



**Research Experiences at the Biology-Mathematics Interface (REBMI)  
and  
Claremont Center for Mathematical Sciences (CCMS)  
Summer 2009 POSTER Session  
Marian Miner Cook Athenaeum - Claremont McKenna College  
Wednesday, September 16, 2009**

**(R1) The Correlation of Postural Sway to Lower Extremity Maximal Muscle Strength**

*Josh Shapiro, (PO) and Rachel Bellows (PI), Professor Michele LeBlanc (Cal Lutheran)*

Abstract: The purpose of this study was to determine the correlation of lower limb muscle strength with the various methodologies of measuring postural sway. Forty-two healthy subjects (age range from 4 to 74 years) were recruited to participate in the study and measurements were taken after subjects signed a university-approved consent form. Two Kistler force plates collecting at 500 Hz were used to compute the whole body center of pressure during 40-second trials of static balance. Each subject completed four trials with eyes open and four trials with eyes closed. This data was then used to quantify the subject's postural sway creating the following parameters: (1) mean displacement velocity, (2) sway path (total, mediolateral and anteroposterior), (3) total sway area, (4) 95% confidence ellipse area, and (5) mean amplitude for low and high frequency transformations. The 30 adult subjects' lower extremity isometric joint peak torque was determined by using the Biodex System 3 to measure values at the hip and ankle. After normalizing for body weight, gender specific T-scores were computed for dorsiflexion (DF), plantar flexion (PF), hip flexion (HF) and hip extension (HE). Correlation coefficients were computed between all postural sway measurements for the group of all 43 subjects. Of the 45 comparisons that were made, 16 pairs showed a statistically significant relationship with  $p < 0.01$  and an additional 13 pairs with  $p < 0.05$  for the trials with eyes open. The same comparisons with eyes closed found 14 pairs and 10 pairs, respectively. A simple correlation test did not find many strong relationships between the strength values and the postural sway values. A more complex analysis may reveal other relationships.

**(R2) Modeling Mammalian Limb Tactile Sensation in a Spinal Like Regulator**

*Cullen McMahon (HMC) and Alex Labby (JSD), Professors Gerald Loeb and George Angelo Tsianos (USC)*

Abstract: Neuroscientists debate as to the contribution of the spinal cord versus that of the brain in mediating limb movement. The research goal was to gather information to assist in the creation of a working spinal cord model, such that the feasibility of a "dumb brain" and a "smart spinal cord" could be assessed. This model would include both a tactile transduction component, as well as how tactile information affects upper limb movement through various interneurons. A literature review of tactile mechanoreceptor models and spinal reflex research was used to first determine if such models exist, and if not, to create them. A new model of the fast adapting type I (Meissner Corpuscle) was created, a model of the fast adapting type II (Pacinian Corpuscle) was found, and the slow adapting type I & II (Merkel cell and Ruffini ending) mechanoreceptors were determined to require further research to model. In addition, the effects of cutaneous stimulation on different muscle groups acting through propriospinal and group Ib interneurons were collected and a set of models for the connectivity was created. These results together could be added to an existing model of the spinal circuitry to include the effects of tactile sense on upper limb movement

**(R3) Observing and Modeling Dynamics of the Min Protein System**

*Max Mautner (CMC) and Liana Engie (PI), Professors Eric Cytrynbaum (U of British Columbia) and John Milton (JSD)*

Abstract: At the end of their cell cycle, bacteria divide in half to form two daughter cells. The Min proteins form the mechanism by which the location of the division in E. Coli cells is determined. The Min system's proteins oscillate between the poles of the cylindrical cells; this strange behavior is a popular system for mathematical modeling as the reasons behind the oscillations are unknown. Our project consisted of two aspects: experimental study of live E. Coli cells, and computer simulations of the system.

**(R4) Infant Bouncing Paradigm**

*Ian McLaughlin (PI) and Jacob Feldman (HMC), Professors Heidi Sveistrup, Andre Longtin and Natalie Baddour, (U of Ottawa) and John Milton (JSD)*

Abstract: The infant-bouncing paradigm serves as an indicator of a nervous system's capability to acquire novel motor skills and sequences, and can potentially present an isolation of proprioceptive and/or vestibular functions through experimental inhibition of visual input. Bouncing at the natural frequency for the system in a Jolly Jumper presents several advantages, and might be considered to be the goal of this motor-acquisition paradigm. Eight healthy infants, some with prior experience in Jolly-Jumpers, were placed in an experimental apparatus analogous to the spring-system characterizing Jolly Jumpers. From those infants that expressed higher frequencies of bouncing, bouts of the behavior were assessed for commonalities across observed behavior in effort to distinguish effective from ineffective bouncing. It was quickly realized that synchrony in the joint-angles at the knees was predictive of the level and quality of bouncing behavior exhibited; while the amplitude of knee flexion from each leg, as well as degree of lateral hip rotation, varied in active bouncers - so long as the timing and angle of knee flexion of both knees were phase locked, longer and more pronounced bouts of bouncing were observed. Furthermore, the data lends some support to an amalgamation of the models of motor-skill acquisition proposed by Goldfield and Doyon et al.; infants appear to exhibit transitions from assembly to consolidation to tuning phases, in cycles of progressively restricted degrees of freedom. The proposed model offers a system analogous to that of an infant in a bouncing apparatus, characterized by a probabilistic progression from primitive to more skilled stages of skill acquisition reflecting observed behavior. Additionally, the model provides an optimization program that will indicate the changes experimenters might apply to experimental parameters in order to render observed bouncing behavior to approximate the natural frequency of the system. The applications of this model include perturbation studies of infant motor-sequence acquisition, investigation of sensory weighting, as well as a framework for the development of treatment paradigms for patients of various motor deficits. After assessing the behaviors of eight healthy infants in an experimental bouncing apparatus, consistent characteristics of effective and ineffective bouncing were extracted and utilized in the development of a model with modifiable parameters that simulates an infant in such an apparatus.

**(R5) A Comparison Between Visual and Acoustical Whisker Localization Techniques**

*Sophia Yang (PO) and Matthew Phillips (HMC), Professor Tansu Celikel (USC)*

Abstract: Mice are very reliant on their whisker sensory systems in collecting information about the environment. In the past few decades, in part due to the simplicity in representation of the barrel cortex system, the rodent whisker sensory system has proven to be a useful model for the study of plasticity and sensory information processing. In a complete representation of such a model, both the sensory input information and the neural responses, as well as the behavioral response, need to be represented. Although much work has been done on the quantification of neural responses via electrophysiological methods, the ability to quantify the sensory input information from whiskers is still in need of development. We thus implement and compare two different methods for the quantification of tactile information during the whisking of freely behaving mice. In the first method, a newly developed sensor in the form of a microphone array against a surface allows for acoustical triangulation analysis, allowing for the precise localization of whisker contacts against a given surface. In the second method, simultaneous high-speed visual recordings in a two-camera setup improve on current visual whisker tracking methods.

**(J1) Geometric Analysis of a Generalized Wythoff's Game**

*Scott M. Garrabant (PI) and Ilona K. Phipps-Morgan (SC), Professor Adam S. Landsberg (JSD)*

Abstract: We analyzed a class of impartial combinatorial games called "Linear Nimhoff," which is an extension of Wythoff's Game. These games are defined by a rule set of vectors,  $R$ , and a token on a square grid. On each player's turn, he/she may select any vector from  $R$  and move the token toward the bottom left corner along that vector any number of times. The exact locations of the P-positions in this game are nontrivially distributed, but they exhibit an overall geometric structure in that all of them lie near some finite set of lines passing through the origin. The number of lines, their slopes, and the densities of P-positions near them depend on  $R$ . We develop a method which, we conjecture, consistently determines the number, slopes, and densities of these lines. These lines allow us to approximate the locations of the P-positions in this general class of games.

**(J2) Mathematical Modeling of Dendritic Cell Immuno-Therapy for Cancer**

*Megan Hunter (PO), Chris DeBoever (HMC), and Helen Wu (HMC), Professors Ami Radunskaya (PO) and L.G. de Pillis (HMC)*

Abstract: One of the most promising immune therapies for cancer is dendritic cell (DC) treatment. In this work, we modify and extend a previous differential equations model with delays of murine dendritic cell trafficking model to include a cancer compartment. We used the data collected in experiments on tumor growth in the presence of varying levels of DC injections to determine parameters relevant to the tumor-immune system interaction. We fit parameters using least squares regression. There are two equilibria associated with our model and parameters. We would like to move our parameters into a region with three equilibria. Latin hypercube sampling was performed for parameter sensitivity analysis; tumor growth rate and the steepness coefficient of the fractional tumor kill by CTLs were the most sensitive parameters. Spreading DCs over many injections cause the body to have a higher immune response.

**(C1) Compact Models for Quantum Effects in Single Gate MOSFET Devices**

*William Feldman (CMC), Professor Ellis Cumberbatch (CGU) and Dr. Henok Abebe (MOSIS Chip Fabrication Services)*

Abstract: In order to increase computing power in the future the semiconductor industry has focused on constantly reducing the size of the most basic electronic device that makes up computer chips, the transistor. As transistors are scaled down to lengths in the nanometers, the classical models which have described transistor behavior break down when they run into quantum mechanical behavior. As the size of transistors decreases, the number of transistors per chip increases accordingly. When simulating hundreds of millions to or even a billion transistors, simple models are required to describe the transistor function; these are called compact models. New compact models describing quantum effects are necessary in order to provide efficient and accurate simulation of chip properties. We analyzed the widely used single gate metal-oxide-semiconductor field effect transistor (MOSFET) using a new approximating model to achieve better approximations of the energy bands and electron density in the semiconductor, and a new approximation for the current loss due to quantum tunneling.

**(C2) (t-s)-Rack Invariants**

*Jessica Cenicerros (CMC), Professor Sam Nelson (CMC)*

Abstract: Racks are self-distributive algebraic structures with axioms inspired by the Reidemeister moves. In this talk, we define an enhancement of the rack counting invariant for knots and links using the extra structure of (t-s) racks, a type of rack which generalizes Alexander quandles.

**(H1) Surfactant Spreading on Thin Liquid Films**

*Georgi Dinolov (HMC), Professors Rachel Levy (HMC) and Karen Daniels (NCSU)*

Abstract: Surfactants are used in industry for their ability to lower surface tension, and there remain many questions about how to mathematically model their dynamics. A droplet of surfactant on a liquid surface spreads away from itself due to imbalance of forces at its leading edge. These forces also act on the liquid to create an expanding surface wave. Our experiment tracks a radially symmetric, inward-moving wave and the surfactant which induced it. We directly image the surfactant by using lipid molecules containing fluorescent functional groups which glow under ultraviolet light. We also measure the location of the surface wave ridge by refraction of a laser line. By combining these two novel experimental techniques, and employing a digital camera, we capture the surfactant spreading and wavefront movement on a millimeter-thick liquid film. We compare our results to mathematical models, which predict power-law behavior with an exponent of  $1/4$ , for outward-moving waves.

**(H2) Vortex Tracking in Numerical Simulations of Fluid-Structure Interactions**

*Oliver Ortlieb (HMC), Professors Jeff Eldredge (UCLA) and Rachel Levy (HMC)*

Abstract: This project sought to quantify the behavior of vortex pairs in two dimensional simulations of fluid-structure interactions. A viscous vortex particle method simulator, developed by Professor Jeff Eldredge, was used to collect experimental vorticity data. Vortex centroids were designated as the best reference point from which to track a vortex, and so a centroid tracking tool was developed.

**(P1) The Geometry of the Ratio Field of Values of Two Matrices**

*Eduard Einstein (PO), Professors Charles Johnson and Ilya Spitkovsky (College of William and Mary) and Brian Lins (Hampden Sydney College)*

Abstract: This project examines a generalization of the usual field of values, the ratio field of values of two matrices given by:

$$R(A, B) = \left\{ \frac{x^*Ax}{x^*Bx} : x \in \mathbb{C}^n, x \neq 0 \right\}$$

when  $A, B \in M_n(\mathbb{C})$  with  $0 \notin F(B)$ . We aim to develop theory for the ratio field, concerning ourselves primarily with its geometry in the complex plane. In particular, we focus on convexity, the existence of interior and simple connectedness.

**(P2) Statistics of Metagenomic Analysis**

*Chris Peterson (PO), Naneh Apkarian (PO), Collaborators Michelle Creek (Chapman) Eric Guan (Torrey Pines HS), Myra Hernandez (SDSU), Kate Isaacs (SJSU) and Todd Regh (Southern Oregon U), Professors Barb Bailey, Liz Dinsdale, Rob Edwards, Vadim Ponomarenko, Peter Salaman and Imre Tuba (SDSU).*

Abstract: Metagenomic data is comprised of a sampling of DNA sequences from microbial communities within an environment. Examining the functional diversity represented by these sequences gives insight into the biological processes within an environment. Most research has focused on single specific environments; there has been little comparative study of how metagenomes change across environments. Dinsdale et al used canonical discriminant analysis to investigate 45 microbial metagenomes in Functional metagenomic profiling of nine biomes, *Nature*, 452, (2008), 629-632. We expand on this work by applying a variety multivariate statistic and machine learning techniques to study over 300 metagenomes from various environments. In addition, we attempt to model the impact of environmental variables on microbial communities by analyzing changes in functional profiles. This second analysis focuses on a comparison of ocean pollution data to marine microbial metagenomic data, and seeks to determine the impact of human activity on marine microbes.

**(P3) Commuting Power Series over  $p$ -adic Rings**

*Minsoo Kim (PO), Emily Ognacevic (U of St. Louis), Jessica Olsen (U of Puget Sound), Sam Schiavone (Amherst) and Joel Specter (Wesleyan), Professor Ghassan Sarkis (PO)*

Abstract: Using a new notion of absolute value that measures the divisibility of a number by a given prime, we developed the idea of  $Z_p$ , the ring of  $p$ -adic integers. Examining questions of when power series would commute over this ring led us to Lubin's conjecture, which states that when two such power series exist, they must be related to the endomorphisms of a formal group in  $Z_p$  as well. This poster presents two possible directions to follow Lubin's conjecture: on one hand, creating counter examples with "condensation" in order to refine the statement of the conjecture, while on the other hand, attempting to show the conjecture as true in a special case, namely when we have a non invertible, invertible non torsion, and a  $p-1$  torsion power series all in  $Z_p$  that commute with each other.

**(S1) Completions and Minimal Prime Ideals**

*Rachel Karpman (SC), N. Arnostic and J. Levinson (Williams College) and C. Levenson (Wellesley College), Professor Susan Loepf (Williams College)*

Abstract: Consider the set of complex polynomials in one variable. We can a distance function on this ring, which turns out to be a metric. However, the resulting metric space is not complete. Completing the space yields the ring of complex power series. The notion of completing a polynomial ring generalizes to a class of commutative rings called local rings. Our research focuses on the relationship between a local rings and its completion. Given a complete local ring  $T$  with  $k$  minimal prime ideals, let  $C_1, \dots, C_j$ , be finite collections of prime ideals of  $T$ . We find necessary and sufficient conditions for  $T$  to be the completion of a ring  $A$  such that  $A$  has exactly  $j$  minimal prime ideals  $Q_1, \dots, Q_j$ , and for each  $Q_i$ , the set of prime ideals  $P$  of  $T$  whose intersection with  $A$  is equal to  $Q_i$  is precisely the collection  $C_1$ .

**Legend:** **R** - Research Experiences at the Biology-Mathematics Interface (REBMI), **J** – Joint Projects, **JSD** - Joint Science Department, Claremont Colleges, **C** or **CMC** - Claremont McKenna College, **H** or **HMC** - Harvey Mudd College, **PI** - Pitzer College, **P** or **PO** - Pomona College, **S** or **SC** - Scripps College