HCURA Student Research Spotlight
Summer 2008 Edition

Dear members of the Harvard undergraduate research community,

When HCURA was founded a mere one and a half years ago, one of our main goals was to bring students from different research backgrounds together into one cohesive, interdisciplinary undergraduate research community. Now, with a large number of you presenting at the Harvard Undergraduate Research Symposium (HURS) and attending the exciting faculty talks, developmental workshops, study breaks, you all have made it evident that the undergraduate research community at Harvard is as vibrant as ever.

PRISE students enjoying a nice summer day with President Faust. Photo courtesy of Carol Suh '11.

We want to take a moment to spotlight some of the ways a few of you have explored the exciting world of research this summer.

We hope you enjoy our summer 2008 research spotlight!

Best,
HCURA Board

Scott Duke Kominers 2009
Mathematics and Economics

www.scottkom.com

A senior in Kirkland House, Scott Duke Kominers spent his summer pursuing research in both mathematical economics and theoretical mathematics. His economics research focused on new mathematical approaches to economic geography (supervised by Prof. Edward L. Glaeser, FAS and KSG, advised by Prof. Andrei Shleifer, FAS, and some in collaboration with Prof. William R. Kerr, HBS) and position auctions (supervised by Prof. Susan Athey, FAS). This work was supported by the A. Alfred Taubman Center for State and Local Government and by fellowships from the Harvard College Program for Research in Science and Engineering and the Harvard Institute for Quantitative Social Science. His research in pure mathematics was predominantly concerned with quadratic form representation theory, doubly-even self-dual codes (supervised by and in collaboration with Prof. Noam D. Elkies, FAS), and extremal combinatorics (in collaboration with Paul M. Kominers, MIT 2012). This research was supported by a Harvard Mathematics Department Highbridge Fellowship.

Economic geography is the study of the spatial location and distribution of economic activity. The literature on this subject has addressed a variety of concerns, including the location of industries, demographics, and labor pooling. Under the supervision of Prof. Edward L. Glaeser, Kominers is pursuing a multifaceted research program on the relationship between economic geography, social interactions, and the behaviors of innovators. This summer, he developed one stage of this program: a closed-form measurement of the "social multiplier"—the effect of an individual's choice on others' utility benefits from social interactions. The measurement Kominers obtained illustrates a direct link between aggregate social outcomes and the magnitude of the social multiplier in a discrete choice framework with social interactions and multiple locations. This research could theoretically be applied to determine the strength of social interactions effects in different industries, impacting managers' decisions regarding whether to innovate.

Kominers also conducted theoretical work in the theory of position auctions, the auctions used by Google, Microsoft, and other search engines to allocate sponsored advertising links. As the market for sponsored advertising links is presently a multibillion dollar industry, there is substantial interest in understanding the behavior of these auctions. Prof. Susan Athey, Kominers's adviser for this research work, has recently developed a new model of single-round position auctions in joint work with Glenn Ellison. This novel model not only studies the auction itself, but also includes an explicit model of consumer behavior. Building upon the model of Athey and Ellison, Kominers showed several asymptotic results for repeated position auctions in the presence of consumer search, including the convergence of the bidding behavior in such an auction. When combined with earlier work, Kominers's results suggest that the convergence of position auctions is a robust fact, rather than an artifact of modeling. This, in turn, has import for search engines, advertisers, and consumers.

Additionally, Kominers pursued several research projects in theoretical mathematics. Early in the summer, he proved a result in the field of quadratic form representation theory which elegantly answers a question he has been working on since high school. In collaboration with Prof. Noam D. Elkies, Kominers began work on his mathematics thesis in the theory of doubly-even self-dual codes. Additionally, in joint work with his brother, Paul M. Kominers, he showed that combinatorial "candy-passing games" stabilize in polynomial time.

In August, Kominers spoke in Madison, Wisconsin, at MathFest 2008 on "Configurations of Extremal Even Unimodular Lattices," his work forthcoming in *International Journal of Number Theory*. He has authored numerous research articles, problems, and reviews, many of which have already been accepted by refereed journals.

As to pursuing undergraduate research in theoretical fields such as economics and mathematics, Kominers strongly encourages students to read current research, think of ideas, and talk to faculty. "Harvard faculty are really approachable, and theorists especially enjoy discussing new ideas," he says.

More information on Kominers and his work can be found at his website, http://www.scottkom.com/.

Amelia Lin 2011
Physics

To many, a scanning electron microscope (STM) image of carbon nanotubes effects little more than a resigned "ooh" or "aah." To Amelia Lin, a sophomore in Cabot House, it spelled an exciting research journey. Ever since coming across carbon nanotube STM images as a 10th grade volunteer in the NanoExplorers program at the University of Texas at Dallas's Nanotech Institute , Lin has become enraptured by those tiny tubes and their seemingly endless applications, such as encapsulation of carbon nanotubes in hydrogels

Lin at the 2008 IEEE Conference. Photo courtesy of Amelia Lin '11.

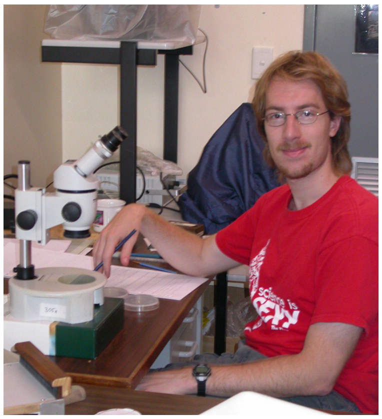
for introduction into the human body. This summer, Lin returned to the Nanotech Institute at the University of Texas at Dallas to intern as a research assistant under Dr. Ray Baughman. Although she started her research career in Dr. Baughman's lab washing glassware, Lin's research status has quickly elevated to producing and manipulating carbon nanotube "yarns," tiny, threadlike fibers spun from "ribbons", elongated aggregates, of carbon nanotubes (CNTs). One of Lin's projects over the summer was experimenting with different methods of creating carbon nanotube fibers. To produce these nanotube yarns, as Lin describes, a popular method is to start by "growing" CNTs via chemical vapor deposition. By this method, researchers can grow CNTs on a substrate, thus called a "CNT forest." If grown under the right conditions, the CNT forest will be "spinnable", meaning that the Van der Waals forces between the walls of the CNTs will be strong enough for the CNTs to stick together. A spinnable CNT forest allows researchers to pull a small aggregate of CNTs by hand, held together by those inter-tube forces, as a ribbon. The ribbons are then twisted by machine, to create a "yarn," much like knitting yarn is comprised of intertwined threads.

Lin describes her favorite part of the project as perfecting the skill of spinning carbon nanotube yarns, an art that took two months to learn. Even though the spinning was performed by a motorized machine, Lin cites the difficulty of hand drawing the ribbon and keeping the fiber moving through the machinery through the spinning process. She credits the experience as allowing her to develop extremely steady hands due to constant work with the yarns, which are typically about 10 microns in diameter and up to 25 meters in length. For comparison, a human hair is about 70 microns in diameter. Lin presented her summer work on spinning carbon nanotube yarns at the 2008 Institute of Electrical and Electronics Engineers Conference.

Another project Lin worked on over the summer was to making yarns out of buckypaper to increase the tensile strength of the fibers. Buckypaper is comprised of CNTs tangled together and pressed into a sheet, as opposed to the straight, vertical CNT forests grown on a substrate. She experimented with cutting and twisting thin strips of buckypaper to create fibers for the yarns. She also successfully manufactured an inexpensive laser diffraction set up to quickly and accurately determine a fiber's diameter. Lin predicts that this device will be useful in future investigations of whether fibers of even smaller diameters, perhaps from this buckypaper, can yield higher tensile strengths.

For the school year, Lin plans to work in Professor Charles Marcus's lab, continuing her research interests in nanotechnology. For students wishing to become involved in research, Lin has only two words: Be proactive. She stresses to not only be proactive in contacting professors to find research labs but also "… in the sense that you need to ask for more responsibility if you want it. … If you feel like you're not being challenged or you want to learn more, don't hesitate to ask." Wise words from a girl who started her research career in nanotechnology cleaning glassware for free.

Matan Shelmoi 2009 Organismic and Evolutionary Biology



While many Harvard students spent their summer sweating in humid Cambridge, Massachusetts, Matan Shelomi, a senior in Mather House, chose to spend his summer in the Australian winter for senior thesis research in Organismic and Evolutionary Biology. Why, you ask? The all-expense paid trip, including airfare and housing, from the Harvard University Committee on Australian Studies, headed by Professors Janet Hatch and David Haig, might have been persuasive. Shelomi saw the fellowship, which offers up to $15000 USD for students interested to perform senior thesis work in Australia, advertised on a biology concentrators' open list and applied immediately. Although it was a challenge to find a lab, his scientific passion for studying insects and experience of international travel on Harvard's budget – also count the Dominican Republic, Brazil, and Costa Rica on his list – saw his way through.

Stationed in Brisbane, Queensland, Australia, Shelomi worked in the School of Integrative Biology at the University of Queensland, under the mentorship of Professor Myron Zalucki. He studied the feeding behavior of neonatal *Helicoverpa armigera* larvae, commonly known as the cotton bollworm and widespread pest of plant species such as cotton, tobacco, legumes, lettuce, and cabbage. Shelomi was interested in finding a pattern in the larvae's eating habits and determining whether their feeding behaviors differ depending on the type of leaf. Shelomi tested soy, garden pea, tomato, tobacco, cabbage, an artificial diet made of bean paste, and two varieties of canola leaves – one being more waxy than the other , all varying in nutritional content, surface substrate, and defensive chemicals.

To simulate a real-life environment, Shelomi fixed leaves placed topside down in agar, because the caterpillars feed on the underside of the leaf. Larvae hatched the night before are carefully laid on each leaf using a fine paintbrush. By watching the larvae through a dissecting microscope, Shelomi waited for the larvae to take their first bite and then recorded the larvae's action every minute for three hours. Shelomi remarks that he has often spent over 4 hours recording larvae movements in case of finicky larva that may take a more leisurely eating pace. One of the eating pattern models Shelomi tested was ultradien periodicity: that larvae initiate feeding bouts at peaks of a cycle. For instance, larvae may not start feeding every 8 minutes, but will always start feeding at a multiple of 8 minutes. Shelomi has found no evidence for ultradien periodicity in 1st instar (newly hatched) larvae, but hopes to find predictable eating behavior in feeding bout length and number for different types of

Shelmoi with a fellow Australian. Photo courtesy of Matan Shelomi '09.

Helicoverpa armigera. Photo courtesy of Matan Shelomi '09.

leaves. Evidence has shown that feeding bout length is longer for waxier canola leaf type. Shelomi proposes that this finding may be because the waxier canola leaf is significantly thicker – implying more food per feeding hole, less toxic – requiring less resting time spent processing the chemicals, or because larvae must spend time removing wax before eating. Shelomi used a scanning electron microscope to examine the feeding sites more closely, specifically searching for telltale balls of wax the larvae would have to make and push out of their way if the latter theory is supported.

Shelomi predicts that his work could be used as information for pest control design, as the species is ubiquitous and a threatening pest. However, he says, how to kill the larvae is not his concern. Shelomi is excited by the opportunity to understand the feeding behavior of this larvae, as little to no work has been done before on larvae this young. "It's groundbreaking science," he says. "If the data show something interesting, it will open the door to a whole wave of research in first instar larvae."

Amongst all the painstaking work, Shelomi still found time to explore the land Down Under. Dining on crocodile and kangaroo meat, a.k.a. "roo steaks," scuba diving in the Great Barrier Reef, and swimming in Surfer's Paradise are just some of the perks of being an organismal zoologist. He exuberates much appreciation for the Australian Studies Fellowship for allowing him this wonderful research opportunity and emphasizes that students should never be afraid to apply to a good program. "The competition may be fierce or nonexistent, but you'll never win if you don't try."

Lisa Rotenstein 2011 Neurobiology

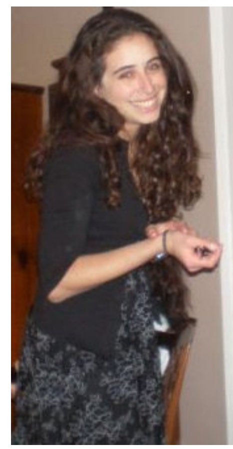


Photo courtesy of Lisa Rotenstein '11.

Ranked as the third leading cause of death worldwide, only behind heart disease and cancer, stroke stands as an urgent global issue. Fortunately, researchers such as Lisa Rotenstein, a sophomore in Eliot, are on to solving the science of stroke. She spent the past summer at the Neuropharmacology Laboratory at Stanford University School of Medicine in the Maclver Lab untangling the chemistry of stroke.

Funded by a grant from the Anesthesia Department at Stanford, Rotenstein used electrophysiological analysis to measure neuron recovery of rat brain slices subjected to ischemic (stroke) conditions and then different neuroprotection solutions. Her work comprised of two main projects, testing the neuroprotective efficacy of postconditioning or concurrent conditioning with low or no calcium cerebrospinal fluid solutions (the basis behind which failed to show results in clinical testing) and anesthetics (whose efficacy has been shown in cellular models and is accepted as a valid preconditioning mechanism). After thinly slicing healthy rat brains, Rotenstein obtained baseline recordings and then, to induce a stroke-like effect, subjected the rat brain to an oxygen and glucose deprivation environment. She then immersed brain slices into either a low or no calcium cerebrospinal fluid solution or subjected the slice to an anesthetic. Rotenstein tested calcium solutions because current thought believes calcium inflow through a variety of channels post ischemia causes long term damage and cell death through eventual mitochondrial overload and failure. She was encouraged by the fact that few or no studies had previously tested the effect of low or no calcium solutions electrophysiologically. She concluded that calcium deprivation does not improve the recovery profile, perhaps pinpointing electrophysiologically one of the reasons clinical trials with calcium channel blockers had been unsuccessful. She also tested the efficacy of isoflurane, a commonly used volatile anesthetic whose postconditioning properties had been demonstrated thus far in cell injury studies. Previous work had clearly showed isoflurane effective at preconditioning stroke, but such a paradigm was somewhat irrelevant in the clinical setting. Her experiments also denied any improvement in the overall recovery profile when brains are subjected to isoflurane either during or after ischemia, though she speculates there may be some potential for the anesthetic to speed recovery.

She also tested what role the potassium ion plays in the ischemic profile, specifically in the initial damage phase. Collecting electrophysiological data on the different characteristics of population spikes, their amplitudes and patterns, as produced by varying the solution of the immersion of the brain slices, she analyzed wave characteristics using biostatistics, Fourier transformations, curve fitting, and pure visual comparisons. Rotenstein concluded that a high potassium concentration created by the ischemic insult mediates the most damage in stroke. Rotenstein said she was especially excited that her summer work allowed her to finally apply physics, chemistry, and math to solve a biological problem. Her summer work will be showcased at the Winter Conference on Brain Research and the American Society of Anesthesiology Conference. The MacIver lab will further her work by investigating long term cell studies and the role of astrocyte damage in ischemic insult.

However, Rotenstein's summer was not all lab work. Time in the lab included good breaks for darts (a mandatory lab-wide activity), learning to appreciate rat rock (always blaring from the lab speaker system), and plentiful chocolate chip cookies and drinks for brain stimulation. In her spare time, she self-researched the subject of astrocytes and their death by acidosis, taught her labmates about the problems of African development thanks to her HNMUN Study Guide, took Drug Abuse Education in lab form from watching firsthand the effects of restricted substances on brain waves, oh, and discovered the charming streets of San Francisco. She advises students choosing a lab to visit the lab and observe the social and academic dynamic. Finding a lab that is socially comfortable and willing to let students be intellectually engaged is an important considerations to any lab experience, she says.

All articles written conjointly by the spotlighted student and Koning Shen '10.