Neuroethology Symposium
Genes, Neurons and Behavior
May 7, 2004
Nyumburu Cultural Center, University of Maryland, College Park

9:00-9:15	Welcome
9:15-9:30	**Laura Tucker, University of Maryland** Motor patterns in the spinal cord of larval lamprey.
9:30-9:45	**Dr. Michele Halvorsen, University of Maryland** A delicious fish with auditory specializations.
9:45-10:00	**Dr. Philip Johns, University of Maryland** Sexy males and selfish genes.
10:00-10:15	Coffee Break
10:15-11:15	**Dr. Steve Nowicki, Duke University** Why birds sing, why brains matter.
11:15-11:30	Coffee Break
11:30-12:30	**Dr. Jeff Hall, Brandeis University** What, if anything, is neuroethology in the context of behavioral genetics and molecular neurobiology?
12:30-2:00	Lunch
2:00-3:00	**Dr. Greg Ball, Johns Hopkins University** Interactions among photoperiod, testosterone and song behavior in the regulation of adult neuroplasticity in the song control system of European starlings (Sturnus vulgaris).
3:00-3:15	Break
3:15-4:00	**Dr. Elizabeth Quinlan, University of Maryland** Deafferentation-induced cortical reorganization in adult somatosensory cortex.
4:00-4:45	**Dr. Jonathan Fritz, University of Maryland** Active listening - the role of dynamic receptive field changes in rapid task-related cortical plasticity.

<u>Abstracts</u>

Tucker, Laura. Motor patterns in the spinal cord of larval lamprey. The lamprey spinal cord has an intersegmental coordinating system composed of ascending, descending, and long and short fibers. These fibers maintain a single frequency of burst activity among all segments of the spinal cord, and proper timing among the segments to produce adaptive swimming behavior. Fitting a model of stochastic phase oscillators to data suggests that intersegmental coupling in the adult lamprey spinal cord is very strong, and that there are contributions of both ascending and descending fibers. Little is known about the propriospinal system of larval lamprey, though this preparation is often used to assess recovery of function after spinal cord injury. In the current experiment, spinal cords of larval lamprey were isolated and placed in a bath of D-glutamate to induce fictive swimming. Ventral root activity was recorded from three or four segments placed along one side of a 50-segment piece of isolated spinal cord. A model of two stochastic phase oscillators was used to estimate functional coupling strength between pairs of recording electrodes. Most of the ammocoetes had coupling strengths lower than adults, suggesting that the spinal coupling system is not fully mature in larvae. The ascending fraction was less than 0.5 in all preparations to date, indicating that descending coupling is stronger than ascending coupling in ammocoetes. These data confirm that significant reorganization occurs in the spinal cord during the larval stage and/or metamorphosis.

Halvorsen, Michele. A delicious fish with auditory specializations. American shad (*Alosa sapidissima*) are a clupeid fish that has the ability to detect frequencies up to ~180 kHz. They also show strong escape behavior in response to ultrasonic pulses between 70 and 110 kHz and can determine the azimuthal location of the sound source (Plachta and Popper, 2003). Many species of cetaceans use high-frequency clicks (60-170 kHz) to 'see' their environment; this includes American Shad. The specific mechanisms of ultrasound detection are not clear at this point, but anatomical specializations of the utricular end organ offer support that this end organ is involved. Furthermore, electrophysiological evidence within the midbrain and brain stem contain neurons sensitive to ultrasonic frequencies. Direct evidence is needed to prove the utricle is involved. This will be done using electrophysiological recordings from the brain and applying neural tracers to follow the pathway from an ultrasound sensitive neuron to the end organ involved in ultrasonic hearing.

Johns, Philip. Sexy males and selfish genes. Flies in the family Diopsidae have their eyes at the ends of stalks that can, in some taxa, exceed the length of their bodies. Previous research has shown that in the stalk-eyed fly, *Cyrtodiopsis dalmanni*, eyestalks act as classically sexually selected characters: males assess rivals by eyestalk length, females prefer males with longer eyespan as mates. A X-linked meiotic drive factor exists that causes affected males to sire nearly all-female broods, which is deleterious in already female-biased populations. Here, I examine the possibility that eyespan acts as an indicator of whether males bear the drive alleles. Females that avoid males with short eyespans also avoid males bearing the drive alleles.

Nowicki, Steve. Why birds sing, why brains matter. Analyzing the function and evolution of behavior provides an essential backdrop for understanding the genetic and physiological mechanisms responsible for the expression of behavior. The reverse is equally true – understanding the mechanisms underlying behavior provides insight into the evolutionary origins and maintenance of behavior. Studies of bird song illustrate the interplay between ultimate and proximate questions that is necessary for a comprehensive understanding of why animals behave the way they do. Bird song has two primary signal functions: to repel other males from a defended space, and to attract females and stimulate their courtship. Evolutionary theory suggests that these two classes of receivers should only respond to song to the extent that there is some cost that ensures the reliability of the signal. The nature of these costs has been a long-standing puzzle to behavioral ecologists, but can be readily understood when considering the brain mechanisms involved in song learning, perception and production. An understanding of the physiological basis of signal reliability in turn suggests novel insights into song function and evolution.

Hall, Jeff. What, if anything, is neuroethology in the context of behavioral genetics and molecular neurobiology? Behavioral genetics of course involves variations in animals actions. Do any of the behaviors studied in this manner speak to naturally occurring such phenotypes? Perhaps not, because so many behavior- and neuro-mutants are so severely abnormal or anomalous in their activities. However, behavioral mutations also define the genes changed accordingly. This permits not only pinning down the pertinent genetic loci, but also isolating the corresponding pieces of DNA. Having in hand a cloned behavioral gene - if there is such a thing – allows one to tap into naturally varying forms of this factor: "isoalleles" that may not have been readily identifiable otherwise, although in other cases were expected to exist because those genetic variants involve different species. It has been possible to bio-assay the behavioral meanings of certain such DNA-defined variations, with two considerations operating experimentally: (1) sharp focus on real behaviors that connect with adaptively significant activities occurring in the wild (as opposed to narrowly construed stimulus-response phenomena, mutants of which were isolated solely to "get us to the genes" and their encoded products); and (2) phenotypic analyses of more than extant variants per se, in that manipulations of the relevant genes and judicious creation of transgenic animals has been of paramount importance. Other facets of these molecular-genetic approaches take behavioral geneticists into the organisms' nervous systems – at least in terms of neural tissues in which behavioral genes are expressed, significantly augmented by transgene-based manipulations aimed at "dissecting" neural substrates of the behaviors in question. Therefore, it could be that the rather myopic views of behavior-genetic analysis and its associated neurobiology – perspectives that define many neurogenetic inquiries – have been augmented by the subset of this field that unwittingly scrapes up against the edges of neuroethology. Whether this hopeful claim has any validity will be addressed by presenting certain neurogenetic and molecular neurobiological studies that involve insect behavioral rhythms, on the one hand, and *Drosophila* reproduction, on the other.

Ball, Greg. Interactions among photoperiod, testosterone and song behavior in the regulation of adult neuroplasticity in the song control system of European starlings

(***Sturnus vulgaris*****)**. Seasonal changes in the vocal control system of songbirds are one of the most dramatic examples of naturally occurring adult neuroplasticity. In male European starlings, the volumes of telencephalic nuclei that control song such as HVC are significantly larger in the spring than in the fall. Long days promote testis growth and the concomitant increase in plasma testosterone that clearly can stimulate increases in HVC volume. Testosterone is most effective when birds are photosensitive (i.e. responsive to long days characteristic of spring) as opposed to photorefractory (non-responsive to long days characteristic of late summer). Long photoperiods can also stimulate growth in HVC size even in castrated birds. Thus testosterone interacts with other factors in the regulation of seasonal neuroplasticity. Testosterone treatment increases HVC size in part by inducing the expression of brain-derived neurotrophic factor (BDNF). Interestingly, singing behavior itself promotes the release of BDNF in HVC independently of testosterone. We investigated the importance of such activity-dependent release of BDNF in testosterone-treated castrated birds by manipulating song rate with central lesions to the preoptic area (blocks motivation to sing) and with peripheral lesions to the syrinx. In both cases preventing song production significantly decreases HVC volume even in the presence of testosterone. Seasonal changes in HVC volume involves interrelations among photoperiod, endogenous testosterone and behavioral responses to such variables.

Quinlan, Elizabeth. Deafferentation-induced cortical reorganization in adult somatosensory cortex. The ability of synaptic strength to be regulated by experience (synaptic plasticity) underlies the maturation of sensory systems, enhanced performance during learning, and adaptive functional reorganization following injuries such as stroke. It is well documented that synaptic plasticity is greater at immature synapses than at mature synapses. However, peripheral denervation can induce an adaptive reorganization of somatotopy in the deafferented somatosensory cortex (S1), even in the adult. We tested the hypothesis that the active balance between cortical excitation and local inhibition, which maintains the restricted receptive fields (RFs) characteristic of mature somatosensory cortex, is disrupted following deafferentation. We tracked changes in synaptic AMPA receptor (AMPAR), NMDA receptor (NMDAR) and $GABA_A$ receptor ($GABA_AR$) levels in the deafferented somatosensory cortex of adult raccoons following single digit amputation. At 1-9 days post-deafferentation, we observe a significant increase in the level of synaptic AMPARs and a coincident appearance of new excitatory inputs and enlarged RFs. At 2-7 weeks post-deafferentation, we observe a significant increase in $GABA_ARs$, coincident with the return of inhibitory input to deafferented cortex and decreased RFs. The experience-dependent changes in the levels of the major cortical ionotropic receptors were transient, returning to pre-experimental baseline by $\geq$ 17 weeks post-deafferentation, when RFs return to original size, but are remapped to different loci. This suggests that deafferentation-induced cortical reorganization is generated by activity-dependent potentiation of weak excitatory synapses, followed by an increase in the strength of inhibitory synapses, resulting in finely tuned, remapped cortical RFs.

Fritz, Jonathan. Active listening - the role of dynamic receptive field changes in rapid task-related cortical plasticity

In active listening, we attentively focus on particular salient features of the soundscape. For example, we may selectively listen to one conversation at a cocktail party, follow a melody being played by one instrument in an orchestra, try to identify a faint birdcall. How does the auditory cortex adapt to different salient cues in such a variety of auditory tasks? Our results suggest that auditory cortical neurons are in a constant state of task-related flux, allowing the brain to adaptively tweak acoustic filters to optimize analysis of incoming sound. We studied such dynamic cortical change while the animal was engaged in simple spectral tasks such as tone detection or tone discrimination. By measuring the spectrotemporal receptive field (STRF) of single neurons in A1, we could quantitatively describe the STRF changes in shape which resulted as the animal went from a passive condition to different active behavioral conditions. We initially trained ferrets, using aversive conditioning, to detect variable tonal targets against a background of rippled noise stimuli. They quickly learned a variety of other tasks, all of which were variations on a basic task paradigm, in which the animal learned to discriminate between a set of reference stimuli and distinct target stimuli. We studied adaptive responses by comparing STRFs in the awake, but non-behaving ferret (passive condition) vs. STRFs measured while the ferret was performing various auditory tasks. The STRFs were derived using standard reverse correlation techniques. Neuronal responses to the same ripple stimuli were then measured in the context of an active detection or discrimination task. In trained animals, we found that > 60% of neuronal STRFs changed during behavior in a consistent pattern: e.g. (1) Spectral Detection task: at the tonal target frequency, excitatory responses in the STRF were enhanced and inhibitory responses were reduced, (2) Spectral Discrimination task: at the reference frequency, responses were reduced, whereas at the target frequency, responses were enhanced (differential effect). The time course, magnitude, specificity and statistical significance of STRF changes were quantitatively analyzed at a single cell, multi-unit and at a population level. The changes in STRF shape were often highly selective (+- ¼ octave) and could occur within a few minutes of task onset. The duration of STRF change was variable and could persist for hours. Such long-term changes may contribute to auditory sensory memory. OUR working hypothesis is that these adaptive changes may serve to enhance task performance. We discuss these results in terms of a general model of adaptive cortical plasticity.