THIRD ANNUAL RABI SCHOLARS RESEARCH SYMPOSIUM
12 noon to 2 p.m., Friday, September 19, 2008
569 Lerner Hall

ABSTRACTS

AGNE, Michael R.

Mentor: Angelo Cacciuto

Simulations Regarding the Deformation of a Cylindrical Membrane

Computer simulations mimic such nano-scale systems, allowing them to be more readily measured and predicted. One of the most important consequences of an applied force to a cylindrical membrane is a "persistence" of this interaction emanating from the central force and continuing far along the membrane's length; its physical extent is known as "*persistent length*." (If one imagines folding a piece of paper into a cylinder and pushing one's finger into the side, *persistent length* measures how far that bending perpetuates.)

Using a molecular dynamics simulator LAMMPS and C programming, we created a virtual cylindrical membrane, and virtually applied a force to the cylinder in order to monitor how it reacted/folded, focusing on how deep the indentation extended and how far the *persistent length* radiated, with varying radii. There is a relation between this depth, persistent length, and radius, in cooperation with the inherent flexibility of the membrane. Data also included the ratios of the force applied to depth of indentation and notation of where (at which applied forces and indentation depths) the persistent length reached the length of the cylinder, and thus a maximum.

ALLOCCO, Elizabeth

Mentor: Joy Hirsch

The Self Face and Conflict Adaptation Effects

The Stroop task requires subjects to overcome the interference caused by a written color word in order to identify the physical color of the word stimulus, for example, identifying the color of the word "blue" printed in yellow ink. The word and the ink color may be either congruent or incongruent, with the latter eliciting a longer reaction time. The sequence in which the Stroop stimuli are presented has a significant effect on subject performance: a decrease in reaction time to an incongruent, high-conflict, stimulus is observed if the preceding stimulus is also incongruent, relative to the reaction time observed if the preceding stimulus is congruent and low-conflict. This conflict adaptation interaction effect is facilitated by a cognitive control mechanism executed by the anterior cingulate cortex that identifies the input most important to accurate task performance and causes it to be processed more efficiently. In this experiment, the Stroop task has been incorporated into a paradigm involving both self and personally-familiar faces, where the color word is overlaid on a pseudo-colored face in order to investigate the influence of the face identity on the previously described interaction effect. Imaging studies have established unique processing networks elicited by the self face, and self-related stimuli have been shown to attract attention and affect performance in a flanker task. Preliminary psychophysical data suggest that the presence of the self face eliminates the conflict adaptation effect observed in the classic Stroop paradigm by overpowering the cognitive control mechanism, which is active in the presence of stimuli containing personally familiar faces. The study will be extended to include functional data collected using fMRI, and a structural investigation of white-matter tracts connecting functionally identified areas using diffusion tensor imaging (DTI).

ATANASOV, Atanas
LOPEZ, Christopher
PERRY, Alex

Mentor: Michael Thaddeus

Polyhedral Cones and their Intersections with Lattices

The Nash blow-up is a procedure that aims to resolve singularities in algebraic geometry. We apply this procedure to affine toric varieties, which correspond to polyhedral cones in n-dimensional Euclidean space. Cones isomorphic to the standard orthant lead to immediate termination of the Nash blow-up process. Otherwise we obtain new cones on which the process is repeated. It is unknown whether the Nash blow-up terminates in a finite number of steps for all dimensions. In two dimensions, we have solved the problem affirmatively. In three dimensions, we have obtained large amounts of data and proved some interesting properties of these cones.

BECK, Samuel

Mentor: Norman Christ

Deconfinement in SU(2) Lattice Quantum Chromodynamics

Lattice quantum chromodynamics provides a reasonable means of determining the behavior of otherwise intractably complicated processes. I used a Metropolis-Hastings algorithm to generate populations of gluonic fields (SU(2) gauge fields), to approximate the Feynman path integral in Euclidean space-time. By varying the coupling constant, I found a clear phase transition from a confined phase to a deconfined phase.

BELOPOLSKI, Ilya
Collaborator: Alexandra Taborga, University of Chicago

Mentor: Szabolcs Márka

Simulating LIGO Noise for Gravitational Wave Detection

Gravitational waves (GW) promise to provide a new window on the universe by allowing scientists to observe astrophysical phenomena for the first time without dependence on light. However, although the existence of gravitational waves has been predicted theoretically for nearly one hundred years, these waves have not yet been directly detected because they interact so weakly with matter. Indeed, despite substantial improvements in recent years, detector systems such as the Laser Interferometer Gravitational-Wave Observatory (LIGO) still output data contaminated by many sources of environmental, instrumental, and fundamental noise. One current strategy is to develop a technique that will extract a GW signal from the non-Gaussian/non-stationary noise outputted by LIGO. An important first step toward this goal is to synthesize LIGO noise whose statistical characteristics are well determined and consistent with real data. Then, a modeled gravitational wave signal could be mixed into this synthetic noise, providing a controlled test environment to analyze different ways to extract useful signals from noise. Here, we develop an algorithm that generates synthetic LIGO noise. Starting with white Gaussian noise (WGN), we weighted the frequency components of the WGN with the power spectrum of the desired output noise. The result is regularized output noise with the same statistical characteristics as a given type of genuine LIGO noise. These results could be used to develop, validate, and compare different algorithms to extract useful gravitational wave signals from noisy LIGO output. In addition, by starting with 'pure' WGN and non-stationary LIGO noise, our algorithm can output noise of any given quality between the best-case (white noise) and worst-case (genuine noise) scenario. Furthermore, our algorithm allows different power spectra to be analyzed for their potential to uncover useful GW physics, so that the next generation of GW detectors can focus on improvements in specific frequency ranges. This will allow more efficient and economical development of GW detectors in the future.

BREGMAN, Corey

Mentors: Maksim Lipyanskiy and Thomas Peters

Computer Implementation of Poincaré's Polyhedron Theorem in Hyperbolic 3-Space

One of the important consequences of Poincaré's celebrated polyhedron theorem is that any subgroup of isometries of a space that satisfies the hypotheses of the theorem is in fact discrete. Thus the theorem affords us with a means of proving if a group is discrete merely by checking certain hypotheses of the theorem. In the case of hyperbolic 3-space, the group of isometries is isomorphic to PSL(2,C). In this study we develop a program in Python that is capable of rigorously checking the hypotheses of Poincaré's fundamental polyhedron theorem for certain subgroups of PSL(2,C). Thus, given the generators of a subgroup of PSL(2,C), our computer program constructs the Dirichlet domain for the subgroup. Making additional assumptions about the combinatorial structure of the surface, it is also possible to prove, given adequate precision, that the domain meets all the requirements of the theorem, and determine if the group is discrete. We first present the relevant background information concerning hyperbolic 3-space in the Projective Disk (Klein) model, then describe the program routines associated with constructing the domain and verifying the hypotheses of the theorem. Included in the program is a method for calculating the hyperbolic volume of the Dirichlet domain and hence the volume of the manifold associated with it. Finally, for several exceptional subgroups of PSL(2,C) we apply the program described above and calculate the volumes of the manifolds generated.

CHOU, Kevin

Mentor: Daniel Bienstock

Statistical Modeling of the MTA Transit System

MTA transit system data was provided by the Columbia University Mailman School of Public Health to study the effects of an epidemic in New York City. A statistical simulation of point-to-point ridership for the MTA subway system was designed in Excel, programmed in R, and finally optimized using the mathematical software package ILOG CPLEX. Modifications to the model unveiled the consequences of closing certain subway lines, which are possible decisions made in the case of an epidemic. The impact of such events on transit patterns was then observed, assuming each individual chose the route that minimized his own sense of congestion.

CHOY, Megan

Mentors: Paul A. Marks and Raphael Parmigiani

Effects of Histone Deacetylase (HDAC) Inhibitors on Cancer Cell Motility

Metastatic cancers are difficult to treat because of their aggressive ability to spread undetected throughout the body. Breast and prostate cancer are two common types of metastatic cancers that affect one-third of all cancer patients. It has been previously shown that some HDAC inhibitors can decrease cancer cell motility by affecting tubulin, a known HDAC6 target. In this study the migratory effects of different HDACi's as well as knocking down various combinations of HDAC's in human breast epithelial carcinoma cell line MDA-MB-231 and human prostate adenocarcinoma cell line LNCaP were studied. Migration chamber assay results showed that HDACi MS-275 induced cell migration in HDAC6 positive cancer types. However, the increased migratory effects of MS-275 can be negated when cells are treated with HDAC6 specific inhibitor Tubacin. Further experiments are needed to determine the cause behind increased cell migration with MS-275.

DHULDHOYA, Jay

Mentor: Brian Cole

Examination of ATLAS Heavy Ion Jet Reconstruction Algorithm

High-energy nuclear physics is vital in understanding Quantum Chromodynamics (QCD), the theory that describes the strong force that binds quarks and gluons within nucleons. Heavy ion collisions can be used to study QCD because when the ions collide, the high temperature allows the bound quarks and gluons to dissociate into an unbound quark-gluon plasma (QGP). Within the QGP, individual high-energy quarks or gluons interact with the medium, and subsequently fragment into a spray of hadrons, called a jet. These jets serve as probes into the properties of the QGP and consequently are useful in studying the underlying QCD. These heavy ion collisions were simulated using a description of the ATLAS detector at the LHC. The primary focus of the project was to study the reconstruction algorithm, which takes the simulated data and reconstructs the jets in an event. First, the reconstructed jets were analyzed to determine the algorithm's efficiency, the percentage of reconstructed jets that correlated with expected results. The efficiency showed that the percentage of jets that were indeed reconstructed as expected increased drastically as the energy of the jet increased and then maintained 100% efficiency after 85 GeV. Next, the data was examined to determine the energy scale, the discrepancy in the energy value of the reconstructed jet with expected results. The energy scale was, on average, zero for jets above 50 GeV with low deviation (< 20%). The reconstruction algorithm performed with high efficiency and accuracy and will soon be used to analyze actual data from the ATLAS detector at the LHC.

GEORGESCU, Alexandru

Mentors: Charles Hailey, Kaya Mori, and Jason Koglin

Simulating X-Ray Scattering on Random Particles

Experimental data obtained by Hung Jun An NuStar, a telescope working in the hard X-ray radius (6Kev-80MeV), due to the much lower incidence angles needed, encounters a problem normal telescopes do not: incoming light interacts with randomly distributed epoxy molecules that are “stuck” to the glass after evaporating. My summer project consisted of a library search for a better understanding of Mie scattering for a single particle, elaborating a theory of how multiple particles in a row might influence the scattered light, writing a program in IDL language to model theoretically the incoming light's scattering pattern, and fitting the experimental data to obtain information about the particle sizes. Our modeling has determined approximatively the size of the epoxy particles as 10^{-8} m, with surprisingly few difficulties in spite of the fact that we approximated the epoxy molecules as spheres, and considered them to be organized like the corners of a chess table. The work is significant because it provides an example on which to build, and because it has influenced the choice of epoxy for the NuStar telescope.

GRAY, Zachary

Mentor: Szabolcs Marka

Probing for Gravitational Waves: The Implications of a Theoretical Model for Supernova Wave Radiation in the Design of Ground-Based GW Detectors

Gravitational waves, a theoretical consequence of general relativity, are characterized as ripples in spacetime generated by the motion of massive objects. In contrast to electromagnetic radiation, which is propagated *through* space, gravitational waves act *within* the fabric of spacetime itself, manifested as alternating periods of elongation and contraction of the distances separating objects. The existence of these waves has been demonstrated only indirectly – through the repeated verification of Einstein’s relativistic framework (of which they are a part) and a Nobel Prize-winning experiment by Hulse and Taylor in which the decreased orbital period of a binary pulsar system was observed to coincide with the predicted quantities of energy loss due to gravitational waves.

Gravitational waves pass nearly unperturbed through matter, rendering their observable effect insignificant on the human scale; however, by tracking astrophysical phenomena, scientists hope to employ the technology of detectors such as LIGO and Advanced LIGO to study gravitational waves. This capability would provide astronomers with a heretofore inaccessible faculty for perceiving the Universe: if the electromagnetic spectrum is representative of vision, gravitational waves are analogous to sound and detectors such as LIGO our ears.

With Advanced LIGO still a project of the future, information about gravitational wave sources will fundamentally impact its design as the instruments are tuned to those phenomena for which they must probe. A promising wave source is the supernova; however, knowledge regarding the precise mechanism for gravitational wave propagation by supernovas is incomplete. Theoretical studies by Professor Adam Burrows of Princeton proposes a novel hypothesis that attempts to revise and revolutionize our prior understanding of this phenomenon. At this point, however, the data of Burrows et al. remains untranslated between computer quantities and the observed signal as it would appear to LIGO scientists. This study aims to reconcile Burrows’ theoretical model with the experimental approach of wave detectors. By depicting the gravitational wave signal of a supernova explosion (as hypothesized by Burrows et al.) in the language of LIGO, insight may be provided into the nature of wave sources as they apply to detectors. As Advanced LIGO is tuned for optimal function, information present in this research may prove integral to the instrument’s ultimate design.

GURNANI, Lalit

Mentors: Mitchell Cairo and Jess Hochberg

Genetic Reengineering of Natural Killer (NK) Cells for Targeted Cellular Tumor Immunotherapy for CD20+ PreB-ALL/B-NHL

PreB-ALL and Non-Hodgkin Lymphoma (NHL) are two common childhood malignancies. An emerging area of research that has shown much promise is targeted immunotherapy against high risk or resistant malignancies. This research involves using NK cells that have been genetically modified with chimeric antigen receptors specifically targeting a specific tumor marker. The chimeric antigen receptors can overcome inhibitory signals that would make tumor cells resistant to NK cells. Our hypotheses are 1) Cord Blood (CB) NK cells can be expanded and activated by a genetically modified human leukemia K562 cell line and 2) the expanded and activated CB NK cells will significantly enhance in vitro and in vivo killing of CD20+ NK resistant PreB-ALL and B-NHL cells. After fourteen days, NK cells expansion after exposure to the K562 cell line was at 90% demonstrating that the NK cell expansion system was successful. The second part of our hypothesis will be tackled next.

HANCOCK, Stephen
KENNELLY, Michael

Mentor: Amber Miller

Filter Development in the CEPSR Clean Room

Many current Cosmic Microwave Background Radiation measurements are taken with bolometers, devices that measure the energy of incident electromagnetic radiation by measuring the temperature difference between an absorber strip and a heat sink. However, bolometers suffer from extreme susceptibility to out-of-bandwidth noise, and require filters for band definition. For the past four years, The Miller CMB Group at Columbia University has been working in the CEPSR clean room to produce narrow bandwidth millimetre and sub-millimetre filters. With an EM wave incident on one side, transmission to the other side is frequency-dependent according to the geometry of the mesh. This results in a surface that reflects some frequencies while allowing others to pass through. The group works on both using computer modelling to predict the transmission curve for a given mesh geometry to design filters for certain wavelengths and the fabrication of filters of copper evaporated onto Low-Density Polyethylene and Polypropylene.

HORLBECK, Max

Mentor: Rodney Rothstein, Columbia University Medical Center

Exploring Nucleolar Structure in Sacchromyces Cervisiae

Both the nucleosome and the nucleolus play important roles in transcriptional regulation, DNA repair, and genomic stability. The nucleosome, which is made up of histones H2A, H2B, H3, and H4, coils the DNA into chromatin and, by interactions with transcription factors or histone-modifying enzymes (i.e. phosphorylation, methylation), allows other proteins to interact with target sequences. However, the chromatin structure is much different in the nucleolus, allowing ribosomal DNA to be constitutively transcribed. Regulation and repair mechanisms in the nucleolus are largely uncharacterized. To begin to elucidate these mechanisms and gain better understanding of nucleolar structure as a whole, we studied the localization of the four histones to the nucleolus using fluorescence microscopy. Colocalization was studied both in wild-type and number of different mutant backgrounds. While nuclear pore protein deletions caused mainly nucleolar fragmentation, *uaf30Δ,* an rDNA-specific transcription factor, noticeably increased colocalization of H2A.

MISRA, Vedant

Mentors: Alberto Nicolis and Janna Levin

Constructing a Periodic Table of Orbits in Reissner-Nordstrom Spacetime

An understanding of the nature of particle trajectories in black hole spacetimes is important for ongoing and future gravitational wave experiments. Orbits of charged particles in Reissner-Nordstrom spacetime (outside charged, non-rotating black holes) were generated. A taxonomy of orbits described in earlier literature for characterizing particle geodesics in Kerr spacetime (outside uncharged, rotating black holes) was applied to trajectories in Reissner-Nordstrom spacetime (outside charged, non-rotating black holes) to establish a correspondence between equatorial geodesics and the rational numbers.

MOY, Man-Yu

Mentor: Julide Tok Celebi, Columbia University Medical Center

CYLD Gene Mutations in Squamous Cell Carcinomas

Missense mutations in the CYLD protein have been linked to various cancers. Logically, it was probable that mutations in this protein could also be linked to squamous cell carcinomas, a type of skin cancer. In a search for this link, PCR-based mutation detection was employed to seek missense mutations in the CYLD gene of SCC tumors collected from human patients. Eighteen samples were screened for mutations in this gene. Of these samples, 2 tumors were found to contain unique silent mutations in the gene. While, neither of these mutations would have resulted alterations in the amino acid sequence of the CYLD gene, they provided proof that mutations in the CYLD gene in connection with squamous cell carcinoma were possible.

PRZYTYCKI, Pawal

Mentor: Dana Pe’er

Determining Regulatory Relations Based on Gene Expression Data of Knockout Yeast Strains

Obtaining biological insight from large amounts of data has been an important goal of computational biology for many years. In intervention data, causality in expression changes is implied, and the question is whether relations are direct or indirect. The Iyer data set is a comparison of the expression of mRNA in knockout yeast strains versus wildtypes. Traditionally, graphs are built from this type of data by starting with a regulator hub connected to all the genes it affects both directly and indirectly, and then repeatedly refining the network. In this project, we use a Bayesian learning algorithm to create a directed network. A Bayesian network provides a more global picture of interactions. However, a standard Bayesian algorithm doesn’t utilize the knowledge of deletions. So the network we came up with could explain only a small part of the whole picture. To make better use of deletions, we will create a network by starting with connections based on biological knowledge, and then applying a Bayesian learning algorithm. After this model has been created, it will be thoroughly compared to known results.

RUBENSTEIN, Mitchell

Mentors: Irving Herman and Austin Akey

Separation of Metallic and Semiconducting Carbon Nanotubes by Density Gradient Ultracentrifugation

As synthesized, single-walled carbon nano-tubes form a heterogeneous mixture of metallic and semiconducting nanotubes. This arrangement is undesirable since most useful optical and electrical semiconductor devices require as nearly homogeneous a sample of metallic nano-tubes as possible. To separate metallic from semiconducting carbon nano-tubes, a technique called density gradient ultracentrifugation was employed. In this process, heterogeneous nano-tube mixtures were placed in a density gradient of surfactant solution and ultra-centrifuged to separate their metallic and semiconducting contents. This process's success relied on the difference in buoyant density between semiconducting and metallic nano-tubes.

SCHUBMEHL, Caitlin

Mentor: Frances Champagne

CRH-1 Receptor Differences in High vs. Low Exploratory F2 Hybrid Male Mice

CRH is a major stress response hormone; however, little is known about the differences in CRH-1 receptors in the brains of animals that exhibit high vs. low anxiety-like behavior. In this study, F2 hybrid male mice were bred in order to create a wide range of exploratory behaviors (which is considered to equate to anxiety-like behavior in this experiment). The brains of the mice exhibiting the highest and lowest levels of anxiety-like behavior (measured with an open field test) were sliced, autoradiography was performed, and the density of CRH-1 receptor binding was measured in various brain regions. Most of the regions examined did not have a significant difference in CRH-1 binding; however, the arcuate hypothalamic nucleus (Arc) and the lateral hypothalamic area (LH) did have significant differences in binding. These results make sense, as the Arc is involved in the HPA-axis, or the pathway which CRH is known to follow, and the LH is involved in appetite regulation. These preliminary findings provide a basic map of the differences between the densities of CRH-1 receptors in the brains of high vs. low exploratory mice.

STEWART, Daniel

Mentor: Victor Steinberg, Weizmann Institute, Rehovot, Israel

Laser-Doppler Velocimetry of Taylor-Couette Flow in Non-Newtonian Polymer Solutions

Despite the relatively macroscopic scale of fluid motion, the principles governing it are largely unknown. The Navier-Stokes equations, which describe fluid dynamics at its most fundamental level, are non-linear and often cannot be solved analytically. As a consequence, the physics of fluid dynamics relies heavily on an interplay between experimental observation and approximation. The motion of fluids in the non-Newtonian regime (motion that is associated with a high relaxation time) has been studied considerably less than that of Newtonian fluids.

However, a greater understanding of such fluids has the potential for extensive application, particularly in the fields of industrial manufacturing and materials engineering. In an effort to better characterize the flow of non-Newtonian fluids, the transitions between distinct flow instabilities in Taylor-Couette flow (the flow between a rigid tube and a cylinder rotating inside of it) of polymer solutions are being studied using laser-Doppler velocimetry (LDV). In this approach, the polymer solution is supplemented with a number of microscopic particles, the velocities of which are measured as they pass through the point at which two lasers cross, one frequency-shifted by 100 kHz, resulting in an interference pattern that scans at 100 kHz. When a particle passes through the crossing point, it emits a frequency equal to the velocity of the particle divided by the interference fringe spacing, plus or minus 100 kHz depending on the direction in which the particle is moving. Initial results of this research relate to the measurement of viscosities and relaxation times.

TANDON, Olivia

Mentors: Christine Sheppard and Nancy Clum, Ornithology Department, Bronx Zoo

Using Video to Study Lek Behavior in the Lesser Bird of Paradise (*Paradisaea minor*)

Although the lesser bird of paradise (*Paradisaea minor*) is held up as a prime example of sexual dimorphism and lek breeding, little is known about how the lek system works, to what degree females choose a mate rather than relying on a pre-existing hierarchy among males and how young males learn the complicated display sequences of their species. One of the major problems in captive breeding of this species is that creating an actual lek in captivity is very difficult due to aggression between animals. In this study, four 30 minute video clips were shown to lesser birds of paradise at four different zoos and their behavior while watching the videos was recorded. The videos showed a blank screen, a tree, a female lesser bird of paradise and a male lesser bird of paradise. Although analysis has not yet been completed, the data will be tested for differences in behavior towards the bird videos and non-bird videos. This analysis may shed light on the ways in which birds see and interpret video and has important implications in captive breeding techniques using video to simulate a lek environment. Further research may also use video to examine lek structure and learning of breeding behaviors in these birds.

WANG, Xuran

Collaborators: Yael Degany and James Ouyang

Mentor: Adam Knapp

Computation Involving Heegaard Floer Homology

We developed a computer program that computes the knot Floer homology of any knot that admits a symmetric grid presentation. In general, a *knot* is an embedding of a circle in $\mathbf{R}^3$. *Knot Floer Homology*, or $\widehat{HFK}$, is a topological invariant for null-homologous knots in a closed, oriented three-manifold. Various programs that compute $\widehat{HFK}$ have been developed previously using an algorithm that simplifies the “tree diagram” for the knot Floer chain complexes. We developed a new algorithm that particularly computes $\widehat{HFK}$ for knots that admits a 180^o-symmetric grid diagram. Our program preserves the symmetry while simplifying the tree complex, and hence sheds some light on the automorphisms of the knot Floer homology.

YANG, David

Mentor: Hong Shen

Palladium-Catalyzed Suzuki-Miyaura Coupling of Pyridyl-2-Boronic Esters with Aryl Halides Using Highly Active and Air-Stable Phosphine Chloride and Oxide Ligands

The Suzuki-Miyaura reaction or Suzuki Coupling is an important organic reaction for the synthesis of, among other compounds, multi-ring systems. As one of the most powerful C-C bond formation methods, the Suzuki-Miyaura coupling has been routinely practiced in medicinal and process chemistry leading to a wide range of drugs and clinical candidates. Despite the tremendous progress in this arena, the Suzuki-Miyaura coupling reactions of 2-substituted (as opposed to 3- or 4-substituted) nitrogen-containing heteroaryl boronic esters with aryl or heteroaryl halides are extremely challenging.

By testing numerous combinations of catalysts, solvents, and bases, a fairly general method for the cross-coupling reactions of several 6-substituted pyridyl-2-boronic esters with aryl and heteroaryl halides was developed. While optimal reaction conditions are often substrate-dependent, the convenient reaction protocol and reasonably general reaction scope demonstrated its potentially wide applications in medicinal chemistry.

ZHANG, Andrew

Mentors: Jason Behrstock and Eli Grigsby

The Tower of Hanoi Problem

The Tower of Hanoi problem is a century old problem which consists of three wooden pegs and a series of wooden disks of varying sizes. The disks are stacked from largest to smallest (forming a "tower") on one peg. The problem is to move the disks one at a time from one peg to another. It is known that for three pegs and N disks, the optimal solution will take 2^N-1 moves. However, for four pegs, the optimal solution is unknown. One particularly useful way to study this problem is to create a graph with all possible states as the vertices and all legal moves as the edges. I have investigated the properties of this graph with four pegs and found particularly useful ways to partition this graph to further our understanding of this problem.

ZHANG, Sherry

Mentor: Shanshan Lin, Jilin University, People's Republic of China

Quantitative Research on Bacteria Contributed to Reduction of Excess Sludge

The traditional technique for dealing with polluted water results in a large excess of sludge. This is both costly and potentially harmful to the environment. Quantitative research on bacteria, using real-time fluorescent quantitative PCR technology, shows that the amount of excess sludge and water pollution can both be reduced. Our group added waste water from a nearby factory to a gravel contact oxidation reactor. A biofilm produced in this way allows sludge to be separated from other contaminants in the water. A conventional way of dealing with excess sludge is to bury or burn it. Our approach is to seek a biologically based procedure that will be less harmful to the environment and less expensive. Polymerase Chain Reaction (PCR) technology has proven useful for analyzing the bacterial DNA of biofilms. In this procedure, DNA polymerase is used to amplify a piece of DNAor a few copies by several orders of magnitude and hence to perform a wide array of genetic manipulations.

FOSTOR INTERNS (FRONTIERS OF SCIENCE TRYING OUT RESEARCH)

BARRIENTOS, Deiby
BENZAQUEN, Oren
FISHER, Louis

Mentor: Peter deMenocal, Lamont-Doherty Earth Observatory

Changing Holocene Environments of the Eastern Tropical Atlantic

The Holocene epoch in Africa saw a major climate change as the African Humid period came to a close. Monsoon seasons in northern Africa became more like they are today and, as a result of increased aridity, human settlements would have been abandoned in the search for remaining sources of freshwater. Our project set out to understand how this climate change took place, and specifically if it was an abrupt or gradual change, through a study of ocean sediment cores collected off the eastern tropical Atlantic in 2007 and currently stored at Lamont-Doherty Earth Observatory. Through systematic sampling of the mud we were able to construct charts of calcium carbonate (CaCO3) levels at 10 cm intervals for the cores stretching from the waters off Portugal to Cape Verde. These calcium carbonate levels were measured by coulometry, and are used as a proxy for humidity levels on the African savannah. In addition to these measurements, we also extracted at the same 10 cm spacing samples of fractions coarser than 64 μm for oxygen isotope analysis. Oxygen isotopes in the tests of marine foraminifera provide a proxy for continental ice cover at high latitude, and hence for climate change in general. Critical intervals in each core determined in this way are currently being dated.

CLINE, Brenden

Mentors: Bob Newton, Peter Schlosser and Gisela Winckler, Lamont-Doherty Earth Observatory

Calculating the Source of Mantle Helium to the World Ocean

Helium enters the ocean via three primary processes: gas exchange with the atmosphere, tritium decay from nuclear weapons' tests, and through volcanic activity on the sea floor. While gas exchange is fairly uniform and abundant, and tritium decay is a modern phenomenon, volcanic activity can reveal the nature of ocean circulation over the past several millennia. Volcanic helium enters the ocean mainly along the crests of mid-ocean ridges, about 2.5 km below the surface. It is strongly enriched in ^{3}He, a suitable tracer of circulation away from vent sites for hundreds of kilometers and a proxy for mantle degassing. As a first step toward creating an integrated global database of helium measurements, I downloaded all of the World Ocean Circulation Experiment (WOCE) cruise data into a relational database; exported the data relevant to the study of mantle helium; and quality-controlled the helium isotope data, using semi-automated QC routines that I wrote in Matlab. Helium measurements are made using a noble gas mass spectrometer, and are reported as helium concentration and δ^3He. δ^3He describes the ^{3}He/^{4}He ratio as a percent difference from the atmospheric ratio. In order to obtain the mantle helium concentration in seawater, it is necessary to subtract the fraction of helium from air. Neon, which is conservative in the ocean and has no source other than the atmosphere, is used as a proxy for the amount of dissolved air in a water sample. We found that the δ^3He data are of high precision. Once obvious "fliers" are removed, the scatter of the measurements, relative to a smooth profile, is generally close to analytic (laboratory measurement) errors. Absolute concentrations of helium and neon, on the other hand, are not nearly as precise. The scatter of profiles exceeds analytic errors, pointing to issues in sampling or sample extraction and storage.

KOVALCHUKE, Lyuda

Mentors: Jim Hone and Anurag Mathur

Fabrication Techniques for Cell Biology

Cells interact mechanically with their environment through a cyclic process of sensing, signal transduction, and response. The rigidity and geometry of the external environment affect a variety of important cell responses, including growth, differentiation, shape changes, and death. Nanofabrication techniques have allowed for the production of nano- and micro-scale features that make it possible to gain a deeper understanding of the mechanisms involved in the mechanical interactions of cells with their environment. It has been demonstrated that fibroblast cells loaded onto microridged surfaces align themselves with the direction of the ridges. However, fibroblasts missing the motor protein myosin II-A show a much weaker alignment response. The goal of this research is to compare normal and myosin II-A knock-down cell behavior on curved ridges and on ridges of different heights (50 nm to 850nm); such data offer the prospect of enhancing our understanding of the role of myosin II-A in a cell's interaction with its environment in addition to providing data on a cell's threshold of sensitivity to ridges, and its response to curved features. Creating useful curved microridges is challenging, however, and three different techniques involving electron-beam lithography are being explored. Photolithography coupled with dry etching is being used to create ridges of different heights.

LEE, Charlene

Mentors: Kevin Griffin, Lamont-Doherty Earth Observatory; and Stephanie Searle, Canterbury University, Christchurch, New Zealand

The effects of Night-Time Warming on Chlorophyll Fluorescence of *Quercus rubra* L. Along an Urban to Rural Gradient

Urbanization and climate change are occurring at rapid rates across the globe, but the way plants will respond to this change is not completely understood. Studies have predicted that warming will be more pronounced at night than during the day, which will lead to a decrease in diurnal temperature range, similar to what many urban cities are experiencing today. Using a naturally occurring temperature gradient from New York City extending northwards into more rural areas, we measured Fv/Fm (an measure of maximum photosynthetic efficiency), height, diameter, and biomass of common red oak seedlings (*Quercus rubra* L.) grown along a transect. Oak seedlings were also grown and measured in growth chambers. Our results show that Fv/Fm was significantly higher in the most urban site than the most rural site for all sampling periods along the transect, and for most sampling periods in the growth chambers. Biomass was negatively correlated with distance from the city for all sampling periods along the transect. It is hypothesized that the difference in diurnal temperature range is one of the factors that is responsible for these differences.

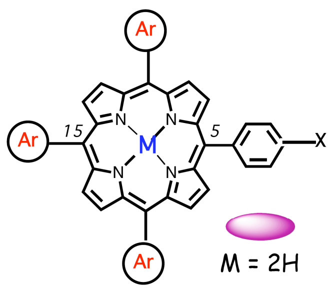
McGEE, Warren

Collaborators: Ana Petrovic, Regina Monaco, George Ellestad, and Koji Nakanishi

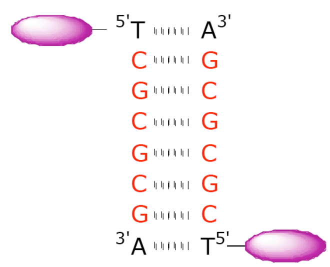
Mentor: Nina Berova

Modeling Intramolecular Motion of Porphyrin-DNA Macromolecule

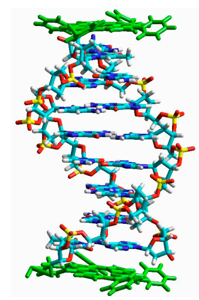
Molecular modeling of DNA has grown immensely in the past 25 years. Yet there is still much to learn. One system of interest is a double-stranded DNA octamer, d(TGCGCGCA)$_2$, which contains covalently attached to it, at each 5' end, non-metallated tetra-aryl porphyrin (see figures below). Porphyrin has been found to be a very powerful CD reporter group, and thus can be utilized in a study of a sample molecule's absolute configuration. Using molecular dynamics, a computational method that studies the motions of a molecule that emerge out of the random vibrations of the individual atoms, we sought to understand the flexibility and mobility of this porphyrin-DNA system. We ran simulations of 0.5 ns and 2 ns using the OPLS-AA force field within the new and powerful Desmond modeling package. Explicit water molecules and NaCl counterions were used to model the DNA as in solution. Results show an inter-conversion between "capped" and "uncapped" forms (see figures below) of the porphyrin-DNA system, supporting the possibility that this system exists in a continuum of configurations.



Tetra-aryl Porphyrin with a non-metallated center.



A cartoon depiction of the "uncapped" porphyrin-DNA system.



The "capped" porphyrin-DNA system rendered with CGI.

MacLEAN, Ashley

Mentor: Beth O'Shea, Lamont-Doherty Earth Observatory

The Influence of Metamorphism on Arsenic Distribution in the Bedrock of Greater Augusta, Maine, USA

Studies have shown that groundwater in some areas of the world, such as Maine and Bangladesh, has very high concentrations of arsenic, and this problem is aggravated by the fact that more and more of the world's drinking water is coming from wells rather than surface waters. Arsenic in drinking water is a serious problem as it has long term health effects to exposure. It is generally agreed that the arsenic is derived from surrounding rocks or sediments, but the way in which arsenic is released into groundwater systems is not yet well understood. Our hypothesis that the metamorphic state of the rocks in Maine, together with subsequent changes in mineralogy, is responsible for the release of arsenic is supported by the data collected this summer. Using a naturally occurring metamorphic gradient along a formation in Maine, USA, we tested the hypothesis by gathering samples throughout the greater Augusta area and testing for arsenic levels (ppm) and looking at the chemistry of the samples to determine mineralogy. Arsenic levels were obtained by using a handheld XRF, and SEM images and spectra were analyzed to determine mineralogy. Given the complexity of groundwater flow in the fractured metamorphic bedrock of Maine, we are not able to determine exactly where it is safe to drill a well, but we have obtained important new clues about the factors that lead to high As concentrations in groundwater.

WANG, Dili

Mentors: David Schiminovich and Jacqueline van Gorkom

The Relationship Between Star Formation and HI Content from UV Photometry of Virgo Galaxies

The purpose of this project is to investigate the relationship between young stars and gas in select galaxies of the Virgo Cluster and Rogues Gallery, a collection of galaxies that have strange images in the optical and HI. Using Near UV (NUV ~ 190-280 nm) and Far UV (FUV~ 135-185 nm) images from GALEX, or the Galaxy Evolution Explorer, we have measured several properties of galaxies such as total magnitude, profile magnitudes, and surface brightness. Images in UV are of interest because UV light detection probes hotter objects, which are very likely young massive stars formed in the last billion years. The most basic process used is that of aperture photometry, which integrates the pixel counts of light within a given area and then subtracts the sky background, resulting in the flux over that area of the galaxy. Experiments used to find the apparent magnitude of over 400 galaxies included using shapes of polygons, ellipses, and annular elliptical rings for the perimeters of these galaxies. The final step in this project was the examination of HI contour maps in comparison to the NUV and FUV images. HI, neutral Hydrogen gas, is the key ingredient of the interstellar medium (ISM), which serves as the fuel for creating new stars. HI images from the Very Large Array Observatory can be mapped using contour regions drawn around areas within a range of intensities; these contours are then superimposed on the corresponding UV images of the same galaxy mainly to study the differences in flux between HI and UV regions. This study was done for 7 galaxies – NGC4298, NGC4302, NGC4383, NGC4396, NGC4424, NGC4569, and IC3355 – all of which have unusual HI data. With the exception of NGC4569, the galaxies have extended HI disks, meaning the HI contour that overlaid the UV images extended beyond what were the optical boundaries of the galaxies. In each of these six cases, additional UV light was found between the optical boundary of the galaxy and the boundary of the HI. This may suggest the continuing formation of stars in these outer regions. As for NGC4569, the HI contours only outline the nucleus and inner regions, thus exhibiting extended NUV and FUV far beyond the HI borders. For this particular galaxy, one possible conclusion is that although the stars in the outer regions are young, the HI gas may have been recently stripped, rendering the galaxy unable to continue star formation in these outer regions.

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*Rabi Scholars not undertaking research projects in summer, 2008.