4th Annual Neuroethology Symposium
Evolution and Mechanisms of Timing and Rhythmic Behaviors

Stamp Student Union
Juan Ramon Jiminez Room
University of Maryland, College Park

May 6, 2005

9:00 – **Introduction** – Dr. Norma Allewell, Dean, College of Life Sciences

9:15 – **Short talks by trainees**
Dan Fergus – Song Variation in the Hawaiian Cricket Genus Laupala
Laura Tucker – Ontogeny of the Serotonergic System in the Lamprey
Dr. Michele B. Halvorsen – Ultrasound Detection by American Shad
Dr. Philip Johns – Eyespan and Sperm Length in the Stalk-eyed Fly, *Cyrtodiopsis dalmanni*

10:15 – 10:40 – Break

10:40 – **Dr. Michael Menaker, University of Virginia**
Circadian Organization in the Vertebrates

11:30 – Lunch (provided)

1:15 – **Dr. Otto Friesen, University of Virginia**
Neural Control of Animal Locomotion: Timing is Everything

2:05 – 2:30 – Break

2:30 – **Dr. Paul Katz, Georgia State University**
The Neural Basis and Evolution of "Sluggish" Behaviors

3:20 – 3:45 – Break

3:45 – **Dr. Avis Cohen, University of Maryland**
How Biological Principles of Central Pattern Generators Help to Build a Better Robot – or Playing with Toys

4:25 – 5:00 – Break

5:00 – **Roundtable Discussion. "Does Timing Scale?"**

7:00 - ? **Dinner and discussion** at Cindy Moss' house (directions will be provided at the symposium)

<u>Abstracts</u>

Dr. Michael Menaker
Department of Biology
University of Virginia

Circadian Organization in the Vertebrates

If one takes a broad view of vertebrate circadian systems what emerges is a picture containing some common threads which only very roughly follow phylogenetic lines, overlain with a good deal of variability in the important details. It is not possible to say that all members of one vertebrate class are organized in a particular way with the possible exception of the mammals. Indeed among the reptiles not all lizards nor even all iguanid lizards have similarly organized circadian systems. Identifying the common threads and accounting for the variability are major challenges; until they have been met we will not fully understand the system we are studying nor be able to make the most productive use of the many experimental models with which natural selection has provided us. Our hypothesis is that the vertebrate circadian axis is very old--indeed as old as the vertebrates themselves; further, that it is relatively "easy" to modify and has in fact been modified many times in the last 500 million years, each time in response to selection pressures in particular environmental niches. If that were all there were to it, the task of unraveling 500 million years of response to the many environments occupied by the vertebrates during that time would be hopeless, but it may not be because it seems likely that circadian systems are influenced predominantly by one aspect of their environment--light. A corollary of our hypothesis therefore is that the differences in circadian organization that one finds among the vertebrates are to a large extent the consequence of rapid adaptation to particular photic niches into which groups have been pushed by a variety of unrelated selection pressures. If that were true then it should be possible to correlate particular aspects of circadian organization with the photic history of the groups in which they are found. The attempt to establish such correlations is made difficult by several uncertainties; among them are: *(i)* it is hard to define the photic niche occupied even by living organisms much less those that have become extinct; *(ii)* we don't know the photic histories of most organisms (*i.e.*, the photic environments that they occupied during their evolution) in much detail; *(iii)* we have no idea how quickly circadian organization can be modified by selection; *(iv)* there are undoubtedly other undefined pressures acting on the system at the same time as those from the photic environment. Nonetheless some interesting correlations can be made and that fact alone encourages us to believe that our hypothesis may prove to be fruitful.

Dr. Otto Friesen
Department of Biology
University of Virginia

Neural control of animal locomotion: Timing is everything

The central tenet of Neuroethology declares that animal behavior arises from ensembles of functionally delimited neuronal circuits. During locomotion, central neuronal oscillators orchestrate exquisitely timed movements of appendages, or of the entire body, to generate efficient movements. Biological clocks synchronize behavior with our spinning earth, while neuronal oscillators, resembling coupled metronomes, set the beat for movement rhythms. Swimming behavior in many elongated aquatic animals arises from whole-body undulations, with slightly more than one cycle of a quasi-sinusoidal body wave expressed at any time. The dynamics expressed in such locomotion arise from: a) the central neuronal oscillators that set cycle periods, b) the neuronal interactions that establish local and intersegmental phase relationships, and c) phase- and period-dependent sensory feedback, which modifies central oscillator output to ensure appropriate body movements for existing peripheral structures and environmental conditions. This presentation will focus on timing processes that underlie leech swimming movements--derived from more than a century of behavioral, physiological and modeling investigations. Critical elements include a) broadly distributed central oscillator circuits that set cycle periods within a range of about 0.6 to 1.0 s, b) equally widely distributed intersegmental synaptic interactions that, redundantly, set intersegmental phase lags during fictive swimming to about 100 per segment, and c) phase-dependent sensory feedback via muscle tension receptors that decrease centrally generated cycle periods, and increase intersegmental phase lags to values characteristic of intact animals.

Dr. Paul Katz
Department of Biology
Georgia State University

The Neural Basis and Evolution of “Sluggish” Behaviors

This talk will use the neural circuits underlying swimming behaviors in sea slugs to illustrate how neuromodulatory actions can convey timing information in neural circuits and how homologous neurons can function differently in closely related species. Rhythmic movements are produced by neural circuits called central pattern generators (CPGs). We found that neurons intrinsic to the swim CPG in the sea slug, Tritonia diomedea are serotonergic and evoke spike-timing dependent neuromodulatory actions. These time-varying changes in synaptic strength are caused by serotonin activating two different intracellular biochemical signaling pathways with different time courses. Such Temporal properties of biochemical signaling may also play a role in determining the periodicity of the motor pattern. Homologues of these serotonergic neurons are present in other sea slugs with different swimming behaviors, but they are not part of the pattern generating circuit in those species. Thus, homologous neurons can play different roles in the generation of analogous behaviors.

Dr. Avis Cohen
Department of Biology and Institute for Systems Research
University of Maryland

Locomotion in all its various forms is an oscillatory phenomenon. The limbs swing periodically, or the body moves periodically if limbless. Any form of locomotion is a function of 1) the mechanics of the body, plus interactions with the environment, 2) the neural control of the muscles, and 3) the sensory feedback from the body and the environment. All are necessary for fully functional and adaptive locomotion. The same applies to legged robots. My colleagues and I have used these principles to develop efficient biped and quadruped robots. I will describe how we have implemented these robots, including the first and second generation chips and the sensorimotor feedback principles used to control the limbs. For the second generation chip, we expect to employ adaptive learning circuits and models developed for co-activation of antagonistic muscles.