

Jim's recent publications:

- J. P. Keener, A model for length control of flagellar hooks of *Salmonella typhimurium*, *J. Theoretical Biology*, 234, 263-275 (2005).
- B. E. Peercy and J. P. Keener, Coupled cell model of border zone arrhythmias, *SIAM J. Appl. Dyn. Sys.*, 4, 679-710 (2005).
- N. Cogan and J. P. Keener, Channel formation in Gels, *SIAM J. Appl. Math.*, 65, 1839-1854 (2005).
- J.P. Keener, Stochastic Calcium Oscillations, *Math. Med. Biol.* 23, 1-25 (2006).
- J. P. Keener, How *Salmonella Typhimurium* measure the length of their flagellar filaments, *Bull. Math. Biol.* 68:1761-1778 (2006).

Information for Prospective Students

The NSF-IGERT Program for Cross-Disciplinary Research Training in Mathematical Biology aims to train graduate students to use the tools of Applied Mathematics to study the challenging problems of modern biology.

IGERT fellows have experiences that are normally missing from traditional graduate programs. Students start engaging in research earlier in their graduate study. First-year journal clubs get students reading and understanding current research from the start. Lab rotations and internships further diversify their skills. Attending conferences is expected and supported. Students organize seminars and workshops. IGERT fellows leave the program having taken on roles as lab assistant, researcher, teacher, presenter, collaborator, and administrator.

The broad research emphases of the program are Biofluids, Ecology, and Evolutionary Biology, Neuroscience, and Physiology. A small sample of current research projects includes the dynamics of ant-parasitoid interactions, formation and degradation of blood clots, biofilm dynamics, pattern formation in the visual cortex, mechanisms and control of cardiac arrhythmias, the dynamics of Multiple Sclerosis, and the flow of water in plants.

The IGERT Program is housed administratively within the Mathematics Department at the University of Utah and the primary faculty are members of the Mathematics Department. Affiliated faculty include 27 members of life science departments from around the campus.

Application Process

Students with a strong background in undergraduate mathematics are encouraged to apply. This includes those with a major in another topic with substantial mathematical content. A strong background in biology is not required. Upon completion of the program, students will receive a Ph.D. in Mathematics.

Application forms can be found on-line at www.math.utah.edu/grad. An application to the Mathematics Department Graduate Program should also include an additional statement indicating interest in the IGERT Graduate Program or the Mathematical Biology Graduate Program.

Students that apply prior to January 31st, will be considered for participation in the IGERT recruitment weekend. Held in early March, this weekend gives applicants an opportunity to learn about the program and the Salt Lake area. The schedule is comprised of interviews with faculty, meetings with students and postdocs, and visiting classes, seminars, and research group meetings. Travel, local accommodations, and meals will be covered for participants. After the recruitment weekend, formal fellowship offers will be made to some applicants.

Financial Support

IGERT supported fellows will receive at least two years of financial support, with additional support coming from teaching and research assistantships.

IGERT Newsletter

Integrative Graduate Education & Research Training



From left to right: (Back row) Fred Adler, James Keener, Jay Newby, Chris Remien, Dave Goulet, Sean Laverty, Dane Maxfield, Elijah Bogart; (Middle row) Aaron Fogelson, Alla Borisyuk, Brittany Bannish, Karin Leiderman, Lindsay Crowl, Erica Graham, Zack Kilpatrick, Will Nesse, Elijah Newren, Amber Smith; (Front row) John Zobitz, Giao Huynh, Darci Taylor, Blerta Shtylla.

2005-2006 Update

The IGERT Program is entering its fifth year in the Mathematics Department at the University of Utah. This newsletter provides a summary of our recent research and training activities.

The third annual recruitment weekend was held the first weekend in March. Ten candidates travelled to Utah to learn about our Math Biology community. Recruits attended interviews with faculty, research group meetings, classes, a graduate student dinner, and a reception with IGERT-affiliated faculty. Current graduate students assisted recruits by sharing their experiences and showing them around our Department. On the last day, recruits were free to

ski, snowboard, cross-country ski, or explore Salt Lake. The weekend culminated in a party at Jim Keener's cabin in Big Cottonwood Canyon.

The second annual IGERT Workshop was organized by Courtney Davis, Amber Smith, and Nessay Tania on May 5-9, 2006. The featured speaker was Leah Edelstein-Keshet, a math biologist at the University of British Columbia. The topic of focus was biological polymers and cell motility. The workshop was geared toward beginning math biology graduate students. Details of the workshop are located here: www.math.utah.edu/research/mathbio/igert/Student_Workshop2006.html

PhD Recipients

Young-Seon Lee completed his thesis this year under the supervision of James Keener: Mechanisms of Calcium Alternans in Cardiac Cells, 2006. He is now a postdoc in the Department of Biomedical Sciences at Cornell University where he is working with Flavio Fenton and Robert Gilmour.

Andrew Oster completed his thesis this year under the supervision of Paul Bressloff: Models of cortical development, 2006. He is currently a postdoc at the Mathematical Biosciences Institute at The Ohio State University.

Newcomers

Peter Roper is the new IGERT Postdoctoral Fellow. He came here after a five year fellowship at the Mathematical Research Branch at the National Institute for Diabetes, Digestive and Kidney Diseases (NIDDK), which is one of the largest institutes at the National Institutes of Health, Bethesda, MD.

He works on models of endocrine and neuroendocrine cells in the hypothalamus and pituitary. In particular, he's interested in how the cells can regulate both their own activity and that of their close neighbors by secreting transmitters from their dendrites into the extracellular space. He is specifically looking at which pathways become activated and how that feeds back to affect the cell's electrical activity. He has started to work with Christopher Del Negro (College of William and Mary) on models of cells in the pre-Botzinger complex that control the rhythm of breathing. They have recently been awarded a three-year NSF grant to facilitate this work.

Peter's recent publications:

- P. Roper, C. Brown and W.E. Armstrong "Auto-regulation of bursting in the rat hypothalamus", in Coombes, S. (Ed.) Neural Bursting, World Scientific Press (2006)
- P. Roper "Frequency-dependent depletion of

secretory vesicle pools modulates bursting in vasopressin neurones of the rat supraoptic nucleus", Neurocomputing (2004)

- P. Roper, J. Callaway, and W.E. Armstrong "Burst initiation and termination in phasic vasopressin cells of the rat SON: A combined mathematical, electrical and calcium fluorescence study", Journal of Neuroscience, 24(20), 4818-4831 (2004)

- P. Roper, J. Callaway, T. Shevchenko, R. Teruyama and W.E. Armstrong "aHP's, HAP's and DAP's: How potassium currents regulate the excitability of rat supraoptic neurones", Journal of Computational Neuroscience, 15(3), 367-389 (2003)

New IGERT students are Brittany Bannish, Elijah Bogart, Erica Graham, Jay Newby, Christopher Remien, and Darci Taylor.

Brittany Bannish studied mathematics at Mount Holyoke College. She is interested in ecology, and possibly physiology. She did undergraduate research about the spread of infectious disease. She also participated in an REU at the University of Nebraska. The research she did that summer with 3 other undergrads was published in the Pan American Mathematical Journal in a paper titled "The Henstock-Kurzweil delta integral on unbounded time scales."

Elijah Bogart majored in physics at Harvey Mudd College. He is interested in neuroscience, immunology, and cell physiology. As an undergraduate, he spent two summers studying DNA methylation and histone modification in Neurospora in Eric Selker's lab at the University of Oregon.

Erica Graham studied mathematics at Bryn Mawr College. Her potential research interests include ecology, immunology or physiology. As an undergraduate, she studied human population dynamics and disease epidemics.

Jay Newby completed his undergraduate degree at the University of Utah. He did an REU on stochastic waves and a senior project on traffic modeling. His research interests are primarily in molecular biology,

- S. Coombes and P. C. Bressloff (editors). Bursting: The Genesis of Rhythm in the Nervous System. World Scientific (2005)

- A. M. Oster and P. C. Bressloff. A developmental model of ocular dominance formation on a growing cortex. Bull. Math Biol. 68 73-98 (2006).

- P. C. Bressloff. Stochastic model of intraflagellar transport. Phys. Rev. E 73 061916 (2006).

- P. C. Bressloff. Stochastic model of protein receptor trafficking prior to synaptogenesis. Phys. Rev. E 74 031910 (2006).

- A. Angelucci and P. C. Bressloff. The contribution of feedforward, lateral and feedback connections to the classical receptive field center and extra-classical receptive field surround of primate V1 neurons. Prog. Brain Res. 154 93-121 (2006).

- L. Schwabe, A. Angelucci, K. Obermayer and P. C. Bressloff. The role of feedback model in shaping the extra-classical receptive field of cortical neurons: a recurrent network model. J. Neurosci. 26 9117-9129 (2006)

Aaron Fogelson gave invited talks at the Biomedical Engineering Society Fall Meeting in Baltimore at the end of September 2005 and at the 5th World Congress on Biomechanics in Munich in July 2006. He gave a series of lectures at the Institute for High Performance Computing in Singapore in January 2006. He gave a plenary lecture at the Physiological Flow Network annual meeting at Oxford in April 2006. He gave a keynote talk at the symposium on Immersed Boundary Methods at the 7th World Congress on Computational Mechanics in Los Angeles in July 2006. He was invited to give a plenary talk at the ECCOMAS-CFD 2006 conference in the Netherlands. He gave research seminars at Nottingham University in England and at the University of California, Irvine, and undergraduate colloquium talks at Bowdoin College and the Claremont Colleges.

A paper he coauthored with Nessay Tania, "Coagulation under Flow: The influence of flow-mediated transport on the initiation and inhibition of coagulation," appeared in the journal Pathophysiology of Haemostasis and Thrombosis. Another paper,

"Fibrin gel formation in shear flow," he wrote with Bob Guy and Jim Keener was accepted by the journal Mathematical Medicine and Biology. "Unconditionally stable discretizations of the Immersed Boundary Method" that he wrote with Elijah Newren, Bob Guy, and Mike Kirby was accepted by the Journal of Computational Physics.

Aaron supervised Elijah Newren's work on immersed boundary methods. He worked with Karin Leiderman and Laura Miller on the effects of endothelial glycocalyx on flow near the endothelium. With Lindsay Crowl, he worked first on bone mechanics and currently on lattice Boltzmann methods for calculating fluid flows. He has been working with Bob Guy and Grady Wright on developing multiphase flow models of gels (in which different materials have different velocities) and in developing numerical methods to solve the equations that arise in these models.

Along with Jim Keener, Bob Guy, and Vickie Hsu, Aaron received a 5-year, \$2,000,000 grant from the NSF/NIGMS program to study the formation and function of physiological gels including those that are formed during blood clotting and those that protect the stomach from gastric acid. With Mike Kirby from the School of Computing and experimenters at the Illinois Institute of Technology he submitted a grant to the NIH to support tandem computational and experimental studies of blood clotting (this grant is pending).

Aaron was the organizer of the symposium on Immersed Boundary Methods at the 7th World Congress on Computational Mechanics in Los Angeles in July 2006.

James Keener gave talks in departmental colloquia at U North Carolina, Cambridge, Dublin, Colorado, Wyoming, UC Merced. He also gave lectures for the general public at Ohio State (MBI) and the University of Utah Frontiers of Science. He gave talks at conferences in Bristol, Notre Dame, Keele, Nottingham. He also lectures at two short courses at Cambridge and Ohio State (MBI).

In addition, she attended the joint SMB-SIAM conference on the Life Sciences in Raleigh, NC and passed the Differential Equations qualifying exam.

Giao Huynh attended two conferences this summer: Ecology and Evolution of Infectious Diseases (EEID), May 18-20, at Penn State University and Evolution, June 23-27, at Stony Brook University. She also participated in the IGERT workshop. Giao passed the Differential Equation exam.

Faculty

In collaboration with Ted Liou and with immunological advice from Meagan McNulty, **Fred Adler** bravely submitted the following manuscript to the New England Journal of Medicine:

T. G. Liou, F. R. Adler, B. Cahill and D. R. Cox. Lung transplantation fails to improve survival for children with Cystic Fibrosis.

In a project worked on by Courtney Davis, they have finally submitted some analysis of the data on deer mouse density and prevalence:

F. R. Adler, J. M. C. Pearce-Duvet and M. D. Dearing. How host dynamics translate into time-lagged prevalence: an investigation of Sin Nombre Virus in deer mice. American Journal of Tropical Medicine & Hygiene, (submitted).

A project worked on by former IGERT student Katherine Fitzgerald finally bore fruit in the following, soon to appear, publication (check out <http://www.journals.uchicago.edu/AN/papers.html> for a preview):

F. R. Adler and E. G. LeBrun and D. H. Feener Jr. Maintaining diversity in an ant community: Modeling, extending, and testing the dominance-discovery tradeoff. The American Naturalist (in press).

Alla Borisyuk served as a minisymposium organizer and speaker at the SIAM life sciences (joint

with SMB), August 2006, in Raleigh, NC. She was also an invited speaker at the Joint Mathematics meeting, January 2006, in San Antonio, TX at a special session on theoretical neuroscience.

Alla attended the following conferences:
- Society for Neuroscience, November 2005, Washington DC (poster)
- Gordon research conference on theoretical biology, June 2006, Tilton, NH (poster)
- Computational Neuroscience, July 2006, Edinburgh, UK (poster)

She published a paper:
J. Best, A. Borisyuk, J. Rubin, D. Terman, M. Wechselberger. The dynamic range of bursting in a network of synaptically coupled square-wave bursting respiratory pacemaker cells, SIAM J. of Appl. Dyn. Syst. 4: 11071139, 2005.

Paul Bressloff was a plenary speaker at the Conference on Fluids and Waves - Recent advances in applied analysis, University of Memphis (May 2006). He was the chair of the Gordon Research Conference on Theoretical Biology and Biomathematics (June 2006), and an invited speaker, School on Neuromathematics of Vision, Scuola Normale Superiore, Pisa (Sep 2006).

Paul's recent publications:
- A Prat, Y-X Li and P. C. Bressloff. Inhomogeneity-induced bifurcation of stationary and oscillatory pulses. Physica D 202 177-199 (2005).
- S. E. Folias and P. C. Bressloff. Stimulus-locked traveling waves and breathers in an excitatory neural network. SIAM J. Appl. Math. 65 2067-2092 (2005).
- P. C. Bressloff. Weakly interacting pulses in synaptically coupled excitable neural media. SIAM J. Appl. Math. 66 57-81 (2005)
- P. C. Bressloff. Spontaneous symmetry breaking in self-organizing neural fields. Biol. Cybern. 93 256-274 (2005)
- S. E. Folias and P. C. Bressloff. Breathers in two-dimensional neural media. Phys. Rev. Lett. 95 208107 (2005).

development, and neuroscience.

Christopher Remien is interested in learning more ecology and physiology. He graduated from St. Olaf College with a double major in mathematics and Russian and competed on the alpine ski team. He was a participant in the math practicum at St. Olaf, working in a group on a math problem for the Minnesota Orchestra.

Darci Taylor completed undergraduate studies at the University of Utah and masters studies at Caltech. Her summer undergraduate research was focused on engineering. Currently, she is interested in studying mathematical neuroscience.

IGERT Alumni

Courtney Davis participated in a lab rotation with Rob de Boer (and Vitaly Ganusov, a postdoc) at the University of Utrecht, The Netherlands in May and June of 2006. The research involved creating models to describe Simian Immunodeficiency Virus data taken by Perelson et al. Specifically, the data shows that it takes high immune levels to control virus load during the chronic phase of infection. If immune levels are lowered 10-fold, virus levels increase 2-3 orders of magnitude but do not expand to uncontrolled levels. Courtney developed models to both qualitatively and quantitatively capture the data while also explaining why virus levels do not grow uncontrollably in the presence of insufficient immune levels. Courtney also co-organized the IGERT student workshop.

Aaron McDonald gave talks in the ecology and physiology group meetings this past year. He was also invited to give a talk at Rockhurst University in Kansas City, Missouri. The talk focused on choosing a Mathematics graduate program and Math Biology in general.

Will Nesse did a lab rotation this summer on Electrophysiological experiments on the Hermisenda photoreceptor network model system with Greg Clark at the Friday Harbor Laboratories, Friday

Harbor, WA.

Will presented posters:
- Will Nesse and Paul C. Bressloff. Spatiotemporal activity patterns in two-layer networks of thalamocortical-reticular cell integrate-and-fire-or-burst neurons, Computational and Systems Neuroscience (COSYNE) conference March 2006 Salt Lake City.
- Will Nesse, Gregory A. Clark, and Chris Butson. Sensory encoding, phase locking, and noise: Lessons from the Hermisenda eye, Computational and Systems Neuroscience (COSYNE) conference, March 2006 Salt Lake City.
- Will Nesse and Paul C. Bressloff. Analysis of spike patterning statistics of a noisy phase oscillator given periodic inhibition: Noise is integral! Gordon conference in theoretical biology, Tilton school NH. May 2006.
- Will Nesse and Gregory A. Clark. Sensory encoding, phase locking, and noise: Theory and Experiment on the Hermisenda eye. Mountain west biomedical engineering conference (MWBME) September 2006.
- Will Nesse and Gregory A. Clark. Sensory encoding, phase locking, and noise: Lessons from the Hermisenda eye (same title as before but entirely new results). Society for neuroscience (SFN) annual meeting Atlanta GA. October 2006.

Amber Smith spent this summer doing a lab rotation, attending conferences, and giving talks at the Center for Nonlinear Studies at the Los Alamos National Laboratory. She worked with Dr. Alan S. Perelson and Dr. Ruy M. Ribeiro. They worked on mathematical models of the synergistic interactions of influenza and Streptococcus pneumoniae. She attended the Workshop on Optimization in Complex Networks and Socio-Technical Systems: Bridging the Scales both held at the LANL. She also gave two talks: "Synergistic Interactions of Influenza and Streptococcus pneumoniae" and "Models for Viral-Bacterial Synergism: Influenza and Streptococcus pneumoniae".

Nessy Tania attended two conferences this year:

Workshop on Applications of the Methods of Stochastic Systems and Statistical Physics in Biology at the University of Notre Dame, October 2005 and the NSF IGERT Project Meeting in Arlington, VA, May 2006. At those conferences Nesy also presented posters: Graded calcium release in a stochastic model of cardiac muscle, N Tania and JP Keener, at Notre Dame and Control of calcium release in cardiac muscle, N Tania and JP Keener, at the IGERT Project Meeting. She did a lab rotation at the University of Auckland, New Zealand, with Professor James Sneyd. They modeled Actin-Myosin crossbridges in smooth muscle.

John Zobitz has been busy traveling and presenting his research throughout the country.

John attended conferences:

- Global Change Education Program End-of-Summer Workshop, August 21-24, 2005, Washington D.C.

- Fluxnet Science Team Meeting, October 18-20, 2005, Boulder, Colorado

- American Geophysical Union Fall Meeting, December 5-8, 2005, San Francisco, California

- Global Change Education Summer Orientation Workshop, June 13-17, 200, Portland, Oregon

He gave talks:

- Comparison and Assessment of Methods to Partition Net Ecosystem Exchange of CO₂ in Heterogeneous Environments, August 22, 2005, Global Change Education Program End-of-Summer Workshop, Washington D.C.

- Consistent Linear Regression, November 1, 2005, Mathematics Department Graduate Colloquium, University of Utah, Salt Lake City, Utah

- High-resolution stable-isotope partitioning of net ecosystem exchange into respiration and photosynthesis, December 5, 2005, American Geophysical Union Fall Meeting, San Francisco, California

- High resolution atmospheric monitoring of urban carbon dioxide sources, June 15, 2006, Global Change Education Program Summer Orientation Workshop, Portland, Oregon

He has published three papers this year:

- J. M. Zobitz, J. P. Keener, H. Schnyder, D. R. Bowling, "Sensitivity analysis and quantification of uncertainty for isotopic mixing relationships in carbon cycle research," 2006.

Agricultural and Forest Meteorology, 136:56-75, doi:10.1016/j.agrformet.2006.01.003.Zobitz CV 1

- D. Pataki, D.R. Bowling, J.R. Ehleringer, J. M. Zobitz, "High resolution atmospheric monitoring of urban CO₂ sources," 2006. Geophysical Research Letters, 33, L03813, doi:10.1029/2005GL024822.

- J. M. Zobitz, S. P. Burns, J. Ogée, M. Reichstein, D. R. Bowling, "Partitioning net ecosystem exchange of CO₂ in a high-elevation subalpine forest: Comparison of a Bayesian/isotope approach to environmental regression methods," In review at Journal of Geophysical Research-Biogeosciences.

IGERT Students

Noelle Conforti, now a second year IGERT student, completed her summer lab rotation in the Samlowski laboratory at the Huntsman Cancer Institute at the University of Utah. The lab focuses on translational Immunotherapy research involving interleukin-2, one of the only approved treatments for advanced melanoma. This means the primary goal of the lab is to move promising new drugs from the lab to human clinical trials. Noelle's research interests are now expanding to include immunology and, if her advisor Fred Adler can convince her they are "cool" enough, viruses. Noelle hopes to find an exciting area for thesis research while exploring immunology and virology this year. In addition, she passed the Applied Mathematics qualifying exam this August.

Zack Kilpatrick gave a review of a paper by Paul Bressloff to the Graduate Student Colloquium discussing front propagation failure in an inhomogeneous neural network. This work was loosely related to his lab rotation and current work with Paul.

During a lab rotation this summer, he worked with

Alessandra Angelucci, at the Moran Eye Center, who studies primate vision. He observed and assisted in two major experiments. Single extracellular neuron recordings were used in the first experiments to determine the modulatory effects of long-range feedback connections from extrastriate cortex on processing in primary visual cortex. Macaque monkeys are presented with an annular stimulus, which is moved to be in different parts of the receptive field of the recorded neuron. The second experiment used a heat sensing camera to monitor blood flow in the vasculature feeding visual cortex to infer neural activity of a population in visual cortex. In an effort to recover the orientation mapping, marmosets were presented with horizontal and vertical moving gratings as visual stimuli, and the population responses were then cross correlated. While this experiment was unsuccessful, likely because both animals used were too deeply anesthetized, he learned much about optical imaging.

Zack's research project with Paul Bressloff consisted of analytically studying a one dimensional neural network model with long range connections. They approach this by finding the existence and stability of traveling pulses in different parameter variations of the model. He was able to complete an ample portion of this project and present a talk at the joint SIAM/SMB Conference on the Life Sciences in early August in Raleigh, NC. Currently, he is trying to complete enough of this work such that a manuscript could feasibly be submitted to a refereed journal.

Zack was able to pass the two qualifying exams in Differential Equations and Applied Mathematics at the end of August.

Sean Lavery was involved in a project at the Center for Infectious Disease Dynamics (CIDD) at Pennsylvania State University during the past summer. He worked in Pete Hudson's lab with a team of postdocs, grad students and undergrads on field and lab work. The project involved community (host-parasite-predator) interactions under the

influence of pesticides.

Dane Maxfield worked in Dr. Markus Babst's lab (University of Utah) working on a project involving a possible new protein complex in the ESCRT III complex called complex X. To study complex X, they knocked out the genes that make the proteins involved in complex X in different strains of yeast and then looked at the yeast under the microscope to see if there was any noticeable phenotypes (physical or kinetic phenotypes). They observed both a weak physical phenotype and a weak kinetic delay phenotype which is good news because that suggests that this protein complex may exist in vivo and, even better, may actually be involved in the ESCRT complex.

Ben Murphy was focused on class work and self-study relating to biophysics, probability theory, and stochastic differential equations. He did some exploratory reading into a few different topics relating to bio-polymers, molecular motors and the underlying math and physics. Over the summer, he attended the Gordon conference at the Tilton School, NH. Topics included probability in neuroscience, the effects of noise in biological systems, and ecological networks. He also did a lab rotation with Dr. Rabbitt from the U of U Bioengineering department over the summer. He worked on formulating fractional differential equation models relating to vestibular semicircular canals in toadfish. He also spent some time studying for the Numerical Analysis prelim and received a passing score.

During last spring semester, **Lindsay Crowl** worked with Aaron Fogelson on bone cell dynamics. They studied how the lack of mechanical loading/unloading on bones (caused by walking, etc.) can affect the normal remodeling process of bone cells. This summer she learned about Lattice-Boltzmann methods for solving computational fluid flow problems with Aaron Fogelson. She is hoping to write her own LBM code in Fortran and use it to study blood flow problems. She also worked with Dr. Keener on a project investigating how the shape of the border of an SA node can affect its critical mass.