocal behavior in the context of social dyads. To address this gap, we investigated the effect of an audience on the male production of female-odor-elicited ultrasonic vocalizations. We found that both vocalization rate and the proportion of complex vocalizations increased when a male mouse was exposed to female urine in the presence of another male, as compared to when no audience was present. Male urine and playbacks of male ultrasonic vocalizations were insufficient to elicit the observed vocal changes associated with the presence of an audience, but an anesthetized male audience partially reproduced the effect. Finally, similar changes in vocal behavior were observed when the sex of the audience was female instead of male. These results provide evidence that audience effects play a role in the production of mouse ultrasonic vocalizations.

[Topic1]Social Behavior

[Topic2]Sensory: Audition

Poster Session 2

PO-2165(14:30 - 15:30)

Social Behavior II: A cross-species socio-emotional behaviour development revealed by a multivariate analysis

*Mamiko Koshiba[1], Genta Karino[1,2], Koki Mimura[3], Shun Nakamura[1], Masanori Shukuya[4], Hirohisa Kishino[5], Tetsuya Kunikata[1], Hideo Yamanouchi[1]

Saitama Medical University[1] , Tokyo University of Agriculture and Technology[2] , National Center of Neurology and Psychiatry[3] , Tokyo City University[4] , University of Tokyo[5]

Recent progress of computation analysis technology has contributed in affective neuroscience and social neurobiology. The complex neuronal mechanisms may be able to be suspected by integration of multiple information from psychology, neuro-imaging, molecular biology and physiology based on behavioral dynamics. It needs also comparative research approach over species with a certain common quantitative manner. We developed a method for socio-emotional behavior measurement that is based on the video recordings under well-defined social context in animal models, domestic chicks and two primate species, common marmoset and human. Many kinds of multivariate statistical analyses to seek any correlation must let us inspect the neuronal network with information structures in spatiotemporal analytic visualization. We attempted to use mainly principal component analysis. The clustering of heterogeneous parameters on it suggested the existence of species- and stage-specific as well as cross-species behavior modules. These modules were used to characterize the children behavior with or without autism spectrum disorders (ASDs). We found that socio-emotional behavior is highly dependent on social context and the cross-species behavior modules may predict neurobiological basis of social developmental disorders. In our latest approach in preterm infants, these translation seemed to be helpful to acquire the primitive but possibly predictive initial development.

[Topic1]Social Behavior

[Topic2]Computational Modeling

Poster Session 2

PO-2166(15:30 - 16:30)

Social Behavior II: The effect of ubiquinol supplementation and training after sensitive period on acquiring social skill in avian model

*Genta Karino[1,2], Hideo Yamanouchi[2], Tetsuya Kunikata[2], Wakako Tsugawa[1], Koji Sode[1], Shun Nakamura[1], Mamiko Koshiba[1,2]

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Socio-emotional behaviors are diagnostic factors to understand developmental disorders like autistic spectrum disorders. Previously, we established a methodology to assess the growth of peer-social skills in domestic chick (*Gallus gallus*) of white leghorn. It had been shown that grouped chicks (Grp) could form the social skills but isolated chicks (Iso) could not. Furthermore, there might exist a sensitive period to learn the social skills around postnatal one week (K. Mimura, 2013, M Koshiba, 2013). In this Iso model, we attempted to explore any possible educational treatments even after the sensitive period. We focused on a strategy of nutritive control, particularly, with antioxidant, ubiquinol (QH), reported its positive effect in primate psychology (Shirakawa, 2013). Iso chicks fed QH from postnatal day 5 (P5) to 21, and experienced social skill training from P13 to 15, named Iso-QH. To trace their behavioral development of social skills, it was evaluated at three phases, P13, 16 and 21 with multivariate correlation analysis, BOUQUET. Consequently, Iso-QH showed Iso-like behavior in P13, but were gradually getting to express Grp-like behaviors through P21. This result might suggest some synergistic effects with both QH supplementation and social skill training as an instance of complex treatment program

[Topic1]Social Behavior

[Topic2]Development

Poster Session 2

PO-2167(16:30 - 17:30)

Social Behavior II: Nucleus taeniae of the amygdala (TnA) lesions affect song learning in Bengalese finches

*Maki Ikebuchi[1,2,3], Sanae Nanbu[3], Kenta Suzuki[2,3,4], Hans-Joachim Bischof[5], Kazuo Okanoya[1,2,3]

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Social interaction is one of the most important factors in avian song learning and human language acquisition. Nucleus taeniae of the amygdala (TnA) is one of the avian brain areas involved in social behavior control. We speculated that TnA also contributes to song learning in birds. To test this idea, young Bengalese finch males that received a operated TnA lesion with ibotenic acid. After surgery, they were housed with their family until adulthood. When older than 150 days, we compared the songs of the lesioned males with those of the brothers and of the fathers. The comparison revealed that lesioned birds uttered smaller numbers of song elements than the brothers and the fathers. Song length was not significantly different. The variability of song length, which is higher in directed songs (DS) compared with undirected songs (US) in normal Bengalese finches, was not significantly different in lesioned birds. A characteristic click sound made by the bill was more frequent in DS compared with US, and the speed of the song was higher in DS than US in all groups of birds. The detected alterations in lesioned birds support the idea of an involvement of TnA in song learning.

[Topic1]Social Behavior

[Topic2]Development

Poster Session 2

PO-2168(17:30 - 18:30)

Social Behavior II: Development of brain and behavioural asymmetries

*Peter, L. Hurd[1], Michele, K. Moscicki[1]

University of Alberta[1]

Recent interest in the biological basis of individual differences in behavioural propensities has resulted in an explosion of studies aimed at finding the evolutionary or ecological causes of this variation. Here we describe experimental attempts to create fish with personalities that vary along the proactive-reactive stress coping style dimension, and a study of the development of the relationship between these traits and individual variation in growth rate.

[Topic1]Social Behavior

[Topic2]Development

Poster Session 2

PO-2169(14:30 - 15:30)

Social Behavior II: Limits on evolution in correlated suites of traits

*Eva K. Fischer[1], Kim L. Hoke[1]

Colorado State University[1]

Mechanistic links among behaviors shape the evolutionary trajectory of those behaviors, as suites of behaviors that depend on shared mechanisms cannot independently evolve in response to selection pressures. Neuroendocrine systems typically influence multiple behaviors that may be important for survival and reproduction, suggesting that hormone and neuromodulatory systems may influence the joint evolution of multiple behavioral traits. We took advantage of individual differences in behavior of Trinidadian guppies (*Poecilia reticulata*) to explore to what extent the correlated evolution of behavioral traits is influenced by shared neuroendocrine mechanisms. We assayed courtship, aggression, and openfield behaviors and measured estrogen, testosterone, 11-ketotestosterone and cortisol levels. We found that courtship, aggression, and openfield behaviors were correlated with one another. Lower estrogen levels were associated with increased courtship behavior, and higher testosterone levels were associated with increased aggression. Hormonal influences on social behaviors did not mediate behavioral trait correlations in guppies. Ongoing work is examining reliance on neuromodulators as an alternative mechanism by which behavioral correlations arise.

[Topic1]Social Behavior

[Topic2]Evolution

Poster Session 2

PO-2170(15:30 - 16:30)

Neuroanatomy: Convergent evolution of ear loss in bufonids

*Molly C. Womack[1], Jakob Christensen-Dalsgaard[2], Kim Hoke[1]

Colorado State University[1] , University of Southern Denmark[2]

Most terrestrial vertebrates have outer and middle ear structures to transmit airborne sound from the environment to the inner ear sensory cells. Frogs and toads (anurans) are no exception; most anurans use middle and outer ear structures to transmit mate calls and other acoustic communications. Yet, all over the world numerous anuran species independently evolved " earlessness " , the loss of middle and outer ear structures. Our work aims to determine whether direct selection, relaxed selection and/or pleiotropy are responsible for the rampart ear loss and regains in the bufonid (true toad) family. To distinguish among these evolutionary modes, we are investigating the physiological consequences and the structural modifications associated with earlessness by comparing hearing and morphological data of eared and earless bufonid species within a phylogenetic context. Our neurophysiological data shows that earless species are less sensitive to acoustic stimuli at high frequencies and typically more sensitive to vibration at lower frequencies when compared to eared toads. Our morphological data reveals patterns of skull modification across ear loss and regain events. We conclude that earlessness is likely driven by pleiotropy, facilitated by relaxed selection and that directional selection possibly plays a role but requires more natural history studies.

[Topic1]Evolution

[Topic2]Sensory: Audition

Poster Session 2

PO-2171(16:30 - 17:30)

Neuroanatomy: Inner ear determinants of sensitivity in bats and cetaceans: curvature and inputs

*Darlene R. Ketten[1,2,3], James Simmons[4], Hiroshi Riquimaroux[5]

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The similarity of odontocete and microchiropteran auditory tasks suggests they have common ultrasonic signal processing mechanisms but there are media and prey dependent differences; e.g., peak spectra and interaural time differences. We compared ears of four species of bats and dolphins (*Eptesicus fuscus, Pipistrellus abramus, Phocoena phocoena, Tursiops truncatus)* with mid and low frequency ears via 11 to 100 micron isotropic voxel helical and microCT (http://csi.whoi.edu). Species-specific auditory anatomies varied significantly for inner ear length, basilar membrane gradients, neural distributions, curvatures, and membrane suspension. Length correlates with body mass, not hearing ranges. High and low frequency cut-offs correlated with basilar membrane ratios and the radius of curvature. These features are predictive of high and low frequency hearing limits in all ear types. The ears of the echolocators had significantly greater stiffness, higher basal basilar membrane ratios, and bilateral bony support up to 60% of the basilar membrane. Some species had “foveal” regions with “stretched” frequency representation. Echolocators had high basal stapedial inputs and more complex curvatures, which may reduce low frequency cochlear penetration and enhance high frequency signal resolution. Supported by Western Australia Premier’s Fellowship, NIH, JIP, LMR-US Navy, N45/EnvDiv, and ONR Global.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Sensory: Audition

Poster Session 2

PO-2172(17:30 - 18:30)

Neuroanatomy: Tomographic analyses of afferent synapses in utricular hair cells

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We are utilizing conical transmission electron microscopy (TEM) tomography and serial section field emission scanning EM to investigate the comprehensive ultrastructure of ribbon synapses within utricular hair cells. The objectives are to elucidate morphologic heterogeneities based upon hair cell type and utricular topography, in order to ultimately investigate synaptic plasticity associated with adaptations to spaceflight. The specimens for this study were obtained from mice that served as controls for the Russian BION M1 biosatellite mission. Serial section reconstructions revealed that the synaptic ribbons (SRs) extend up to 1μm into the hair cell, further than previously appreciated. The most prevalent morphology of SRs is plate-likeorganized individually or in multiple SR complexes. Close apposition of SRs with the presynaptic membrane is limited, indicating that the area of the active zone is confined despite the large complex of SRs and vesicles. Analyses of SRs and synaptic vesicles enabled by tomography indicate mean vesicle diameters of 37.5 ± 3.8 nm, without apparent heterogeneity associated with hair cell type or utricular topography. SR-vesicle distances may exhibit heterogeneity associated with utricular topography. These analyses are contributing to a more comprehensive understanding of synaptic physiology and how it may adapt to demands of altered sensory environments.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2173(14:30 - 15:30)

Neuroanatomy: Mouse ultrasounds activate auditory cortical fields and layers differentially according to the “ meaning ” of the sounds

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Mother mice preferentially respond to pup ultrasounds right after delivery, virgin females need more than 1 day experience with pups for perceiving the acoustic quality of ultrasounds to prefer them against inadequate call models (Ehret & Buckenmaier, *J Physiol Paris* 88, 315-329, 1994). On that background of perception, we studied activation of the auditory cortex (AC) in mothers and virgins with 1 or 5 days pup-experience while perceiving adequate or inadequate ultrasound models. Neural activation was shown via c-FOS immunocytochemistry and quantified by counting strongly labelled cells (Geissler & Ehret, EJN 19, 1027-1040, 2004) in the 6 cellular layers of 5 AC fields in the left and right brain hemisphere. We found biological significance (“ meaning ”) not represented in activation of three primary fields (AI, AAF, UF). Labelling patterns in the higher-order field AII (second auditory field) discriminated between instinctive and learned perception. Ultrasound recognition occurred as left-hemisphere dominant labelling in the higher-order field DP (dorsoposterior field) which also reflected differences in motivation to respond. Differences in activation showed up most clearly in cortical layers 2/3 in all fields. Cognitive and emotional/motivational evaluation of communication sounds is a domain of higher-order AC in the mouse (supported by the DFG, EH 53/20).

[Topic1]Sensory: Audition

[Topic2]Cognition

Poster Session 2

PO-2174(15:30 - 16:30)

Neuroanatomy: Different brain activity, measured by immediate early genes expression, in chicks exposed to a predisposed or a non-predisposed social stimulus

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Center for Mind/Brain Sciences, University of Trento[1]

The ability to detect animate creatures is of biological relevance and is apparent in newborn vertebrates. Based on the finding that naive chicks (Gallus gallus domesticus) preferentially approach a stimulus resembling a conspecific rather than an artificial object we aimed to investigate the neuronal mechanisms that mediate this early predisposition by staining the immediate early gene products (c-Fos and ARC).
In a spontaneous choice test, we obtained a significant preference for approaching the stuffed fowl over a scrambled fowl (pieces of an identical fowl assembled without anatomical regularity). This stimulus, provided an optimal control condition for brain activity studies, being matched to the fowl in colour, luminance and texture. Comparison of brain activation of chicks that approached the stuffed fowl with those that approached the control stimulus revealed differential activation in an area relevant for imprinting (IMM), suggesting that a different level of plasticity is associated with approach to predisposed and non-predisposed stimuli. Both IEG products where present also in some layers of the optic tectum whereas only ARC was present in the nucleus rotundus. These areas belong to the main visual pathway in birds and represent plausible candidates for processing early social predispositions.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Social Behavior

Poster Session 2

PO-2175(16:30 - 17:30)

Neuroanatomy: Seasonal plasticity in the telencephalon of a non-songbird, the Ruffed Grouse (*Bonasa umbellus*)

*Andrew N. Iwaniuk[1], Justin M. Krilow[1]

University of Lethbridge[1]

Decades of research have shown that songbirds undergo major seasonal changes in song and the size of associated brain regions. Whether non-vocal courtship behaviours are accompanied by similar seasonal changes in brain regions has, however, remained largely uninvestigated. Here, we examine seasonal changes in the brain of a wild galliform that relies on non-vocal courtship display, the Ruffed Grouse (*Bonasa umbellus*). Unlike related species, Ruffed Grouse do not use vocalizations, but instead generate a low frequency ‘ drumming ’ sound through rapidly beating their wings during the spring breeding season. Using unbiased stereology, we measured the sizes of multiple brain regions in males collected in spring and fall. We found no significant differences in brain, telencephalon or cerebellar volumes between spring and fall males. Further examination of the telencephalon, however, revealed that spring males have significantly larger arcopallial and basal ganglia volumes than fall males. Not only do these results indicate that seasonal plasticity in the telencephalon is not restricted to songbirds, it also demonstrates that non-vocal courtship behaviours vary with neuroanatomy in a similar fashion to that of song and the song system.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Ecology

Poster Session 2

PO-2176(17:30 - 18:30)

Neuroanatomy: Dopaminergic neurons in the brain of the cockroach, *Peri planeta americana*

***Yoshitaka Hamanaka[1], Makoto Mizunami[1]**

Graduate School of Life Science, Hokkaido University[1]

The catecholamine dopamine encodes aversive information in associative learning. Despite of the importance, however, the distribution of dopaminergic neurons has been largely overlooked in *P. americana* brains. As the first step to understand a neural basis underlying aversive learning, we studied their distribution using two antibodies against dopamine itself and tyrosine hydroxylase (a rate-limiting enzyme for dopamine biosynthesis), especially focusing on a higher brain center to process odor information, that is, the mushroom body (MB). The MB is composed of intrinsic neurons, namely Kenyon cells, and comprises the calyx, pedunculus and lobe; the calyx being a dendritic and the lobe being a terminal site for Kenyon cells. Both antibodies labeled almost the same populations of neurons in the brain. Among these, the most promising candidate participating in learning is a set of dopamine-immunoreactive neurons with the somata close to the calyx and with the axons projecting to the vertical lobes. This is why our accumulated pharmacological data propose that i) memory retrieval induced by conditioned odor and ii) synaptic reinforcement accompanied by associative learning occur in the vertical lobe. Besides the MB, the central body, which is involved in visual leaning of *Drosophila*, is also supplied with rich dopamine-positive fibers.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2177(14:30 - 15:30)

Neuroanatomy: Neural circuitry of insect antennal mechanosensors

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Apart from being primary olfactory organs, insect antennae serve important mechanosensory functions including tactile sensation, audition, flight stabilization etc. Insect antennae consist of two primary sets of mechanosensors- the Böhm ’ s bristles (or hair plates) and Johnston ’ s organs. Böhm ’ s bristles are arranged in distinct fields on basal segments of the antennae and mediate antennal positioning response through rapid, direct activation of the underlying muscles. Johnston ’ s organs, on the other hand, consist of several hundred scolopidial units spanning the pedicel-flagellum joint. These range-fractionated sensors respond to minute flagellar vibrations and mediate audition, graviception, etc. We investigated central projection patterns of antennal mechanosensors in the Oleander hawkmoth *Daphnis nerii* using fluorescent neuronal tracers. Böhm ’ s bristle axonal arbors overlap extensively with dendritic arbors of antennal motor neurons within the ipsilateral Antennal Mechanosensory and Motor Centre (AMMC) in the brain. In contrast, scolopidial arbors appear spatially distinct from antennal motor dendritic arbors. Because the basic antennal architecture is conserved across diverse insects, we comparatively surveyed antennal mechanosensors in insects. Preliminary indications show that Böhm ’ s bristle-like structures occur in diverse insects, and they may be ancestral features in Neopteran insects. These studies aim to relate the structure, function and evolutionary history of antennal mechanosensory systems.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2178(15:30 - 16:30)

Neuroanatomy: New insights into the connectivity between photoreceptor cells and two large interneurons in the locust lamina

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To understand the processing of visual information it is vital to know how signals are transmitted in a neuronal circuit.
We investigated the connectivity between photoreceptors (R-cells) and two large interneurons L1 and L2 in the lamina of the locust, *Schistocerca gregaria*. For this purpose a 3D-reconstruction of these cells is indispensable and the new electron microscopy technique SBEM (Serial block-face scanning electron microscopy) was utilized. Sectioning throughout the lamina was performed at 70 nm thickness over 45 µm in total. The detailed reconstruction revealed not only the distribution of input and feedback pathways, but also the presence of dyads, triads and tetrad synapses onto L1 and L2. L1 and L2 differ in their size and in the number of synapses they receive or make with R-cells. The bigger one, L1, has more synapses from R-cells (input), onto R-cells (feedback) and with unclassified neurons, in total (283) than L2 (89). One interesting finding is that a feedback pathway exists between L1 and R-cells but not between L2 and R-cells. Examining each synapse in 3D helped us identify all the postsynaptic partners and revealed that up to 40 % of the synapses between R-cells and L1 or L2 are tetrads.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Sensory: Vision

Poster Session 2

PO-2179(16:30 - 17:30)

Neuroanatomy: Ocellar structure and neural innervation in the honeybee

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National Vision Research Institute, Australian College of Optometry[1] , Department of Optometry and Vision Sciences, University of Melbourne[2]

Honeybees have a visual system composed of three ocelli (simple eyes) located on the top of the head, in addition to two large compound eyes. In this study, we present three-dimensional (3-D) reconstructions and optical properties of the honeybee ocelli to assist in determining the role of ocelli in honeybees. The 3-D model shows the viewing angles of the ventral and dorsal retinas of each ocellus. The dorsal retinas view the horizon while the ventral retinas view the sky, suggesting quite different roles in attitude control. Using the hanging drop technique, it is shown that the lateral ocelli have considerably higher spatial resolution compared to the median ocellus. In both types of ocellus the dorsal retina has a higher spatial resolution than the ventral retina. In addition, we established the inputs of the five pairs of large ocellar descending neurons in relation to the retinas. Four of the neuron pairs had their dendritic fields in the dorsal retinas of the lateral ocelli, while the fifth had fine dendrites in the ventral retina. One of the neuron pairs also sent very fine dendrites into the border region between the dorsal and ventral retinas of the median ocellus.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Sensory: Vision

Poster Session 2

PO-2180(17:30 - 18:30)

Neuroanatomy: Reproducible segmentation method of neural morphology from LSM images

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The morphology of a neuron must affect its response property and connectivity. We have been investigating a vibration sensitive neuron in the honeybee brain, named DL-Int-1, by reconstruction of the morphology from its confocal images. A reproducible segmentation method is indispensable for evaluation of the morphological properties quantitatively. In this study, we provide a semi-automatic protocol for segmentation and reconstruction of neurons based on the combination of image processing methods. In our protocol, several image processings, deconvolution, binalization and noise reduction, are applied to obtain the neuron image in regular quality. Our original software, SIGEN, automatically segments and reconstructs neuron structure. In this software, fragmentations in images are connected based on the least both distance between fragmented segment and the branch, and its volume. The error connections in thick branches are manually corrected based on the continuity and direction of branches. We can check the reconstructed structure on some image viewers. Our method was tested on the confocal image data of olfactory nerves in the DIADEM-challenge. We could get reliable results on them, and then, applied for analyzing morphological difference of DL-Int-1 by age. The DL-Int-1 of the newly emerged bees has very dense structure in comparison of forager bees.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Computational Modeling

Poster Session 2

PO-2181(14:30 - 15:30)

Neuroanatomy: Brain atlas of pygmy squid, *Idiosepius paradoxus*

*Motoki Koizumi[1], Nobuaki Tanaka[1]

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Cephalopods have very unique behaviors, for example camouflage and also show some intelligent behaviors such as observational learning. Although these behaviors have fascinated many biologists, the brain functions underlying these behaviors still remain unclear. To understand the mechanisms, we have started to analyze the brain circuit of pygmy squids *Idiosepius paradoxus* as a model (*I. paradoxus* is kindly provided by Dr Takashi Kasugai, Nagoya Public Aquarium), because an adult whole brain, even deep areas, can be observed under a conventional confocal microscope without slicing. In addition, this smallest animal has similar behaviors such as camouflage as observed in other squids. By clearing the central brain accompanying the optic lobes, pedal lobe, and chromatophore lobe with methyl salicylate, we measured the volume of each lobe and its content from the confocal images of them and also analyzed the connectivity between sensory systems. The sexual dimorphisms in the volume of these lobes will be discussed.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Evolution

Poster Session 2

PO-2182(15:30 - 16:30)

Neuroanatomy: The unusual brains in deep-sea hydrothermal vent environment: the neural circuitry and multi-layer cellular wrappers of alvinellid worms

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The deep-sea alvinellid worms, the hydrothermal vent endemic species, have considered as one of the most thermotolerant animals on record with their adaptability into the toxic heavy metals, highly reductive, and oxidative stressful environment. Despite a number of recent studies focused on the stress proteins, it remains uncertain how the sensory and neural centers could resist in such harsh condition. We have addressed this question through the ultrastructural and neuroanatomical studies for the epidermal ciliated sensory cells and their higher brain centers. We observed the mitochondria rich and many electron dense granules in these cells, and found the specialized glial cells and serial myelin-like repeats for the head chemosensory systems of the worms. Also, the major sensory pathways were identified, in which we found a pair of distinct mushroom bodies or small interneuron clusters know as a typical chemosensory learning and memory system in insects and annelids. Our evidences shed light on the novel cellular and system-wide adaptive structure to sense, process, and act against the deep-sea hydrothermal vent environment.

[Topic1]Anatomy & Neuroanatomy

[Topic2]Evolution

Poster Session 2

PO-2183(16:30 - 17:30)

Neuroanatomy: Brain DNA damage may cause reduced longevity in WNIN obese rats

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Early accumulation of DNA damage in brain can result in devastating genetic instability and wide array of physiological problems. WNIN obese rats have significantly reduced longevity (average lifespan of 15-18 months). The extent of DNA damage in brain was studied as a hallmark of senescence in order to establish this rat as a model of aging related studies. DNA damage was assessed at the single cell level in neocortex and hippocampus of WNIN obese rats, WNIN lean littermates and normal WNIN controls at 3 and 15 months of age by Comet Assay. The samples were processed for neutral and alkaline electrophoresis, followed by fluorescent staining and analysis. The extent of DNA damage in the form of single-strand breaks (SSBs) as well as double-strand breaks (DSBs) in cells of neocortex and hippocampus of young WNIN obese rats was comparable with those seen in the 15 months old normal WNIN rats. Interestingly the extent of SSBs and DSBs in young WNIN lean littermates and WNIN controls were comparable. Onset of significant DNA damage in different brain regions of obese rats at a much younger age is a plausible cause of reduced longevity observed in this novel obese rat model.

[Topic1]Cellular Properties

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2184(17:30 - 18:30)

Neuromodulation: Administration of glucocorticoids ameliorates cerebral neuronal damage in heat stroke

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An exogenous glucocorticoid, dexamethasone, is a known immunosuppressive drug used in controlling inflammation. In the present study, we purpose that dexamethasone acts to diminish the hypercoagulable state and reduce overproduction of pro-inflammatory cytokines, and eventually improve the arterial hypotension, cerebral ischemia and damage, and vital organs failure in rats of heat stroke. The results indicate that all heat-stressed animals displayed systemic inflammation and activated coagulation, evidenced by increased tumor necrosis factor-α and interleukin-1β, prothrombin time, activated partial thromboplastin time, and D-D dimer, and decreased protein C. Biochemical markers evidenced cellular ischemia and injury/dysfunction: plasma levels of blood urea nitrogen, creatinine, glutamic oxaloacetic transaminase, glutamic pyruvic transaminase, and alkaline phosphatase, and striatal levels of glycerol, glutamate, and lactate/pyruvate were all elevated during heat stroke. In contrast, the values of MAP, plasma levels of interleukin-10, and striatal levels of local CBF were all significantly lower during heat stroke. The circulatory dysfunction, systemic inflammation, hypercoagulable state, and cerebral ischemia and damage during heat stroke were all significantly suppressed by dexamethasone. These findings demonstrate that treatment with dexamethasone therapy may ameliorate heat stroke victims by attenuating activated coagulation, systemic inflammation, and vital organs injury during heat stroke.

[Topic1]Neuromodulation

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2185(14:30 - 15:30)

Neuromodulation: Neuropeptide control of host-seeking behavior in *Aed es aegypti*

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Female *Aedes aegypti*, the primary dengue vector, require blood from hosts to develop and lay eggs. These mosquitoes show a strong attraction to human hosts when seeking a blood source. After a blood meal, attraction to host cues, such as CO_2 and human odor, is suppressed until the female lays her eggs up to 4 days later when she will seek another blood meal. The cycle of blood feeding and egg laying is critical to disease transmission. Although early stages of host-seeking suppression are mediated by abdominal distension, neuropeptide signaling is likely involved in maintaining behavioral inhibition. NPY-related signaling pathways have previously been implicated and we show evidence that a class of NPY-like receptors mediate host-seeking suppression following a blood meal. Using a behavioral screen of host-seeking we identify biologically active agonists and antagonists that modulate this behavior. Using a cell based assay, we implicate specific members of this receptor class as targets of the compounds identified in our behavioral screen. Current work focuses on using CRISPR/Cas system to generate targeted mutations to the genes encoding these receptors. Identification of the signaling underlying host-seeking behavior may inform the development of novel methods of pest and disease control.

[Topic1]Neuromodulation

[Topic2]Genes and Behavior

Poster Session 2

PO-2186(15:30 - 16:30)

Neuromodulation: Cholinergic regulation and in vitro reconstitution of synchronized oscillatory networks in the olfactory center of the slug, *Lima x valentinaus*

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Synchronous oscillatory activity is common in the olfactory behavior of both vertebrates and invertebrates. In the terrestrial slugs, periodic oscillation is recorded from the surface of the laminar structure of procerebrum (PC) and its frequency changes are suggested to encode the olfactory information and memory. Acetylcholine (ACh) is known to increase the frequency of the local field potential (LFP) oscillation in the PC. In the present study, we thus examined what role cholinergic system plays in the PC oscillatory network of *Limax valentianus*. First, the acetylcholinesterase (AChE) inhibitor enhanced the excitatory effect of ACh, and furthermore, AChE alone increased frequency of the LFP oscillation in the PC. Second, nicotine increased the LFP frequency and induced the inward Cl^- currents of the PC neurons. Third, the synchronized oscillatory networks composed of the cultured PC neurons were activated by the application of nicotine or AChE inhibitor. These results show ACh can function as an excitatory transmitter for PC neurons via mainly nicotinic ACh receptors activation. Finally, enhancement of the nicotine-induced LFP increase after the olfactory tentacle amputation suggests the presence of feedforward inhibition in the cholinergic afferents from the tentacles to the PC.

[Topic1]Neuromodulation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2187(16:30 - 17:30)

Neuromodulation: Intrinsic membrane properties of acutely dissociated Kenyon cells and their modulation by nitric oxide signaling pathway

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To characterize the properties of the ionic currents mediating excitability of Kenyon cells, we recorded from neurons acutely dissociated from the mushroom bodies of adult cricket and present data on whole cell Na (fast and persistent type), Ca (DHP-sensitive L-type), and Na-activated K currens, and single BK channel currents.During the course of this study, we found the presence of functional coupling between persistent Na channel and Na-activated K channel, and also the functional coupling between Ca channel and BK channel. To determine how these ionic channels contribute to neuronal firing properties, we examined the effect of drugs that target different current components on evoked and spontaneous firing. Next, I examined how these ionic channels are modulated by the nitric oxide (NO)/cGMP/PKG signaling pathway. Our results indicate that activation of NO/cGMP/PKG pathway could modify these ionic channels. NO donor increased the open probability (Po) of Ca channel and BK channel whereas decreased the Po of the Na-activated K channel via cGMP/PKG signaling pathway. NO donors also increased both the fast and persistent Na currents. As a result of these modulatory action of NO, the membrane excitability of Kenyon cells increased remakably. The functional significance of the increased membrane excitability by NO is discussed in relation to the formation of associative olfactrory long term memory.

[Topic1]Neuromodulation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2188(17:30 - 18:30)

Neuromodulation: A NO/cGMP pathway modulates the rhythmic bursting activity of swimmeret motor neurones in the crayfish

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Yamagata University[1]

Free radical nitric oxide (NO) is a well known neuromodulator that affects neural circuits, in particular, rhythmic motor activity induced by central pattern generators (CPGs). The swimmerets are paired appendages located on the ventral side of each segment of the crayfish abdomen and show rhythmic beating activity during forward swimming. The modulatory effects of NO upon the beating activity of the swimmeret motor neurones were examined. In an isolated abdominal nerve cord preparation, swimmeret motor neurones were usually silent. Application of 8 μM carbachol, a cholinergic agonist, elicited rhythmic bursts of motor neurone spikes. The co-application of L-arginine, the substrate for NO synthesis with carbachol increased the beating frequency of the motor neurones. The co-application of NO donor, SNAP also increased the beating frequency of the motor neurones. By contrast, co-application of a NOS inhibitor, L-NAME decreased beating frequency of the motor neurones. Furthermore, co-application of a membrane-permeable cGMP analogue, 8-Br-cGMP, with carbachol increased bursting frequency of the motor neurones. The facilitatory effect of L-arginine was cancelled by co-application of a sGC inhibitor, ODQ. These results suggested that NO activated sGC to promote the production of cGMP that affected rhythmic beating activity of the swimmeret motor neurones.

[Topic1]Neuromodulation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2189(14:30 - 15:30)

Neuromodulation: Modulation of dopamine signaling in honey bees by 20-hydroxyecdysone

*Charles W. Ellen[1], Alison R. Mercer[1], Uli Müller[2]

Otago University[1] , Universität des Saarlandes[2]

A honey bee ' s ability to associate environmental cues with reward or punishment is vital for its survival and important for the success of the colony as a whole. Recent studies indicate that aversive learning in the honey bee, *Apis mellifera*, can be modulated by 20-hydroxyecdysone (20HE), the active metabolite of the steroid hormone, ecdysone (Geddes *et al*. Learn. Mem. 2013 20:399-409). We are interested in the mechanisms that underlie the modulatory actions of 20HE. As dopamine released at the level of the mushroom bodies (MB) of the brain is postulated to be a key player in the neural events that underlie aversive learning, we examined the effects of 20HE first, on dopamine-induced changes in intracellular cAMP and calcium in the MB intrinsic neurons (Kenyon cells), and second on the expression of dopamine receptor genes in these cells. We found that physiologically relevant levels of 20HE enhance the cAMP response to dopamine, and increase the expression of dopamine receptor genes in MB neurons. The amplitude of DA induced calcium signals, on the other hand, was not affected by 20HE. Our data may help explain the modulatory effects of 20HE on aversive learning performance in the honey bee.

[Topic1]Neuromodulation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2190(15:30 - 16:30)

Neuromodulation: Efferent octopaminergic innervation of the honeybee antennal system

Stephan Shuichi Haupt[1]

Bielefeld University[1]

Sensory neurons in insect appendages are known to display sensitivity changes in response to stimuli that are correlated with factors such as satiation state and circadian rhythyms. In numerous species, exogenous biogenic amines have induced similar changes and are supposed to be the substances acting on the sensory neurons. In several hymenopterans as well as the cricket, two ventral or dorsal unpaired median neurons (VUM/DUM) of the suboesophageal ganglion are known to innervate the antennal system. In the honeybee, these neurons can be labeled through the antennal nerve and are shown to be octopaminergic (OA) by immunohistochemistry. Since there are no other OA neurons in the antennal and antennal motor nerves, all OA fibers in the antennal system belong to the two antennal VUM neurons. OA innervation has been demonstrated in the scapus and pedicellus muscles as well as in the pedicel and the flagellum. Varicosities of OA fibers are found in the vicinity of somata and processes of many types of sensory neurons, for instance cells of Johnston's organ, of taste hairs, and different types of olfactory sensilla. Work is under way to determine sensory modulation by endogenous OA and the natural circumstances under which OA modulation occurs.

[Topic1]Neuromodulation

[Topic2]Anatomy & Neuroanatomy

Poster Session 2

PO-2191(16:30 - 17:30)

Neuromodulation: The effects of juvenile hormone iii and chelerythrine chloride in the selectivity of phonotaxis and its neuronal correlates in female cricket Acheta domesticus

*Benjamin Navia[1], Ashley Groeneweg[1], Gordon Atkins[1], John Stout[1]

Andrews University[1]

Female *A. domesticus* exhibit variability in their phonotactic behavior. Some females respond to syllable periods (SPs) typical of the males ’ calling song (CS; 50–70 ms), others respond additionally to CSs with shorter or longer SPs, outside the range of males ’ calls. Other females are not selective to SP and respond to the full range of SPs. Nanoinjection of Juvenile Hormone III (JHIII) into the prothoracic ganglion increases phonotactic selectivity. Nanoinjection of chelerythrine chloride (a protein kinase C inhibitor) reduces the effect of JHIII.
The L3 prothoracic interneuron responds selectively to the SP of the male ’ s CS and is proposed to be involved in controlling SP-selective phonotaxis. Prothoracic nanoinjection of JHIII increases selective responses of L3 which parallels its ’ effects on phonotaxis. This increase in selectivity seems to result from a decrease in decrement, predominantly at the shorter and longer SPs. Such effects increase selectivity in response to the SPs that are most attractive phonotactically. The data support the hypothesis that processing by L3 contributes to the SP selective phonotaxis observed in this species. Data currently being evaluated suggest that chelerythrine chloride opposes the effect of JH III on L3 ’ s SP-selective responses.

[Topic1]Neuromodulation

[Topic2]Learning, Memory, & Behavioral Plasticity

Poster Session 2

PO-2192(17:30 - 18:30)

Neuromodulation: Subtle spike pattern changes due to axonal neuromodulation can dramatically alter postsynaptic responses

*Nelly Daur[1], Dirk Bucher[1]

New Jersey Institute of Technology[1]

Information flow in neurons is usually thought to have a clear polarity, consisting of dendritic integration, proximal spike initiation, and axonal spike propagation. However, recent findings emphasize the role of distal axonal (ectopic) spike initiation in neural processing, for example in cortical and hippocampal neurons. We use the stomatogastric nervous system of the lobster, *Homarus americanus,* to investigate the role of axonal properties for motor pattern generation. The pyloric dilator neurons serve a dual function as part of the pacemaker of the pyloric rhythm-generating network, and as motor neurons that send axons to dilator muscles of the pylorus. These axons are modulated by dopamine (DA). During centrally generated fast bursting activity, a DA-mediated depolarization counteracts slow after-hyperpolarization (sAHP) and improves temporal fidelity of spike propagation. The changed temporal fidelity of the axon leads to subtle changes in the spike pattern which dramatically alters muscle responses.
During slow centrally generated bursting, DA-mediated depolarization is sufficient to overcome sAHP and elicits ectopic spike initiation. We show that this occurs when pyloric activity is suppressed or slowed by inhibitory descending histaminergic neurons. Low frequency tonic ectopic spiking during interburst intervals has a priming effect and dramatically increases muscle responses to bursting input.

[Topic1]Neuromodulation

[Topic2]Motor Systems

Poster Session 2

PO-2193(14:30 - 15:30)

Neuromodulation: Tyraminergic/Octopaminergic neurons and some of their functions in locusts and fruit flies

*Hans-Joachim Pflueger[1], Florian Bilz[1], Marco Schubert[1], Konstantin Lehmann[1], Sergej Hartfil[1], Natalia L Kononenko[2]

Freie Universitaet Berlin, Biology/Neurobiology[1] , Charité Universitaetsmedizin Berlin[2]

The biogenic amines Tyramine and Octopamine have profound effects on insect behavior and are major metabolic regulators and neuromodulators. We study the properties and function of aminergic neurons of fruit flies, Drosophila melanogaster, and desert locusts, Schistocerca gregaria, in various behavioral contexts. In transgenic fruit flies, these neurons were labeled with green fluorescent protein or with the Calcium sensor GCaMP3 to monitor their patterns of activity. These neurons exhibit rhythmic activity during motor behavior. As these neurons, like some motor neurons persist during pupal development, their axons retract during metamorphosis in the pupa (P4/P5) before innervating the new adult muscles. Axon terminals of these tyraminergic/octopaminergic neurons belong to type II and appear morphologically different between larvae and adults.
We also identified a population of descending projection neurons in the locust brain that synthesize octopamine behavior-specific, in particular, after stress. This population of neurons is activated by mechanosensory stimuli to the thorax and abdomen and their axons run posterior to the fourth abdominal ganglion at least. We suggest that these neurons may, therefore, be able to release octopamine in all thoracic ganglia and, thus, may contribute to the effects of arousal and motor network modulation.

[Topic1]Neuromodulation

[Topic2]Motor Systems

Poster Session 2

PO-2194(15:30 - 16:30)

Neuromodulation: Modulation of neural thresholds in a decision-making circuit

*Jens Herberholz[1,2], Matthew E. Swierzbinski[1,2], Ruilong Hu[1,2]

University of Maryland, Department of Psychology[1] , Neuroscience and Cognitive Science Program[2]

The neurocellular mechanisms underlying inter-individual behavioral differences are still poorly understood. Like most other animals, crayfish facing an attack from a potential predator or from an aggressive conspecific must quickly select the most desirable behavioral response. However, when exposed to a danger signal, some crayfish will freeze in place while others quickly escape with a tail-flip response. During agonistic encounters, some crayfish will respond to the opponent ’ s attack with a counter-attack while others will tail-flip away. This implies individual differences in the activation threshold of the medial giant (MG) interneurons that generate the tail-flip response. Combining extracellular and intracellular recordings with neuropharmacology in semi-intact preparations, we found that octopamine facilitates the MG ’ s response to sensory inputs whereas serotonin either enhanced or suppressed the response, which may depend on the social history of the animal. We also found that the MG neurons are tonically inhibited, and this inhibition can be reversed with picrotoxin, a GABA receptor blocker. Thus, differences in neural thresholds and corresponding behavioral output are likely mediated by multiple interacting neurochemical mechanisms. Since the MG circuit integrates multimodal sensory information, we will be able to investigate these mechanisms in more detail across different sensory modalities.

[Topic1]Neuromodulation

[Topic2]Sensorimotor Integration

Poster Session 2

PO-2195(16:30 - 17:30)

Neuromodulation: Coding Context: Neuroendocrine modulation of receptor-mediate endocytosis

*Emma J. Coddington[1], Audrey Davis[1], Erin McEvoy[1], Emily Abraham[1], Dana Crosby[1], Ashley Turnidge[1], Laura Nay[1]

Department of Biology, Willamette University, Salem, OR[1]

We are investigating how hormones provide context and modify behavior-controlling neurons in rough skin newts, *Taricha granulosa.* We hypothesize that glucocorticoids rapidly modify behaviors by 1) upregulating endocannabinoid signaling, and 2) interfering with vasotocin signaling. Our methods capitalize on the understanding that G-protein coupled receptors are internalized during signaling processes by receptor-mediated endocytosis (RME); we track RME using corticosterone and vasotocin conjugated to fluorophores (CORT-cascade blue, vasotocin-oregon green VTog) under different scenarios. We have found that CORT and VT target the same clasp-controlling region in the hindbrain, CORT and cannabinoid agonists suppress 30-50% VTog RME, and 24% of this this action of CORT is blocked by cannabinoid type 1 (CB1) receptor antagonists. It is notable that CB1 antagonists do not block all of CORT ’ s effects on RME of VTog. We have identified an alternative cannabinoid receptor type, TPRV1 receptors, is located in the same clasp-controlling region, therefore, we hypothesize that TRPV1 receptors might mediate some of the cannabinoid effects in regulating clasp-controlling neurons. Collectively our research suggests a novel way that context can be provided by neuroendocrine signaling and that neuroendocrine modulation can occur by modifying the availability of receptors for subsequent signals.

[Topic1]Neuromodulation

[Topic2]Neuromodulation

Poster Session 2

PO-2196(17:30 - 18:30)

Neuromodulation: The cys-loop ligand-gated ion channel gene family of the spider *Cupiennius salei* nervous system

*Paivi H. Torkkeli[1], Andrew S. French[1]

Department of Physiology and Biophysics, Dalhousie University[1]

Cys-loop receptors are ligand-gated pentameric ion channels that mediate rapid neurotransmission. Due to their importance as targets of insecticides and parasiticides, many invertebrate cys-loop receptor subunits have been sequenced, and some crystal structures resolved. We have significant evidence of the physiological roles of several cys-loop receptors in synaptic modulation of spider (*Cupiennius salei*) mechanosensory neurons. However, the molecular structures or subunit compositions of these receptors are not known in any spiders. Here, we searched *C. salei* central and peripheral nervous tissue transcriptomes for homologous sequences to other arthropod cys-loop receptors and assembled genes using the transcriptome walking method. We found eleven putative cys-loop subunits that are predicted to form ion channels gated by GABA, glutamate, histamine, pH or acetylcholine. These same agonists have previously been shown to modulate spider mechanosensory neurons. Phylogenetic analysis placed the *C. salei* sequences in known subclasses of arthropod cys-loop receptors, with closest homologies to other arachnid subunits. Sequence alignment and molecular modeling predicted channel functions and found potential binding sites for endogenous modulators, drugs and commonly used control agents. Future experiments will combine molecular biological and electrophysiological tools to investigate the physiological and behavioral roles of these receptors in spider mechanosensilla.

Supported by: CIHR

[Topic1]Neuromodulation

[Topic2]Sensory: Mechanosensation

Poster Session 2

PO-2197(17:30 - 18:30)

Neuromodulation: Non-invasive electrophysiology and DPOAE techniques reveal an expanded frequency hearing in moths

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Moth ears are adapted to perceive bat echolocation signals and may also mediate detection of potential mates. Characterization of moth hearing has been approached by different techniques focused on different levels of auditory processing, but used independently thus limiting comparisons across studies. In this work, ear tuning in the noctuid Empyreuma pugione was simultaneously evaluated by neurophysiological recordings and by measuring distortion-products otoacoustic emissions (DPOAE).These approaches allowed us to investigate how the mechanical nonlinear tympanum response is reflected on neural processing. We propose a novel electrophysiological method to record the moth auditory nerve response without body dissection (intact moth, i.e. closed), and compare its results with those of the traditional recording method (dissected moth, i.e. open). For both conditions (closed and open) we used a matrix of frequency-level combinations to evaluate the acoustic response to different stimulus patterns: continuous tones, repetitive pulses, and real bat call sequences. Neural audiograms matched to DPOAE audiograms revealing relation to a unique filtering mechanism. All auditory threshold curves obtained are V-shaped with best frequencies between 22 and 52 kHz depending on recording condition and temporal design. Our experiments revealed a significant change in mechanical properties of the tympanum determined by body dissection: best hearing frequency decreases in both DPOAE and electrophysiological audiograms. By studying DPOAE in other intact 12 moth species we identified best hearing ranges in the frequencies between 30 and 96+ kHz, thus matching the range of peak frequencies of echolocation calls from the Cuban insectivorous bat fauna. In addition, every moth showed a dynamic hearing with a spectral up-tuning further expanding the species-specific best frequency range by 10-30 kHz. In contrast, dynamic hearing disappeared with dissection. With the advantage of using a non-invasive approach, our experiments revealed that moth hearing is more diverse than previously thought.

Poster Session 2

PO-2198(17:30 - 18:30)

Neuromodulation: How do complex visual behaviours emerge from simple nervous systems in *Drosophila melanogaster*?

*Alex Dewar[1], Antoine Wystrach[1], Paul Graham[1], Andrew Philippides[2]

School of Life Sciences, University of Sussex[1] , School of Informatics, University of Sussex[2]

Adult *Drosophila melanogaster* possess only around 100,000 neurons, yet are still able to perform many behavioural tasks. Among these is a capacity for discriminating visual stimuli that differ in properties such as orientation, elevation and size. Recently published data (Seelig & Jayaraman, 2013) describe the receptive fields for two classes of visually responsive neurons in the lateral triangle (R2 and R4d), which have some of the same properties as mammalian simple cells, though the retinal area over which individual cells are responsive is far greater and they are small in number (28 and 14 neurons, respectively). It has been reported that these neurons are essential for pattern recognition (Liu *et al*., 2006). We investigated (Wystrach *et al*., 2014) whether the information implicitly conveyed by these neurons is sufficient for a real-world task, such as discriminating visual stimuli. We simulated the receptive field data and found that differences in the overall activation of these cells matched the pairs of patterns also discriminable by flies; conversely, the model failed to distinguish pairs of patterns on which flies failed. Using artificial neural networks to interrogate the output of the R2 and R4d cells, we can show that information is preserved through this narrow bottleneck. The results will be discussed in terms of behavioural experiments and their relation to visually guided behaviours in insects more generally.

Liu, G.; Seiler, H.; Wen, A.; Zars, T.; Ito, K.; Wolf, R.; Heisenberg, M. & Liu, L. (2006). Distinct memory traces for two visual features in the *Drosophila* brain. *Nature*, 439, 551–556.

Seelig, J. D. & Jayaraman, V. (2013). Feature detection and orientation tuning in the *Drosophila* central complex. *Nature*, 503, 262–266.

Wystrach, A., Dewar, A. D. M. & Graham, P. (2014). Insect Vision: Emergence of Pattern
Recognition from Coarse Encoding. *Current Biology*, 24(2), 78–80.

Plenary Lecture 7 by Lidia Szczupak

PL-7
Recurrent inhibition in motor systems, a functional analysis in the leech nervous system

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Motor systems of invertebrates and vertebrates are constituted by hierarchical networks, where stimulation of neurons at their highest level activates complex sets of movements; at the bottom of the hierarchy, motoneurons and premotor neurons form local networks that determine the spatio-temporal pattern of muscle contraction. Local circuits present a variety of phylogenetically conserved functions, among which recurrent inhibition has been repeatedly identified, and yet a clear description of its function(s) has been elusive. Different than classical reflexes, recurrent inhibition is a feedback mechanism where the activity of the motoneurons is modulated by their output and not by the activity of their targets. In leeches, a recurrent inhibitory circuit has been described, centered around a pair of nonspiking (NS) neurons, that combines chemical and electrical synapses. Functional analysis of this circuit has shown that it exhibits a variety of functions: i) heteronymous motoneurons in leeches are electrically coupled and this coupling is modulated by NS membrane potential; ii) in the course of crawling NS influences the activity of motoneurons through a direct path, and iii) it also influences the activity of the central pattern generator responsible of this rhythmic behavior.

[Topic1]Motor Systems

[Topic2]Cellular Properties

Invited Symposium 7

IS7-1(10:00 - 10:30)

Neural and behavioral studies of the cockroach central complex reveal roles in directing locomotion and action selection

*Roy E Ritzmann[1], Joshua P Martin[1]

Case Western Reserve University[1]

At least one important factor that distinguishes animal behaviors from robots is their capacity to rapidly adjust movements so that they are appropriate for ever changing conditions. How might the central complex (CC) function in this critical role? We know that it receives inputs from numerous sensory sources and that damage to various regions of the CC can significantly impact specific behaviors. Affected behaviors include optomotor responses which are reversibly blocked by procaine injected into the CC. Consistently, CC neurons respond to moving stripe patterns with phasic or tonic activation and many are directional. Moreover, activity in the CC of tethered insects is correlated with and often precedes changes in motor activity, including altered walking speed and turn direction.Furthermore, stimulation in the same regions can evoke similar motor responses. New recordings in freely-walking animals now reveal additional complexity. Finally, numerous neuromodulators have receptors in specific regions of the CC and these substances can alter locomotory behavior. Some species of praying mantis, a predatory relative to the cockroach, stalk prey using precisely targeted behavior but shift to an ambush strategy as they reach satiety. A conference poster shows that this effect can be mimicked by injection of insulin in the hemocoel.

[Topic1]Sensorimotor Integration

[Topic2]Motor Systems

Invited Symposium 7

IS7-2(10:30 - 11:00)

Common principles within the insects for encoding sky compass cues in the central complex

*Stanley Heinze[1], Ken Green[3], William Wcislo[2], Eric Warrant[1]

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To navigate their environment, animals have to identify behaviorally relevant features in their surroundings and obtain information about their relative position to them. In migratory insects polarized skylight is used to compute body orientation within the central complex (CX), a conserved brain structure. We ask whether this principle is valid across insects, how it is modified between species, and which other cues are integrated with body orientation information. We target two sweat bee species and two moth species. The two solitary bees inhabit different sensory environments, but share a behavioral strategy of central place foraging. While both moths are strictly nocturnal, one is a long-distance migrant. An LED-based virtual reality apparatus, in which an artificial sky is combined with a 360 ° LED arena, has allowed us to analyze responses of CX-neurons to skylight compass cues and to begin illuminating which other visual features are represented in the CX. We have confirmed that polarized light is indeed represented in CX-neurons of nocturnal bees and moths, irrespective of their behavioral strategy. Additionally, numerous neurons respond strongly to motion cues and other unpolarized light stimuli, suggesting a complex role of the CX in integrating different visual modalities.

[Topic1]Sensory: Vision

[Topic2]Orientation and Navigation

Invited Symposium 7

IS7-3(11:00 - 11:30)

Computational modelling of the central complex: which way to go?

*Barbara Webb[1], Thomas Stone[1]

University of Edinburgh[1]

To model a brain region we can take a top-down or bottom-up approach. We can try to describe the function that this system computes - what input is transformed to what output? Or we can ask what this neural system is capable of - what algorithms are suggested by the structure and connectivity? In the case of the central complex, where we only have partial information to address each question, it would seem productive to use these complementary strategies together.
Of interest here is that aspects of the known structure of the arthropod central complex are similar to of attractor network architectures studied in computational neuroscience. Moreover, these architectures have been used to model a range of capabilities strikingly reminiscent of the diverse functional roles suggested for the central complex: vertebrate head direction cells, path integration, short term visual and spatial memory, orientation tuning, neural multiplication of inputs, stimulus selection and attention, and control of movement trajectories. These parallels may provide useful insight allowing us to link structure and function in explaining the role of the central complex in arthropod behaviour.

[Topic1]Computational Modeling

[Topic2]Orientation and Navigation

Invited Symposium 7

IS7-4(11:30 - 12:00)

Linking vision and action in the *Drosophila* central complex

Vivek Jayaraman[1,2]

Janelia Farm Research Campus[1] , Howard Hughes Medical Institute[2]

Studies from many labs and in different insects have implicated the central complex in a broad range of functions including sun-compass navigation and locomotion. In *Drosophila*, behavioral genetics experiments have suggested that the region is required for short- and long-term visual memory, motor control and spatial navigation, among other things. Over the past few years, we have developed techniques to monitor neural activity in head-fixed behaving flies in a virtual reality arena. We record from genetically identified neural populations during tethered flight and tethered walking on an air-supported ball. We have also developed techniques to map functional connectivity between identified neural classes in the adult fly brain using optogenetics and physiology. I will discuss our results from using a combination of such techniques to probe the central complex ’ s role in visuomotor integration in flies.

[Topic1]Sensorimotor Integration

[Topic2]Orientation and Navigation

Plenary Lecture 8 by Malcolm A. MacIver

PL-8

Convergent evolution of mechanically optimal locomotion and its implications for information acquisition

Malcolm A. MacIver[1,2,3,4]

Northwestern University[1] **, Department of Mechanical Engineering**[2] **, Department of Neurobiology**[3] **, Department of Biomedical Engineering**[4]

Biology often defies attempts to find simple quantitative laws underlying its vast diversity. But while evolution is more tinkerer than engineer, it occurs within the hard constraints of physics. Some such constraints underlie how an animal can move its body and limbs. We may therefore expect the evolution of similar motions among unrelated animals that must abide by the universal limitations imposed by physics. Despite this, examples of convergent evolution of body movements that quantitatively agree with the mechanically optimal solution are very rare. Here we show that, with respect to a very diverse group of aquatic animals spanning vertebrates and invertebrates, a mechanically optimal method of swimming with elongated fins has evolved independently at least eight times. In one of these clades, electric knifefish from South America, antagonistic forces due to counter-propagating waves along the elongated fin results in simultaneous enhancement of stability and maneuverability. Recent work on ergodic control strategies for active exploration suggests that this enhanced maneuverability may be important for optimal information harvesting.

[Topic1]Motor Systems

[Topic2]Sensory: Electrosensory

Invited Symposium 10

IS10-1(15:00 - 15:20)

Unveiling principle of neural circuits underlying learning, memory and decision-making

Ikue Mori[1]

Nagoya University[1]

The nematode *Caenorhabditis elegans* is an ideal organism with which to address how information is processed in the neural circuit to generate a behavior. Thermotaxis in *C. elegans* is a learning-based behavior and the execution of this behavior requires the simple neural circuit consisting of only several types of neurons. Optogenetics, calcium imaging and behavioral analysis showed that thermosensory neuron AFD not only perceives temperature information, but also memorizes the temperature at which the animals were previously cultivated. This thermal memory is independent of synaptic transmission, since a cultured neuron AFD devoid of any synaptic connections enabled to form and maintain temperature memory. AFD neuron appears to send both excitatory and inhibitory signals to its postsynaptic interneuron AIY, thereby generating opposing thermotactic behaviors. We also found that the activity of RIA interneuron, postsynaptic to AIY, is highly stochastic and is inhibited by the temperature nearly corresponding to the thermal memory in AFD. Given that RIA interneuron regulates the head movement, we suggest that the RIA is a decision-making neuron and that shutdown of the stochastic activity in RIA triggers switching of the behavioral modes from exploration to the memory dependent behavior.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Invited Symposium 10

IS10-2(15:20 - 15:40)

The gain-gating mechanism implements decision making in fruit fly *Dros ophila*

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Active action selection is one of the main tasks of the brain. We have designed a 'color/position' dilemma in the visual flight simulator. Individual flies were conditioned to choose a flight path in accordance with the color (green and blue) and position (upper and lower) cues and then confronted with choice test with color and position cues reversed after training. Our results revealed that wild-type flies are able to resolve this paradoxical situation by evaluating the 'value' of the current information and making a nonlinear 'winner-takes-all' decision. The decision curve exhibited a clear-cut and sigmoid-like function. We found that flies with defective dopamine system or MBs (mushroom bodies, a part of fly's central brain) function have trouble in deciding between the two conflicting visual features. We further discovered that the GABAergic anterior paired lateral (APL) neurons which densely innervate the MBs were involved in the decision-making, and the genetic silencing of APL neurons turned the nonlinear choice behavior into linear one.
Together, we suggest a *Gain-Gating Mechanism* of decision making that once a decision is made, the chosen option's value will become inflated by *Dopamine Gain Mechanism*, while the less salient alternatives will be rejected by *GABA Inhibition Gating Mechanism.*

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Cognition

Invited Symposium 10

IS10-3(15:40 - 16:00)

Habenula as a switch board of emotion

Hitoshi Okamoto[1]

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Animals first show panic response to danger, but gradually learn to cope with it adaptively. However, the neural circuit that controls this transition is not known.

The transgenic zebrafish in which the neural transmission from the vHb to the MR is specifically inhibited showed the significant impairment in learning the active avoidance, but no defect in learning the classical fear conditioning. After the conditioning trials, the vHb neurons initially showed tonic increase in firing during presentation of the conditioning red light, suggesting that the vHb neurons and their target serotonergic neurons in the MR learn to represent the shock-predicting negative reward expectation value.

To examine whether the activation of the vHb neurons is sufficient for the assignment of the negative reward expectation value to an arbitrary cue, we optogenetically activated the vHb neurons in freely swimming zebrafish only when the fish was swimming on the red-colored floor. These fish swam to the opposite green-colored floor where the optogenetic stimulation was interrupted.

These data showed that the vHb-MR projection transmits the shock-predicting negative reward expectation value to the reinforcement learning system and enables the behavioral transition to cope with fear initially by panic and then adaptively.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Invited Symposium 10

IS10-4(16:00 - 16:20)

Imaging neural ensembles during learning

Takaki Komiyama[1]

University of California San Diego[1]

One of the most fascinating properties of the brain is its ability to change and learn from experience. To identify fine-scale learning-related changes in the brain, we use in vivo two-photon microscopy in mice over weeks of learning and experience. We will share some of our recent findings with this approach.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Motor Systems

Invited Symposium 8

IS8-1(10:00 - 10:30)

Imprinting, recognition memory and sleep

Brian J. McCabe[1]

University of Cambridge[1]

Imprinting is a type of learning by which an animal restricts its social preferences to an object following exposure to that object. Filial imprinting occurs shortly after birth or hatching and is an effective experimental system for investigating memory mechanisms, particularly those responsible for recognition. Extensive evidence implicates a restricted part of the chick forebrain, the intermediate and medial mesopallium (IMM), as a memory store for visual imprinting. Presumed inhibitory neuronal activity and a range of biochemical changes in the IMM have been implicated in memory for an imprinting stimulus. Many such changes occur predominantly in the left IMM, which concomitantly shows specialised organisation of oxidative metabolism. After exposure to a visual stimulus, neuronal responsiveness in the IMM is specifically biased toward that stimulus. Both this bias and imprinting strength measured behaviourally depend on uninterrupted sleep shortly after exposure. Memory is impaired by sleep disturbance contingent on slow-wave (SW, 0.75 Hz) electroencephalographic activity, but not disturbance at other times. The memory impairment is prevented by transcranial stimulation at either SW or theta (6 Hz) frequency. The results resemble the effect of SW stimulation during sleep in human subjects and may therefore elucidate sleep-dependent memory mechanisms common to both species.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Social Behavior

Invited Symposium 8

IS8-2(10:30 - 11:00)

Thyroid hormone confers “ memory priming ” to start the sensitive period of imprinting in birds

Koichi J. Homma[1]

Teikyo University, Tokyo, JAPAN[1]

Filial imprinting in birds is the process of forming a social attachment during a sensitive or critical period, restricted to the first few days after hatching. Imprinting is considered to be part of early learning to aid the survival of juveniles by securing maternal care. I show in this conference that the thyroid hormone determines the start of the sensitive period. Imprinting training in chicks (*Gallus gallus domesticus*) causes rapid inflow of thyroid hormone. The hormone thus initiates and extends the sensitive period to last more than 1 week via non-genomic mechanisms. It can also confer what we term 'memory priming (MP)' to prime subsequent learning. Once chicks have achieved MP, it is maintained for long periods. Even in non-imprinted chicks whose sensitive period has ended, exogenous thyroid hormone enables imprinting. It is possible that the sensitive period closes only if MP is not conferred at an appropriate time of development. In a sense, the closing of the sensitive period for learning may not exist under usual physiological conditions. This study elucidates the critical role of imprinting to subsequent learning as being governed by thyroid hormone. There may exist determining factors among higher intelligent animals as well that can cause the opening of a sensitive period.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Genes and Behavior

Invited Symposium 8

IS8-3(11:00 - 11:30)

The domestic chick as an animal model of early social predisposition

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The ability to identify animate creatures early in life is of biological relevance for species as distant as birds and primates. One most robust finding in the literature is that naïve chicks preferentially approach a stimulus resembling a conspecific (a stuffed fowl) rather than a less naturalistic object. Our recent work has uncovered some of the specific features of the stimuli that elicit these preferences: face-like patterns, self-initiated or semi-rigid motion. We are now investigating other elementary motion cues creating the impression of animacy in human observers, such as spontaneous changes in the speed of a moving object. Chicks preferentially approach objects that are capable of autonomous accelerations and decelerations, indicating sensitivity to motion patterns typical of self-propelled creatures.
To investigate the neural mechanisms underlying these early predispositions we stained the transcription factor c-Fos in naïve chicks that approached a predisposed stimulus (a stuffed fowl) or a control stimulus (a random collage of pieces of an identical fowl). This revealed differential activation in an area relevant for imprinting (IMM), indicating that different level of plasticity could be elicited by approach to predisposed and non-predisposed stimuli.

[Topic1]Social Behavior

[Topic2]Development

Invited Symposium 8

IS8-4(11:30 - 12:00)
Predispositions to conspecifics in human infants

Atsushi Senju[1]

Birkbeck, University of London[1]

Johnson & Morton (1991) proposed two systems model to describe the preference for conspecifics in human infants, in which innate predisposition to orient to face-like configuration (CONSPEC) interacts with early learning (CONLERN) to develop face processing. I will present how this model, now advanced into a more generalized 'interactive specialization' model, can explain the early development of face and gaze processing in human infants. I will particularly focus on infants developing in a unique familial environment, sighted infants of blind parents, and discuss how infants' predispositions interacts with familial environment to develop face and gaze processing.

Reference

Senju, A., Tucker, L., Pasco, G., Hudry, K., Elsabbagh, M., Charman, T., & Johnson, M. H. (2013). The importance of the eyes: communication skills in infants of blind parents. Proceedings of the Royal Society B: Biological Sciences, 280(1760).

Senju, A., & Johnson, M. H. (2009). The eye contact effect: Mechanisms and development. Trends in Cognitive Sciences, 13, 127-134.

[Topic1]Cognition

[Topic2]Social Behavior

Invited Symposium 11

IS11-1(16:20 - 16:40)

Ecology, predation, and neural ground patterns in deep time

*Nicholas J. Strausfeld[1], Gregory D. Edgecombe[2], Xiaoya Ma[3]

UNIVERSITY OF ARIZONA[1] , NATURAL HISTORY MUSEUM LONDON[2] , NATURAL HISTORY MUSEUM LONDON[3]

Rapid evolutionary diversification known as the Cambrian explosion provides the first view of definable ecological niches. Relationships amongst animals then, and their habitats, were not principally different from those in today ’ s shallow seas where predatory euarthropods prey on smaller animals. 520 million years ago bilaterians crawled along the seabed, climbed and browsed on marine vegetation, and segmented arthropod-like animals walked, swam, and burrowed. Menacing this menagerie were the top predators - Radiodonta - equipped with large stalked compound eyes flanking a cone-like mouth lined with small teeth. Radiodonta differed from other segmented animals with jointed appendages or swimmerets in possessing just one pair of appendages extending preocularly from the front of the head, articulating downwards to seize prey. Elsewhere along the body, metameric flaps provided a metachronal wave that propelled the animal through the water. A radiodontan ’ s smörgåsbord included animals simpler than extant arthropods, most not corresponding to living groups within phyla. Were their nervous systems fundamentally different from todays? Can we recognize features that suggest similar sensory integration and motor control? I will demonstrate that nervous systems preserved in 520-million-old fossils from southwest China suggest that modern behavioral repertoires originated long before the evolution of morphologies characterizing modern taxa.

[Topic1]Evolution

[Topic2]Evolution

Invited Symposium 11

IS11-2(16:40 - 17:00)

Ancient memories: genealogical correspondence of learning and memory centers across phyla

*Gabriella H. Wolff[1,2,3], Nicholas J. Strausfeld[2,3]

University of Arizona, Graduate Interdisciplinary Program in Neuroscience, USA[1] , University of Arizona, Center for Insect Science, USA[2] , University of Arizona, Department of Neuroscience, USA[3]

In bilaterally symmetrical animals with brains, primary sensory neuropils send information to morphologically distinct processing centers in the forebrain. Relays from the vertebrate olfactory bulbs, for example, project to hippocampi. In insects and crustaceans, olfactory lobes send efferents to higher order centers called mushroom bodies and hemiellipsoid bodies, respectively. These centers further integrate signals encoded by pathways mediating chemosensation, vision, and mechanosensation. Evidence from insects and mammals demonstrate that these centers play crucial roles in olfactory learning and memory, exploratory behaviors, and in place memory. Here we address the question whether these centers evolved independently across phyla or whether they may have been present in the last common ancestor of the Bilateria. Despite superficial differences in their morphology, these centers share the same neural ground pattern of nerve cell arrangements and protein expression across Arthropoda, Annelida, and Mammalia. Our studies likewise resolve these centers in the brains of planarians, which serve as a proxy for deep bilaterian ancestors. Together, these finding have important implications regarding behaviors of bilaterian organisms that existed before the advent of the Cambrian explosion. They suggest an ancestral role of mushroom body circuitry in exploratory foraging and allocentric memory.

[Topic1]Evolution

[Topic2]Anatomy & Neuroanatomy

Invited Symposium 11

IS11-3(15:00 - 15:20)

Evolutionary conserved neural circuitry for the selection and maintenance of behavioural activity

Frank Hirth[1]

King's College London, Institute of Psychiatry, Department of Neuroscience, London/UK[1]

The coordination of adaptive behaviour is a prerequisite for survival and reproduction. Its development and manifestation must be a reliable event for species where predators impose strong selection pressure. Accordingly, adaptive behaviour can be described as a phylogenetically acquired activity that depends on the physiological function of central nervous system sub-structures. Lorenz and Tinbergen already postulated that the heritable ontogeny and reliable performance of these CNS structures relies on a genetically-determined program, referred to as a *ground plan*. In this talk I will present evidence that the insect central complex and vertebrate basal ganglia are built according to a common ground plan and that their neural activity regulates homologous functions in the coordination and control of adaptive behaviour. Using temperature preference in *Drosophila* as a paradigmatic example, I will illustrate some emerging principles underlying the selection and maintenance of behavioural activity.

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[Topic1]Genes and Behavior

[Topic2]Anatomy & Neuroanatomy

Invited Symposium 11

IS11-4(15:20 - 15:40)

Evolution and diversity of mechanosensory organs for flight control

Jessica L. Fox[1]

Case Western Reserve University[1]

Most flying insects possess a pair of wings on their mesothoracic and metathoracic segments. In flies (Diptera), however, the metathoracic wings evolved into structures called halteres that no longer generate lift, but serve a mechanosensory purpose, providing information used to stabilize flight. Campaniform sensilla detect forces acting on the halteres and signal the occurrence of body rotations to forewing motoneurons, neck motoneurons, and the central nervous system. Despite their importance for behavior, halteres show an intriguing evolutionary pattern. They are not present in other insects (although non-homologous organs of equilibrium appear in Strepsiptera), and there are not extant intermediate forms. Furthermore, the haltere itself shows a large diversity of shapes across species, and those species experience different haltere motions as a function of their different wingbeat frequencies and body rotation velocities. Despite these differences, haltere neurons show a surprising lack of diversity in encoding properties both within and between species. Thus, the shape and motions of the haltere itself are crucial to information processing. Current research focuses on understanding how haltere motions affect information processing and influence behavior. By changing the haltere ’ s shape through genetic mutations and physical manipulations, we can examine selective pressures that may have driven haltere evolution.

[Topic1]Evolution

[Topic2]Sensory: Mechanosensation

Invited Symposium 9

IS9-1(10:00 - 10:30)

Endocrine disruption of evolutionary evolved maternal and paternal behaviors in monogamous, biparental California mice (*Peromyscus californicus*)

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Few rodent species are monogamous and exhibit well defined patterns of bipaternal care. One species that is monogamous and biparental is the California mouse (*Peromyscus californicus*). Environmental factors, such as the endocrine disrupting compound (EDC), bisphenol A (BPA), can disrupt maternal care in other rodents. BPA is one of most ubiquitous EDCs, and its stability and pervasiveness has ensured inevitable exposure of wildlife and humans. No previous study though has considered how BPA or other EDCs affects biparental responses. Consequently, we examined biparental behaviors in developmentally BPA-exposed F1 male California mice paired with control (CTL) females and a group of CTL males paired with CTL females. Females whose offspring had been fathered by BPA-exposed F1 males spent less time nursing their pups ($P<0.0001$). BPA-exposed males and their CTL female partners spent significantly less time in the nest and grooming the pups compared to CTL pairs ($P < 0.01$). F1 pups whose P1 parents had both been exposed to BPA, showed no difference in body weight, but their body temperature was less than those of CTL pups (P value < 0.05). Notably, the findings suggest that acute and developmental exposure to BPA significantly compromises aspects of biparental care in California mice.

[Topic1]Evolution

[Topic2]Hormones and Sex Differences

Invited Symposium 9

IS9-2(10:30 - 11:00)

Providing parental care in a stressful environment: a study of the endocrine regulation of parental behavior in birds

Frédéric Angelier[1]

Centre d'Etudes Biologiques de Chizé, CNRS[1]

The parental phase is often considered as a constraining period because individuals have to provide parental cares to their offspring and this parental investment is usually made at the expense of parent ' s own condition/survival. Importantly, several factors can affect this " cost of reproduction " : for example, this cost is amplified when stressful situations occur because resources are too limited to sustain both reproduction and survival. In that context, evolution predicts that individuals should adjust their parental behavior in order to optimize their fitness. Here, I will focus on the physiological ability of wild birds to adjust their parental behavior to such a stressful context. Thus, I will emphasize the important role of two hormones involved in allostasis (corticosterone) and parental behavior (prolactin). I will show that (1) the expression of parental care is under control of these hormones; (2) corticosterone and prolactin are affected by stressful events; (3) these two hormones are not independent and may interact in some situations; (4) corticosterone and prolactin levels also depend on several individual characteristics (age, condition). Therefore, I will demonstrate that these hormones mediate parental investment, and thus, govern the trade-off between survival and reproduction in birds.

[Topic1]Ecology

[Topic2]Hormones and Sex Differences

Invited Symposium 9

IS9-3(11:00 - 11:30)

The soft side of a killer: neuroendocrine basis of parental care in poison frogs

Lauren A. O'Connell[1]

Harvard University[1]

Specialized parental care strategies have evolved in multiple taxa, yet the molecular and neural mechanisms underlying the convergent evolution of these behavioral phenotypes are not fully understood. Poison frogs have distinct parental care strategies that vary among closely related species. I will discuss my research on the hormonal and neural basis of parental care in the Dyeing Dart Frog (*Dendrobates tinctorius*) with male uniparental care and the Little Devil frog (*Dendrobates sylvaticus*) with female uniparental care. Hormone profiling across different stages of parental care shows dynamic changes in plasma testosterone and 17b-estradiol but not progesterone or cortisol. Quantification of brain gene expression using RNAseq has revealed patterns of expression that are similar in *D. tinctorius* males and *O. sylvatica* females that care for offspring, including specific neuroendocrine factors found to be important for parental care in mammals. These studies suggest that although parental care has evolved independently across taxa, similar neuroendocrine factors may have been repeatedly recruited to facilitate these behaviors.

[Topic1]Genes and Behavior

[Topic2]Evolution

Invited Symposium 9

IS9-4(11:30 - 12:00)

The evolution of sex differences in parenting

Allen J. Moore[1]

University of Georgia[1]

Parental care, especially elaborate parental care, is unusual. Biparental care is rare across species that care for their young. Where parental care is found, it is typically the female that cares. Sexual conflict theory predicts that the resolution of parental care depends on selection arising from costs, benefits, and the nature of selection. However, like all traits, parental care is highly variable even within species. In the burying beetle, *Nicrophorus vespilloides*, females (uniparental female care), males (uniparental male care) and both sexes (biparental care) are seen. Why is such flexibility in care seen in *N. vespilloides*? We use quantitative and molecular genetic studies to examine how genetic variation among individuals influence the evolution of parental care. Comparing fitness effects of different forms of care and RNAseq studies suggest biparental care may actually be uniparental female care. Genetic studies help explain how behavioural diversity and complexity evolves despite a strong theoretical prediction for a simple outcome.

[Topic1]Evolution

[Topic2]Genes and Behavior

Invited Symposium 12

IS12-1(15:40 - 16:00)

Brain structure and visual abilities for foraging in the Japanese yellow swallowtail butterfly, *Papilio xuthus*

Michiyo Kinoshita[1]

The Graduate University for Advanced Studies (Sokendai-Hayama)[1]

Like honeybees, flower visiting butterflies rely on visual cues for finding nectar sources. *Papilio* butterflies were the first insect in which the ability to see red light as color was discovered. Behavioral experiments over the last ten years demonstrate the sophistication of *Papilio xuthus'* visual capabilities. Its color vision covers from UV to red with high sensitivity in terms of wavelength discrimination. In addition to color vision involving color constancy and color contrast, brightness and polarization vision also contribute to detecting flowers.
Visually mediated foraging behavior can also be investigated by examining the highly specialized structures of the brain. Visual information is first processed in the optic lobe before being sent to the central brain. Dye injection has revealed that the mushroom body (MB) of *P. xuthus* receives prominent direct visual inputs from the optic lobe. These visual inputs project from the medulla, the lobula, and a newly-identified small area of the lobula. Considering the olfactory inputs to the MB and the importance of olfaction as a cue in foraging, the MB may serve to integrate visual and olfactory information in the brain of *P. xuthus,* as in Hymenoptera.

[Topic1]Sensory: Vision

[Topic2]Sensory: Vision

Invited Symposium 12

IS12-2(16:00 - 16:20)

Neural circuits for colour discrimination and learning

*Hiromu Tanimoto[1,2], Katrin Vogt[2], Christopher Schnaitmann[2], Yoshinori Aso[3], Gerald M. Rubin[3], Thomas Wachtler[4], Christian Garbers[4]

Tohoku University[1] , Max-Planck Institute of Neurobiology[2] , Janelia Farm Research Campus[3] , Ludwig-Maximillians-Universitaet Muenchen[4]

In nature, animals form memories associating reward or punishment with stimuli from different sensory modalities, such as smells and colors. It is unclear however how distinct sensory memories are processed in the brain. We established appetitive and aversive visual learning assays comparable to widely used olfactory learning in Drosophila. These behavioral assays were designed to be very similar in terms of reinforcing stimuli, conditioning regimes, and evaluation of associative memories. Using these learning assays combined with various genetic intervention, we identified 1) the photoreceptor types that contribute to color vision; 2) visual and olfactory memories share overlapping yet partially distinct circuits of the mushroom bodies. We will discuss the recent results in addition.

[Topic1]Learning, Memory, & Behavioral Plasticity

[Topic2]Sensory: Vision

Invited Symposium 12

IS12-3(16:20 - 16:40)

The polarization-vision pathway of bees

*Maximilian Zeller[1], Annuska Berz[1], Tanja Heinloth[1], Martina Held[1], Ronja Hensgen[1], Sarah Peters[1], Uwe Homberg[1], Keram Pfeiffer[1]

Philipps-University Marburg, Germany[1]

The year 2014 marks not only the 100th anniversary of the first publication by Karl von Frisch on honeybee color vision, but also the 65th anniversary of his discovery that honeybees are able to use polarized light for spatial orientation. In his 1949 article, von Frisch demonstrated this fascinating sensory-motor capability for the first time in any animal. Honeybees have since been used extensively as a model organism for research into polarization vision. However, the vast majority of studies have focused on the behavior, whereas the neuronal basis thereof has received little attention.
Using tracing techniques and intracellular recordings in honeybees and bumblebees, we were able to characterize the polarization vision pathway from the polarization sensitive dorsal rim area of the compound eyes, via the medulla, the anterior optic tubercle, and the bulbs in the median protocerebrum to the central complex. We found that subpopulations of tangential neurons of the medulla target hitherto undescribed subcompartments of the anterior optic tubercle. Most neurons in the pathway showed remarkable similarities to polarization-sensitive neurons in other insect species. Intracellular recordings demonstrate that polarization-sensitive neurons of the bee's central complex also respond to the azimuth position of an unpolarized light spot.

[Topic1]Orientation and Navigation

[Topic2]Sensory: Vision

Invited Symposium 12

IS12-4(16:40 - 17:00)

Innate colour preferences of the Australian native stingless bee *Tetragonula carbonaria*: lessons from a geologically separated land

*Adrian, G. Dyer[1,2], Skye Boyd-Gerny[3], Bob, B.M. Wong[3]

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The demonstration of colour vision in honeybees [1] opened up our understanding of plant-pollinator interactions. Hymenoptera have conserved trichromatic vision, and flower spectra from Israel and Australia independently evolved 'colours' that fit to bee visual capabilities [2]. Australia is interesting due to a sea barrier for >34 million years [2], and *Tetragonula carbonaria* stingless bees from Australia last shared an ancestor with most other bees >80 mya [3]. We tested innate colour preferences of *T. carbonaria* with ten broad-band cards and modelled stimuli in a colour Hexagon [2-4]. The factors of dominant wavelength, brightness, spectral purity, chromatic contrast or green-receptor contrast were considered for three different backgrounds. The only significant factor was dominant wavelength; UVA-'white' (437nm) was preferred to all other stimuli, whilst yellow (530nm) or pink (422nm) were preferred to grey. Interestingly, the results are consistent with innate preferences in honeybees [4], and such preferences may contribute to 'consistent' patterns of flower colour worldwide [2].

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[Topic1]Sensory: Vision

[Topic2]Ecology