

UROP Summaries

Effects of noise on quantum dot systems

Summer 2003

Department of Physics

Principal Investigator: Professor Marc A. Kastner

Mentor: Ghislain Granger, Graduate student

Dheera Venkatraman, Class of 2006

Majors: Physics, Electrical Engineering

Experimental quantum dot devices (functioning as single-electron transistors) running at low temperatures can easily be affected by radiation and other sources of noise. It is thus important to develop a reliable and flexible simulation method to predict the response of these devices, a useful tool in error analysis. A quantum dot apparatus was set-up and tested at a temperature of 15 mK inside a dilution refrigerator. A computer simulation program was also developed to predict the conductance of this system as a function of both drain-source and gate voltages. The simulation method was subsequently used to study the effects of electrical noise on these results.

Inhibition of β -sheet content in the Alzheimer's Disease peptide Abeta1-42 by DAPH and its analogs

June 2004 – Present

Department of Biology

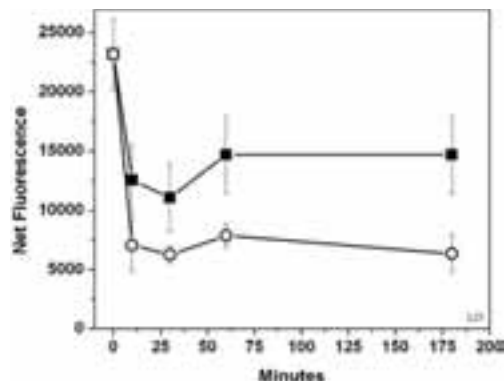
Principal Investigator: Professor Vernon Ingram

Leslie Rozeboom, Class of 2006

Major: Biology

Minor: Biomedical Engineering

Alzheimer's disease is believed to be caused by extracellular plaques of aggregated Amyloid Beta fibrils. The protein Ab(1-42) is cleaved from the Amyloid Precursor Protein and misfolds into aggregates with high β -sheet content. The Ingram lab is investigating a small molecule called DAPH (4,5-dianilinophalimide) which decreases this harmful aggregation. I assay for β -sheet content with the fluorescent dye Thioflavin T. I am investigating the kinetics and concentration dependence of DAPH. I am also investigating analogs of DAPH for those that work most quickly and at the lowest concentrations. We hope that DAPH or one of its analogs will prove to be an effective intra-nasal Alzheimer's disease treatment.



The Net Fluorescence per Minute

black squares: 10 μ M DAPH open circles: 20 μ M DAPH

Cytokine response to *Citrobacter*-induced infection in TCR α and TCR β knockout mice

January 2003 – Present

Division of Biological Engineering

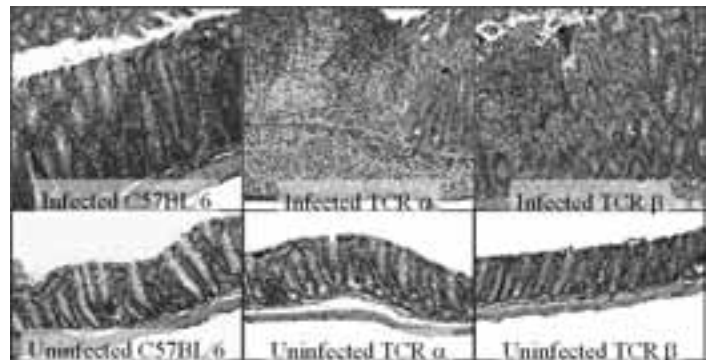
Division of Comparative Medicine

Principal Investigator: Professor David B. Schauer

Issel Anne L. Lim, Class of 2005

Major: Biology

Minors: Biomedical Engineering, Toxicology



Colon samples from control mice and mice infected with *C. rodentium*.

Patients with inflammatory bowel disease (IBD) of the colon are known to have an increased risk and early onset of colon cancer. A number of immunodeficient mouse models have been used to study human IBD. Although the cause of IBD is not known, genetic and environmental risk factors appear to induce an inappropriate immune response in the gut. When combating a pathogen, the body induces an immune response that involves various chemical signals called cytokines. The two types of immune responses are the cell-mediated Th1 response, which kills damaged cells that usually contain intracellular pathogens, and the humoral-mediated Th2 response, which fights parasites by activating B cells, the cells in the immune system that produce antibodies. Certain pathogens usually induce a Th1 or Th2 response, and certain genetically-deficient mice tend to exhibit either a Th1 or Th2 response. *Citrobacter rodentium* was the first recorded noninvasive pathogen to produce a Th1 response, with a phenotype similar to that of IBD. We wished to create an effective mouse model for ulcerative colitis, the Th2-type form of IBD, by inducing a Th2 response in TCR α knockouts. I measured the cytokine profiles via endpoint RT-PCR and quantitative RT-PCR in order to determine the immune response of each organism. Now, I plan to further analyze my data, which will hopefully show whether the genetic predisposition of the animal or the composition of the pathogen most significantly affected the immune response. Future work will involve continued searching for a suitable mouse model for ulcerative colitis.

Cell cycle characterization

September 2003 – Fall 2004
Department of Biology
Center for Cancer Research

Alison Taylor, Class of 2006
Major: Biology

In my cancer research lab, I performed cell cycle re-entry assays. The purpose of these assays was to determine how often cells of different genotypes enter the S phase of the cell cycle (DNA synthesis); cancer cells enter the S phase faster than normal cells. In this procedure, I plated cells of varying genotypes and incubated them in media without growth serum for three to four days. This would stop their growth at the first stage of the cell cycle, after which they were stimulated to grow with addition of serum. At four hour intervals, I incubated the cells for one hour in radioactive [³H]-thymidine. I then filtered the samples and measured their radioactivity readings. Samples with higher readings had more cells that incorporated [³H]-thymidine in their DNA synthesis, which indicated that they entered the S phase faster. Consequentially, I could determine which genotypes were more likely to become cancerous.

Turbulent drag reduction via biopolymer additives

Spring 2004 – Present
Department of Mechanical Engineering
Hatsopoulos Microfluids Laboratory
Principal Investigator: Professor Gareth McKinley

Christopher MacMinn, Class of 2005
Major: Mechanical Engineering with Applied Math

Fluid flows are present in nearly every engineering system. When such a flow transitions to turbulence, the energy necessary to drive the flow increases sharply. This effect—known as turbulent drag—impacts engineering design significantly. Because nearly all flows in engineering practice are turbulent, much stands to be gained from the development of an effective method of reducing turbulent drag.

One promising method—polymer drag reduction (PDR)—is based on the fact that the addition of a very small amount of high molecular weight polymer (HMWP) to a turbulent flow can substantially reduce the turbulent drag of the flow.

Unfortunately, HMWPs tend to degrade and lose their drag reducing properties under even short-term use. In addition, most synthetic polymers used in PDR are toxic. Recent experiments, however, have demonstrated that surfactants and micro-fibers also effectively reduce turbulent drag, and are less easily degraded than synthetic polymers. Natural biopolymers share many of the characteristics of synthetic HMWPs, often contain rigid micro-fibers and/or surfactants, and are environmentally friendly. The potential significance of the discovery of a readily available, biodegradable, and effective drag reducing biopolymer can hardly be overstated.

The goal of this project is two-fold: first, to design and implement a simple, adaptable, low-cost apparatus for PDR experiments, and, second, to evaluate the drag reducing properties of a specific biopolymer, suspected to be an extremely effective drag reducing agent.

To measure the drag reducing effectiveness of polymers experimentally, researchers typically measure a pressure drop in pipe flow as a means of indirectly measuring the energy lost to flow turbulence.

This is most often done using two pressure sensors along a long, straight tube through which fluid is driven. Pressure, however, is a difficult flow property to measure: it varies greatly along the flow cross-section, and pressure sensors are delicate, difficult to calibrate, and expensive. A simpler method of measuring turbulent drag involves applying a known pressure gradient to a pipe and measuring the resulting fluid mass flow rate.

This measurement can be made directly using an electronic mass balance and a stopwatch. The flow exiting the tube is collected in a reservoir situated on the mass balance, and the mass of the reservoir is recorded as a function of time; time rate of change of this function is the mass flow rate. The driving pressure gradient and tube diameter can then be easily adjusted and the experiment repeated.

Such a series of experiments will first be carried out with tap water for comparison with well-known empirical relationships to verify the reliability of the apparatus. Experiments will then be carried out with a dilute polyacrylamide solution for comparison with previous experimental PDR results. Finally, experiments will be carried out with a dilute solution of the biopolymer in question.

Investigating density effects on stem cell kinetics

June 2004 – Present
Department of Biological Engineering
Principal Investigator: Professor James Sherley
Mentor: Sumati Ram-Mohan, Graduate Student

Nupur Garg, Class of 2007
Major: Chemical Engineering
Minor: Biomedical Engineering

My experiments involve maintaining a supply of stem-like cells to use for investigating their kinetic properties. Maintaining cells requires techniques such as freezing, thawing, and splitting cells. Freezing and thawing cells help keep a usable stock of cells to maximize the use of a particular line. Splitting cells keeps the cell density in a range at which the cells will continue to display their kinetic properties. These techniques allow stem cells to maintain the proper condition and stability in order to be viable in kinetic-related experiments.

The effects of artificial gravity on the neurovestibular system

Department of Aeronautics and Astronautics
The Man Vehicle Laboratory

Jenny Hu, Class of 2006
Major: Aeronautics and Astronautics

The Man-Vehicle Lab is conducting research on the effects of artificial gravity on the neurovestibular system. To prevent physical degeneration in space, it would be valuable for astronauts to spend time subjected to artificial gravity; astronauts must be capable of working in an artificial gravity environment. I studied the effects of head turns on the neurovestibular system while subjects were placed in artificial gravity through centrifugation. I operated the centrifuge and collected eye movement data, along with subjective data on the sensations felt by subjects during the head turns. The ultimate goal of the project was to find a way to help astronauts become acclimated to the effects of artificial gravity.

Control circuits for Class D amplifiers

Summer 2004 – Present

Department of Electrical Engineering and Computer Science

Laboratory for Electromagnetic and Electronic Systems

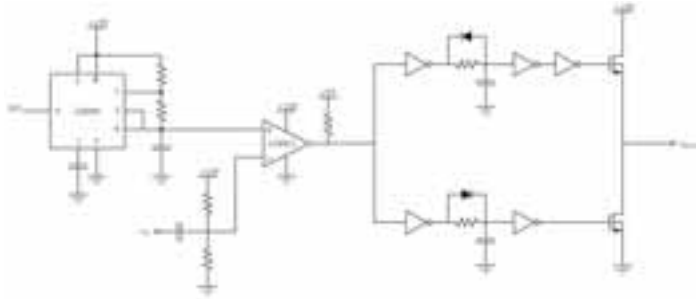
Principal Investigator: Professor Steven B. Leeb

Mentor: Mariano Alvira IV, Graduate Student

Ariel Rodriguez, Class of 2005

Major: Electrical Engineering and Computer Science

How do you make MOSFETs run cold while driving a 1kW stereo system? My research this past summer involved creating control circuits capable of driving high power systems such as electronic lamp ballasts and high current motors for electric go-carts. In order to maximize their efficiency, I had to learn about, construct, and generate the



Class D Stereo Amplifier with Comparator-Based PWM Control: a circuit that students build in 6.188 in order to control their amplifiers.

appropriate control signals for Class D (also known as switching) amplifiers, which are highly efficient and can therefore drive many high power systems.

Since switching amplifiers are constantly turning their load “on” and “off,” driving a motor with a certain signal is not as straightforward as placing a high power version of that signal across its terminals. In the case of stereo amplifiers, I investigated several different analog and digital Pulse Width Modulation (PWM) techniques in order to find the one that best improved sound with little or no excess power dissipation. During that process I encountered several problems including sound signal aliasing depending on the frequency of the PWM.

In order to build a prototype on a solderless breadboard, I first read about particular circuit components and techniques. After thorough testing with a test load, I then soldered my circuit to a vector card that fit inside the Power Electronics Laboratory (6.188) lab kit designed by my UROP mentor Mariano Alvira. On that vector card, I was able to push my control circuit to its limits on more high power loads such as large wattage bass speakers or three phase motors. Afterwards, I usually had a design review conference with Prof. Leeb where we discussed the future of the circuit. Some circuits became more complicated control systems planned for future work as part of my Undergraduate Advanced Project. Others were simplified for classroom instruction. At the end of the review conference, I would also typically get a new load and circuit to develop, thus repeating the process. Through 6.188, future MIT students will discover the same concepts I worked on this summer.

Submit your
UROP Summary
by February 12, 2005

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