Golubitsky Named Next Director of the MBI

Professor Marty Golubitsky has been appointed the next director of the Mathematical Biosciences Institute at the Ohio State University. Golubitsky’s appointment is effective September 1, 2008.

Professor Golubitsky is a world leader in the fields of nonlinear dynamics and bifurcation theory. His fundamental work on the role of singularities and symmetry in the formation of patterns in physical systems is recognized internationally. His recent research concerns the dynamics of networks of differential equations, work that was inspired by mathematical neuroscience.

Golubitsky has been for many years Cullen Distinguished Professor of mathematics at the University of Houston. He served as the President of the Society of Industrial and Applied Mathematics (SIAM) as well as on the Councils of SIAM and the American Mathematical Society (AMS), and as the Chair of the SIAM Activity Group on Dynamical Systems. Golubitsky is a Fellow of the American Academy of Arts and Sciences.

“Biology is increasingly becoming more quantitative and the relationship between the mathematical sciences and biology is becoming more sophisticated. For these reasons I believe in the MBI mission, and I am honored and excited to have been given the opportunity to lead the institute,” Golubitsky said. “The MBI, under Avner Friedman’s leadership, has evolved into an internationally recognized institute in the mathematical biosciences, and I am dedicated to ensuring its continued success.”

The MBI receives major funding from the National Science Foundation Division of Mathematical Sciences and is supported by The Ohio State University. The Mathematical Biosciences Institute adheres to the AA/EOE guidelines.

Suggest New Ideas and Programs

The MBI programs are aimed at bringing mathematical scientists and bioscientists together to interact on significant problems from the biosciences. It is expected that such activities will also open new research areas for mathematicians and statisticians.

The MBI wishes to encourage the mathematical sciences community and the biosciences community to solicit program ideas.

Your suggestions may be submitted in the form of a preproposal for

- a workshop that falls within a thematic year;
- a stand-alone workshop;
- an extended program, several months to a year; and
- a summer education program.

We welcome ideas from the broad spectrum of mathematical biosciences: you may focus more on the mathematics/statistics motivated by biology, or on biological problems which will require the development of new mathematical/statistical methods.

Please submit your ideas in the form of a few pages describing the background and motivation, and what the program is going to accomplish.

If you want to suggest a specific workshop, we would like to have a list of organizers, a description of the workshop, and a tentative list of speakers and participants.

Please contact the Director or one of the Associate Directors as you develop your ideas for pre-proposal:

- Avner Friedman, Director: afriedman@mbi.osu.edu
- David Terman, Senior Associate Director: terman@math.ohio-state.edu
- Libby Marschall, Associate Director: marshall.2@osu.edu
- Dennis Pearl, Associate Director: dpearl@mbi.osu.edu
- Andrej Rotter, Associate Director: arotter@mbi.osu.edu
Scientific Program 2007-2008 Mathematical Bioengineering

Organizing Committee: Philip J. Holmes, Melissa Knothe Tate, Art Kuo, Michael Savigeau, Allen Tannenbaum, Dawn Taylor

Bioengineering lies at the interfaces of biology, the applied sciences and engineering. It combines the excitement of multi-disciplinary research with the promise of making improvements to society, especially in health care, e.g. in the diagnosis and treatments of degenerative diseases. However, it is a relatively new field that is still finding its way among the established engineering and biological disciplines. As a multi-discipline it presents particular problems for the seasoned researcher as much as for the new student: indeed, we are all new students when it comes to subfields in which we have not trained.

The 2007-2008 MBI Year in Mathematical Bioengineering will focus around six workshops on Metabolic Engineering, Cell and Tissue Engineering, Neuroengineering, Brain Imaging, and Neuromechanics, the latter being covered in two linked workshops. Tutorials will be offered to prepare participants, especially students and postdoctoral fellows interested in entering the field. While omitting large areas, these workshops provide examples of the central subject matter, and they highlight two key modes of operation of bioengineering: as a conduit for experimental methods, modeling and analytical tools from the physical sciences and mathematics into biology, and as a conduit for biological inspiration to the applied sciences and engineering, as in bio-inspired design of new devices and materials.

A common feature of the topics chosen, and indeed, of much of bioengineering, is their integrative nature. Biological systems are unavoidable complex, often containing many apparently redundant parts or pathways. In trying to understand, predict, control, change, or build such a complex system one must successfully reduce and combine a mass of detail. In this endeavor mathematical modeling and analysis offers a unifying language and set of principles that can draw together disparate ideas from genomics, molecular biology, neuroscience, biochemistry, physiology, imaging and signal processing (to name only topics germane to the six MBI workshops). Mathematics can also reveal common principles operating on different time and space scales, and guide the development of computational algorithms for simulation and data analysis.

Workshop on Neuromechanics of Locomotion

March 31-April 4, 2008
Organizers: Philip J. Holmes, Robert J. Full and Ansgar Bueschges

This workshop focuses on the question of how animals are deceptively simple. They push against the world, with legs, fins, tails, wings, or their whole bodies, and the rest is Newton’s third and second laws. But of course locomotion emerges from complex interactions among animals’ neural, sensory and motor systems, their muscle-body dynamics, and their environments. Three broad approaches reflect this:

1) Neurobiology has successfully studied the role of central pattern generators (CPGs) in the control of locomotion. CPGs are networks of neurons that can generate muscular activity in the absence of sensory feedback. By its action, the nervous system can generate a basic neural output that can signal the muscles when to contract. In this mode, the nervous system tells the muscles what to do and muscles pass the message on to limbs, which move the body.  

2) A closely related approach concentrates on proprioceptive feedback in intralimb and interlimb coordination for shaping locomotory patterns. Thus, what the limbs are doing now, tells them what to do next.

3) Biomechanical studies focus on body-limb-environment dynamics and often ignore neural detail. Thus, Newtonian mechanics, with (mostly) passively-generated forces, tell the body what it must do.

All three approaches have generated rich mathematical models of individual neurons and circuits, sensory pathways and state estimators, and body-limb mechanics. Further mathematical modeling, at various spatial and temporal scales, can play a central role in synthesizing these approaches into neuromechanical descriptions of locomotion. Thus, Hodgkin-Huxley meets Newton with A.V. Hill as matchmaker.

This workshop, and the closely-related ones on muscle bio-mechanics (Workshop 2) and neuroengineering (Workshop 5) will emphasize the development of integrative models. The major mathematical tools will include dynamical systems, stochastic ODE, control theory, and (non-)classical mechanics with intermittent contacts and impacts in running and walking, and unsteady fluid mechanics in swimming and flight.
Mini-workshop on Restoration of Movement Via Peripheral Nerve Stimulation

April 29, 2008
Organizer: Dawn Taylor

The aim of the workshop is to determine the current state of neuroengineering with respect to restoration of movement via peripheral nerve simulation, and to discuss future directions. The main themes will include optimizing stimulation through modeling of the nerves, electrode designs for improved recruitment and selectivity, and testing movement control via musculoskeletal modeling.

For more details visit: http://www.mbi.osu.edu/2007/mw4description.html
To apply visit: http://www.mbi.osu.edu/applyworkshop.html

Workshop on Real Time Brain Interfacing Applications

May 12-15, 2008
Organizers: Dawn Taylor and David Terman

The field of neural engineering has been transformed by the growth in computer processing power in the last several years. It is now possible to read in multiple neural signals, process those signals, and respond to that processed data in real time. The capability to interact with the nervous system in real time has great potential for the development of new treatments for neurological disorders as well as enabling new experimental studies to further our understanding of the nervous system. For example, areas where real-time interaction can result in improved therapies or treatments include:

► Direct brain control of assistive devices for the paralyzed
► Closed-loop control of deep brain stimulation (DBS) (e.g., for Parkinson’s disease)
► Prediction and intervention of epileptic seizures
► Closed-loop stimulation of paralyzed nerves to restore function

This real-time interaction possesses special challenges because device design requirements often include minimizing power consumption and device size for implantation. This necessitates implementing efficient algorithms and quantifying the tradeoffs between making algorithms more efficient versus more effective. Another issue common to most chronic neural engineering applications is non-stationarity of the neural interface and of the biological system itself.

The themes of the workshop will include: spike sorting and tracking; cortical decoding of command signals for control of assistive devices; deep brain stimulation; and epilepsy detection and intervention.

For more details visit: http://www.mbi.osu.edu/2007/ws5description.html
To apply: http://www.mbi.osu.edu/applyworkshop.html
Workshop on Brain Imaging

June 9-13, 2008
Organizers: Allen Tannenbaum, Stefano Soatto, Sylvain Bouix and Kaleem Siddiqi

Medical imaging has been undergoing a revolution in the past decade with the advent of faster, more accurate, and cheaper imaging modalities. This powerful new hardware has driven the need for corresponding software development, which in turn has provided a major impetus for new algorithms in signal and image processing. Many of these algorithms are based on partial differential equations, curvature driven flows, geometry, and novel statistical techniques. The purpose of this workshop is to bring together researchers from all aspects of medical imaging with the emphasis on brain imaging for a multi-disciplinary workshop in which various views may be shared, and hopefully new research directions may be opened.

A key research area is to formulate biomedical engineering principles based on a rigorous mathematical foundation in order to develop general-purpose software methods that can be integrated into complete therapy delivery systems. Such systems support the more effective delivery of many image-guided procedures--biopsy, minimally invasive surgery, and radiation therapy, among others.

Mathematical models form the basis of biomedical computing in general and medical imaging in particular. Basing those models on data extracted from images continues to be a fundamental technique for achieving scientific progress in experimental, clinical biomedical, and behavioral research. Images, acquired by a range of techniques across all biological scales, are central to understanding biological problems and their impacts on human health purely because images now encompass so many techniques beyond the visible light photographs and microscope images of biology’s early years. Today, imaging is better thought of as geometrically arranged arrays of data samples measuring such diverse physical quantities as time-varying hemoglobin deoxygenation during neuronal metabolism or vector-valued measurements of water diffusion through and within tissue. The broadening scope of imaging as a way to organize our observations of the biophysical world has led to a dramatic increase in our ability to apply novel processing techniques and to combine multiple channels of data into sophisticated and complex mathematical models of physiological function and dysfunction.

The workshop will bring together a diverse group of researchers from the medical imaging community with various backgrounds including radiology, psychiatry, signal and image processing, surgery, physics, mathematics, and neurophysiology. The workshop will focus on the following topics:

► Medical Imaging Modalities for Brain Imagery: MRI, fMRI, DTI, PET, SPECT, CT;
► Medical Imaging Processing and Computation: Registration, segmentation, visualization, computer graphics, shape theory;
► Mathematical Algorithms: Statistical, geometric, partial differential equations;
► Applications: Image guided surgery (e.g., interventional magnetics), imaging for understanding pathology (Alzheimer’s disease, Parkinson’s, OCD, clinical depression), image processing and deep brain stimulation.

For more details and how to apply visit: http://www.mbi.osu.edu/2007/ws6description.html

Workshop on Systems Biology of Decision Making

June 16-20, 2008
Organizers: Kevin Passino, Thomas Waite, Roger Ratcliff, Thomas Seeley, Nigel Franks and Naomi Leonard

Experimental biology is uncovering the mechanisms supporting decision-making in individual animals (e.g., in monkeys) and social animal groups (e.g., bees and ants). Multiscale mathematical models are being developed and validated for several species, including those for the (i) neuron-to-behavioral levels in cognitive neuroscience (e.g., diffusion or decision field theory models), (ii) organism-to-group levels for social insects (e.g., differential equations and individual-oriented models), and (iii) individual/group-to-ecological levels in behavioral ecology (e.g., optimization or evolutionary game-theoretic models). Several of these models and species share common features; hence there exists significant opportunities for cross-fertilization and progress toward an understanding mechanisms and whole-system emergent properties. Mathematical, statistical, and computational analyses are being used to study (i) properties of the dynamics of decision making (e.g., feedback mechanisms, coupling, stability, and speed-accuracy trade-offs), (ii) cross-scale effects (e.g., impact of massively parallel mechanisms at one level on emergence of choice discrimination or distractor elimination abilities at a higher level), (iii) effects of context (e.g., similarity and attractiveness effects), and (iv) Darwinian evolution of robustness or reliability in the presence of uncertainty (e.g., isolated failures at one level and environmental variations). The goal of this workshop is to facilitate the development of an integrated “systems biology” of decision-making processes that spans multiple spatio-temporal scales and levels of biological organization, and accounts for the perspectives of biologists, psychologists, economists, mathematicians, and engineers.

For more details and how to apply visit: http://www.mbi.osu.edu/2007/ws7description.html
2008 Summer Program in Mathematical Bioengineering

July 7-25, 2008

Each summer the MBI hosts a three-week education program. The first week is spent in a tutorial, which combines morning lectures with active learning laboratories in the afternoon. The following two weeks are spent working on guided team projects and participating in a mini-conference to share project results. The program is meant primarily for graduate students; college instructors and qualified undergraduates will also be considered.

The lecturer for the first week will be Richard Bertram (Department of Mathematics, Florida State University). He will discuss examples of how mathematical modeling is used in the areas of neuroscience and physiology. Topics include the dynamics of electrically excitable cells, calcium dynamics and waves, fast and slow time scales, bursting oscillations, phase oscillators, circadian gene oscillations, and synchronization of oscillators. A basic familiarity with ordinary and partial differential equations is assumed. Techniques for the analysis of nonlinear ordinary differential equations using phase plane and bifurcation diagrams will be discussed throughout the series of lectures.

For more details visit: http://www.mbi.osu.edu/eduprograms/2008description.html

To apply: http://www.mbi.osu.edu/forms/summerapplication.html

2008 Workshop for Young Researchers in Mathematical Biology

September 2-4, 2008
Organizers: MBI Postdoctoral Fellows

The workshop is intended to broaden the scientific perspective of young researchers in mathematical biology and to encourage interactions with other scientists.

Workshop activities include plenary talks and poster sessions, as well as group discussions on issues relevant to mathematical biologists. Tentative topics include angiogenesis, biostatistics, calcium signaling, and neuroscience. We cordially invite young mathematical biologists to participate.

The accepted speakers are Carson Chow, Steven Coombes, Jun Liu, Markus Owen, and John White.

For more details visit: http://www.mbi.osu.edu/postdocworkshop/wyrmb2008.html

Application: http://mbi.osu.edu/forms/wyrmbapplyworkshop.html

Board of Trustees

The Board consists of individuals with leadership experience in the public and private sectors, and of recognized scientists in fields related to the MBI activities. The Board meets annually to review the institute management and programs and to advise and approve the strategic priorities of the institute. The current members are:

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Healthy kidneys filter wastes from blood and keep body chemicals in balance. When the kidneys fail to perform their functions to full capacity, one cannot live long without some form of renal replacement therapy. One available treatment is hemodialysis, in which the patients’ blood is pumped into an artificial kidney where metabolic waste products diffuse out of the blood, and the cleansed blood is then returned back to the body. Most people have 3 dialysis sessions every week, each session for about 3 to 4 hours.

In order to perform hemodialysis, the patient must have suitable vascular access to allow adequate flow of blood to the dialysis circuit. The most common types of vascular access used for hemodialysis are the arteriovenous (AV) fistula and the expanded polytetrafluoroethylene (ePTFE) graft. A surgeon creates an AV fistula by directly connecting an artery to a vein, usually in the forearm. The increased blood flow causes the vein to hypertrophy so that it can be used for repeated needle insertions. A graft connects an artery to a vein by using a synthetic tube of ePTFE, usually in the shape of a loop. It does not require as much time to mature as a fistula, so it can be used soon after placement.

Both types of vascular access can have complications that require further treatment or surgery. As a well-functioning vascular access is essential for hemodialysis, extensive morbidity exists among end-stage renal disease (ESRD) patients. How long can someone live on dialysis and how well can someone do, depend heavily on the quality of the medical care. The expense of creating and maintaining vascular access for patients on dialysis accounts for a significant portion of any health care system. In the US alone, more than 20% of patients with ESRD are hospitalized for vascular access procedures, at an annual cost of 1 billion dollars.

The leading cause of access failure is from loss of patency due to venous stenosis (50% narrowing of the blood vessel), as the result of neointimal hyperplasia formation either at the site of venous anastomosis or in the downstream vein. It is then of critical importance to detect access stenosis in a timely manner so that appropriate corrective steps can be undertaken prior to thrombosis (total occlusion of the blood vessel). However, while the occurrence of stenosis is well recognized, the pathogenesis of it is complex and still not well understood. The process involves a number of growth factors, migration and proliferation of different types of cells, and excessive production of extracellular matrix. The release of growth factors due to oxidative stress and turbulent flow has been suggested as a possible mechanism for neointimal hyperplasia formation.

At the Mathematical Biosciences Institute, postdoctoral researchers Paula Budu-Grajdeanu and Richard Schugart, together with mathematician Avner Friedman, work closely with the Interventional Nephrology Team of The Ohio State University Medical Center, Anil Agarwal, Chris Valentine and Brad Rovin, to analyze the biological mechanisms that lead to vascular access stenosis and direct attention to potential therapies to prevent and treat stenosis. Using partial differential equations to describe the complex pathogenic network relevant to neointimal hyperplasia formation, they have developed a mathematical model, in which all growth factors (TGF-, PDGF, ET-1) are lumped together into one generic chemical species and all cellular species (smooth muscle cells, fibroblasts) are lumped together into one generic cell type. The model accounts for oxidative stress by having the growth factors increase as the luminal radius decreases.

This relatively simple model captures some of the main features of intimal hyperplasia formation and it realistically predicts the stenotic event (red line) as a function of the initial concentration of the growth factors inside the intimal-luminal space (black curve). It also shows that a drop in the initial concentration of growth factors delays the access stenosis, prolonging the lifespan of the vascular access (blue curve).

The results imply that one mechanism by which the functional state of the hemodialysis vascular accesses can be extended is to control the concentration of the growth factors in the proximal vein. In particular, interventions aimed at specific chemical mediators involved in VNH formation may be successful in reducing the human and economic costs of vascular access dysfunction. With cooperative efforts, i.e., interplay between computational experiments and data, the mathematical model can be expanded and used by clinical researchers as a testbed for exploring and evaluating various therapies that can target both the traditional and the alternative pathways that are involved in the pathogenesis of vascular stenosis. As only limited empirical data for various parameters is available at present, clinical studies need to be conducted in parallel with the development of the model to improve its reliability.
Rasmus is from Stockholm, Sweden, and received a PhD in Systematic Zoology from Stockholm University in 2006. The title of his thesis was “Molecular phylogenetics and taxonomic issues in Dragonfly systematics (Insecta: Odonata)”. He has worked in both the ‘green’ (entomological field work and taxonomy) and ‘white’ (molecular biology and phylogenetic analysis) sectors of biological research as a graduate student.

His current research interest in phylogenetic studies of emergent infections disease with a focus on Influenza. By creating a genealogy over virus sequences, and mapping them geographically we can trace the events that enables a bird flu virus to infect humans. Influenza viruses have a segmented genome, consisting of 8 separate single-strand RNA fragments coding for 10 proteins.

Re-assortment between different strains of Influenza has been thought to cause the large pandemics. The Spanish flu of 1918 is believed to have originated as strain that jumped hosts directly bird to humans, while the Hong Kong flu of 1968 is thought to have passed through a genetic re-assortment between relatively benign bird flu and human flu viruses in pigs. These assumptions are based on the immunological characteristics of surface proteins: the Hong Kong strain appeared to have one protein from pig flu, and another from seasonal human flu. With new methods and computer implementations, we can examine possible genomic rearrangements in a rigorous phylogenetic context.

Rasmus will also be working on insect molecular phylogeny, focusing on bluet damselflies, with a group at the Department of Entomology.

MBI Welcomes New Postdoc and Long-Term Visitor

Rasmus Hovmoller

Shili’s research interests are in statistical genetics, genetic epidemiology, genomics, and bioinformatics. The focuses of her current efforts are on the development of statistical methods for the analysis of genetic and genomic data as well as their applications. As a long term visitor at the MBI, she works with post-doctoral fellow Dr. Shuying Sun on a number of projects. They include work on disease and genetic polymorphism (such as single nucleotide polymorphism) associations as well as the identifications of hypermethylated promoter CpG islands among breast cancer samples.
The mission of the MBI is:

- to foster innovation in the development and application of mathematical, statistical, and computational methods for the solution of significant problems in the biosciences;
- to engage mathematical and biological scientists in the solution of these problems; and
- to expand the community of scholars in mathematical biosciences through education, training, and support of students and researchers.

Apply for a visit!

Long-term visit: http://mbi.osu.edu/forms/visitorapplication.html
Workshop/Tutorial: http://mbi.osu.edu/applyworkshop.html
Postdoctoral fellowship: http://mbi.osu.edu/forms/papp.html

If you would like us to include information on upcoming meetings/programs or employment opportunities, please contact David Terman at terman@mbi.osu.edu.